Abstract Title: Inquiry and Didactic Instruction in a Computer-Assisted Context: a Quasi-Experimental Study

MSP Project Name: Greater Birmingham Mathematics Partnership

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120 word summary:

We compare incorporating inquiry-based sessions versus traditional lecture sessions, and a blend of the two approaches, in an elementary algebra course in which the pedagogy consistent among treatments is computer-assisted instruction. We hypothesize that inquiry-based sessions benefit students significantly in terms of mathematical content knowledge, problem-solving, and communications. Students are randomly assigned for the semester to one of three treatments (two inquiry-based meetings, two lecture meeting, or one of each, weekly). Measures, including pre- and post-tests with both open-ended and objective items, are described. Statistically significant differences have previously been observed in similar quasi-experimental studies of multiple sections of finite mathematics (Fall, 2008) and elementary algebra (Fall, 2009). Undergraduates, including many pre-service elementary teachers, take this developmental algebra course.

- Section 1: **Questions for dialogue at the MSP LNC**.

  - Are the results of this study generalizable to other mathematics courses with different content and source materials.
  - If all treatments result in similar course grades and course test scores, is there value added in addressing the "softer" areas of problem-solving and communications that withstands cost/benefit analysis?
  - If all treatments result in similar gains in accuracy on the objective part of the pre/post-test, what does this say about the added value of inquiry-based instruction?
  - Are blended treatments more accepted by teachers and students?
  - Should pedagogical decisions be based on whether or not students perceive (in the short term) any value in the inquiry-based components of the treatment?

- Section 2: **Conceptual framework**.

  Our definition of *student success* for the aspect of our project on which we are reporting can be operationalized as follows:

  1. Statistically significant growth on the part of students in terms of conceptual understanding, problem solving, explanation, and accuracy as evaluated by educators according to pre-established criteria.

2. Statistically significant growth on the part of students in terms of accuracy as evaluated by objective measures.
3. Effective size of at least 0.5 pre- to post-test in terms of accuracy as evaluated by objective measures.

In order to measure student success as defined above, we gave all students participating in the study, regardless of treatment, a Pre/Post-Test consisting of two parts:

- Part I is a test of content knowledge which incorporates three open-ended problems, evaluated on rubric dimensions of conceptual understanding, evidence of problem-solving, adequacy of explanation, and accuracy. This part is graded blind by four teams of two consensus-reaching graders.
- Part 2 is a test of content knowledge consisting of 25 objective questions whose responses are multiple choice, yes/no, or always/sometimes/never format.

Our research hypothesis is that, of the three treatments (described below), the one affording the most inquiry-based involvement to the students will differentially benefit the students in terms of mathematical content knowledge, reasoning and problem-solving ability, and communications. Our work addresses directly the call for research in this direction in a recent collection of articles "Constructivist Instruction: Success of Failure" (Tobias and Duffy 2009).

The focus of our study is to compare three pedagogical treatments, and evaluate them in terms of their impact on student success. Our methodology is quasi-experimental in that it seeks to remove from consideration as many confounding factors as possible, and to assign treatment on as random a basis as possible, constrained only by students being able to choose the time slot in which they take the course. All students involved in the courses have identical computer-assisted instruction provided in a mathematics learning laboratory. 86% of the grade in the course is determined by evaluation in the computer-assisted context (online homework and supervised online quizzes and tests). The remaining 14% of the grade is determined by one of three pedagogical treatments, described below. Students registered for one of three time periods in the Fall 2010 semester schedule, a 9:00 AM, 10:00 AM or noon time slot, for three days a week (MWF), for their 50 minute class meetings and 50 minute required lab meeting. Students in each time slot were randomly assigned to one of the three treatments for the semester. Three instructors agreed to participate in the experiment. Each instructor teaches in three time slots. In one slot the instructor administers the twice-weekly inquiry-based treatment, in another time slot, the twice weekly lecture treatment, and in a third time slot, the blended treatment. The three instructors consist of a full professor, a regular full-time instructor, and a graduate student with prior teaching experience. All instructors had previous experience in both didactic and inquiry-based teaching, and in computer-assisted instruction. A graduate teaching assistant works with each instructor in the inquiry-based meetings, and in evaluating written student work product from such meetings. Each instructor also meets with each class in the mathematics computer lab. The computer lab meeting for all treatments occurs on Wednesday.

The three pedagogies to be compared are:

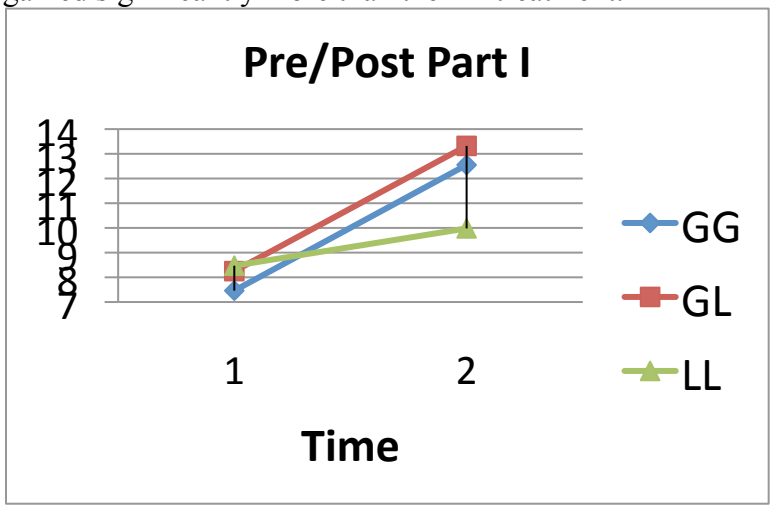
(1) two sessions weekly of inquiry-based group work (random, weekly changing, groups of four) without prior instruction, on problems intended to motivate the topics to be covered in computer-assisted instruction;
(2) two sessions weekly of traditional summary lecture with teacher-presented examples on the topics to be covered in computer-assisted instruction, and
(3) a blend of treatments (1) and (2), with one weekly meeting traditional lecture, and one weekly meeting inquiry-based group work.

In the inquiry-based treatments, each student turns in each class meeting a written report on his/her investigation and solution of the problem(s) posed in that class period. This report is evaluated based upon the same rubric as the open-ended items on the pre/post-test. Students are aware of the rubric and receive written feedback consistent with the rubric. In the lecture treatment, the instructor gives a traditional lecture on the upcoming material. All instructors operate from the same outline of topics for each lecture. The 14% (140 of 1000 points) of the final grade determined by the class meetings differs among the three treatments as follows: (1) 5 points are earned for each of the two weekly reports on the group work; (2) 5 points are earned for attendance at each class meeting; (3) 5 points are earned for the one weekly report on the group work meeting, and 5 points are earned for attendance at the lecture meeting.

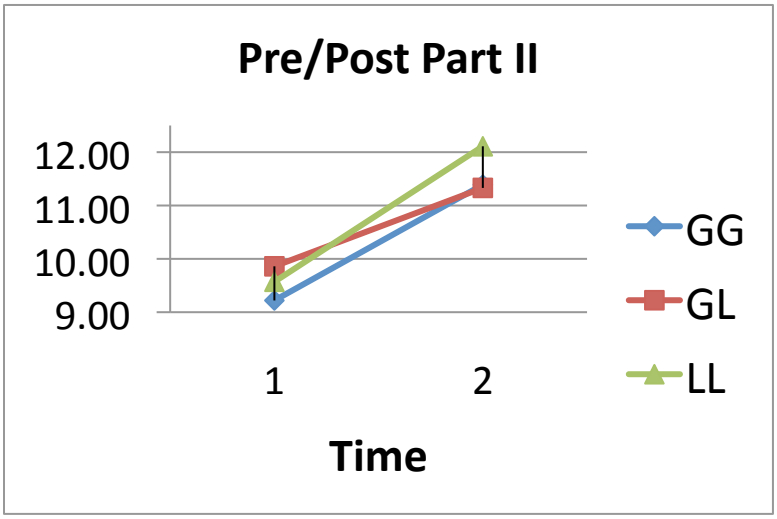
- Section 3: **Explanatory framework**.

Prior to the two most recent studies (Mayer, 2009, 2010), the methodology of simultaneously comparing different pedagogies within one semester, had few direct comparisons in the literature (Doorn, 2007). Some studies have compared different pedagogies over a longer time frame (Gautreau, 1997; Hoellwarth, 2005). The results of the quasi-experimental studies in (Mayer, 2009) of a finite mathematic course, and in (Mayer, 2010) of an elementary algebra course showed in both cases that students in the inquiry-based treatment did significantly better ($p<0.05$) comparing pre-test and post-test performance in the areas of problem identification, problem-solving, and explanation. Moreover, students, regardless of treatment, performed similarly (no statistically significant differences) when compared on the basis of course test scores. Outcomes of the two studies differed in gain in accuracy, pre- to post-test: in the finite mathematics study, there was no significant difference between treatments; in the elementary algebra study there was a significant difference between treatments in favor of the inquiry-based treatment. A limitation of both studies by Mayer was that accuracy was assessed on a small set of open-ended problems. The previous studies also did not test a blend of inquiry-based and traditional class meetings in a single treatment (Marrongelle, 2008). A limitation of the studies by Mayer (2009, 2010) is that the pre/post-test consisted of only three or four open-ended problems which made a reliable evaluation of accuracy gains, if any, problematic. The pre/post-test in the study described herein includes 25 objective questions which have been validated for testing algebraic content knowledge in previous studies. A battery of the previously validated (for content) objective questions was piloted in Summer 2010 on students in the same course, and item analysis was used to select the items for the pre/post-test in this study. As a result of the more careful test design, we expect that differential gains in accuracy between treatments, if present, will be more detectable than in the two earlier studies cited.

Pre- to Post- gains on Part I of the test show that all treatments had statistically significant gains in conceptual understanding, problem-solving, explanation, and accuracy, as scored by the rubric. In the following graphs, GG is the treatment with two weekly inquiry-based class meetings, LL is the two lectures treatment, and GL is blended. Both GG and GL treatments gained significantly more than the LL treatment.



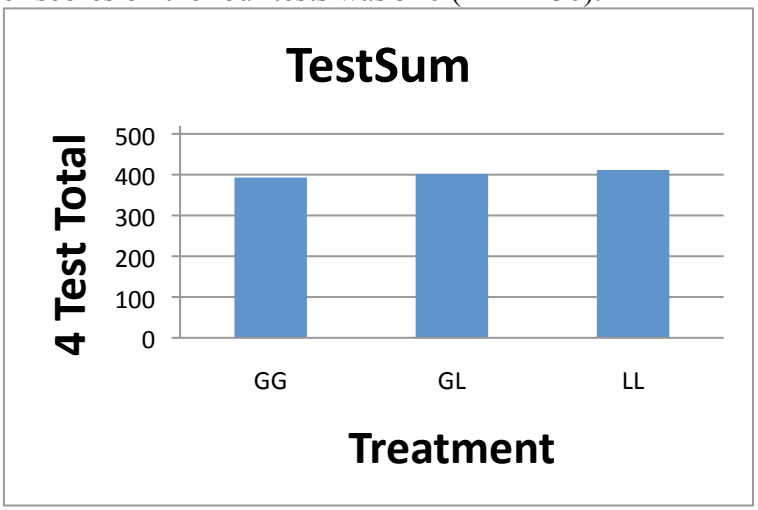
Pre- to Post- gains on Part II of the test, the objective accuracy assessment, showed statistically significant gains for all treatments, but there was not a statistically significant Time*Treatment interaction effect.



The following table indicates that the effect size is moderate to good for all treatments.

	Mean		Standard Deviation		Effect Size
Treatment	Pre	Post	Pre	Post	
GG	9.22	11.39	3.02	2.98	0.72
GL	9.86	11.33	3.44	3.38	0.43
LL	9.57	12.11	3.00	3.32	0.84

There were no statistically significant differences in student scores relative to treatment on the first four of five tests in the course, as shown in the following chart. The maximum sum of scores on the four tests was 520 (= 4 x 130).



We expect this research to inform our teaching of elementary algebra. We value the differential gains made by students in the inquiry-based treatments in conceptual understanding, problem-solving, and ability to explain their thinking. That this impact is made with no diminution in either course test scores, nor objective measures of accuracy gains, pre- to post-, underscores that our judgments about pedagogy must be made based on added-value considerations. Moreover, we expect to extend this study in subsequent years to credit-bearing courses such as intermediate algebra, college algebra, and pre-calculus (Oehtrman, 2008).

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