Inquiry-Based and Didactic Instruction in a Computer-Assisted Context

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One direction taken by course reform over the past few years has been the development of sophisticated computer-assisted instruction. This approach has been applied to large-enrollment service courses in mathematics, including algebra. Elementary algebra is typically taken by under-graduate students who do not place into a credit-bearing course. Traditionally, the goal of such a developmental algebra course has been to enhance students' "algebra skills," for example, dealing procedurally with rational numbers and expressions. Higher-order thinking may be largely absent. Alternately, one might focus on developing quantitative reasoning and communications skills, rather than, or in addition to, training to acquire a set of specific algebraic skills (Wiggins, 1989; Blais, 1988). Our position is that incorporating an inquiry-based component, either together with, or in place of, a didactic component, into a computer-assisted instructional environment may enhance student learning. Two previous studies in the literature bear this out (Mayer, 2009, 2010).

Fundamental Question. We compare three treatments in a quasi-experimental design: (1) two weekly inquiry-based class meetings, (2) two weekly lecture meetings, and (3) one of each meeting weekly. The computer-assisted component is the same for all treatments. Our hypothesis is that, of the three treatments, 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.

Prior Research. 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).

Research Methodology. 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.

The research is underway in Fall, 2010. Data to be gathered includes (1) course grades and test scores, (2) pre-test and post-test of content knowledge based upon a test which incorporates three open-ended problems, evaluated on rubric dimensions of conceptual understanding, evidence of problem-solving, and adequacy of explanation (3) pre-test and post-test of content knowledge based upon a test consisting of 25 objective questions, (3) focus groups selected from each of the nine class sections, (4) student course evaluations using the online IDEA system (IDEA, 2010), and (5) RTOP observations of the instructors in each of the nine class sections (RTOP, 2010; Sawada, 2002). The above data will be gathered and analyzed and will form the basis of the proposed preliminary report. Data and preliminary analysis will be available by December 15, 2010 should this be needed by the committee reviewing proposals.

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 consists of two parts: (A) three open-ended problems, evaluated by a rubric as described above, and (B) 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.

Questions that we pose to ourselves and the audience are as follows:

- Will all treatments result in similar course grades and course test scores?
- Will all treatments result in similar gains in accuracy on the objective pre/post-test?
- Will the inquiry-based and blended treatments result in differentially improved conceptual understanding, problem-solving ability, and mathematics communications skills, as assessed by the open-ended pre/post-test?
- Do students perceive any value in the inquiry-based components of the treatment?

We expect this research to inform our teaching of elementary algebra. Moreover, we expect to extend this study in subsequent years to credit courses such as intermediate algebra, college algebra, and pre-calculus (Oehtrman, 2008).

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