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A Comparison of the Characteristics of Computer-mediated and Lecture Students in Developmental Mathematics

Abstract

This study examined students' responses to a variety of constructs related to learning developmental mathematics. Students were allowed to self-select into either a computer-mediated or lecture course. The constructs included: attitudes about math, attitudes about computers, beliefs about math, meta-cognition, depth of processing, intellectual engagement, and visual learning. The primary result of the study was that students who selected into computer-mediated courses responded significantly higher on items related to attitudes about computers than students in lecture courses. The responses of students in lecture courses indicate that they were significantly more likely to rely on an instructor to show them how to do the problems while students in computer-mediated courses were significantly more likely to prefer to learn by reading than by listening.

Many institutions now offer developmental mathematics classes using both computer-mediated and lecture instruction. Typically, students are allowed to enroll in the instructional format that they believe will best support their learning style. To assist a student in selecting the instructional format that will best meet their preferences, an advisor may meet with the student to discuss the teaching and learning process used in each instructional format. Further, some institutions have developed a set of questions that can be used to assist students in selecting the instructional format that will best meet their preferences. In this study, we selected eleven constructs related to learning mathematics to investigate if there are differences in the students' attitudes towards learning mathematics based on whether they are enrolled in a lecture class or a computer-mediated class.

Lecture and Computer-mediated Instruction

The instruction in a lecture class is typically delivered through direct instruction. Rosenshine and Meister (1987), found that direct instruction usually includes (a) presenting new material in small steps, (b) modeling of procedures by the teacher, (c) thinking aloud by the teacher, (d) guiding initial student practice, (e) providing systematic corrections and feedback, and (f) providing expert models of the completed task. In addition to providing direct instruction, the instructor may lead whole-class discussions and develop activities that students work on together in groups while in class.

Computer-mediated instruction is defined by Gifford (1996) as a learner-centered model of technology-mediated instruction. The instruction in the computer-mediated classes in this study was delivered by interactive multimedia software called *Interactive Mathematics* (Academic Systems, 2000). Najjar (1996) defines multimedia as the use of text, graphics, animation, pictures, video, and sound to present information. The interactive features of the software allow students to control both the path of instruction and the pace at which they learn. Najjar (1996) reviewed the research related to interactivity and concluded that "interactivity appears to have a strong positive effect on learning."

The software (Academic Systems, 2000) used in this study: (a) presents the concepts and skills; (b) imbeds items requiring student interaction within the instruction; (c) provides immediate feedback, including detailed solutions after the second attempt on an item; (d) provides provisions for the development of skills; (e) offers online quizzes; and (f) includes a class management system that tracks students' time on the computer and provides detailed individual progress reports. The instructor's role in a computer-mediated class is to develop a course structure that promotes student success, to provide feedback to students regarding their understanding of the course content and progress in the class, and to provide individual or small group assistance as requested. The instructor typically does not lecture in a computer-mediated class since the software is the primary source of instruction.

Constructs Selected for Inventory

Eleven constructs were selected that research suggests may be related to students' success in mathematics in computer-mediated and lecture classes. The inventory items were developed by examining studies and theoretical articles related to the constructs that we selected. We specifically attempted to identify items related to the learning of mathematics. Surveys that were examined include Aiken, 1974; Bessant, 1997; Chiu, 1997; Harrison and Rainer, 1992; Hermans, 1970; Murphy, Coover and Owen, 1989; Popovich, Jyde and Zarajsek, 1987; Schraw and Dennison, 1994; and Taylor, 1997. Most of the items on our survey were the result of revising items on the surveys that we examined to better fit the comparison of students in computer-mediated and lecture developmental mathematics courses. A few items were taken directly from other surveys. These include item 5 and 6 from Aiken, 1974; item 7 from Taylor, 1997; and item 21 from Schraw and Dennison, 1994.

1. *Attitudes about computers.* Nearly all of the students in this study had used a computer prior to enrolling in a mathematics course. Research indicates that females have been found to have less favorable attitudes toward computers and are less likely to register for computer classes (Davis & Bostrom, 1992), but when computers are used to accomplish a particular task, gender differences are smaller (Popovich, Hyde, Zakrajsek, & Blumer, 1987). Females may also have higher performance expectations and exhibit more effort in working with computers

(Lockheed, 1985), although they still exhibit more anxiety about testing (Rozell & Gardner 1999).

2. *Attitudes about mathematics.* Developmental students often have had negative experiences related to mathematics or mathematics classes in their past (Higbee & Thomas, 1999; Ma & Kishor, 1997). These experiences may still pervade students' attitudes toward mathematics in their current classes. Attitudes about mathematics, however, are often not a unidimensional factor (Leder, 1987). A particular student, for example, may enjoy solving rote problems, but experience anxiety when asked to engage in problem solving.

3. *Beliefs about mathematics (skills or concepts).* Mathematics can be thought of as conceptual in nature with an underlying structure. Or, it can be thought of as a series of procedures and skills. Students who hold the latter view may have difficulty processing the material in a way that allows easy retrieval and thus will have difficulty remembering when asked to do so (Schommer, Crouse, & Rhodes, 1992; Schoenfeld, 1992). They may also be unable to process material or work problems because they have inaccurate preconceived notions about the nature of problem solving (Hart, 1990). Those who view mathematics as conceptual in nature should be better able to understand the material and to remember what they have learned since it may lead to deeper processing (Bruning, Schraw, & Ronning, 1995).

4. *Depth of Processing:* The depth of processing view of learning as developed by Craik and Lockhart suggests that differences in processing level will affect memory for learned material (Craik & Lockhart, 1972, Martin & Debus, 1998). Shallow processing involves surface aspects or physical analysis of the stimulus, while deep processing involves semantic analysis centered on meaning and more elaborate encoding. Deep processing of information is centered on meaning. On the other hand, surface or shallow processing focuses on the more superficial aspects of the material. Knowledge, or at most comprehension of the information, is the goal. This type of processing does not lead to elaborate encoding and thus will not be remembered as well (Bruning, Schraw, & Ronning, 1995).

5. *Intellectual engagement.* Cognitive engagement has been found to be significantly related to achievement (Miller, Greene, Montalvo, Ravindran, & Nichols, 1996). Engaged students are more likely to engage in deep level processing (Ames, & Archer, as cited in Covington, 1999). Lack of engagement can lead to negative affects on performance, and monitoring (Lester, Garofalo, & Kroll, 1989). Engagement can lead to perseverance and an effort to find personally satisfying methods to solve problems (Lester, Garofalo, & Kroll, 1989). Sometimes challenging problems can lead to engagement, but at other times the challenge may lead to not even trying. Students who are intellectually engaged not only want to solve problems, but are interested in using intellectually satisfying methods to do so (Lin, Zabrucky, & Moore, 1997).

6. *Future Value.* As students begin to view future goals as important, persistence increases (Miller, Greene, Montalvo, Ravindran, & Nichols, 1996). Also,

deeper processing and better retention occur when students view future goals as important (Brophy, 1999). Students need to feel that the subject has a purpose and value in their future endeavors, whether a future class or a future career (Brophy, 1999). Evidence also suggests that the importance, utility and interest students feel toward mathematics are better predictors of long term engagement than beliefs about success (Wigfield & Eccles, 1992). Future value also leads to self-regulation, deep processing, and persistence on goal related tasks (Miller, Greene, Montalvo, Ravindran, & Nichols, 1996).

7. *Metacognition.* Metacognition consists of knowledge about how we think and knowledge about what strategies to use and when to use them. Metacognitive actions have been regarded as driving forces in problem solving, influencing all aspects of problem solving behavior (Silver, 1987; Schoenfeld, 1983, 1985). Success in a mathematics class is seen as being related to problem solving ability, since a large proportion of the mathematics curriculum involves solving problems. Successful problem solvers use more metacognitive monitoring skills, while less successful students are unaware of or fail to use these skills (Schoenfeld, 1989). Swanson (1990) found that students with higher metacognitive ability needed fewer steps toward problem solutions than those with lower metacognitive ability. Mevarech (1995) found that metacognitive knowledge was highly correlated with mathematical performance even after general ability was controlled.

8. *Motivation.* Students with greater motivation work harder and longer than those with less motivation (Middleton & Toluck, 1999). Motivation is one of the most pervasive explanations for success or failure in academics. Mathematics classes are no exception, particularly developmental classes where many of the students have had difficulty in the past. Motivation has a pervasive effect on student decision making, supporting engagement and persistence (Meyer, Turner & Spencer, 1997). Lack of motivation prevents students from expending the effort necessary to succeed in mathematics (Kloosterman, 1997).

9. *Persistence.* Persistence has been found to significantly contribute to achievement (Miller, Green, Montalvo, Ravindran, & Nichols, 1996). Many students have the mistaken idea that a person can either do mathematics or cannot (Schoenfeld, 1987). Schoenfeld also found that many students believe that a mathematics problem should be completed in five minutes or less or else it cannot be solved (at least they will be unable to solve it). Students often do not realize that they must persist at a particular problem, even after initial difficulty, if one expects to obtain the correct solution.

10. *Self-efficacy and Perceived Ability:* Self-efficacy is a person's perception of his or her ability to successfully accomplish a task in a particular domain. It is influenced by previous experience, observation of other's experience, verbal persuasion, and affective arousal (Bandura, 1986; Schunk, 1989). It is a domain specific perception and one can have high self-efficacy in one domain and low self-efficacy in another. Self-efficacy is very similar to the idea of perceived ability in the domain. Students who perceive themselves as competent in the domain

are more likely to engage in strategic effort and persist toward achieving their goals (Schunk, 1989). Perceived ability also influences the student's involvement in academic work. Self-efficacy influences willingness to attempt the task, the effort expended, persistence in the face of challenge and academic achievement (Miller, Green, Montalvo, Ravindran, & Nichols, 1996).

11. *Visual Learning.* Learning style theorists have suggested that students are primarily either visual, auditory, or haptic (doing) in their style of learning (Lemire, 1998). Further, instruction that allows students to use their preferred learning style may lead to improved student outcomes (Higbee, Ginter, & Taylor, 1991). There is some evidence that highly visual learners perform better when working with computers (Davis & Bostrom, 1992). Computer generated visual images have also been shown to be beneficial in developing students' understanding of algebraic ideas (Dreyfus & Eisenberg, 1987).

Method

The Participants

Students in this study were enrolled in Elementary Algebra or Intermediate Algebra in the General College at the University of Minnesota. General College provides a lower division curriculum and admits about 900 students each year. Students admitted are from the bottom two-thirds of their high school classes. Approximately 30% of the students are students of color and over half are first generation college students. Students, after taking a mathematics placement exam, consulted with their advisor to determine the course level that they were prepared for and to select the instructional format that they believed would best meet their preferences.

Data Gathering Procedures

In the first year of the study, an inventory was administered that contained 94 items based on the eleven constructs from the education literature. The items were randomly assigned to either Form A or Form B. Within each computer-mediated and lecture class, students were randomly administered either Form A or Form B on the first day of class. To reduce the number of items for use in the second year of the study, three criteria were used. First, items that resulted in the largest differences between the computer-mediated and lecture classes were considered. Second, items that correlated with students' final exam scores were considered. Third, at least one item from each of the constructs discussed earlier was retained. Through this process, the number of items was reduced to 26. These items were administered to all students in the computer-mediated and lecture classes the following year.

In the second year, the inventory containing 26 items was administered to all classes on the first and last days of class during fall semester. Students were asked to indicate their preference for type of instruction. They had the option to mark: (1) computer-based, (2) lecture, and (3) no preference. The results reported in this study are for students who were consistent in their preference for the instructional format that they were enrolled in. That is, they indicated on both the beginning and end of the semester inventories a preference for the same type of instruction, computer-based or lecture. Students who indicated "no preference" at both the beginning and end of the semester are not included. Also, the data reported for each item is only for those students who marked the item on both the pretest and posttest.

Results

The results of the inventory were examined in two ways. First, we examined the results to see if there were any significant differences between the responses of students in the computer-mediated and lecture courses (See Figure 1). An independent samples t-test was used. This test can handle unequal sample sizes. The p-value from a modified t-test was used because it is robust to violations of the equal variances assumption.

Students were given the following choices when answering each item:
(1) disagree
(2) more disagree than agree
(3) more agree than disagree
(4) agree

Thus, it was possible for the means to range from 1 to 4. The end of the semester inventory was selected because we were most interested in students' responses to these items after experiencing computer-mediated or lecture instruction at the General College.

Figure 1. End of semester inventory.

	Course Format	N	Mean	Std. Dev.	Std. Error Mean
1.*I think that computers make life easier.	computer	102	3.60	0.65	0.06
	lecture	184	2.86	1.00	0.07
2.*Computers are not difficult to understand and work with.	computer	101	3.51	0.76	0.08
	lecture	180	2.96	0.94	0.07
3.*I have had a lot of experience using the computer.	computer	101	3.54	0.67	0.07
	lecture	184	2.99	0.92	0.07
4.* I frequently use the internet.	computer	101	3.66	0.62	0.06
	lecture	184	3.34	0.91	0.07
5. I like trying to solve new problems in mathematics.	computer	102	2.72	0.96	0.09
	lecture	184	2.73	0.91	0.07
6. I usually enjoy doing mathematics in school	computer	102	2.68	1.03	0.10
	lecture	184	2.83	1.01	0.07
7. Mathematics is interesting to me.	computer	100	2.72	1.07	0.11
	lecture	184	2.76	1.02	0.08
8. I try to organize the information from mathematics class into main ideas.	computer	102	2.83	0.85	0.08
	lecture	183	2.87	0.86	0.06
9. I think that mathematics concepts can be explained by an underlying structure.	computer	102	2.98	0.70	0.07
	lecture	184	2.93	0.79	0.06

10. If I memorize the rules, I will do well in this mathematics class.	computer	102	3.25	0.74	0.07
	lecture	184	3.11	0.81	0.06
11. *I rely on the instructor to show me how to do the problems.	computer	102	2.14	0.78	0.08
	lecture	183	2.85	0.95	0.07
12. I forget much of what I've studied within a week of the test.	computer	102	2.25	0.91	0.09
	lecture	184	2.34	0.88	0.06
13. I don't want to be embarrassed by not being able to do the work.	computer	102	2.89	1.03	0.10
	lecture	184	2.76	0.98	0.07
14. I classify problems into groups before I begin to work on them.	computer	101	2.49	0.80	0.08
	lecture	184	2.57	0.86	0.06
15. When I finish working a problem, I check my answer to see if it is reasonable.	computer	102	3.24	0.75	0.07
	lecture	184	3.30	0.72	0.05
16. Before I begin a problem, I make sure that I understand what I am being asked.	computer	102	3.32	0.66	0.07
	lecture	184	3.38	0.63	0.05
17. Mathematics is very important to my future studies.	computer	102	2.96	1.02	0.10
	lecture	184	3.02	0.99	0.07
18. Mathematics helps people learn to think.	computer	102	3.35	0.77	0.08
	lecture	184	3.32	0.77	0.06
19. Mathematics is necessary in my chosen field.	computer	102	2.96	1.09	0.11
	lecture	184	2.93	1.02	0.07
20. Learning mathematics will help get me the things I want in life.	computer	102	2.87	0.99	0.10
	lecture	183	2.91	0.89	0.07
21. I periodically review to help me understand important relationships.	computer	102	2.90	0.78	0.08
	lecture	183	3.03	0.76	0.06
22. I am taking this mathematics course because it is important to learn mathematics.	computer	102	3.01	0.93	0.09
	lecture	184	2.97	0.95	0.07
23. If I encounter a difficult problem, I do not give up easily.	computer	102	3.16	0.85	0.08
	lecture	184	3.07	0.81	0.06
24. If I set my mind to it I can solve most math problems.	computer	102	3.25	0.80	0.08
	lecture	184	3.22	0.77	0.06
25. I know how to choose the procedure to use when I start a problem.	computer	102	3.11	0.73	0.07
	lecture	183	3.15	0.71	0.05
26. *If I have a choice between listening and reading I will usually read.	computer	102	2.39	1.18	0.12
	lecture	184	2.05	1.03	0.08

Note. $*p < 0.05$.

Second, we examined the differences (posttest minus pretest) to examine changes in students' responses between the beginning and end of the semester within the computer-mediated and lecture courses (See Figure 2). A positive number indicates that students responded, on average, higher at the end of the semester. A negative number indicates that students responded, on average, lower at the end of the semester. A dependent samples t-test was used for each group.

Figure 2. Differences (posttest-pretest) on the inventory.

		Elementary Algebra		Intermediate Algebra	
Construct		computer	lecture	computer	lecture
Attitudes about computers.	1. I think that computers make life easier.	0.09	0.03	0.11	-0.01
	2. Computers are not difficult to understand and work with.	0.12	0.13	0.18*	0.10
	3. I have had a lot of experience using the computer.	0.27*	0.45*	0.22*	0.08
	4. I frequently use the internet.	0.28*	0.40*	0.19*	0.29*
Attitudes about Math.	5. I like trying to solve new problems in mathematics.	0.08	0.06	0.31*	0.21*
	6. I usually enjoy doing mathematics in school.	0.24	0.32	0.22*	0.26*
	7. Mathematics is interesting to me.	0.09	0.01	0.21*	0.22*
Beliefs about Math.	8. I try to organize the information from mathematics class into main ideas.	0.19	0.01	0.11	0.15
	9. I think that mathematics concepts can be explained by an underlying structure.	-0.02	-0.11	0.13	0.16
	10. If I memorize the rules, I will do well in this mathematics class.	0.09	-0.09	0.17	-0.01
Depth of Processing	11. I rely on the instructor to show me how to do the problems.	-0.45*	-0.31*	-0.44*	-0.27*
	12. I forget much of what I've studied within a week of the test.	-0.34*	0	0	0.10

	13. I don't want to be embarrassed by not being able to do the work.	-0.23	-0.33*	-0.16	-0.31*
	14. I classify problems into groups before I begin to work on them.	0.25	0.22	0.20	0.31*
Intellectual Engagement.	15. When I finish working a problem, I check my answer to see if it is reasonable.	-0.18	-0.30*	0.09	-0.07
	16. Before I begin a problem, I make sure that understand what I am being asked.	0.09	-0.05	0.10	-0.01
Future Value.	17. Mathematics is very important to my future studies.	-0.17	-0.05	0.16	-0.15
	18. Mathematics helps people learn to think.	-0.21	-0.22*	0.06	0.04
	19. Mathematics is necessary in my chosen field.	0.03	-0.07	0.10	-0.13
	20. Learning mathematics will help get me the things I want in life.	-0.13	-0.17	-0.10	-0.03
Meta-cognition.	21. I periodically review to help me understand important relationships.	0.11	0.23	0.04	0.10
Motivation.	22. I am taking this mathematics course because it is important to learn mathematics.	-0.43*	-0.29*	0.01	-0.10
Persistence.	23. If I encounter a difficult problem, I do not give up easily.	0.12	0.08	0.17	0.03

	24. If I set my mind to it I can solve most math problems.	0.32*	-0.11	0.12	0.08
Self-efficacy and perceived ability.	25. I know how to choose the procedure to use when I start a problem.	0.54*	0.30*	0.40*	0.29*
Visual Learning.	26. If I have a choice between listening and reading I will usually read.	0.26	0.21	0.05	0.05

Note. *$p < 0.05$.

Because a large number of significance tests were conducted we also considered familywise Type I error rates. Each test was conducted using $\alpha = .05$ as a criterion to determine significance. A Type I error rate of $\alpha = .05$ indicates that there is a 5% chance that a result identified as significant was in fact due to chance. In Figure 1, there were 26 tests conducted so we would expect that slightly more than one significant result was due to chance. In Figure 2, there were 104 tests conducted so we would expect to obtain about 5 significant results due to chance alone.

Discussion of the Inventory

Students in the computer-mediated courses responded significantly higher on the items related to attitudes about computers than students in lecture courses as shown in Figure 1. To some extent this is not surprising since students in the computer-mediated courses used computers during class. However, most of the students in this study were also enrolled in a writing course that made extensive use of computers. In Figure 2, questions 1 and 2, it is worth noting that the posttest minus pretest difference was positive for the computer-mediated students. This provides evidence that, at the very least, the computers themselves were not an obstacle to students learning mathematics.

The outcomes that we found most interesting in Figure 1 were those for items 11, 25, and 26. In item 11, "I rely on the instructor to show me how to do the problems," the responses for the lecture students at the end of the semester were significantly higher than for students in the computer-mediated courses. What was most interesting, however, is that the posttest minus pretest differences for both groups, as shown in Figure 2, were negative and significant. This means that students in each group were significantly less likely to rely on the instructor to show them how to do problems at the end of the semester. This suggests that both groups of students exhibited greater depth of processing at the end of the semester than at the beginning of the semester.

In item 25, "I know how to choose the procedure to use when I start a problem," the responses for computer-mediated and lecture students were not significantly different at the end of the semester. However, the posttest minus pretest differences for students in both groups, as shown in Figure 2, were positive and significant. This means that students in both groups were significantly more likely to feel that they knew how to choose the procedure to solve a problem at the end of the semester than at the beginning of the semester. This is encouraging since it suggests that students in both computer-mediated and lecture courses exhibited greater self-efficacy at the end of the semester than at the beginning of the semester.

In item 26, "If I have a choice between listening and reading I will usually read," the responses for the computer-mediated students were significantly higher than for students in lecture courses. Students in all groups exhibited a greater tendency to prefer to read than to listen by the end of the semester, though none of the posttest minus pretest differences were significant. This is encouraging as far as computer-mediated instruction is concerned since it suggests that students' experiences using software to receive instruction were sufficiently adequate that they continued to prefer to learn primarily through reading using the software, as opposed to primarily listening in a lecture course.

At the end of the semester we conducted focus groups in part to better understand why students self-selected into computer-mediated classes. The most common reason was that students simply wanted to avoid learning math in a lecture course. Some students had poor experiences learning math through lecture in high school for a variety of reasons, including instructors who did not effectively present the content, instructors who were rude to students, and because the pace of the class did not move at the pace that fit the student's preferences. To these students, the attraction of computer-mediated instruction was primarily that they could avoid lecture instruction. Only one student out of 33 in the focus groups thought she had any idea at all about computer-mediated instruction when she enrolled. Besides wanting to avoid lecture, students also mentioned wanting greater control over their own learning, which includes the pace that they navigate through the lessons. Students who enrolled in lecture classes did so primarily because they wanted to learn by watching and listening to the teacher explain the material, and because they wanted to be in a class where there is whole class discussion.

This study shows that while the characteristics of students who enroll in computer-mediated and lecture classes are likely different in some respects, it also shows that they have much in common. Even though many of the items in this study did not result in significant differences between the computer-mediated and lecture students, the information is still useful. As instructors and institutions attempt to determine which students are best suited for computer-mediated and lecture courses, they can draw upon the results of this study as they develop instruments or guidelines for placing students into computer-mediated and lecture courses.

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