Spring 2008

Technology in Mathematics Education and Ti-Navigator in the Mathematics Classroom

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TECHNOLOGY IN MATHEMATICS EDUCATION AND TI-NAVIGATOR IN THE MATHEMATICS CLASSROOM

by

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A Research Project Presented in Partial Fulfillment
of the Requirements for the Degree
Master of Education

REGIS UNIVERSITY

May, 2008

ABSTRACT

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Over the past couple of decades, several studies have shown that mathematics achievement in the U.S. is either stagnate or declining while achievement in mathematics education in other countries has been improving. The current state of mathematics achievement on our nation is particularly daunting at a time when knowledge of mathematics is becoming increasingly important to acquire quality jobs. Some researchers believe that the lack of mathematics achievement may negatively affect technological developments and the standard of living in the U.S. One particularly promising technique may be the infusion of technology into mathematics classrooms. The proper use of technology may help raise mathematics achievement and interest in mathematics. More specifically, graphing calculators and the TI-Navigator can be used by teachers to help show increased interest in mathematics subjects and increased conceptual understanding of the material. A PowerPoint presentation summarizing the importance of mathematics and STEM education in the U.S. was developed for this project. The PowerPoint also highlighted material from the creation of a 3 hour staff development introducing the TI-Navigator to mathematics and science teachers.

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Chapter 1

INTRODUCTION

There has been a growing awareness of the pressing need to improve mathematics achievement. The authors of *Rising above the Gathering Storm* (National Academy of Sciences, National Academy of Engineering, & Institute of Medicine (NAS/NAE/IM; 2007) considered that teachers can provide the "highest leverage" (p. 30) in order to increase students' mathematics achievement in school. Secondly, teachers may integrate technology and, more specifically, the TI-Navigator into their mathematics classrooms as a way to teach this current generation of students and to help them to learn mathematics.

Statement of the Problem

Although technology has become an essential part of mathematics classrooms**,** its proper use and the time it takes to learn it can detract from learning the content of mathematics. It is important to know what is reported in the literature in regard to the state of current mathematics education as well as the best use of technology in the mathematics classroom**.** More specifically, what is the effect of the TI-Navigator in the mathematics classroom? What are the benefits of the TI-Navigator and what are the possible pitfalls? How can the TI-Navigator be used to: (a) increase student engagement, (b) increase achievement, and (c) maximize learning?

Background of the Problem

For the past couple of decades, there has been an ongoing discussion about the state of mathematics education. One reason for the discussion was based on the results from the Third International Mathematics and Science Study, also called TIMSS (Mullis et al., 1998)   The study was conducted in 1995 by the International Association for the Evaluation of Educational Achievement (IEA). Twelfth grade students in the United States ranked second for per capita spending while their rank was 21 of 24 for mathematics achievement (Mullis et al.). However, on the accompanying survey, U.S. 12th grade students self-reported the second highest perception of their mathematics abilities. In most of the participating countries, there appeared to be a technology connection. Students with “the highest average achievements were those who reported the highest level of calculator use” (p. 8). While 4th and 8th grade students are tested every 4 years, 12th grade students have not been retested since 1995.

This year, on the upcoming Trends in International Mathematics and Science Study Advanced 2008 Assessment, 12th grade students from 10 countries will be tested (IEA, 2007). However, the U.S. will not participate. The TIMSS was not the only indicator of student mathematical progress in high school. Also, the U.S. 15 year old students who took the Program for International Assessment test in 2003 scored below the International average (NSB/NSF; 2006).

According to the staff of the NSB/NSF (in press), the “science, technology, engineering, and mathematics, STEM, education system is failing to ensure that all American students receive the skills and knowledge required for success in the 21st century workforce” (p. 1). What should people conclude about the U.S. educational system when high school seniors are not prepared for college courses and almost 30% of students in their first year of college are required to take remedial science and mathematics classes?

Stumbo and Lusi (2005) explained that all students need more mathematics than their predecessors because the previous requirements for college admission have become the new requirements for entry level jobs. Currently, those who are employed in minimum wage jobs are required to use more: (a) sophisticated technology, (b) mathematics, and (c) logic skills. Without a strong mathematics education, it will be increasingly difficult for U.S. students to acquire entry level jobs.

According to Stumbo and Lusi (2005), content that used to be expected of college bound students now applies to all students whether they plan on college attendance or joining the workforce. Entry level requirements for noncollege jobs require content that was typically expected only of college bound students. The reason for this change is that the average worker needs higher mathematical skills, including the ability to solve "non-routine, multi-step problems" (p. 2)

Deficient mathematics skills of U.S. students may have a greater impact on the U.S. than many people realize. According to the staff of the NAS/NAE/IM (2007), the danger exists that "many Americans do not know enough about science, technology, and mathematics to contribute to, or benefit from, the knowledge-based society that is already taking shape around us" (p. 314). The potential impact could affect both the standard of living and technological advancements in the U.S. The staff stated,

> The United States is today an importer of high technology products. Its trade balance in high technology manufactured goods shifted from plus $54 billion in 1990 to negative $50 billion in 2001. (p. 14)

It is important to consider the long term trends in the number of graduates who earn natural science and engineering degrees relative to the number of graduates who earn similar degrees in other countries. In 1975, the U.S. (NSB/NSF, 2003) ranked third in the number of graduates of natural science and engineering degrees. By 1999, the U.S. ranked 14th in the number of natural science and engineering degrees obtained by graduates. The U.S. had fallen 11 places in 14 years.

> The critical lack of technically trained people in the United States can be traced directly to poor K-12 mathematics and science instruction. Few factors are more important than this if the United States is to compete successfully in the 21st century. (NAS/NAE/IM, 2007, p. 2)

One of the most important uses of technology may be in the mathematics classroom to help U.S. students increase both motivation and achievement in mathematics.

Purpose of this Project

The purpose of this project was to determine the best use of technology in the mathematics classroom and compare best practices for the use of the TI-Navigator. In addition, this author attempts to simplify the use of TI-Navigator for teachers. Part of the project is the development of a staff inservice which includes a PowerPoint presentation on the TI-Navigator and modeled materials with this instrument.

Chapter Summary

Due to technology, the world is in the process of change. With technological advancements, the general population needs to know more mathematics to be able to understand how to use the technology. With the increasing awareness and availability of technology, many mathematics teachers have incorporated the use of technology into their classrooms. What are some of the applications of technology and what is the purpose for using technology? More specifically, how can the use of the TI-Navigator improve mathematics achievement and interest in mathematics? In Chapter 2, the review of literature includes: (a) the purpose of technology in the mathematics classroom, (b) the impact of technology on student learning, (c) technology trends, (d) examples of technology in mathematics classrooms, (e) TI-Navigator in mathematics classrooms, and (f) possible pitfalls.

Chapter 2

REVIEW OF LITERATURE

To date, the current literature appears to support the growing importance for the provision of a strong mathematics education to students in the United States. There is support for the use of technology in the mathematics classroom as well. Can the technology be used to improve both mathematics engagement and achievement? How can technology such as TI-Navigator be used effectively to engage students and improve achievement? These are relevant questions which pertain to most secondary classrooms. The purpose of this project was to review the current literature on the use of technology and, more specifically, the TI-Navigator in mathematics classrooms. Also, the project includes the development of an introductory PowerPoint presentation which introduces mathematics and science teachers to the TI-Navigator and its features.

Purpose of Technology in the Mathematics Classroom

One goal for the use of technology in the classroom is to raise student skill levels and achievement due to changing economics (Stumbo & Lusi, 2005) that require the "average" (p. 2) worker to demonstrate a higher level of mathematics skills. A second goal for the use of technology in the mathematics classroom is to increase students' engagement and interest. A third goal for the use of technology in the mathematics classroom is to help students internalize the concepts behind the mathematical problems. For clarification purposes in this paper, this author considers technology to be any electronic device that can be used in the delivery of education. This includes both hardware and software.

During the last 15 years, most of the focus on technology has been to teach staff members how to use the computer (NSB/NSF, 2006). The result was that, primarily, educators used the technology to collect data. There has been a shift away from learning how to use technology to learning from technology, such as the use of PowerPoint presentations in class. More recently, there has been a shift to learning with technology (Li, 2005). Mathematics technology, for use in learning in this way, would be technology in the hands of the students.

Impact of Technology on Student Learning

Currently, students think and process information differently than their predecessors. Prensky (2001) described these differences and termed the current generation of students as “digital natives” (p. 1). Contemporary students have been raised from infancy with digital technology. They have learned to use digital technology in the same way that a young child learns a native language. Their thinking patterns have changed, and there is a discontinuity between their way of learning and the way that previous generations learned. Prensky stated that “It is likely that the new student’s brains have physically changed and are different from ours” (p. 1).

According to Prensky (2001), digital natives like to multitask or parallel process. They can study with the television, ipod, and the radio on at the same time. They prefer to see visual graphics before they read the text. They like to: (a) network, (b) receive frequent rewards, and (c) play computer games. These students are the target audience of educators. Currently, many of them have to turn off technology when they come to school because “today’s students are no longer the people our educational system was designed to teach” (p. 1).

Most U.S. teachers learned in traditional classrooms and teach in a language that is foreign to their students (Prensky, 2001). These teachers could be described as “digital immigrants” (p. 2). When these teachers learn new technology, it is stored differently in their brain, similar to the way a second language would be stored. Teachers who recognize the discontinuity, who are flexible, and who are willing to learn new technologies will be better able to reach their students.

Technology Trends

According to the results from the Speak Up 2006 survey, conducted by the staff of Project Tomorrow (2007), students wanted more real world problem solving included in their mathematics courses. Also, students responded that they liked to practice skills with the use of: (a) Internet games, (b) digital cameras, and (c) MP3 players. On the survey, questions were asked about mathematics, science, and technology. When the student participants were asked which subject would be liked better with more technology, the subject which received the highest response across Grades K-12 was mathematics. The survey was administered to: (a) 232,781 students, (b) 21,272 teachers, and (c) 15,317 parents.

Both students and parents reported that they wanted greater integration of technology in mathematics courses (Project Tomorrow, 2007). Two-thirds of the parents believed that technology is still unsatisfactorily integrated in their student’s core subjects. Of these parents, 70% reported that they visit a school or district website weekly, and communication between parents and teachers has improved due to e-mail. A majority, 75% of teachers, responded that their students were more engaged when they used technology. Teachers believed that improved student engagement was linked to improved test scores, but the majority of teachers believed that the lack of instructor preparation time was the primary factor that impeded the integration of more technology into their lessons. When teachers were asked about desired technology, the most requested items included: (a) laptops, (b) digital projectors, and (c) interactive white boards.

In a discussion about the “push” (p. 131) of technology, Selden (2005) described the current trend in “technology as an engine driving pedagogical change” (p. 131). The use of technology has become commonplace and, also, it may change the entire way that teachers teach. It may not seem like a big change to move from a single overhead to a digital projector, but use of the additional visual technology helps the visual learner.

Obvious examples of technology include the Internet, which currently provides many sites for: (a) virtual simulations, (b) online surveys, and (c) interactive games. Also, online classes have grown in popularity. Seldon (2005) referred to the Massachusetts Institute of Technology where, in 2001, courses have been offered online free for noncommercial use.

According to Li (2005), the use of technology lends itself to higher order thinking skills. Selden (2005) suggested that more technology should be used for this purpose because shallow learning is one of the difficulties with which incoming college students struggle. In college, students may study less material, but go more deeply into the material. This point may be one of the biggest advantages of the use of technology in the classroom.

Examples of Technology in the Mathematics Classroom

According to Forster (2006), the use of Computer Algebra Systems has become commonplace. When computers are utilized in mathematics classrooms, students can visualize difficult ideas and focus on internalization of the concepts. Many teachers use interactive white boards to work problems and leave the solutions with a substitute teacher or post the answers on their websites. In regard to calculators, the question is no longer whether to use calculators but how to use graphing calculators.

Gillespie and Trapp (2005), in Texas, conducted a research project on the effects of the use of graphing calculators in the mathematics classroom. Both teachers taught in schools of similar socioeconomic status. Both teachers knew each other, taught with similar strategies, and even shared materials. The intent of their study was to compare the effects of graphing calculators on two student populations. At the start of a unit on functions, both groups were given a pretest. The students in Motley County scored 33% on the pretest while the students in Lyford scored 16%. Students in Motley County had experienced a greater access to calculators before the study, therefore, they were chosen to receive unlimited access to graphing calculators. Students in Lyford County received limited access to graphing calculators during class. Not surprisingly, the Motley County students scored the highest passing rate on the posttest. At the end of the first functions unit, the students in Motley County averaged 75% while the students in Lyford averaged 58%. The teachers taught a second unit on kinematics. At the end of the second unit, 83% of the Motley students passed, in comparison to 75% of the Lyford students. Even though the original pre test showed the Motley students scored higher, the teachers believed that the Motley students continued to score higher due to their access to calculators. Even though the study may have been flawed, the teachers concluded that unlimited access to calculators helped the students to score higher. Additionally, both teachers concluded that students' use of the technology would improve achievement on the Texas Assessment of Knowledge and Skills test. Also, they reported that use of the technology would "be a substantial benefit to students' conceptual attainments" (p. 6).

TI-Navigator in the Mathematics Classroom

The TI-Navigator (Texas Instruments, 2007) is one form of technology available to mathematics teachers. The wireless classroom learning system consists of: (a) a wireless access point, (b) a set of hubs to connect to calculators by cables, and (c) software for the teacher's computer. In the process of setting up the room for TI-Navigator, many teachers use a laptop and a digital projector. This combination of equipment turns the room into a sort of visual mathematics laboratory. The projector and laptop were two of the items most requested on the Speak Up 2006 survey conducted by the staff of Project Tomorrow (2007). Use of the digital projector allows the entire class to view graphic representations of the solutions to problems.

The Quick Poll feature on TI-Navigator allows teachers to anonymously poll students to find out their answers (Texas Instruments, 2007). The Activity Center allows students to contribute points, equations, and data to group lists for statistical purposes. Also, students can load calculators with study cards and use the Learn Check feature to instantly grade assignments for real time feedback.

Stanford Research Institute

An early study of the use of the TI-Navigator was conducted by staff of the Stanford Research Institute International (SRII; 2004). At the time this report was published, quantitative data for the TI-Navigator was not available, therefore, the SRII staff summarized relevant outcomes from 26 classroom studies with related systems. An analysis of other classroom response systems that had been used in classrooms allowed the staff to forecast the areas of learning that might be affected by use of the TI-Navigator. They focused on a comparison of the technical capabilities and empirical ideas behind the TI-Navigator. The results supported: (a) sound educational practices, (b) improvements in conceptual understanding of algebraic skills, (c) classroom engagement, (d) interactions, and (e) longer time on task.

The SRII (2004) staff predicted that use of the TI-Navigator would increase student engagement, interest, and enjoyment in mathematics because the focus is on mastery goals which are different from performance goals. To achieve mastery goals, students try to increase their abilities or master new tasks (Elliott & Dweck, 1988, as cited in SRII) The SRII staff pointed to effects of performance goals motivation and learning. The emphasis on performance goals can tempt poor performing students to give up and lead them to avoid challenging tasks. Students who use performance goals attribute failure to poor ability rather than to their level of effort. With the use of the TI-Navigator, the focus turns to the student's learning instead of the student's performance. Increased engagement leads to learning.

Use of the TI-Navigator allows real time feedback to students through the: (a) Quick Poll, (b) Activity Center, and (c) Learn Check features (Texas Instruments, 2007). Teachers are able to perform regular formative assessments. Also, real time feedback allows the teacher to evaluate the students' capability exactly. The teacher can either slow down or increase the speed of a lesson. The teacher can adapt the lesson for the students' understanding and help them to keep on the right track.

The SRII (2004) staff cited several researchers (Johnson & Johnson, 1989; Slavin, 1990; Web & Palincsar, 1996; all cited in SRII), who wrote about community centered classes similar to the TI-navigator classes. One reason for community involvement is the collaborative nature of the technology and students' discussions (Cohen & Scardamalia, 1998, as cited in SRII). Students can see the data that other students have contributed and discuss the output, which encourages a type of team atmosphere. This establishes "positive interdependence" (p. 3). Positive interdependence is a means to promote interaction and commitment to group learning goals (Johnson & Johnson; Palincsar; Slavin; Webb & Palinscar; all cited in SRII). With use of the TI-Navigator, these goals can be accomplished because all students are allowed to participate. Use of the anonymity feature reduces a student's fear of failure.

According to the staff of the SRII (2004), the group contributions lead to comparison and contrast by the students. In a matter of a few seconds, all students in the class can present data to compare. Comparison leads to contrast which encourages students to think. The contrasting questions lend themselves to constructive controversy, higher order thinking skills, and they encourage the student to think about the concepts.

Also, the SRII (2004) staff reported that students who used the TI-Navigator changed their attitudes about mathematics classes. The SRII staff cited a study by Abrahamson (1998) on classroom communications systems. In this study, Abrahamson collected data from the classrooms of 10 teachers who used the TI-Navigator for 1-3 months. It was found that student perceptions of their classrooms changed when the TI-

Navigator was used. Students perceived the class to be more responsive to their individual needs and more community centered. In another study, Davis (2002) reported that, in the TI-Navigator classrooms, the students were more attentive and less anxious.

The Richardson Math Project

According to Alexander and Stroup (2006), in the Richardson Math project conducted in Texas, the TI-Navigator was used to: (a) help motivate, (b) enhance learning opportunities, and (c) increase student achievement. The intent of the study was to increase achievement scores on the Texas Assessment of Knowledge and Skills (TAKS). The data for the study were collected from four different groups of students.

Alexander and Stroup (2006) reported that the first group of students included those students who had performed below grade level on the 2005 TAKS. They were targeted for intervention and placed in classrooms where the TI-Navigator was used. A total of three seventh grade classrooms and four eighth grade classrooms were involved in the study. One requirement for students' participation in the study included a comparison of their TAKS test scores from 2005 and 2006. While all of the students below grade level received the intervention, due to attrition, the data for only 79 students were useable. This was due to the high mobility rate in the district. Eligible students needed test scores from 2 years for the researchers to assess change.

The second group of students consisted of students who performed on grade level and were not targeted for intervention (Alexander & Stroup, 2006). All of the students in the second group were from the same school as the students in the first group. This second group, called the control group, also contained students whose scores were not eligible due to mobility and the lack of two years of data.

The third comparison group included 234 students who did not receive intervention from another school in the same district with similar demographics (Alexander & Stroup, 2006).   Finally, a fourth comparison group who did not receive intervention consisted of all other 7^{th} and 8^{th} graders in the district. There were 1876 students in the fourth comparison group. Alexander and Stroup reported that the students targeted for intervention increased their mean score by seven points. This was particularly significant because the students in the other groups from the same school or district decreased their mean score by one point.

Assessing Technology Based Approaches

The findings from two classroom based studies (Doerr & Zangor, 2000; Schwarz & Hershkowitz, 1999; both cited in Forster, 2004) showed that the time taken to teach the students how to use the technology was at the expense of learning mathematical concepts. Other studies (Boers & Jones, 1994; Mithcelmore & Cavanagh, 2000; both cited in Forster) found that the use of calculators helped students visualize the data and improved learning outcomes. What is the difference between the use of technology that enhances learning and technology that detracts from learning? When technical expertise is missing, students miss the mathematical content of a lesson as a result of their inability to use the technology. When technical expertise is in place, students tend to focus on the mathematical concepts. The use of technological advancements has aided mathematics teachers to produce multiple visual examples quickly. Use of the visual examples helps students connect abstract theory to mathematical understanding (Forster).

Forster (2004) identified decisions at different school levels that impacted student learning. The laptop, Internet connection, and projector were perceived as very supportive of student learning and were provided by the school. The students, however, struggled with the use of graphing calculators; therefore, the teacher deviated from the conceptual intent of the lessons to teach the students to use the calculator. The result was that the students missed the mathematical intent and conceptual understanding of the lessons. Forster concluded that students who use technology regularly need to establish routines to meet basic computation and graphing requirements.

In this study, Forster (2004) raised some very good questions but, failed to conclusively show how to really improve the situation. "Time pressures were a major problem in the class" (p. 159). The teacher attempted to prepare students for successful external examinations, but lost time because of the need to teach the use of the calculator. Forster gave the example of a class in which the students were sidetracked because of the lack of an x on the calculator. They became focused on the technology instead of on the concept the teacher wanted to teach.

Groves and Obregon (2001, as cited in Forster, 2004) used the example of measures of central tendency to explain the difference between translation and transformation. Students can take the numerical data to find the mean, median, and mode. This is referred to as a translation because students found the measurements, but did not change the way the data were represented. With technology, students can quickly graph the data in a histogram or box and whiskers plot. Use of the graph helps them to visualize the mean, median, mode, or quartiles. The change to the visual representation is referred to as a transformation and is considered to be a "major benefit" (p. 147) of technology in the mathematics classroom.

TI-Navigator Technology

Dougherty, Akana, Cho, Fernandez, and Song (2005), at the University of Hawaii, conducted a study at the Curriculum Research and Development Group. The researchers attempted to determine the effect of the use of TI-Navigator technology with eighth grade Algebra I students. They attempted to show achievement in graphing, solving systems of equations, and solving linear equations. The study included a survey, which was used to measure the change in student attitudes and beliefs about the use of calculators and other technology. Finally, the authors attempted to measure changes in student interactions during class.

Two classes of eighth grade students were compared in the Dougherty et al. (2005) study. One class (the experimental group) used TI-Navigator daily, while the second class (the control group) used calculators as appropriate to the regular curricular program. One class consisted of 25 students, while the second class had 26 students. Gender distribution was similar in both classes. The students in the study were similar in: (a) ethnicity, (b) achievement, and (c) socioeconomic status. Students in both classes were assigned a TI-84 Plus graphing calculator to use at school and at home.

Three data collection procedures were used in both the control and the experimental classes (Dougherty et al., 2005). At the beginning of the study, both groups took a content based pretest and an attitudinal survey based on the Fennema-Sherman scales. The survey and content posttest were readministered at the end of the study. The content examination was developed from released items from the National Assessment for Educational Progress (n.d., as cited in Dougherty et al.) and consisted of

15 multiple choice questions. A third party selected the test questions so there would be no project bias.

During the study, Dougherty et al. (2005) asked the students to use writing prompts to write in a journal about the use of the calculators, the TI-Navigator, and their perceptions. Two graduate students conducted classroom observations to determine the quality of student interactions. To maintain fairness, the observers rotated and spent 10 minutes with each group. They used a coding instrument that recorded the level and type of interactions. They tracked: "1) the number of participants in the discourse, 2) quality of discourse and 3) frequencies of interactions" (p. 6).

Dougherty et al. (2005) reported that students in both groups used the calculators for all tasks regardless of the task. Some used the calculator to compute simple numerical operations such as: (a) add, (b) subtract, or (c) divide by 10. As students became more comfortable with the calculators, they migrated toward more efficient use of the calculator. Students started to use the calculator for conceptual and graphing problems or tasks that required higher order thinking.

Also, during the study (Dougherty et al., 2005), the graduate students recorded the average time for students to begin a task. For students who used the TI-Navigator, the average time to begin a task, once presented, was 1.5 seconds while the students in the control group took 19.75 seconds to begin a task. The authors reported the difference as "remarkable" (p. 26) and concluded that the shortened response time could help teachers maximize learning time in the classroom.

Measurement of the group discussions provided some interesting data (Dougherty et al., 2005). Students who used only the calculators were more likely to sit and discuss the problem and then attempt to solve it. Students who used the TI-Navigator preferred to begin work on the problem before they discussed it with their colleagues. Students with the TI-Navigator liked to work on the problem, individually, and then share the data with the entire class. This led to deeper, more involved discussions. With the TI-Navigator, the answers from the entire class were anonymously posted. Students were able to recognize patterns, and compare and contrast answers. The author stated,

> Being able to see your own work displayed and then review it in comparison to other responses allowed students a self-and peer-assessment opportunity that is not always available in classes that do not have the TI-Navigator technology. (p. 27)

The students placed in the room using the calculators were invited to come to the front, plug in their calculator, and share; however, only one student could share work at a time.

The Learn Check component and Quick Poll Feature allowed for formative and summative assessments with real time grading (Texas Instruments, 2007). When students in the group who used the TI-Navigator answered written questions, they wrote “longer and qualitatively better” (Dougherty et al., 2005, p. 27) answers than students in the calculator group who used pencil and paper.

In the control group who used only calculators, 12 of the 25 students improved their overall score between the pretest and the posttest (Dougherty et al., 2005). In the experimental group, where students used both the calculators and the TI-Navigator, 15 of the 25 students improved their overall score.

While use of both technologies showed a positive impact on achievement, the students who used the TI-Navigator showed a slightly higher improvement (Dougherty et al., 2005). In addition, the students who used technology reported a positive attitude about their use of it. While these findings were interesting, this author questioned the validity of the sample size and would like to consider additional data.

Spanish Springs High School

Teachers have begun to narrow their focus on the best ways to use Navigator to produce achievement gains in their classrooms. In Sparks, Nevada, Solomon (2005) used the Quick Poll feature on a daily basis to assess students' retention of prior knowledge from the previous day. Based on the findings from the Quick Poll feature, student participation improved to over 95% of the class. Next, she added the use of Learning Check documents to quickly grade daily homework and obtain a snap shot of class performance. Each day, she put four of the problems on TI-Navigator as Learning Checks. Students then completed the Learning Check and reviewed the accompanying slide presentation. Solomon was able to compare data from 2 different years and reported an average increase of 22% in test scores. She believed the improvement was due, in large part, to an increase in student enjoyment because of the use of the technology.

An Analytical Reflection

Driscoll (2004), a conference speaker and teacher of at-risk students in Ontario Canada, attempted to quantify student performance gained from the use of TI-Navigator in an 11th grade mathematics class on personal finance. Driscoll described his work as a "best attempt" (p. 2) to quantify authentic gain in his classroom. He tracked 198 students over a 3 year period. Driscoll found that the grading standard was consistent throughout the study and that the grades were not inflated in any way.

Several observations and uses of TI-Navigator were noted. First, Driscoll (2004) used the TI-Navigator for formative and summative assessments. The formative assessments allowed him to diagnose gaps, while the summative assessments helped him to determine the students' understandings of the concepts taught. Also, Driscoll integrated real life experiments and involved global learning with students in other cities.

Driscoll (2004) hypothesized that a specific pedagogy, when combined with the use of TI-Navigator, might maximize learning. Driscoll set out to test his theory using TI-Navigator moderately in what he referred to as the transition semester. Next, he moved to high usage and finalized his theory.

Driscoll (2004) started to use the TI-Navigator Learn Check feature to administer short quizzes of five or less questions, which he called a Diagnostic. The Diagnostic was completed after the lesson, before students started the homework. Due to the real time grading ability of TI-Navigator, students were able to see the score of their Diagnostic before they left class each day. Students who performed well were allowed to work on their homework. Students who performed poorly were able to receive additional help from Driscoll during class. Driscoll described the Diagnostic as a type of snapshot of each student's learning. Unlike other TI-Navigator studies, Driscoll reported that students completed the work on a piece of paper before they entered their answers into the TI-Navigator. Also, he reserved some catch up time approximately once every couple of weeks. Use of the TI-Navigator allowed Driscoll to streamline paperwork and quickly provide feedback to students by use of a Smart Book grading system which imported grades directly from the TI-Navigator. Driscoll believed that efficient feedback was essential to student improvement. As students moved from no use of the TI-

Navigator to moderate use, their scores improved. As they moved from moderate use of the TI-Navigator to frequent use, their scores improved yet again. The biggest improvement was demonstrated in the decrease of student failures in the course. During the study, failures dropped from 41% with moderate use during the first semester to 23% with frequent use. The final evidence of growth was when students took the final examination and, once again, showed improvement. Driscoll's results showed that the more frequent use of Navigator resulted in increased performance by his students. Interestingly, Driscoll's (2004) findings were similar to those of the NSB/NSF (2006) who reported that one of the best uses of technology in the mathematics classroom may be for assessment purposes.

Pitfalls of Technology in the Mathematics Classroom

While the majority of the comments and outcomes were positive, an awareness of possible pitfalls can help teachers to avoid problems. In Hawaii, Dougherty et al. (2005) reported down time because of problems with the hardware and software. Also, observers noticed that students became frustrated when they could not participate due to technical issues. In addition, getting out equipment, setting it up, and logging in takes time away from the class. However, an established routine would help to minimize time lost due to set up. During observations, there were some hardware and software failures. The teacher must be prepared for classroom disruptions and management issues that occur when students are bored and have to wait for the teacher to trouble shoot technical issues. Also, the teacher must have alternative material prepared and be ready to use it with the class. Students who lost data during the activities or transmission quickly lost interest. Teachers with student centered environments may find the use of the TI-

Navigator cumbersome. In addition, the scales that the graduate students used in the Dougherty et al. (2005) study to observer data were new. Their reliability is still unproven.

To date, many of the studies have been conducted with small sample sizes and have been funded by Texas Instruments. While this author acknowledges that there may have been some opportunity for bias, there were no obvious biases in the studies.

Chapter Summary

In summary, use of the TI-Navigator appears to: (a) engage students in peer to peer discussions, (b) motivate students with mastery goals, (c) remove fear from the classroom by anonymous contributions, and (d) create comparison and contrast types of lessons. The visual display appeals to visual learners and allows them to see the graph of their data.

The Quick Poll and Learn Check features allow teachers to quickly perform formative and summative assessments. All student responses are collected which allows teachers to know exactly where their students are.

According to the literature, the TI-Navigator lends itself to longer times on task, in-depth responses, and higher order thinking skills. One of the best uses of TI-Navigator may be the use of TI-Navigator for quick summative assessments at the end of each class.

In all of the cases considered, the TI-Navigator contributed to increased engagement. Students who used the TI-Navigator demonstrated improved test scores. Use of the TI-Navigator for short formative assessments posed some of the highest improvements in the articles reviewed. In some of the cases, the TI-Navigator contributed to a change in students' attitudes.

Having completed this review of the literature on technology and the TI-Navigator system, the author prepared a staff development workshop for middle school and high school mathematics and science teachers to introduce them to the TI-Navigator system and model some activities to demonstrate the: (a) Quick Poll, (b) Learning Check, and (c) Activity Center features. In Chapter 3, this author describes the target audience, the staff development goals, the organization of the PowerPoint presentation, and the staff development. Teachers who attend the presentation should acquire a firm realization of the effects of the TI-Navigator in their classroom, and modeled examples of the use of the: (a) Quick Poll, (b) Activity Center, and (c) Learn Check features of the TI-Navigator. The applications would be applicable to middle school or high school mathematics and science classes.

Chapter 3

METHOD

In developing this research project, the author has been motivated by the pressing need to improve students' mathematics achievement. The authors of *Rising above the Gathering Storm* (National Academies of Sciences, National Academy of Engineering, & Institute of Medicine (NAS/NAE/IM; 2007) considered teachers to have the "highest leverage" (p. 30) in the United States educational system. Teachers who correctly integrate technology into their mathematics classes can improve their ability to engage the current generation of digital learners. Also, the use of technology allows the mathematics teacher to present material in visual formats that helps students to internalize the concepts behind the mathematics. More specifically, the TI-Navigator is one form of technology that can be used for multiple purposes in the mathematics classroom.

Target Audience

The material presented in this project would be of interest primarily to middle school and high school mathematics teachers interested in the use of technology in the classroom. The mathematics content could be adapted to middle school through high school. Also, the flexibility of the technology and integrated projects make the technology in the workshop a good choice for middle school and high school science teachers. Teaching staff in schools who are interested in the purchase of a TI-Navigator system or who have recently purchased a TI-Navigator system would gain the most from these materials. This project is designed for school and department staff members who are interested in a 3 hour introduction to the TI-Navigator system.

Organization of PowerPoint Presentation

This project is designed for a 3 hour staff development for middle school and high school mathematics and science teachers. The author will begin with a PowerPoint presentation on the pressing importance of mathematics achievement and science, technology, engineering, and mathematics education in the U.S.   The PowerPoint should update mathematics teachers on the importance of mathematics education in a changing world and encourage mathematics teachers about the important role they fill in the educational system today.

The second goal of this project, then, is to encourage mathematics and science teachers to use technology in the classroom and to help demystify the use of the TI-Navigator system. The PowerPoint introduces mathematics teachers and science teachers to the TI-Navigator.   Attendees will learn how to set up an initial system and participate in activities demonstrating the TI-Navigator features including the: (a) Activity Center, (b) Quick Poll, and (c) Learning Check.

Throughout the staff development, the activities demonstrated model the use of TI-Navigator for guided inquiry based mathematics lessons. The staff development would be most appropriate for those who are interested in working with the TI-Navigator system or who have a newly acquired TI-Navigator system.

Peer Assessment

A PowerPoint presentation that addresses the need for mathematics education and the importance of science, technology, engineering and mathematics education was shared with three colleagues for informal review. The PowerPoint presentation also covered an introduction on the use of TI-Navigator and examples of incorporating the technology. These colleagues critiqued the richness of the PowerPoint, the usefulness of the introduction to the TI-Navigator, and applicability of the material to their own classrooms. Their feedback is discussed in Chapter 5.

Chapter Summary

In this chapter, the author summarized the purpose for this project and the applied project materials for a staff development workshop. The primary goal of the workshop is to introduce teachers to the TI-Navigator while helping to make the system more user friendly to educators. The workshop includes a PowerPoint presentation, modeled activities on the TI-Navigator learning system, and sample activities for mathematics teachers. The workshop materials are most beneficial for middle school and high school mathematics and science teachers. Teachers who attend the workshop should leave with an understanding of the various uses for TI-Navigator and an improved familiarity with the TI-Navigator system.

In Chapter 4, the author includes the PowerPoint slides used for the presentation. The presentation includes materials on mathematics education and an introduction to the TI-Navigator.

Chapter 4

RESULTS

Introduction

Over the past couple of decades, there has been a growing awareness of the pressing need to improve mathematics education and mathematics achievement in the United States. Several studies have shown that mathematics achievement in the U.S. is either stagnate or declining while achievement levels in mathematics in other countries has been improving. The repercussions of a lack of mathematics achievement by the students in our nation are particularly daunting at a time when knowledge of mathematics is becoming increasingly important to acquire quality jobs. The infusion of technology, used properly, may help raise mathematics achievement and interest in mathematics. More specifically, the TI-Navigator is one method of incorporating technology in the mathematics classroom. This project includes material created for a 3 hour staff development workshop which provides current data on math and science education and introduces the TI-Navigator to mathematics and science teachers.

The Importance of Mathematics and Stem Education

The Importance of Mathematics and STEM Education

Kymn Van Dyken
Math Teacher
Aspen Valley High School
Academy District 20

As a nation we expect adults to be able to read…

We do not expect adults
to be able to do math…..

…..Why?

Our K-12th grade students have fallen behind other countries in math.

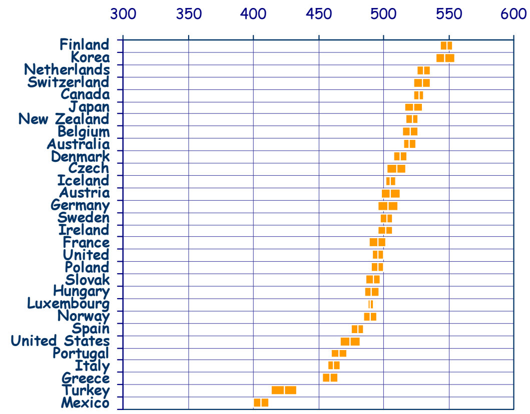
On the 1995 TIMSS, US 12th graders ranked 4th from the bottom.

The United States has opted out of having 12th graders participate in the 2007 TIMSS.

On the 2003 PISA, 15 year olds in the US scored 17 points below the international average for industrialized nations.

More recently…

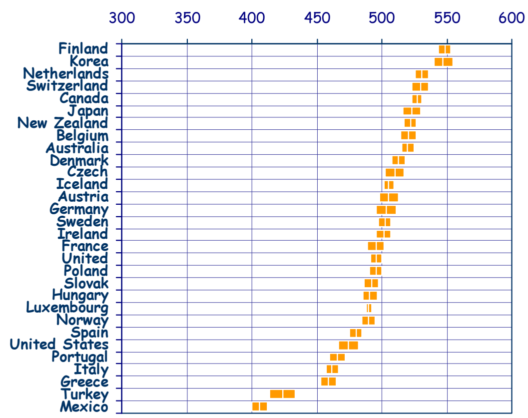
On the 2007 PISA, US 15 year olds scored 24 points below the international average for industrialized nations.



OECD (2007), *PISA 2006 – Science Competencies for Tomorrow's World*, Table 6.2c

Mean Mathematics Scores –OECD countries

If you didn't see it, the US is between Spain and Portugal, 5th up from the bottom.



OECD (2007), *PISA 2006 – Science Competencies for Tomorrow's World*, Table 6.2c

Mean Mathematics Scores –OECD countries

Does it matter?

Math is the foundation of… science, technology and engineering.

A nation with strong math skills has the necessary building blocks to prepare engineers, scientists and experts for advances in technology.

Technology influenced the development of our nation.

In the 60 years between 1890-1950 as much as 85% of measured growth in US income was due to technological change.

20^{th} Century Engineering brought us:

- Electricity
- Automobiles
- Aeronautics
- Water supply
- Television
- Agriculture
- Radio
- Nuclear technology
- Electronics

20^{th} Century Engineering also included:

- Petroleum technology
- Health technology
- Imaging
- Aerospace
- Telephones
- Highways
- Lasers and Fiber optics
- Computers
- Internet
- Spandex

"Our nation, with 6% of the world's population, has for decades produced more than 20% of the world's doctorates in science and engineering."

(NAS/NAE/IM, 2007, p. 70)

Now…

We have a declining number
of
Science,
Technology,
Engineering and
Mathematics
(STEM) graduates.

In 2004, the US graduated approximately half of the physics majors with bachelors degrees as we did in 1956.

Meanwhile other countries are increasing their numbers of STEM graduates.

In 2004, China graduated 350,000 while the US graduated 140,000.

In China, 40% of undergraduates major in engineering.

In Singapore, 20% of undergraduates major in engineering.

In Europe, 12% of undergraduates pursue engineering degrees.

In the US, 6% of undergraduate students pursue engineering degrees.

This is the second lowest rate of any industrialized nation.

Does it matter?

Over the next 15 years, 3.3 million jobs will move to East Asia – <u>not</u> because of cheap labor but because other countries are educating more of their workers to perform in high skill environments.

The lack of STEM graduates may impact our standard of living.

More S&P 500 CEO's obtained their undergraduate degrees in engineering than in any other field.

Math and science education are more critical than ever!

“The critical lack of technically trained people in the United States can be traced directly to poor K-12 mathematics and science instruction. . . . . . .(cont’d)

Few factors are more important than this, if the United States is to compete successfully in the 21st century.”

(NAS/NAE/IM, 2007, p. 114)

Advancements in technology mean that students will require more advanced technology and math to maintain a minimum wage job.

“Math and science are the keys to innovation and power in today’s world, and American parents had better understand…..(cont’d)

that the people who are eating their kids lunch in math are not resting on their laurels."
(Friedman, 2005, p. 1)

Consider….

Our students have grown up in a increasingly digital world and may benefit from learning with technology.

In addition to mathematics, our graduates will need 21st century skills.

"We need people who can figure out how to solve a problem, that's more than just knowing how to plug numbers into a calculator in the right order."
(Stumbo & Lusi, 2005, p. 1)

Innovation
involves collaboration.

Innovation
involves creativity.

Innovation
is global.

Innovation
is global and technologically complex.

Innovation
is increasingly multidisciplinary.

"An educated, <u>innovative</u>, motivated workforce- human capital - is the most precious commodity of any country in this new flat world." (NAS/NAE/IM, 2007, p. 30)

"Virtually all quality jobs in the global economy will require certain mathematical and scientific skills."
(NAS/NAE/IM, 2007, p. 135)

"If you can solve the education problem, you don't have to do anything else. If you don't solve it, nothing else is going to matter all that much."

- Alan Greenspan

(NAS/NAE/IM, 2007, p. 17)

"Where once nations measured their strength by the size of their armies and arsenals, in the world of the future knowledge will matter most."

- President Bill Clinton

(NAS/NAE/IM, 2007, p. 17)

"Science and technology have never been more essential to the defense of the nation."

President George Bush

(NAS/NAE/IM, 2007, p. 17)

Does it matter?

Yes, it does matter.

Math and Science teachers can make a difference.

Introduction to TI-Navigator

Kymn Van Dyken
Math Teacher
Aspen Valley High School
Academy District 20

Why use TI-Navigator?

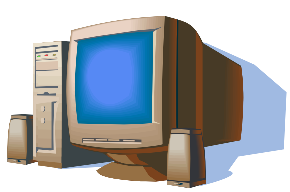
- Gets <u>everyone</u> is involved
- Provides real-time feedback
- The technology appeals to the students
- Great for visual learners
- Formative assessments
- Electronic portfolios

Getting started

may be easier than you think.

Before you start you will need:

- A teacher computer with Windows 2000 or XP
- Compatible calculators for students



Computer Requirements

- Window 2000 with Service Pack 4
  - or
- Windows XP with Service Pack 1 or 2
  - 512 MB RAM is recommended
  - 1.2GHz Pentium-compatible CPU
  - CD-Rom drive
  - Screen resolution set at 1024 X 768
  - approximately 350MB of available hard-disk space to install software

What calculators can you use?

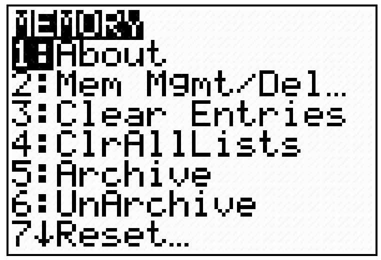
Calculator Type	Minimum Operating System
TI-84 Plus Silver Edition	2.41 or higher
TI-84 Plus	2.41 or higher
TI-83 Plus Silver Edition	1.19 or higher
TI-83 Plus	1.19 or higher
TI-73 Explorer	1.90 or higher

Check the calculator operating system

Press the key and

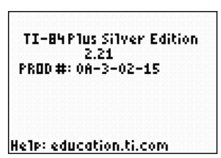
You should see the screen in the picture

Press



Checking the calculator version

- The first number, 2.21, is the version number of the operating system



- The second number is the product ID
- The third number (not showing in this example) is the calculator ID unique to each calculator

If your calculators do not have a compatible operating system you can upgrade for free using TI-Connect.

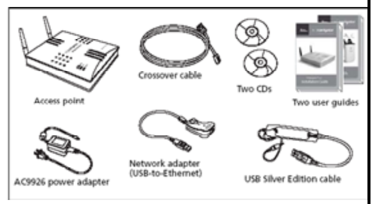
Ti-Connnect is included on the TI-Navigator CD or it can be downloaded from http:www.education.ti.com

Install the TI-Navigator application on the teacher computer.

Load TI-Navigator on the teacher computer by inserting the accompanying CD and following directions.

Add the hubs
Connect the cables

- follow directions on the CD for connecting hardware and loading calculators with the NavNet application
- make sure that the hubs are charged



- If you have any problems, help is available by calling 1-800-ticares.

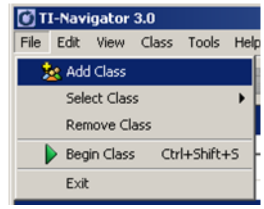
Getting started with a class

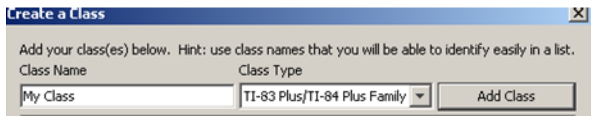
- Charge the hubs
- Connect the calculators to the hubs via a cable
- Open the Navigator application on the teacher computer
- Load calculators with Navigator applications
- Set up classes in TI-Navigator

•

How to Set Up a Class in TI-Navigator

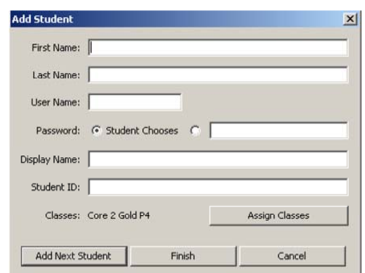
Open the Navigator application
•Go to File
•Click Add Class
•Enter the class name
•Click on Add Class





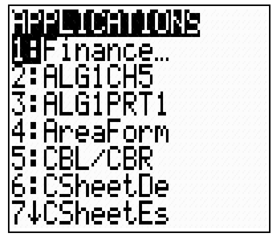
Add Students to the class

- Click on Add Student button
- Follow directions on the screen



How to Log in on the student calculators

- Press the key
- Arrow down to Navnet
- Press
- Press again



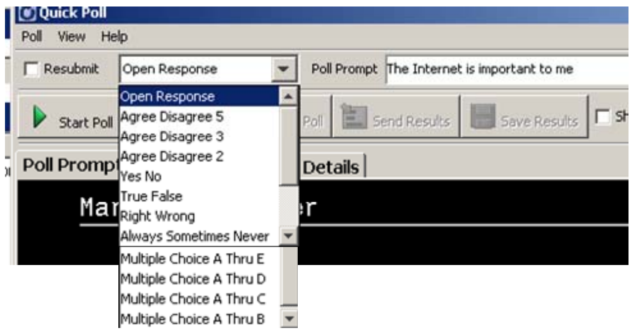
How to use the quick poll

- As the teacher, Click on the quick poll feature

- Questions can be typed in or created ahead of time
- Great for formative assessments

- Quick poll responses include:
- True/False
- Yes/No
- Right/Wrong
- Multiple Choice
- Open Response

View of Quick Poll and Options

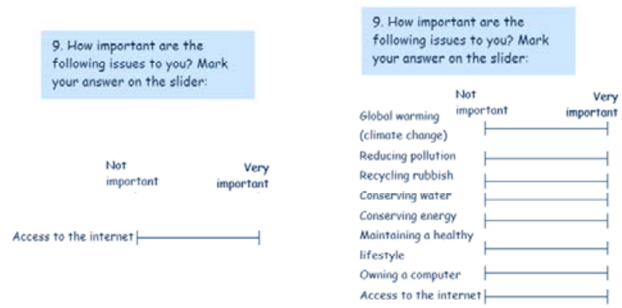


Material for the class example

- The material for the examples used in this workshop was obtained from Census at School.
- “Census At School is a non-profit project funded by organizations interested in promoting good use of statistics and data handling.”
  Students can participate and use their own data for math classes.
- Phase 8 Secondary Survey

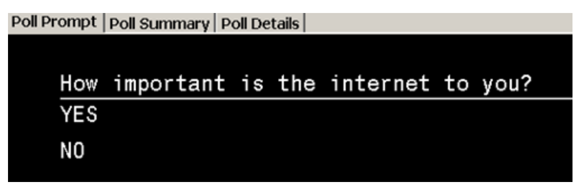
http://www.censusatschool.ntu.ac.uk/default.asp

Census at School Phase 8 Survey



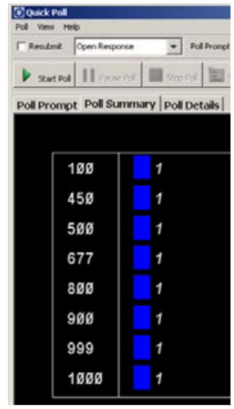
Example of quick poll question

- Answer the following questions in quick poll
- How important is the internet to you?



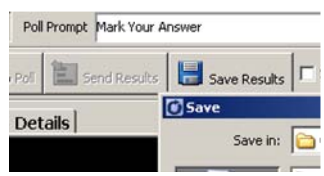
Examples of internet responses

- Sample of the Quick Poll Summary
- Each student rated the importance of the internet on a scale between 0 and 1000



Quick Poll data can be quickly saved

- Quick Poll results are quick and easy to save.
- Click on save results and save
- The results are saved for the entire session.



Uses for the Activity Center

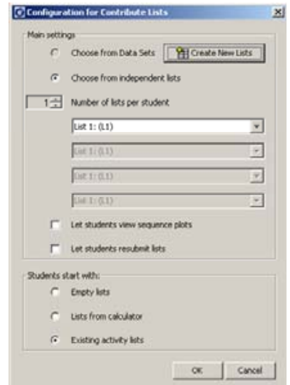
- Students contribute points, lines, or data.
- Students can fill out forms.
- Collected data can be disseminated back to students.
- Activity settings can be prepared in advance.

Screen Capture

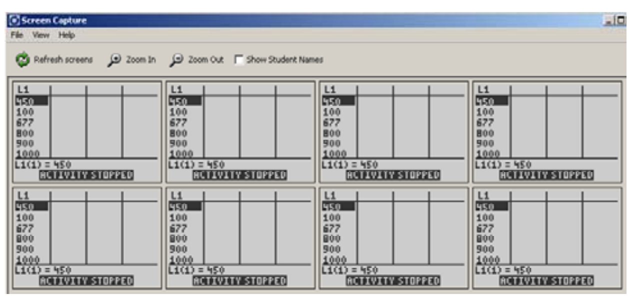
- The screen capture feature can take a snapshot of the class at any one time.
- The shot can be saved as a jpeg.

Activity Center

- The same data can be collected in the activity center and disseminated back out to the class via a list (existing activity lists).
- 0 means “not at all” and 1000 means “very important”.

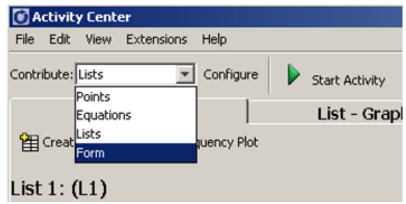


This is the same data collected and returned to the class



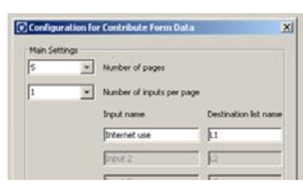
Data can also be collected on forms

- Start by choosing the form option



Forms are easy to set up

Input the name and the list that you want it sent to:

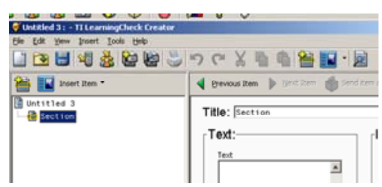


Learn Check can help summarize and assess the lesson

- A Learn Check can be prepared and results shown via the class analysis feature

How to use the Learn Check Feature

- Questions can be written as multiple choice, true or false, open response or fill-in-the-blank questions.
- Images can be added using .8xi files
- Class analysis is a great way to show the class the results.



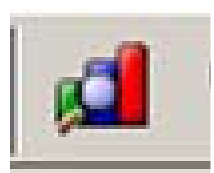
Using the Learn Check in the class

- Learn checks can be used as formative and summative assessments.
- Make great lesson warm ups
- Templates can be used to collect homework.

Class Analysis Feature

- Show the results of a learn check by showing a PowerPoint type of presentation with the
- Question
- Answer
- An spreadsheet of answers for the teacher

- Class analysis icon



TI-Navigator

- Gets the entire class engaged
- Helps students visually comprehend material
- Increases participation with the entire class
- Formative assessments allow the teacher to know where everyone is
- Saves time by instantly grading material

Chapter Summary

In this chapter, the author presented material for a staff development on the importance of math education and the infusion of the TI-Navigator in mathematics and science classes. The PowerPoint presentation highlighted the current trends in mathematics education and considered technology, specifically the TI-Navigator system, as a means of improving both student interest in mathematics and mathematics achievement. The PowerPoint also included a summary of hardware requirements, hints for setting up the system, and examples of how to use the system in the classroom.

Chapter 5

DISCUSSION

Contributions of this Project

Technology has earned a niche in mathematics classrooms; however, the proper use of technology, the time it takes to learn the technology and the benefits of the technology are still undetermined. In this project, the author attempted to summarize the best use of technology in the mathematics classroom and consider current best practices of the TI-Navigator. What are the benefits of the TI-Navigator and what are the possible pitfalls? How can the TI-Navigator be used to maximize learning? In addition, this author attempted to simplify the use of TI-Navigator for teachers by the creation of an introductory PowerPoint.

Limitations

It would be unrealistic not to consider some of the limitations of this material. While the literature on mathematics and science test scores was interesting, the literature was unable to definitively solve the dilemma of lagging test scores. The material was interesting, but it had a tendency to leave teachers hanging and wondering how to solve the problems. At the time of this project, the use of the TI-Navigator was relatively new, so the data included studies with small sample sizes and a summary of similar technology and pedagogical ideas. The sample sizes were too small to guarantee accuracy. Some of the studies were supported by Texas Instruments, which could leave readers questioning possible bias by the authors.

Peer Assessment

The resulting Power Point presentation slides and staff development materials were shared with three colleagues, all of whom teach mathematics or science. Two of the colleagues were high school teachers. The third colleague was a middle school mathematics and science teacher. The reactions from the colleagues were both encouraging and surprising.

One of the teachers expressed that she liked the STEM PowerPoint and was interested in the current importance of mathematics and science education. Unfortunately, she was disappointed that the PowerPoint convinced her that we need to improve mathematics and science education, but it left her wondering what needs to be done to fix the problem. The information shocked and motivated the teacher, but it left her unsure of how to address the issues in her own classroom. The transition between the need for better science and mathematics education, the use of technology to enhance learning, and the purpose of the TI-Navigator, could have been better addressed. The colleague had never used TI-Navigator, so she was not able to comment on the accuracy or efficacy of the introduction to TI-Navigator. She was motivated to use the TI-Navigator in her own classroom.

A second colleague was familiar with much of the information in the PowerPoint presentation. She had also used the TI-Navigator in her own classroom. She agreed with the information in the presentation and focused on smaller improvements that could help enhance the workshop.

The third colleague was shocked and motivated by the first part of the PowerPoint presentation; she was bored in the middle of the second presentation, but then asked to learn how to use the technology in her own room. She was interested in the adaptability of the technology in middle school classes. Both of the teachers who were unfamiliar with the technology expressed an interest in the technology, but felt hindered by a lack of access to funds to purchase the technology and a lack of access to training

Recommendations for Further Development

The importance of mathematics and science education is an important topic. Teachers and administrators should continue to monitor mathematics and science test scores as they become available. Much of the debate centers on the comparison between student test scores in other countries in comparison to student test scores in the United States. The impact that the lack of mathematics skills will have on our country may be overshadowed by the attention the general lack of mathematics education will receive. Both subjects are worthy of continued study.

The infusion of technology in the mathematics classroom is also an additional consideration. Technology has undergone many advances and uses. Many types of technology could be considered other than the technology that was considered in the literature that this author accessed. Smart boards, document cameras, and online resources should be compared and contrasted. The initial cost to purchase the technology and the additional cost to implement the technology are other considerations that should be pursued. The current trend towards putting technology in the hands of the students deserves additional study and more comprehensive data. Which form of technology will have the biggest impact for the least cost?

The use of TI-Navigator was considered as a means of increasing student interest and student achievement in mathematics. TI-Navigator appears to meet both of these goals, but the degree to which TI-Navigator accomplishes this objective is still questionable. Future studies should look to recreate the results from the initial studies, consider the possibility of an implementation dip, and then maximize the gains in achievement that may be possible with this technology in the classroom. Additional studies on TI-Navigator should also consider hardware management, pedagogical differences, and a closer look at formative assessments. TI-Navigator helped students increase their conceptual understanding of visual material, but extra studies are needed to show how well students transfer the knowledge to traditional testing formats.

The most important recommendation is for additional TI-Navigator research on larger sample sizes. While the evidence is not yet sufficient to support more comprehensive growth, this author expects to see future studies validate or exceed the earlier studies.

Project Summary

At the beginning of this study, this author was interested in using technology to engage mathematics students while possibly raising achievement. The current standing of U.S. students on international mathematics exams and the lack of interest in mathematics based occupations appalled and motivated this author. Many people, while aware of the needs in mathematics and science education, may not be aware of the increasing importance of mathematics education for our society.

The general information on technology and the current use of technology in the classroom both interested and disappointed this author. The abundance of material and ideas on technology was interesting. However, this author was disappointed in a lack of agreement on the proper use of technology and the lack of definitive results of technology in the classroom. Some authors favored the use of technology in the classroom, while other authors questioned that too much instructional time was spent teaching students how to use the technology at the cost of students learning mathematical concepts.

The richness of the TI-Navigator surpassed this author's initial perceptions. It appears to be a form of technology that can both engage students while enhancing learning. It is the kind of technology that leaves students wanting more mathematics.

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