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# Performance of Students with Different Learning Preferences in Traditional First Semester Calculus

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## Abstract

The present study sought to examine mathematical performance of students with different learning preferences in traditionally taught first semester calculus as well as its relationship with learning preference, spatial ability, and verbal-logical reasoning ability. Data were collected from 86 students enrolled in two sections of first semester calculus at a large state university located in the Southeastern U. S. Although the study was too small to enable generalizations, the results suggest that mathematical performance is not related to learning preference, and students do not differ in their calculus performance due to a mismatch between the instructional mode and their learning preference.

**Keywords:** Calculus Instruction, Calculus Performance, Spatial Ability, Verbal-Logical Reasoning Ability, Learning Preference

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# INTRODUCTION

Since the beginning of the reform calculus movement in 1990s, efforts have been made to promote the use technology and visualization and to shift the focus from procedural skills to conceptual understanding (Chappell & Killpatrick. 2003; Wilson,1997; Windham, 2008; Wu, 1999). Despite the resistance to the shift in instruction promoted by the new reform (Wilson,1997; Windham, 2008; Wu, 1999), nowadays, in majority of calculus textbooks, topics are presented in multiple representations with emphasis on technology applications and exploration of real-world problems (Hughes-Hallet et al. 2002; Stewart, 2008).

Most research to date has focused on comparing students in traditional and reform calculus courses (Bookman & Friedman, 1994; Chappell & Killpatrick, 2003; Meel, 1998; Park & Travers, 1996; Roddick, 2001). This research is warranted, and the results have provided comprehensive analyses of students' performances and difficulties in calculus courses. However, few studies (Haciomeroglu, 2012; Haciomeroglu, Chicken, & Dixon, 2013; Suwarsono, 1982) examined mathematical performance of students with different learning preference (or style) in traditional courses. The role of learning preference and cognitive ability on calculus performance is still rather unclear. Therefore, the present study not only examined mathematical performance of students with different learning preferences in traditionally taught first semester calculus but also analyzed its relationship with learning preference, spatial ability, and verbal-logical reasoning ability.

## Background

There is evidence that students learn in different ways. Students, who prefer visual component of thinking, learn better with visual representations and methods of instruction. Others, who prefer analytic component of thinking, learn better with analytic (i.e., algebraic, numeric) representations and methods of instruction. Mismatches might occur between the learning styles of students and the teaching style of the instructor, and it is argued that students learn better when lessons are presented in their preferred mode of representation (Mayer & Massa, 2003; Sternberg, Grigorenko, & Zhang, 2008).

Research has identified various factors underlying differences in preference for visual or analytic processing (or solution methods). Ben-Chaim, Lappan, and Houang (1989) found significant differences in preferences among middle school students by grade level prior to the instruction. Haciomeroglu (2012) added the finding that the mode of representation and task difficulty were factors influencing the students' preference for visual or nonvisual methods. The students used more visual methods when presented with graphic calculus tasks and more nonvisual methods when presented with algebraic calculus tasks. Other research has shown that preference for visual or analytic processing was not related to spatial and verbal-logical reasoning abilities (e.g., Haciomeroglu, 2015; Haciomeroglu et al., 2013, 2014; Hegarty & Kozhevnikov, 1999; Lean & Clements, 1981; Moses, 1977; Suwarsono, 1982).

Past studies have shown differences in mathematical performance between visualizers and analyzers. For instance, Lean and Clements (1981) reported that spatial ability and knowledge of spatial conventions were not factors significantly affecting mathematical performance of engineering students, and that analytic students' scores on spatial and mathematical tests were found to be significantly better than visual students. Lowrie (2001), on the other hand, found that students who used visual methods effectively performed significantly better in solving mathematical problems than analytic students. Similarly, Haciomeroglu et al. (2013) concluded that visualizers scored significantly higher than visualizers on the calculus tests, indicating that stronger preference for visual thinking was associated with higher calculus performance. In the study by Galindo (1994), there were no significant differences in calculus performance between visual and analytic students who received different types of instruction (i.e., graphing calculator, Mathematica, and no technology). By the end of the course, no significant change occurred in students' preferred mode of processing mathematical information. Similarly, Samuels (2010) concluded that preference for mathematical representations did not have a significant effect on calculus performance. Having analyzed solution strategies of elementary and middle school students to determine their visual preference, Moses (1977) and Suwarsono (1982) concluded that preference for visual or analytic solution methods and problem-solving performance did not correlate significantly. Hegarty and Kozhenikov (1999) reported a similar finding that preference for visual or analytic solution methods did not correlate with problem-solving performance, spatial ability, verbal ability, and nonverbal reasoning ability. Other research has shown positive correlations between visual preference and mathematical performance. Haciomeroglu (2016), Haciomeroglu and Chicken (2012) and Haciomeroglu et al. (2013) concluded that calculus performance was related to both spatial ability and visual preference. Bremigan (2005) and Ferrini-Mundy (1987) found a strong relationship between spatial visualization ability and calculus. Taken together, these studies appear to suggest that research findings relating mathematical performance to learning preference are not conclusive. Thus, the following research questions were investigated in the present study:

What is the relationship between verbal-logical reasoning ability, spatial ability, learning preference, and calculus performance?

Do students of different learning preference differ in mathematical performance in traditionally taught first semester calculus?

## METHOD

This quantitative study examined mathematical performance of college students with different learning preferences in traditionally taught first semester calculus and its relationship with learning preference, spatial ability, and verbal-logical reasoning ability.

### Participants

A large state university located in the Southeastern U. S. was the setting for the study. The participants were 90 college students who were enrolled in two sections of Calculus I taught by the same instructor. All 90 students agreed to participate in the study. Four students who failed to take all tests were not included in this analysis. Of the 86 students, 52 percent of the students were males, and 48 percent were females. Sixty-nine students took calculus for the first time, and seventeen students took a high school calculus course (i.e., Honor’s Calculus, Advanced Placement Calculus AB, and Advanced Placement Calculus BC)

### Procedure

Three class visits were made during semester: the first visit was at the beginning of the semester, and the other two visits were made after students took a midterm exam covering limits, derivatives, and graphing. All students received standardized instructions and were tested in their classrooms.

### Descriptions of the Textbook and the Instructional Practices

Majority of the calculus texts, including traditional ones with emphasis on procedures and proofs, have been revised to include the use of real-life applications, technology, projects, and multiple representations. The calculus text created by the Harvard Consortium (Hughes-Hallett et al., 2002), addressed the major outcomes of the work of organizations for reform. Compared to the Harvard Consortium Calculus, the Stewart textbook (2008), which is considered as a more traditional text, was used in both sections. This text focuses more on precise definitions, procedures, and proofs. Although it involves the solution of real-life problems and the use of multiple representations, concepts are occasionally presented graphically, and the real-life applications of differentiation are discussed in a separate section rather than throughout the chapter.

The instructor indicated that he had a strong preference for analytic representations when learning a mathematical concept, and that he presented work in analytic form with no graphical or geometric connection at least 75% of the time. Graphs were seldom used. Graphs may occasionally be referenced, but they were not used to demonstrate a concept or solution as a stand-alone description or explanation. The instructor introduced procedures, algorithms, definitions, and concepts with examples from the text. Calculators were not allowed in class and on quizzes and in-class exams.

**Instruments and Measures**

Data were gathered for three cognitive variables (spatial ability, verbal-logical reasoning ability, and learning preference) and three calculus performance variables (midterm, graphic derivative, and algebraic derivative). The version of the Mental Rotation test (Vandenberg & Kuse, 1978), revised by (Peters et al., 1995), was used to measure spatial ability. The Mental Rotation Test MRT(A) consists of 24 multiple choice items, each of which has a three-dimensional target figure and four other drawings are shown to the right of this target. Two of these can be made to match the target after they are subjected to mental rotation, while two cannot be made to match, regardless of how they are rotated. A score of 1 was given if both correct figures were identified, and a score of 0 was given when any other answer was produced.

Verbal-logical reasoning ability was measured by the Nonsense Syllogisms and the Diagramming Relationships tests, which are part of the Kit of Reference Tests for Cognitive Factors (Ekstrom, French, & Harman, 1976). Both of these tests have 15 items. Each item in the Nonsense Syllogisms Test is a formal syllogism, in which statements are nonsense and cannot be solved by reference to past learning. The participant determines whether or not conclusions drawn from the statements show good reasoning. In each item in the Diagramming Relationships test, three groups of things are given, and the participant selects one of five diagrams, which shows the correct relationships among the three groups. The scores on these two tests of verbal-logical reasoning ability were averaged to create a composite score for each student.

At the beginning of the semester, the students were given the Pre-Learning Preference Questionnaire, consisting of 1 item, and were asked to indicate their learning preference, on a 5-point Likert scale ranging from 1 (strongly more algebraic than visual) to 5 (strongly more visual than algebraic), their learning preference for visual or algebraic representations when learning a mathematical concept. After students learned to compute limits and derivatives and took the first midterm exam, their learning preference in the context of specific calculus tasks was assessed by the Post-Learning Preference Questionnaire. The questionnaire consists of 3 items, and each of which presents a calculus task (i.e., limit, differentiability, and sketching derivative graph) algebraically and visually, and requires a response on a 5-point scale ranging from 1 (strongly more algebraic than visual) to 5 (strongly more visual than algebraic). The questionnaires used in this study were inspired by Mayer and Massa's (2003) Verbal-Visual Learning Style Rating (VVLSR).

The scores on the midterm exam were collected. The primary topics covered in the exam included limits and differentiation. In addition, ten derivative tasks (7 graphic and 3 algebraic), which required sketching the graph of the derivative given the graph or the equation of a function, were administered to assess the students' calculus performance. The students received a score of 1 for each correct answer, and a score of 0 for each incorrect answer. The derivative tasks yielded two scores for each student: scores on the seven graphic tasks and three algebraic tasks.

## RESULTS

Means and standard deviations for each of the 7 measures appear in Table 1. Pearson product-moment correlations between all possible pairings of these measures are shown in Table 2. The three measures of calculus performance correlated significantly with each other. Midterm did not correlate significantly with any cognitive measure. Graphic derivative significantly correlated with spatial and verbal-logical reasoning abilities, whereas algebraic derivative only correlated with spatial ability. There was a positive but nonsignificant correlation between pre- and post-learning preferences. The pre- and post-learning preferences did not correlate significantly with any measure.

**Table 1. Means and Standard Deviations of Measures (N = 86)**

| Measure | Label | M | SD | Min | Max |
|---|---|---|---|---|---|
| 1. Midterm Score | Midterm | 76.63 | 12.73 | 31 | 96 |
| 2. Performance on Graphic Derivative | Graphic Derivative | 4.21 | 2.28 | 0 | 7 |
| 3. Performance on Algebraic Derivative | Algebraic Derivative | 0.94 | 0.90 | 0 | 3 |
| 4. Spatial Ability | Spatial Ability | 11.41 | 5.10 | 1 | 22 |
| 5. Verbal-Logical Reasoning Ability | VLR Ability | 6.65 | 2.96 | 0.25 | 15 |
| 6. Pre-Learning Preference Questionnaire | Pre-Learning Preference | 3.30 | 0.92 | 1 | 5 |
| 7. Post-Learning Preference Questionnaire | Post-Learning Preference | 3.72 | 0.97 | 1 | 5 |

**Table 2. Correlation Matrix for Seven Measures**

| Measure | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| 1. Midterm | — | | | | | | |
| 2. Graphic Derivative | .43** | — | | | | | |
| 3. Algebraic Derivative | .28** | .53** | — | | | | |
| 4. Spatial Ability | .16 | .31** | .22* | — | | | |
| 5. VLR Ability | .19 | .32** | .10 | .31* | — | | |
| 6. Pre-Learning Preference | −.13 | −.08 | −.05 | .01 | −.06 | | |
| 7. Post-Learning Preference | −.03 | .09 | .04 | .13 | .04 | .07 | — |

*$p < .05$. **$p < .01$.

The students' learning preferences for visual or algebraic representations were assessed by the Pre-Learning Questionnaire at the beginning of the semester, and the results are shown in Table 3. After they took the midterm exam covering limits and derivatives, the Post-Learning Preference Questionnaire was administered. The students' responses to the questionnaire are summarized in Table 4. The results are interesting in that the number of students who preferred algebraic representations almost remained the same despite traditional instruction, and that almost half of the students with equal preference for visual or algebraic representations developed a strong or moderate preference for visual representations. After the midterm, there were more students with a strong or moderate preference for visual representations than students who preferred algebraic representations or both modes of representation equally. In both groups (i.e., all students and first-time calculus students), approximately 10% of the students had a moderate or strong preference for algebraic representations, and 25% indicated equal preferences for learning with visual and algebraic representations, whereas more than 60% of the students had a strong or moderate preference for visual representations.

**Table 3. Frequencies of the Student Responses at the Beginning of the Semester**

| | Learning Preference | | | |
|---|---|---|---|---|
| | Algebraic | Equally Algebraic and Visual | Visual | Total |
| All Students | 13 (15%) | 39 (45%) | 34 (40%) | 86 |
| First-time Calculus | 8 (12%) | 34 (49%) | 27 (39%) | 69 |

**Table 4. Frequencies of the Student Responses After the Midterm**

| | Learning Preference | | | |
|---|---|---|---|---|
| | Algebraic | Equally Algebraic and Visual | Visual | Total |
| All Students | 10 (12%) | 22 (25%) | 54 (63%) | 86 |
| First-time Calculus | 7 (10%) | 17 (25%) | 45 (65%) | 69 |

A multivariate analysis of variance (MANOVA) tested for differences in calculus performance scores on the midterm, and graphic and algebraic derivative tasks. The factor considered was post-learning preference with three categories (i.e., algebraic, visual, and equal preference for both modes of representation). The multivariate result was not significant, $F$ (6, 164) = 0.431, p = 0.858; Pillai's Trace = 0.031, indicating that students with different learning preferences did not differ in their midterm, graphic derivative, and algebraic derivative scores.

To compare the students with differing levels of calculus performance, they were divided into four groups according to their midterm scores: twelve students with a score of 90 or higher, thirty-one students with scores between 80 and 89, twenty-two students with scores between 70 and 79, and twenty-one students with a score of 69 or lower. A MANOVA did not indicate significant differences in the means of learning preference, spatial ability, and verbal-logical reasoning ability, $F$(9, 246) = 1.472, p = 0.159, Pillai's Trace = 0.153, over the levels of the midterm factor.

## CONCLUSIONS

The present study examined the relationship between calculus performance, learning preference, spatial ability, and verbal-logical reasoning ability. As expected, calculus performance measures correlated with each other. Although significant correlations were found between derivative tasks and spatial and verbal-logical reasoning ability, midterm did not correlate significantly with any measure. A possible explanation is that the midterm exam also covered limits and derivatives requiring mastery of procedural skills and knowledge of procedures.

There were weak positive correlations between learning preference and spatial and verbal-logical abilities, suggesting that cognitive abilities did not predict students' preference for learning with visual or algebraic representations, consistent with previous research findings (Haciomeroglu, 2015; Haciomeroglu et al., 2013, 2014; Hegarty & Kozhevnikov, 1999; Lean & Clements, 1981; Moses, 1977; Suwarsono, 1982).

The results are interesting in that majority of the students indicated a strong or moderate preference for visual representations although the instructor presented work in analytic form with no graphical or geometric connection most of the time. This is not consistent with evidence presented in other investigations of learning preferences (Galindo, 1994), suggesting that students' preferred mode of processing mathematical information did not change under different instructions. The differences in results of these studies may have been associated with the different populations or measures which were used. Given the methodology used in this study, it was not possible to determine why many students who equally preferred algebraic and visual representations developed a strong or moderate preference for visual representations under traditional instruction. Perhaps they relied more on graphs and visual representations in the text as they learned the concepts of limit and derivative. Another explanation may be the fact that that the students, who formed study groups outside of class, might have worked with visual learners or focused more on visual solution methods in their groups.

Differences in mathematical performance between different learners have been widely documented (Haciomeroglu et al., 2013, 2014; Lean & Clements, 1981; Lowrie, 2001). Our analyses of the data showed no significant differences in calculus performance related to learning preference. That is, the students with different learning preferences (i.e., algebraic, visual, and both) did not differ in their scores on the midterm exam and derivative tasks presented algebraically and graphically. This result is in line with previous studies (Galindo, 1994; Samuels, 2010), showing that there were no significant differences between students with different learning preferences. More evidence in support of this finding comes from the comparisons of the students with differing levels of calculus performance. When the students were divided into subgroups according to their midterm scores, no statistically significant differences in spatial ability, verbal-logical reasoning ability, and learning preference were found between students with differing calculus performance levels. Although the study was too small to enable generalizations, the results suggest that mathematical performance is not related to learning preference, and students do not differ in their calculus performance due to a mismatch between the instructional mode and their learning preference.

**Limitations of the Study**

Some of the limitations of the study include a relatively small sample size and volunteer sampling. That is, they were volunteers enrolled in AP calculus classes at the time of the study. Lastly, the students were willing to participate in the study. However, we were unable to administer fewer tests per day due to the time restrictions. Results might have been higher under better research conditions.

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