

TEACHING AND LEARNING COLLEGE ALGEBRA WITH THE TI-NAVIGATOR® WIRELESS HANDHELD NETWORK

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Introduction

The potential role of handheld wireless technology in college algebra is particularly important because technology plays an increasingly central role in the lives of university students and mathematics instructors. For example, the students in this study described ease and comfort with technology, including owning a graphing calculator and using it in virtually all of their mathematics courses since the ninth grade. Additionally, meta-analyses of hundreds of studies on calculator usage report primarily positive effects on student learning and attitudes toward mathematics (Ellington, 2003; Hembree & Dessart, 1986). Students' use of graphing calculators while learning algebra, in particular, is associated with improved abilities to make connections between functions and their graphs and enhanced spatial visualization skills (Penglase & Arnold, 1996). However, some experienced teachers and mathematics education researchers describe an obstacle to using graphing calculators effectively: the relatively small screen-size makes sharing mathematics with peers and the instructor difficult for students (Doerr & Zangor, 2000).

The potential hindrances to interacting via handheld technology in the classroom stands in contrast to the importance placed by educators on regular feedback and communication in mathematics classrooms (National Council of Teachers of Mathematics [NCTM], 2000). Opportunities for students to check their work with peers and for formative assessments, i.e., opportunities for teachers to learn about students' thinking and progress, can have positive effects on achievement (Black & Wiliam, 1998). The TI-Navigator provides an approach to improving graphing calculator use in mathematics classrooms by serving as a wireless network between students' handhelds and a teacher's computer, thus providing new opportunities for students to view each other's work and share ideas through calculator-linked activities, "Quick Polls", and presentations.

In our study on the TI-Navigator in college algebra, we had three primary interests. First, we wanted to find out about the promise that a calculator network could provide instructors with frequent high-quality feedback about their students' understanding of algebra content. Second, we hoped to learn about the potential of the TI-Navigator for promoting student engagement and cooperative learning in a course that traditionally suffers from high attrition and failure rates. Third, we wanted to know if students enrolled in a course that regularly used a TI-Navigator might expect higher achievement on exams than students in a similar course that used non-networked graphing calculators.

Teaching with Navigator: The Building Bins Activity

A serious challenge surrounding using the TI-Navigator in college algebra included

developing poll questions, “Learning Check” quizzes, and in-class activity settings for the device. While the course documents and activity handouts we developed are available online at www.unco.edu/NHS/mathsci/facstaff/Champion/CollegeAlgebra/, the “Building Bins” activity illustrates many of the Navigator features and accompanying small- and whole-group learning strategies we found to promote learning college algebra effectively.

The Building Bins activity is a 60-90 minute college algebra activity that combines small-group and whole-class interactions. The activity is designed to incorporate multiple representations of data, numerical and theoretical modeling, linear and quadratic functions, and maximization. Each group receives a handout (see Appendix) with a unique length of fence (e.g., 60 feet, 180 feet) and is asked to draw several arrangements of rectangular-bottom compost bins with a single separator using the given amount of fence. The individual groups then record the dimensions of possible bins in three forms: tabular, graphical, and equation. After completing the initial exploration in small groups, students are prompted via calculators to input and send their equations to the instructor’s computer, which are automatically projected onto a common graph in TI-Navigator’s software. With the projected equations and graphs as a focus, the students’ submissions are discussed as a whole class, with emphasis on comparing and contrasting the many students’ equations and the relationship between the given amounts of fence and the corresponding equations for length as a function of width in the possible bin dimensions. Following this whole-class discussion, students return to their small groups to explore the areas of the bins they have constructed. This small-group exploration ultimately leads to a second submission of area formulas followed by a whole-class discussion of how the varying lengths of fence resulted in contrasting quadratic functions and parabolic trends.

We have found the discussion of area naturally leads to a discussion of intercepts and vertices of the differing groups’ functions. The vertices of the parabolas correspond to maximizing the area of the bins and individual work time and whole-class discussion can lead to a generalized formula for the maximum area in terms of the given total fence length (the maximum area occurs when the width is one-sixth the total fence length). In addition, we have developed a “Building More Bins” activity (available on the website) that is designed to extend the Building Bins problem to multiple-bin configurations given a fixed length. This second activity ultimately leads to generalized formulas for bin dimensions given *both* a fixed quantity of fence and a given number of bins.



Research Design

To investigate the impact of the TI-Navigator on college algebra students’ learning, we designed a controlled experimental study using mixed methods of data collection. Initially, students self-selected to enroll in two time blocks of college algebra. They were then randomly assigned to one of four sections of 32 students, with one section in each time block acting as the control group and the other section the treatment group (see Table 1). To control for effects on achievement due to time or instructor, one instructor taught the treatment group in the first time block and the control group in the second time block, with the roles reversed for the other instructor. The two instructors were graduate teaching assistants with experience teaching college algebra, used the same course materials, syllabi, and exams, and learned the TI-Navigator software as part of the study.

The study included a wide range of research questions, data sources, and methods. This paper summarizes the questions regarding students' achievement on exams, students' perceptions of the TI-Navigator, and students' experiences of feedback.

Table 1.

Summary of the randomized, balanced, and crossed experimental research design.

		Classes	Instructor	Group
Time Block 1		Section 1	A	Treatment
		Section 2	B	Control
Time Block 2		Section 3	A	Control
		Section 4	B	Treatment

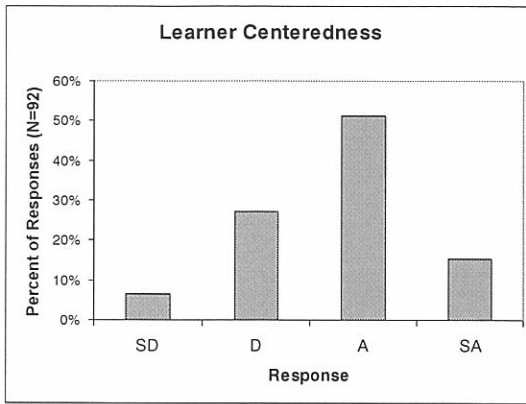
Results and Discussion

Of the 128 students initially enrolled in the four research sections of college algebra, 110 (86% of initial enrollment) completed the course by taking the final exam. This final sample included 72 male students and 38 female students—typical for college algebra at the university. There were no statistical differences in Navigator and control students' performance on the three midterm exams or the final exam. Students in the two groups also performed equally well on procedural and conceptual exam items.

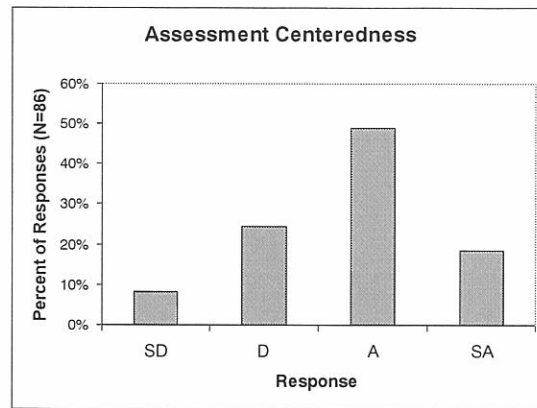
We administered a 16-item Likert-type survey (strongly disagree, disagree, agree, strongly agree) developed by Owens and colleagues (2002) for assessing students' perceptions of the TI-Navigator across four aspects of an effective learning environment: (1) learner centeredness, (2) community centeredness, (3) assessment centeredness, and (4) knowledge centeredness (Bransford et al., 2000). Overall, the students' perceptions of the TI-Navigator on the learning environment were positive. Aggregate survey ratings by students in the two sections were similar along the four dimensions, ranging from 10.2 (learner centeredness in Instructor A's section) to 12.3 (community centeredness in Instructor B's section) out of a possible 16 on each scale. There were no significant differences between the mean survey responses of students in the two Navigator sections. Figure 1 gives the distribution of students' survey responses with some example items.

The qualitative inquiry into students' experiences of multiple sources of feedback also provided some insight into the role of the TI-Navigator and graphing calculators on college algebra students' learning in the courses [see (Champion, 2007) for additional detail]. Students interviewed in both groups cited in-class activities, online homework, and their instructor's non-traditional, limited-lecture style as contributing to their positive perceptions about the course. When it came to feedback about their learning and progress, however, students' cited their classmates, graded assignments, and their instructor as sources of feedback more often than graphing calculators or the TI-Navigator. This led us to the conclusion that the TI-Navigator played a complimentary, if not prominent, role in students' experience of feedback in college algebra.

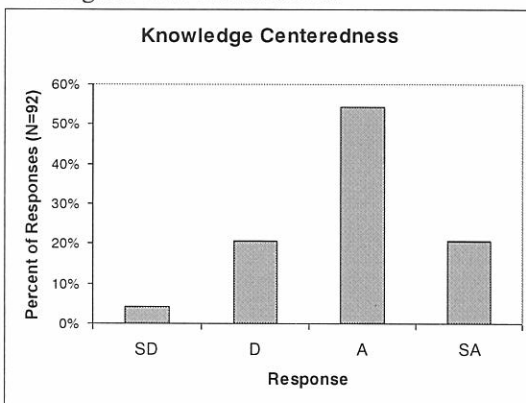
The results of this study indicate the TI-Navigator provides opportunities for interaction among students through interactive activities, which can lead to positive students' perceptions and more informed feedback to instructors about students' understanding.



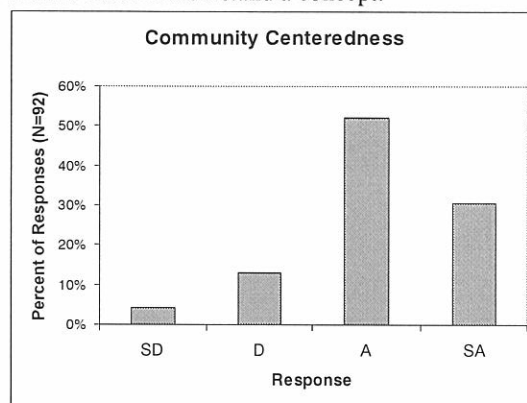
Example Statement: I am more actively engaged in a TI-Navigator class than in others.



Example Statement: The TI-Navigator helps the teacher tell if I understand a concept.



Example Statement: Doing activities in class with the TI-Navigator helps me relate new material to things I already know.



Example Statement: There is a greater sense of community in a TI-Navigator class than in other classes.

Figure 1. Students' survey responses regarding the TI-Navigator.

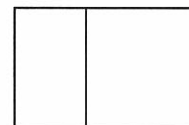
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Appendix: Building Bins

Mary plans to use 60 feet of fencing to make some compost bins in the shape below. Her ultimate goal is to make the largest bins she can.



- 1) Complete the following.
 - a) Draw and label four possible compost bins of different dimensions.
 - b) Create a table that represents the possible dimensions of the bins.
 - c) Briefly describe how the data in the table are changing.
 - d) Graph your data. Put width on the horizontal axis and length on the vertical axis.
 - e) Write an equation that represents length as a function of width.



When prompted, submit your equation to the class through your calculator.

- 2) Based on your observations and the discussion in class, compare your group's equations and graphs to those of the other groups in the class. Include at least two similarities and two differences.
- 3) Now consider the total area enclosed by the bins.
 - a) Find the areas of the bins you drew in the first question.
 - b) Create a table that represents the area as a function of width.
 - c) Briefly describe how the data in the table are changing.
 - d) Graph your data. Put width on the horizontal axis and area on the vertical axis.
 - e) Write an equation that represents area as a function of width.



When prompted, submit your equation to the class through your calculator.

- 4) Mary wants to maximize the area of the compost bins.
 - a) What size should she make the bins to maximize the area? Justify why your answer is correct.



When prompted, submit the dimensions you found to the class through your calculator. If you finish part a) early, move on to the following questions.

- b) How can you use a table to find the maximum area?
- c) How can you use a graph to find the maximum area?
- d) How can you use an equation to find the maximum area?