

**Surprising Effects of Inquiry-Based  
Learning**

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**Math Fest 2005**

**Albuquerque, NM**

**August 5, 2005**

**Abstract:**

When inquiry-based learning is used in classes before the “transitions” course, there are surprising effects on the students ability to write proofs. Students who had a Modified Moore Method Calculus III course have better self-evaluation skills and are more able to ask appropriate questions to improve their conceptual understanding than students who enrolled in a lecture-oriented Calculus III course. These groups and this surprising effect of inquiry-based learning will be discussed.

## Comparison of the Two Calculus III Sections

Weight of assignments for course grade

| Fall 2003<br>Traditional |     | Fall 2004<br>Modified Moore Method |     |
|--------------------------|-----|------------------------------------|-----|
| Presentations            | 10% | Presentations                      | 30% |
| Quizzes                  | 15% | Quizzes                            | 10% |
| Exam 1                   | 15% | Exam 1                             | 15% |
| Exam 2                   | 15% | Exam 2                             | 15% |
| Exam 3                   | 15% |                                    |     |
| Final Exam               | 30% | Final Exam                         | 30% |

## Calculus III

### Fall 2003 (Traditional)

Primarily Lecture

Two quizzes per week

Students present challenging HW on Mondays

### Fall 2004 (Modified Moore Method)

Primarily student presentations

Supplemented with mini-lectures

Two quizzes per week

## Calculus III Demographics

|  | Fall 2003<br>Traditional | Fall 2004<br>MMM |
|--|--------------------------|------------------|
| <i>Gender</i>                          |                          |                  |
| Male                                   | 4                        | 6                |
| Female                                 | 12                       | 9                |
| <i>Grade Distribution from Calc II</i> |                          |                  |
| Retakes                                | 4                        | 3                |
| A                                      | 3                        | 1                |
| B                                      | 7                        | 7                |
| C                                      | 6                        | 6                |
| <i>Class Standing</i>                  |                          |                  |
| Freshman                               | 1                        | 1                |
| Sophomore                              | 5                        | 5                |
| Junior                                 | 5                        | 4                |
| Senior                                 | 4                        | 3                |

**Difference in Course Calculus III Grades?**

| Grade Assigned | Fall 2003   | Fall 2004 |
|----------------|-------------|-----------|
|                | Traditional | MMM       |
| A              | 1           | 5         |
| B              | 4           | 0         |
| C              | 9           | 6         |
| D              | 1           | 1         |
| F              | 1           | 3         |

No statistically significant differences

## A Comparison of Final Exam Questions Calculus III

| <b>Topic</b> | <b>Average % of pts earned</b> |                  |
|--------------|--------------------------------|------------------|
|              | <b>Fall 2003</b>               | <b>Fall 2004</b> |
| Defns        | 48.75                          | 79.78            |
|              | $P = 0.0024_s$                 |                  |
| Proj. motion | 70.31                          | 72.85            |
|              | $P = 0.4286$                   |                  |
| Max/Min      | 69.79                          | 66.43            |
|              | $P = 0.2783$                   |                  |
| Eqn of plane | 64.84                          | 68.57            |
|              | $P = 0.4207$                   |                  |
| Jacobian     | 50                             | 42.85            |
|              | $P = 0.1762$                   |                  |
| Volumes      | 68.75                          | 72.14            |
|              | $P = 0.3557$                   |                  |
| Limit        | 78.125                         | 89.28            |
|              | $P = 0.1314$                   |                  |

## Qualitative Differences on the Calculus III Final

- Compared each pair of “common” questions
- Classified mistakes as:
  - All points earned
  - Minor error
  - Did not complete
  - Major error
  - Skipped
- No statistically significant differences

| <i>Fall 2003</i>                                 |              |              |              |                |
|--|--------------|--------------|--------------|----------------|
| <b>Error</b>                                     | <b>Proj.</b> | <b>Limit</b> | <b>Plane</b> | <b>Max/Min</b> |
| All points earned<br>or Minor error              | 10           | 13           | 10           | 10             |
| Did not complete<br>or Major error<br>or Skipped | 6            | 3            | 6            | 6              |
| <i>Fall 2004</i>                                 |              |              |              |                |
| <b>Error</b>                                     | <b>Proj.</b> | <b>Limit</b> | <b>Plane</b> | <b>Max/Min</b> |
| All points earned<br>or Minor error              | 11           | 12           | 9            | 4              |
| Did not complete<br>or Major error<br>or Skipped | 3            | 2            | 5            | 10             |
| $\chi^2$   | 1.5429       | 0.1831       | 0.9714       | 6.876          |

## Performance in Future Classes

| <i>Traditional Calculus III, Intro. to Math Thought Spring 2004</i> |                                |        |        |         |        |
|---|--------------------------------|--------|--------|---------|--------|
| Grade<br>in Calc III  | Grades in Intro. Math. Thought |        |        |         |        |
|   | HW                             | Exam 1 | Exam 2 | Final   | Course |
| B   | 75                             | 79     | 56     | 49      | 59     |
| C   | 73                             | 77     | 48     | 47      | 57     |
| C   | 69                             | 69     | 46     | 45      | 47     |
| C   | 32                             | 59     | 40     | 27      | 37     |
| C   | 30                             | 55     | 40     | 22      | 32     |
| C   | 13                             | 52     | 35     | no exam | 17.25  |
| C   | 11                             | 39     | 12     | Quit    | Quit   |
| C   | 7.5                            | Quit   | Quit   | Quit    | Quit   |
| F   | 6                              | Quit   | Quit   | Quit    | Quit   |
| <b>Average</b>  | 35                             | 61     | 39     | 38      | 49     |

  

| <i>MMM Calculus III, Intro. to Math Thought Spring 2005</i> |                                |                     |                     |                     |                     |
|---|--------------------------------|---------------------|---------------------|---------------------|---------------------|
| Grade<br>in Calc III  | Grades in Intro. Math. Thought |                     |                     |                     |                     |
|   | Quiz                           | Exam 1              | Exam 2              | Final               | Course              |
| A   | 99                             | 96                  | 92                  | 95                  | 94                  |
| A   | 97                             | 94                  | 90                  | 87                  | 90                  |
| A   | 96                             | 91                  | 89                  | 84                  | 89                  |
| A   | 95                             | 91                  | 79                  | 83                  | 89                  |
| C   | 90                             | 80                  | 79                  | 79                  | 73                  |
| C   | 79                             | 65                  | 60                  | 75                  | 71                  |
| C   | 75                             | 62                  | 57                  | 59                  | 71                  |
| C   | 63                             | 59                  | 43                  | 55                  | 60                  |
| <b>Average</b>  | 86.75                          | 79                  | 85                  | 77                  | 79                  |
| <i>P</i> -value   | 0.0192 <sub>s</sub>            | 0.0162 <sub>s</sub> | 0.0009 <sub>s</sub> | 0.0018 <sub>s</sub> | 0.0015 <sub>s</sub> |

## Conclusions

- No quantitative differences in Calc. III
- No qualitative differences in Calc. III
- Quantitative differences in future mathematics courses

## Future Work

- Test students' retention of Calc. III material
- Follow up with comparisons in future mathematics courses