TI-Navigator Study Interim Report

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Executive Summary

In the 2007-2008 school year – the second year of the TI-Navigator study – we continued to investigate how teachers make use of the TI-Navigator in their classrooms and whether use of the TI-Navigator is beneficial to students in early secondary mathematics. In particular, we focused on helping teachers in the experimental schools extend their implementation in terms of holding class discussions.

This year the study involved 611 Grade 10 students - 454 students from the implementation year (2006-2007), and 158 new students. Sixteen teachers were involved in the study – 8 at the experimental schools and 8 at the control school.

By the start of year two, seven of the eight study teachers at the experimental schools had relatively strong technological backgrounds. We found that all teachers gained additional confidence in use of TI-Navigator, although one was still tentative about general use and troubleshooting by the end of the year. LearningCheck and Quick Poll were the most commonly used applications but all study teachers used activities recommended by colleagues or shared at the PD sessions.

This year we asked teachers at the experimental schools to record in a log their use of technology. From the information provided we determined that TI-Navigator was used approximately once every 4.5 days with academic students and once every 3 days with applied students. However, not all usage was equivalent. For example, though one observed teacher used TI-Navigator infrequently in his academic course (which he was teaching for the first time), his skill level with the technology was high. On the other hand, a teacher who used TI-Navigator more often than the average, was still slow at setting up and less skilled than the other teachers at using the technology in class.

Several of the observed teachers who had followed a traditional pedagogy, showed some movement towards a more open classroom. Although they did not hold full class discussions, they did engage students in analysing responses, and considering the source of errors. These strategies were stressed in the three days of professional development provided to the participating teachers.

While teachers were very positive about the effects of TI-Navigator use on students – noting that students enjoyed the activities and were motivated to participate – the ANCOVA results show that the treatment had a significant effect only in the case of the academic classes. The ANCOVA tests on the Grade 10 test scores revealed a statistically significant difference between the experimental and control students on the post-test (controlling for pre-test differences); the experimental academic students had a significantly higher mean post-test score ($F_{(1,260)} = 9.910$; $p = .002$; $\eta_p^2 = .037$). A partial Eta squared value of .037 is equivalent to d =0.39 and effect sizes of this magnitude are considered moderate in educational research. Academic students who participated in focus group interviews reported that they enjoyed using TI-Navigator, (though students in one class were frustrated by the teacher's ongoing difficulties with set up). We noted that students in the observed academic classes were engaged by the activities and that in one of the classes, student participation was accompanied by a noticeable energy.

No statistically significant difference in adjusted post-test means was found between the control and experimental student groups for applied stream students in year two, ($F_{(1,141)} = 0.300$; $p = .585$, $\eta_p^2 = .002$). However, despite these results, we contend that applied students did benefit from the use of TI-Navigator. We noted that students in the two observed applied classes were actively involved in the mathematics activities, and applied students who participated in a focus group indicated that they enjoyed the technology and particularly appreciated being able to share answers anonymously.

Several teachers at the experimental and control schools have agreed to be part of the study in September as we follow some of the students into Grade 11, and we look forward to continuing our work with them.

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1. Introduction

The focus of the TI-Navigator study is to investigate how teachers make use of the TI-Navigator in their classrooms and whether use of the TI-Navigator is beneficial to students in early secondary mathematics. In the 2007-2008 year, the study involved 611 students - 454 students from the implementation year (2006-2007), and 158 new students. Depending on their timetables, some of the students will be tracked into grade 11. Sixteen teachers were initially assigned to the grade 10 classes in the study – 8 at the experimental schools and 8 at the control school.

The key questions for the research are:

- What are the effects on student achievement in Grade 9/10 applied/academic mathematics?
- What are the effects on the attitudes of Grade 9/10 applied/academic math students towards mathematics?
- What are the effects on teaching practice?
- What support do teachers need to use such technology effectively?

The study is designed around a mixed methods approach. Classroom observations, focus groups, and teacher interviews provide information from the qualitative perspective. Quantitative data have been gathered via teacher and student surveys, and pre-post mathematics tests have been used to assess the impact of the treatment on student mathematics achievement.

In the following sections we provide an overview of the project and a synopsis of results from the implementation year. We then describe the Grade 10 study and present the quantitative and qualitative analyses of the collected data.

2. Project Overview

2. 1 Background and context

The impetus for this study developed out of discussions between researchers at the Faculty of Education at York University and the Toronto Catholic District School Board. Having purchased TI-Navigator systems for all of its secondary schools in 2002-2003, the board was interested in participating in research into whether the TI-Navigator is effective in supporting the teaching of mathematics at the Grade 9 and 10 levels.

The study was designed to follow a typical group of teachers as they implemented the use of the TI-Navigator. Schools for the study were chosen on the basis of several criteria. They were to be co-educational, of average size, full-program (i.e., not specialty schools), and most important, all Grade 9 academic and applied mathematics classes in the 2006-2007 year, and all Grade 10 academic and applied mathematics classes in the 2007-2008 year were to be involved. [Note: mathematics courses in Ontario are destination-based. Academic mathematics courses lead to university; applied courses lead to college and apprenticeships.] This would require that all Grade 9 teachers at the experimental schools agree to use the TI-Navigator. Although we knew that some teachers would be keen to try the new approach in their classroom, we were aware that some might be tentative or even resistant.

2.1.1 Setting

Three secondary schools in an urban school board in Ontario, two experimental (Schools A and B) and one control (School C), were chosen. All three participating schools are co-educational, and offer full programs (i.e., they are not specialty schools). School A is a full year school (courses begin in September and end in June). The other two schools are semestered. (First semester courses run from September till the end of January, and second semester courses run from February till June).

The control and experimental schools were matched as closely as possible according to the following criteria: demographics (e.g., SES, applied/academic ratio), and EQAO scores. [EQAO is the Education Quality and Accountability Office, an agency of the Ontario government that designs and supervises a variety of tests for students in the province.]

School B offers a contrast to the other two schools, which are fairly well matched in terms of demographics and EQAO scores. EQAO mathematics tests, which are given annually to Ontario students in grades 3, 6, and 9, are scored on a four point scale, with a score of 3 representing attainment of the provincial standard. In the 2004-2005 year both School A and School C earned scores close to the board average on the EQAO grade 9 mathematics assessment (see Table 1). At School B, results were lower in comparison. Nevertheless, School B was very interested in participating and we believe it will provide an opportunity for us to research the use of the TI-Navigator with lower achieving students.

Table 1: *Number of Grade 9 students in participating schools and board attaining or exceeding the provincial standard on the EQAO mathematics test.*

School	No. of Applied 9's	% at level 3 or above	No. of Academic 9's	% at level 3 or above
School A	79	20	138	69
School B	99	4	42	19
School C	91	35	317	58
Board	2472	20	4692	58

With regard to socio-economic level, recent data provided by the board shows average income in School A's catchment area as $68,973 and in School C's area as $65,000. In 2001 the average income in the area around School B was $61,149.

2.1.2 Year one set up

In summer, 2006, each of the two experimental school received 2 TI-Navigator systems, plus 2 laptops and 2 projectors. TI-84 calculators were sent to the experimental schools (190 to School A and 130 to School B). Calculators were to be distributed to students to enable them to use the calculators at home and in other courses (e.g., science).

With regard to their Grade 9 course(s) in 2006-2007 and their Grade 10 course(s) in 2007-2008, teachers at the experimental schools agreed to:

- Attend the professional development sessions on the use of the TI-Navigator, provided by the Toronto Catholic District School Board (TCDSB) in conjunction with Texas Instruments (TI).
- Allow us to administer: a student questionnaire at the beginning of each course; a pre-test in mathematics at the beginning of each course; and, a test at the end of one unit in each math course (to be marked by the researchers).
- Use the TI-Navigator system in their class.
- Support students in working with the TI 83 (or TI 84) calculator that they will be given, whenever they find it appropriate for their mathematics work, whether at school or at home.
- Answer a questionnaire at the beginning and the end of each course on their mathematics teaching and their experience of teaching with the TI-Navigator system.

Similarly, teachers at the control school agreed to:

- allow us to administer: a student questionnaire at the beginning of each course; a pre-test in mathematics at the beginning of each course; and, a test at the end of one unit in each math course (to be marked by the researchers).
- answer a questionnaire at the beginning and the end of each course on their mathematics teaching and their use of technology.

Teachers at the control school were not prohibited from using the TI-Navigator; they were expected to teach their courses as usual, i.e., to engage in typical practice.

In addition to participating in the regular aspects of the study, six classes - one academic and one applied, per school - were required for the in-depth part of the study. In these classes, researchers would carry out observations, and hold focus meetings with a group of students.

2.1.3 Synopsis of implementation year

The results of the student baseline survey indicated that although there were a number of instances of statistically significant differences, the control and experimental students had many of the same experiences of and attitudes toward mathematics. In particular, responses suggest that for both groups, mathematics had been taught in a very traditional manner. Students reported that very little use was made of computers for demonstrating ideas or student work, and students rarely engaged in mathematics projects or used an overhead projector to demonstrate their work.

The teacher baseline survey indicated that overall, the study teachers were very experienced, and fairly traditional in approach. Most had used graphing calculators and the CBR/CBL and a majority had used Geometer's Sketchpad, but use of other technologies was sparse. An interesting finding is that proportionally more teachers used Geometer's

Sketchpad with applied classes than with academic classes. Some teachers had used algebra tiles, a strong number had used co-operative learning strategies, and a few had implemented assessment strategies that went beyond tests and quizzes. These, and the very positive response to the questions on the PD survey with regard to in-class help suggest that while some teachers are interested in adopting new approaches, they may require more support than is generally provided.

Six teachers from the experimental schools and five from the control school responded to the technology use survey at the end of the year. Overall, reported use of technology in the implementation year was low except for use of the graphing calculator at the experimental schools, where five out of six reported that they used it every day. Teachers at the experimental schools reported varied frequency of use of the TI-Navigator. This is in line with our classroom observations.

Teachers at the experimental schools were asked to provide feedback on the professional development provided by TI during the year. Some teachers responded that the summer and fall PD sessions did not provide sufficient help with implementation at Grade 9. On the other hand, the prep-time and in-class assistance provided by a teacher hired to provide onsite assistance and mentorship received positive comments; teachers indicated that good ideas and technical help were provided and that materials developed for their classes were helpful. The mentor teacher reported that the support resulted in a gradual improvement in the handling of technical aspects, and in the incorporation of TI-Navigator in the curriculum. In particular he found that the in-class help encouraged the teachers to use the technology in different contexts. For the future, teachers requested training grounded in the Grade 10 curriculum, particularly sessions that are activity-based but include more time for practice.

A post-test data analysis was carried out only for the 480 students who had completed both the pre- and the post-test. Analyses of covariance (ANCOVA) were run on the student post-test scores, using the student pre-test scores as a covariate to partially control for pre-existing individual differences in mathematics knowledge and ability directly related to achievement in the Grade 9 math curriculum. As different post-tests were administered to the applied and academic math classes, the analysis of the two streams had to be conducted separately so as not to violate the necessary preconditions for valid statistical testing. Results of the ANCOVA showed no significant differences between the experimental and control students on the post-test for either the academic stream students ($F_{(1,342)} = .348$; $p = .556$) or the applied stream students ($F_{(1,132)}=2.29$; $p = .132$).

We intended to run partial correlations of level of TI-Navigator use with post-test scores after correcting for pre-test scores. However, in this year of implementation, there was no adequate method to evaluate the level of use in the experimental classes; specifically, frequency of use did not correspond to level of use. In subsequent years we plan to collect data on the depth of implementation of TI-Navigator to allow additional analyses.

Our classroom observations showed that teachers of the experimental classes used a traditional approach, but were willing to try new methods to help their students. The technical aspects of implementation were difficult for most, but by the end of the year both students and teachers were reasonably comfortable with the system. Teachers could load a file, collect, display, and save information sent by the students, and trouble-shoot minor problems with hubs and calculators. They were familiar with LearningCheck and Quick Poll and all had successfully used at least one activity from the summer or fall PD sessions.

At the same time, these teachers had not yet fully embraced the pedagogy that TI-Navigator can enable. Links to other strands and contexts were infrequent and discussions that engaged all students in analysing the images sent to the TI-Navigator, or pulling together the outcomes of the day's activity, were not held. Some progress in these areas was noticed towards the end of the year as teachers gained confidence and experience.

One focus group meeting was held with students from one of the experimental schools. The students were very positive about the use of technology. One said that calculators make math easier, although another pointed out that it makes some people lazy. A third student said that it was faster to do tests – and fun to be able to analyse everyone's answers. Three of the students felt that the technology had not affected their understanding – because "the teacher still teaches you", but one noted: "on the screen you can see how others have done so it's helpful. [And the] teacher goes over the wrong answers so that we can understand where we went wrong." Another commented that it helps to be able to "see it." She said "equation of the line - right? Hit the button and you can see right away if you've done something wrong. Then you can go back and fix it. Try to make sure that it's right before you send it."

Despite the technical difficulties, the responses of teachers during the end of year interviews at the experimental schools were very positive. Overall, the six teachers said that they enjoyed using the TI- Navigator. Some of the benefits mentioned by one or more teachers were: TI-Navigator assisted them to better structure their lessons, using quick checks helped them determine whether the students understood the material; use of the TI-Navigator helped in meeting the diverse needs and abilities of students in the classroom. A number of teachers expressed the belief that more students were actively involved in learning.

Teachers said that it was time-consuming to learn to use the technology seamlessly and to reorganize their lessons to accommodate the use of the TI-Navigator; however, all teachers were enthusiastic about continuing the project with one stating said "I don't see that we have to improve anything. It was a good experience for me and for the students". Another said "I love it! It helps me make [math] more interesting."

The project team interviewed the department heads as well. Both of the department heads regularly use the TI-Navigator system in their classes and are very positive about the benefits to teachers and students. With regard to implementation, one of the department heads noted that incorporating technology into lessons requires a willingness to change one's pedagogy – something that was a problem for some study teachers. The other department head offered a similar idea but from a different perspective; i.e., the positive aspect of TI-Navigator use is that it forces teachers to reflect on different or alternative ways of presenting material.

During the year both heads acted as role models and provided significant support for the new users. They provided materials and advice, visited teachers' classrooms to assist and to troubleshoot technical problems, and invited the teachers to watch them teach with the TI-Navigator. Although schools were not chosen on the basis of school-based expertise with TI-Navigator, it is difficult to imagine how the project could have progressed without the continuous onsite help provided by these two dedicated, and knowledgeable, department heads.

In terms of the research questions, the collected data and our experience this year have given us insights into the nature of TI-Navigator implementation by "typical" teachers and the support they require in order to experience success. Need for support falls into two categories – technical, and pedagogical.

Our research confirms that five of the eight study teachers at the experimental schools had relatively weak technological backgrounds. With regard to the TI-Navigator, although most had attended between 4 and 9 days of formal professional development through summer and fall, troubleshooting technical problems, and loading, entering and saving information were challenges for these teachers. They gained confidence over time, but some were still quite slow at common procedures by the end of the year. This suggests that PD sessions for such teachers need to include additional practice time on technical skills.

While offsite training and virtual presentations may be satisfactory for many teachers, our data on the results of individual support suggest that, teachers who are tentative about technology need substantial onsite support. Although the TI technical support line was available, teachers did not take advantage of it. In this study, the increase in teacher technical competence was the result of ongoing support by the department heads and additional in-class assistance by the mentor teacher.

The observed teachers followed a traditional pedagogy, and most attempted to fit the TI-Navigator into their regular routine of teaching procedures, and ensure that students gained practice. Perhaps for this reason, LearningCheck and Quick Poll were the most commonly used applications. Some teachers tested activities shared at the PD sessions and/or suggested by the mentor teacher, but did not yet take full advantage of the opportunity to use a more open pedagogical approach.

A possible key to helping teachers new to technology adopt a less traditional pedagogy around TI-Navigator may lie in the development of customized materials for their classes. Although teachers had access to existing CD's and printouts, most did not make use of these resources. However, teachers did use the LearningChecks designed for their classes by the mentor teacher – and asked for more. This suggests that teachers recognized the potential of such materials. Since it is not possible to continue providing individualized service, we hope that over the next year teachers will develop their own materials specific to the Ontario curriculum, and will share these within their schools and through the study website.

Despite problems and slow progress this year, all teachers were enthusiastic about continuing the project.

2.2 Grade 10 Study

In the 2007-2008 school year the research addressed the following questions:

- What are the effects on student achievement in grade 10 applied/academic mathematics?
- What are the effects on the attitudes of grade 10 applied/academic math students towards mathematics?
- What are the effects on teaching practice?
- What support do teachers need to use such technology effectively?
- How are the calculators used at home during the course?

The study involved: offering three days of inservice (two in the fall and one in the winter) on teaching with TI-Navigator, developing a variety of instruments, administering of surveys and pre- and post-tests, observing selected classes, meeting with student focus groups, and interviewing teachers and department heads. These tasks are outlined in more detail below. Subsequently, observation and interview notes were transcribed, and survey and test data were input into SPSS. Quantitative findings are discussed in section 3 and qualitative in section 4.

2.2.1 Participants

The total number of participating students was 611, (289 experimental and 322 control), i.e., taken together, the two experimental schools have approximately the same enrolment as the control school. Table 2 shows the breakdown of participation by school and course.

Table 2: *Grade 10 participants by school and course.*

School	Grade 10 students	Grade 10 Academic	Grade 10 Applied
School A (experimental)	168	109	59
School B (experimental)	121	41	80
School C (control)	322	190	132
Totals	611	340	271

All grade 10 students in the schools, with the exception of students in the Essential courses, were to participate. (Essentials courses do not lead to college or university.) Table 3 indicates the number of classes by school and by course, and the number of participating teachers. Tables 4-6 give the breakdown of the classes by teacher for each of the three schools.

Table 3: *Grade 10 classes by school and level; number of participating teachers*

School	Academic classes	Applied classes	Teachers of grade 10
School A (experimental)	5	3	6
School B (experimental)	2	3	3
School C (control)	7	6	8
Totals	14	12	17

As in the first year, teacher changes were made mid-year at School A. The research team was not notified. Most changes simply involved teachers already in the study switching classes. One change brought in an additional teacher (A7) who was familiar with technology and willing to use TI-Navigator. Another removed teacher A6. Teacher ID's (e.g., A1, C1) have been brought forward from the implementation year. New teachers to the Grade 10 study have new ID's and are marked with an asterisk.

In addition, at School C, teacher C5 took a leave at the start of the second semester, which caused some confusion with the distribution of the pre-test in one class. The class wrote the wrong test and consequently could not be included in the pre-post test analysis.

Table 4: *Classes by teacher – School A*

Teacher ID	Grade 10 Academic	Grade 10 Applied
A1	1	
A2	.5 (spring)	.5 (fall)
A3	1	
A4	2	2
*A6	.5 (fall)	
*A7		.5 (spring)

Table 5: *Classes by teacher – School B*

Teacher ID	Grade 10 Academic	Grade 10 Applied
B1	2	
B2		2
B3		1

Table 6: *Classes by teacher – School C*

Teacher ID	Grade 10 Academic	Grade 10 Applied
C1	1	
C4		1
C5	3	
C6	2	
C7		2
C8		1
*C9		2
*C10	1	

The tables indicate that most teachers taught one or two sections of Grade 10 mathematics.

Table 7 shows the observation schedule for the year. As planned, two teachers at each school were part of the in depth study. Observations of their classes were carried out on a regular basis.

Table 7: *Observed teachers by course.*

Teacher ID	Grade 10 Academic	Grade 10 Applied
A3	Full year	
A4		Full year
B1	Spring	
B2		Fall
C1	Spring	
C8		Fall

2.2.2 Professional development

Three days of professional development (PD) were held for participating teachers at the experimental schools – two days in the fall and one day in the winter. All teachers of the experimental classes attended the first two days. At the winter session, one teacher was absent.

Fall. In the fall the group met for two full consecutive days under the leadership of Tom Steinke, a mathematics teacher and former consultant with the Ottawa Carleton Catholic District School Board, who is knowledgeable about teaching with technology. We asked him to plan sessions that would help the teachers to build a community of learners around use of TI-Navigator, that is, to engage students in rich discussions of activity results. The two days were very fruitful; the teachers shared what they were doing with the technology, discussed the effects of TI-Navigator use on their teaching and on classroom dynamics, worked through activities that used TI-Navigator to enhance opportunities for students to participate, and collected technical tips. A teacher who is still somewhat tentative noted after the latest session, "I enjoyed the PD session we had … It gave me more ideas and confidence to continue on with the TI-Navigator. I think it's these days that help me consolidate the information and training." (Email, teacher participant, March 7, 2008).

Winter. In March the group met for a full day under the leadership of Derrick Driscoll. Derrick led teachers through several activities including a Grade 10 trigonometry problem, answering questions, and giving tips and advice about teaching with TI-Navigator along the way. In addition, teachers in the study discussed their experiences, and the two department heads shared TI-Navigator activities they had used successfully.

In school. Although schools were not chosen on the basis of school-based expertise with TI-Navigator, the department heads at the two experimental schools are both experienced TI-Navigator users. They each spent considerable time during the year supporting the study teachers – and were in fact participating in the study as grade 10 teachers. They provided materials, and advice, and visited teachers' classrooms to assist and to troubleshoot technical problems.

2.2.3 Surveys

Two baseline surveys were developed for the study – one for teachers and one for students.

The teacher baseline survey was given at the start of the implementation year. It gathered information about teaching experience, pedagogical approaches (e.g., use of manipulatives, types of assessment), and prior use of technology. Some questions were drawn from a teacher survey used in the author's earlier research into mathematics teaching at the elementary level. These questions probed how teachers supported communication, and whether they used manipulatives, and multiple assessment methods. The results were used to compare the pedagogical environments at the control and experimental schools. Since the teacher surveys gave a picture of teacher backgrounds at the start of the study we did not repeat it in the 2007-2008 school year. The synopsis section of this report includes information on the teacher survey results from the first year.

The student baseline survey was modified from an earlier survey created for the Teacher eLearning Project (Owston, Sinclair, Kennedy, & Wideman, 2005). It included questions about student achievement in and attitudes towards mathematics, and collected data on items such as student use of technology in math, and time spent on homework. The survey was administered in mid-September to all participants at school A and to first semester students at schools B and C, and in mid-February to second semester students at schools B and C.

2.2.4 Observations

Two pairs of researchers carried out observations of the six in-depth classes. Each of the experimental classes was observed on six occasions and each of the control on three.

As in year one, observers, using the forms shown in Appendix A, collected information before the lesson, recorded details about the classroom (e.g., arrangement of desks, available materials), took field notes on the lesson, and paid particular attention to: the use of technology, use of other demonstration methods, level of student engagement, links made to other strands/contexts, and mathematical discussions. Afterwards, the observers met with the teacher briefly to discuss the lesson.

The headings on the observation sheet were developed by modifying a checklist that we had used in a study on supporting school improvement at the elementary school level (Sinclair & Byers, 2006). See the report on the first year implementation for a description of the design of the observation sheet.

2.2.5 Student focus groups

Focus group meetings were held at the end of the school year with students from three of the observed experimental classes. Focus group leaders, guided by a list of questions (see Appendix B) encouraged students to speak openly about their experiences in mathematics and their attitudes towards technology – in particular, the TI-Navigator.

2.2.6 Teacher interviews

The project team used a semi-structured approach to interview all teachers in the experimental schools at the end of the year (see Appendix C for questions). The purpose of these interviews was to determine what teachers liked about using the TI-Navigator in their classroom, and what technical and/or pedagogical challenges they faced. We also wanted to gather their perceptions of the impact of TI-Navigator use on their students' engagement and learning. Since we will be working with some of the same teachers during the next academic year, we asked them for suggestions on how we could work with them better.

During the year we also met with each of the department heads to gather feedback from a school-wide perspective.

2.2.7 Technology use logs

Teachers at the experimental schools were asked to keep a log of their technology use throughout the term. These technology use logs (see Appendix D) were intended to provide the opportunity to investigate any connection between level of technology use on the part of the teachers and student academic achievement.

3. Quantitative Analysis

3.1 Student baseline survey

The student baseline survey was administered in mid-September, 2007 to all participants at school A and to first semester students at schools B and C, and in mid-February to second semester students at schools B and C. The survey gathered data on students' past grades, typical activities, perceptions of teacher practices, and attitudes towards mathematics and the learning of mathematics. The survey was identical to that used at the start of the grade 9 year except that question 13 began: "In grade 9 how often did this happen in your mathematics lessons?" rather than "In grade 8…" In addition, question13 h) was changed from "We used examples from everyday life in solving mathematics problems" to "We had a discussion about math ideas" because we wanted to probe how often students had been involved in discussions during their Grade 9 year.

The survey used multiple choice and Likert scale items for all questions. Results were analyzed using SPSS Crosstabs to determine the average item responses that differed significantly between the experimental and control groups.

In what follows, we present the results for the student sample as a whole; those items for which significant differences were found between respondents in the experimental and control groups are marked with an asterisk. These results tables give the frequency of response at each level of a given item in the form of the percentage of students from the total sample responding at that level. For those survey items where significant differences were found, we break down the results by group (experimental or control) and present the output of the SPSS crosstabulation analysis, including response percentages at each level of the item and the level of statistical significance of the reported difference (the Chi-Square distribution probability value). (Note that the crosstabs tables show the percentages of valid responses – that is, the missing data are not included in the total percentage.)

The total number of students in the 2007-2008 year was 611. Survey results are given for 563 students to reflect the fact that two sections – one experimental and one control were removed for the quantitative analysis because of irregularities in test administration. (see Section 3.2).

3.1.1 Student information

Past grades. When students were asked to report their grades over the past few years, about 3/4 reported receiving mostly As, Bs or Cs (see Table 8).

Table 8: *Final grades in the last few years*

	Mostly Ds	Mostly Cs	Mostly Bs	Mostly As	Not sure	Missing
Percent of respondents	13.0	24.2	23.4	20.2	6.0	13.1

Future educational plans. The large majority of students in both groups planned to attend university or college but there were no were significant group differences (see Table 9).

Table 9: *School plans for the future*

Future plans	High school	Community college	University	Don't know	Missing
Percent of respondents	2.0	19.0	57.2	10.7	11.2

Personal activities. Student estimates of the total amount of time per day spent pursuing various activities are given in Table 10. These estimates suggest that the greatest proportions of student time are spent watching television and playing or talking with friends outside school. One third of the students reported spending 1 to 2 hours on math homework but 43.8% spent less than 1 hour.

Table 10: *Total amount of time spent in one day at listed activity by respondents*

Time spent on activities	No time	Less than 1 hour	1-2 hours	3-5 hours	More than 5 hours	Missing
Watching television and videos	3.0%	17.9%	44.8%	17.9%	6.0%	10.3%
Playing computer games	31.8%	20.1%	22.0%	10.8%	5.0%	10.3%
*Playing or talking with friends outside school	4.1%	22.0%	33.0%	19.5%	11.0%	10.3%
*Doing jobs at home	8.5%	45.5%	29.1%	4.8%	1.6%	10.5%
Playing sports	16.3%	20.4%	32.0%	14.7%	6.0%	10.5%
*Reading a book for enjoyment	33.7%	28.2%	20.8%	3.9%	3.0%	10.3%
Studying math or doing math homework after school	8.0%	43.0%	34.1%	4.1%	0.7%	10.1%
*Studying or doing homework in school subjects other than math	2.7%	29.3%	45.8%	10.8%	1.2%	10.1%

Significant differences were found between the control and experimental groups in the reported time spent for four of the activities displayed in Table 10 – time spent playing or talking with friends outside school, (see Table 11), doing jobs at home (see Table 12), time spent reading a book for enjoyment (see Table 13), and time spent studying or doing homework in school subjects other than math (see Table 14). Significantly more students in the experimental group reported spending more time on average in doing jobs at home, reading for enjoyment, and doing homework in subjects other than math. Control students reported spending more time playing or talking with friends outside school.

Table 11: *Student-reported time spent playing or talking with friends outside school*

Time spent playing or talking with friends outside school	Student experimental/control group		Total
	controls	experimentals	
No time	3.3%	6.1%	4.6%
Less than 1 hour	22.5%	27.1%	24.6%
1-2 hours	40.2%	32.8%	36.8%
3-5 hours	24.3%	18.8%	21.8%
More than 5 hours	9.8%	15.3%	12.3%
Total	100.0%	100.0%	100.0%

Pearson Chi-Square = 10.0, p=.040

Table 12: *Student-reported time doing jobs at home*

Doing jobs at home	Student experimental/control group		Total
	controls	experimentals	
No time	11.9%	6.6%	9.5%
Less than 1 hour	53.1%	48.0%	50.8%
1-2 hours	30.3%	35.2%	32.5%
3-5 hours	2.5%	8.8%	5.4%
More than 5 hours	2.2%	1.3%	1.8%
Total	100.0%	100.0%	100.0%

Pearson Chi-Square = 14.9, p=.005

Table 13: *Student-reported time reading a book for enjoyment*

Reading a book for enjoyment	Student experimental/control group		Total
	controls	experimentals	
No time	41.9%	32.5%	37.6%
Less than 1 hour	30.0%	33.3%	31.5%
1-2 hours	23.5%	22.8%	23.2%
3-5 hours	3.6%	5.3%	4.4%
More than 5 hours	1.1%	6.1%	3.4%
Total	100.0%	100.0%	100.0%

Pearson Chi-Square = 13.7, p=.008

Table 14: *Student-reported time studying or doing homework in subjects other than math*

Studying or doing homework in school subjects other than math	Student experimental/control group		Total
	controls	experimentals	
No time	3.6%	2.2%	3.0%
Less than 1 hour	29.2%	36.7%	32.6%
1-2 hours	56.0%	45.0%	51.0%
3-5 hours	9.4%	15.3%	12.1%
More than 5 hours	1.8%	.9%	1.4%
Total	100.0%	100.0%	100.0%

Pearson Chi-Square = 10.4, p=.035

3.1.2 Student perceptions

Perceived importance of activities. Students were asked about how they and their friends valued sports, mathematics, and "fun" (see Tables 15-17).

Table 15. *Perceived value of activities by percent of respondents*

Question	Strongly Agree	Agree	Disagree	Strongly Disagree	Missing
Most of my friends think it is important to do well in math	11.7%	59.0%	14.0%	4.6%	10.8%
*Most of my friends think it is important to have time for fun	48.1%	38.4%	2.0%	0.9%	10.8%
Most of my friends think it is important to be good at sports.	12.4%	46.4%	26.3%	3.6%	11.5%
I think it is important to do well in mathematics at school.	36.9%	48.5%	2.3%	1.2%	11.2%
*I think it is important to have time for fun	47.4%	38.5%	1.8%	0.9%	11.5%
I think it is important to be good at sports.	18.5%	43.7%	21.1%	5.3%	11.5%

Students clearly value doing well at mathematics, and perceive that their friends consider that important as well. It is perceived as more important than doing well at sports, but not as important as having time for fun. There were some significant group differences here: control students were more likely to strongly agree that friends and they themselves considered having time for fun important.

Table 16: *Perceptions of friends' valuation of fun by percent of respondents*

Friends think it is important to have time for fun	Student experimental/control group		Total
	controls	experimentals	
Strongly agree	58.9%	47.8%	53.9%
Agree	38.5%	48.2%	42.9%
Disagree	1.1%	3.5%	2.2%
Strongly disagree	1.5%	.4%	1.0%
Total	100.0%	100.0%	100.0%

Pearson Chi-Square = 10.2, p=.017

Table 17: *Perceptions of own valuation of fun by percent of respondents*

I think it is important to have time for fun	Student experimental/control group		Total
	controls	experimentals	
Strongly agree	60.3%	45.4%	53.5%
Agree	36.8%	51.5%	43.5%
Disagree	1.5%	2.6%	2.0%
Strongly disagree	1.5%	.4%	1.0%
Total	100.0%	100.0%	100.0%

Pearson Chi-Square = 13.5, p=.004

Perceptions of mathematics. Several questions addressed students' attitudes towards mathematics (see Table 18). About half of the students indicated that they enjoyed learning mathematics, but most did not find it easy, and approximately 50% found it boring. There was however a universal recognition that mathematics was important in life, and just over 1/3 indicated that they would like a job that involved using mathematics.

Table 18: *Student attitudes towards mathematics by percent of respondents*

Attitudes towards mathematics	Strongly agree	Agree	Disagree	Strongly disagree	Missing
*I enjoy learning math	7.8%	42.8%	29.3%	7.8%	12.3%
Mathematics is boring	13.0%	35.7%	32.3%	7.1%	11.9%
Mathematics is an easy subject	3.4%	18.1%	46.2%	19.9%	12.4%
Mathematics is important to everyone's life	32.3%	46.5%	6.6%	2.0%	12.6%
I would like a job that involved using mathematics	7.8%	29.7%	32.7%	17.2%	12.6%

With regard to enjoyment of learning mathematics (see Table 19), there was a significant difference between experimental and control groups with more experimental students reporting that they agreed with the statement.

Table 19: *Student perceptions about their enjoyment of learning mathematics*

I enjoy learning mathematics	Student experimental/control group		Total
	controls	experimentals	
Strongly agree	8.6%	9.3%	8.9%
Agree	43.5%	55.1%	48.8%
Disagree	36.4%	29.8%	33.4%
Strongly disagree	11.5%	5.8%	8.9%
Total	100.0%	100.0%	100.0%

Pearson Chi-Square = 9.64, p=.022

Students were also asked a set of questions designed to tap their perceptions of their own abilities in mathematics and their sense of efficacy as mathematics learners (see Table 20). Most agreed that they would like math to be easier but did not believe that math was more difficult for them than for their classmates. In regard to efficacy, most students did not link mathematics ability to being talented or having a particular strength, and a majority disagreed that they would never really understand an idea if they didn't understand it at first.

Table 20: *Perceptions of mathematics efficacy by percent of respondents*

Perceptions of mathematics efficacy	Strongly Agree	Agree	Disagree	Strongly Disagree	Missing
I would like mathematics much more if it were easier	28.5%	34.2%	13.0%	1.4%	9.2%
Although I do my best, mathematics is more difficult for me than for many of my classmates	9.3%	25.9%	35.1%	6.6%	9.3%
Nobody can be good in every subject, and I am just not talented in mathematics	16.4%	23.4%	28.6%	8.3%	9.5%
When I do not understand a new idea in mathematics at the beginning, I know that I will never really understand it	4.7%	12.9%	41.2%	17.9%	9.5%
Mathematics is one of my strengths	7.8%	21.1%	30.2%	17.5%	9.6%

Students were also asked about what was required to succeed in mathematics (see Table 21). Hard work was seen as the most important determinant of achievement, and was cited by nearly everyone as being necessary to success. Natural ability and the memorization of material were given roughly equal importance as determinants of success by the group as a whole. Most students disagreed that luck was required.

Table 21: *Perceptions of what is needed to do well in mathematics by percent of respondents*

Needed to do well in mathematics	Strongly Agree	Agree	Disagree	Strongly Disagree	Missing
Lots of natural ability	7.5%	43.7%	33.0%	3.9%	11.9%
Good luck	5.5%	16.3%	48.0%	18.1%	12.1%
Lots of hard work studying at home	39.3%	42.5%	5.9%	0.7%	11.7%
To memorize the textbook or notes	8.0%	39.4%	34.5%	5.7%	12.4%

3.1.3 Technology

Internet and computer use. Virtually all (96.2%) students reported having Internet access from home, and 83.1% indicated they had access elsewhere. As Table 22 indicates, significantly more control groups students indicated that they had Internet access at school.

Table 22: *Reported access to Internet at school by percent of respondents*

Internet access at school		Student experimental/control group		Total
		controls	experimentals	
	Yes	97.8%	93.8%	96.0%
	No	2.2%	6.2%	4.0%
Total		100.0%	100.0%	100.0%

Pearson Chi-Square = 5.1, p = .024

Despite the high level of internet access, as Table 23 indicates, use of the Internet for school-related mathematics learning was relatively infrequent; neither email nor Web use was common.

Table 23: *Reported internet activities by percent of respondents*

Internet activities for math	At least once a week	At least once a month	At few times a year	Never	Missing
Use e-mail to work with other students on mathematics projects	9.8%	12.1%	22.7%	43.5%	11.9%
Use the Web to access information for mathematics projects	9.8%	12.4%	27.5%	38.2%	12.1%

Students in the control and experimental groups differed in how much they enjoyed using computers for mathematics (see Table 24). Those in the latter group more frequently reported liking computer use in mathematics.

Table 24: *Reported enjoyment of using computer for math by percent of respondents*

Like using computers for math	Student experimental/control group		Total
	controls	experimentals	
like a lot	9.3%	16.9%	12.8%
like	22.7%	37.8%	29.6%
dislike	35.7%	28.0%	32.2%
dislike a lot	18.2%	7.6%	13.4%
did not use computers	14.1%	9.8%	12.1%
Total	100.0%	100.0%	100.0%

Pearson Chi-Square = 29.6, p=.000

3.1.4 Responses on mathematics teaching

Student perceptions of mathematics teaching. Students were asked to indicate their perceptions of the frequency with which a number of teaching strategies and tools were used (see Table 25).

If we consider only the activities in which there were no significant differences we can see that a majority of students in the study: spent time working on their own with worksheets or textbooks (79.6% almost always or pretty often), used calculators (83.1% almost always or pretty often), and had homework checked by the teacher (67.5% almost always or pretty often). Students reported that they usually began homework in class (49.6% almost always or pretty often), but seldom checked each other's homework (almost 70% said once in a while, or never) or worked on mathematics projects (75.4% - once in a while, or never)

Table 25: *Reported frequency of events in mathematics lessons by percent of respondents*

Mathematics lesson events	Almost always	Pretty often	Once in a while	Never	Missing
* The teacher showed us how to do mathematics	42.8%	26.1%	16.2%	3.6%	11.4%
*We copied notes from the board	21.8%	31.1%	24.2%	11.5%	11.4%
* We had a quiz or test	25.0%	48.7%	14.6%	0.4%	11.4%
We worked on mathematics projects	3.6%	9.9%	46.4%	29.0%	11.2%
We worked from worksheets or textbooks on our own	40.7%	38.9%	7.3%	1.8%	11.4%
We used calculators	58.4%	24.7%	3.9%	1.1%	11.9%
*We used computers	5.7%	6.7%	30.0%	46.2%	11.4%
* We had a discussion about math ideas	9.2%	25.2%	36.4%	17.9%	11.2%
* We worked together in pairs or small groups	11.0%	29.0%	40.3%	8.2%	11.5%
* The teacher gave us homework	51.7%	30.0%	5.0%	2.0%	11.4%
The teacher checked homework	28.6%	38.9%	15.8%	5.5%	11.2%
We began our homework in class	21.0%	28.6%	32.1%	6.9%	11.4%
We checked each other's homework	4.6%	14.9%	33.9%	35.2%	11.4%
* We discussed our completed homework	17.8%	32.0%	26.5%	12.1%	11.7%
* The teacher used the chalk board	44.8%	20.2%	14.0%	9.2%	11.7%
* The teacher used the overhead projector	25.8%	18.1%	24.5%	19.7%	11.9%
* Students used the chalk board	11.7%	25.2%	30.4%	21.1%	11.5%
* Students used the overhead projector	3.0%	5.7%	22.2%	57.5%	11.5%
* The teacher was interrupted	4.8%	12.1%	58.4%	13.0%	11.7%
* The teacher used a computer to demonstrate ideas in mathematics	20.2%	14.2%	18.8%	35.3%	11.4%

Since there were significant differences in control and experimental student responses to a large number of the questions, the results, including Pearson Chi-Square and *p* values are shown together in Table 26. We can see that significantly more students in the experimental group reported that the teacher showed them how to do math, that they copied notes from the board, had a quiz or test, and were given homework.

Students also reported more discussions – about math ideas and about their completed homework. The chalkboard and overhead projector were reportedly used more often by teachers in the experimental classrooms, but interestingly, also by students in the experimental classes; 74.9% of control students reported never using the overhead projector compared to 53.3% of experimental students, and 33.6% of control students reported never using the chalkboard compared to 12.3% of the experimentals.

Table 26: *Frequency, Pearson Chi-square and p values for events showing significant differences between experimental and control groups*

Mathematics lesson events	Group	Almost always	Pretty often	Once in a while	Never	Pearson Chi-square	*p*
The teacher showed us how to do math	Cont.	40.6%	27.7%	25.1%	6.6%	33.5	0.000
	Exp.	57.5%	31.6%	10.1%	0.9%		
We copied notes from board	Cont.	19.1%	30.9%	27.6%	22.4%	51.0	0.000
	Exp.	31.3%	40.1%	26.9%	1.8%		
We had a quiz or test	Cont.	24.3%	54.8%	20.6%	0.4%	9.7	0.022
	Exp.	33.0%	55.1%	11.5%	0.4%		
We used computers	Cont.	8.5%	7.7%	20.2%	63.6%	52.0	0.000
	Exp.	4.0%	7.5%	50.2%	38.3%		
We had a discussion about math ideas	Cont.	5.9%	26.1%	46.0%	22.1%	17.4	0.001
	Exp.	15.8%	31.1%	35.1%	18.0%		
We worked in pairs or groups	Cont.	15.2%	35.2%	42.2%	7.4%	8.2	0.042
	Exp.	9.2%	29.8%	49.6%	11.4%		
The teacher gave homework	Cont.	52.6%	37.1%	7.0%	3.3%	10.6	0.014
	Exp.	65.2%	30.0%	4.0%	0.9%		
We discussed our completed homework	Cont.	14.4%	35.9%	31.5%	18.1%	18.5	0.000
	Exp.	26.9%	36.6%	28.2%	8.4%		
The teacher used the chalkboard	Cont.	40.6%	20.3%	21.4%	17.7%	55.1	0.000
	Exp.	62.8%	26.1%	9.3%	1.8%		
The teacher used the overhead projector	Cont.	33.9%	13.3%	22.9%	29.9%	40.2	0.000
	Exp.	23.6%	29.3%	33.8%	13.3%		
Students used the chalkboard	Cont.	10.0%	22.9%	33.6%	33.6%	34.9	0.000
	Exp.	17.2%	35.2%	35.2%	12.3%		
Students used the overhead projector	Cont.	2.6%	5.5%	17.0%	74.9%	26.4	0.000
	Exp.	4.4%	7.5%	34.8%	53.3%		
The teacher was interrupted…	Cont.	5.5%	11.1%	63.1%	20.3%	16.6	0.001
	Exp.	5.3%	16.8%	69.9%	8.0%		
The teacher used a computer to demonstrate ideas	Cont.	29.4%	8.5%	9.6%	52.6%	95.3	0.000
	Exp.	15.0%	25.1%	35.2%	24.7%		

Another difference is that students in the experimental schools reported more frequent interruptions of their classes. On the other hand, approximately 50% of the control students reported that they worked in pairs or groups “almost always” or “pretty often” compared to approximately 39% of the experimental students.

Two of the mathematics classroom events relate to computers: a) We used computers, and b) The teacher used a computer to demonstrate ideas in math. In regard to the first statement, about 64% of the control students reported never using computers compared to around 38% of the experimental students. This may be related to the availability of bookable lab time in the schools, since none of the regular classrooms used by participants had computers for student use.

In response to the second prompt, significantly more students in the experimental group (75.3%) reported at least some use of the computer as a demonstration tool compared to students in the control group (47.4%). Since these survey questions refer to the grade 9 year when TI-Navigator was introduced, we might have expected a higher incidence of "Never" amongst control responses and a lower incidence amongst experimental responses; thus some comments are in order. Firstly, in the implementation year one teacher at the control school used TI-Navigator frequently in grade 9. (That teacher's classes were removed for analysis purposes in that year). Second, as noted earlier, there are students in the Grade 10 study who were not involved in the first year. And finally, teacher use of TI-Navigator at the experimental schools (especially in the first semester) was adversely affected by fairly serious technical difficulties.

3.1.5 Summary

The results of the student baseline survey indicate that although there were a number of instances of statistically significant differences, the control and experimental students had many of the same experiences of and attitudes toward mathematics.

Virtually all (96.3%) students reported having Internet access from home, and over 83% indicated they had access elsewhere; however, significantly more control groups students indicated that they had Internet access at school. Despite the high rate of Internet access few students used email or the Internet in connection with mathematics.

Surprisingly, there were a large number of statistically significant differences in the students' reports on mathematics lesson events. For instance, students at the experimental schools were more likely to copy notes from the board and to use the blackboard and overhead. They were also more likely to have engaged in discussions in their grade 9 year, and to have had quizzes. We suggest that these latter differences may be related to Grade 9 work with TI-Navigator. Although technical difficulties slowed implementation in the first year, teachers in the experimental classes were trying TI-Navigator activities – which encourage class discussion – and they frequently used LearningCheck and Quick Poll to give quizzes.

3.2 Post-test data analysis

A post-test data analysis was carried out for those experimental and control group students who had completed both the pre- and the post-test. Analyses of covariance (ANCOVA) were run on the student post-test scores, using the student pre-test scores as a covariate to control for pre-existing individual differences in mathematics knowledge and ability directly related to achievement in the Grade 10 curriculum. As different pre- and post-tests were administered to the applied and academic classes because of course content differences, the analysis of the two streams had to be conducted separately.

One of the academic stream experimental classes and one of the applied stream control classes were dropped from the analysis due to test administration problems. In the control school, one applied class of 22 students wrote the wrong pre-test (as per earlier comment regarding teacher C5). In School A the teacher of an academic class of 26 students reported that extreme heat together with heightened commotion in the corridor because of end of year activities created poor conditions for writing the post-test. As a result, many students, knowing that the test did not count towards their final grades, simply stopped writing and put their heads down. Unfortunately there was no later date to administer the test. Subsequent examination of post tests for this class revealed that a majority of students had answered fewer than half the questions. The class in question scored slightly above average on the end of year school-developed common examination, which suggests that the lack of effort was not due to frustration with the material. The descriptive data for the adjusted applied class post-test scores for six experimental and five control classes are given in Table 27, and those for the academic class scores for six experimental and seven control classes are shown in Table 28.

Table 27. *Grade 10 academic mathematics course student post-test descriptive data.*
Dependent Variable: Student academic post-test total score (adjusted)

Student experimental/control group	Mean	Std. Deviation	N
Control	13.10	6.12	161
Experimental	15.16	6.58	102

Table 28. *Grade 10 applied mathematics course student post-test descriptive data.*
Dependent Variable: Student applied post-test total score (adjusted)

Student experimental/control group	Mean	Std. Deviation	N
Control	6.47	4.58	73
Experimental	6.10	4.23	71

The results of the ANCOVA tests on the grade 10 test scores revealed a statistically significant difference between the experimental and control students on the post-test (controlling for pre-test differences) for the academic stream students—the experimental students had a significantly higher mean post-test score ($F_{(1,260)} = 9.910$; $p = .002$; $\eta_p^2 = .037$). The treatment effect size of .037 indicates that approximately four per cent of the total variance in student scores was attributable to their experimental or control grouping. Note: A partial Eta squared value of .037 is equivalent to $d = 0.39$ and effect sizes of this magnitude are considered moderate in educational research. No statistically significant difference in adjusted post-test means was found between the control and experimental student groups for applied stream students in year two, ($F_{(1,141)} = 0.300$; $p = .585$, $\eta_p^2 = .002$).

3.3 Technology use

Experimental. In the 2007-2008 year we asked teachers at the experimental schools to record in a log their use of technology. Despite handing out prepared sheets, which had spaces for each lesson and type of use (e.g., Calculators only, Quick Poll), and giving teachers frequent reminders, compliance with this request was poor. When teachers did send in reports they provided a range of information; some filled in the form, others reported more generally (e.g., "students had access to graphing calculators every day".) From the information provided we determined that TI-Navigator was used 16 times on average in the academic classes (range 9-25) and 25 times on average in applied classes (range 20-30), that is, approximately once every 4.5 days with academic students and once every 3 days with applied students (given that there are approximately 75 'lesson days' in a course after eliminating test days, exam days, and classes shortened for special school events).

This is not to say that all usage was equivalent. For example, though one observed teacher used TI-Navigator infrequently with his two academic classes (he had never taught the course before and was finding it challenging to teach from a new text and incorporate TI-Navigator), his skill level with the technology was high. [Note: this teacher used TI-Navigator more than average with his applied classes – one of which was an observed class.] On the other hand, another teacher, who used TI-Navigator more often than the average, was still slow at setting up and less skilled than the other teachers at using the technology in her lessons.

With regard to calculators: in School A students took their calculators home. Thus, they had access to a graphing calculator on a daily basis. As last year, a number of students in the observed applied class routinely forgot their calculators. These students were supplied with a calculator so that they could participate in the lesson.

At School B, calculators were stored at school and handed out for use in class; students, on an individual basis, could ask to take their calculator home and some in the academic classes did so. On average, classes at School B used graphing calculators (with or without TI-Navigator), 49 times during the semester.

Control. At School C the department head provided information on use of technology. She reported that there was no use of TI-Navigator by study teachers during the 2007-2008 year. Three of the teachers used graphing calculators 5-10 times with each of their classes, one teacher used them once, and one teacher did not use them at all. Only one teacher (Teacher C8) used graphing calculators frequently. The department head noted that one reason for the limited use of graphing calculators is the lack of equipment. The school has only two sets; teachers book a set for particular topics such as intersections of lines and translations of parabolas. Use of other technologies is also infrequent; programs such as *Geometer's Sketchpad* can only be accessed by booking the school computer lab.

4. Qualitative Analysis

4.1 Classroom observations

Findings with regard to observations of the six in-depth classes will be reported according to the following categories: overview of use of technology, use of other demonstration methods, student engagement, links to other strands/subjects, and mathematical discussions. Within each section comments will be separated according to Experimental and Control.

It must be noted that any comments provide only a snapshot since observers were present for a small number of lessons.

4.1.1 Overview of use of technology

Experimental. Teachers A3, A4, B1 and B2 were observed at the experimental schools. By the end of the year all four could successfully use the main programs: Quick Poll, LearningCheck, and Activity Center. They were able to set up to receive student answers, and to save student scores. Teacher A3 was still quite slow at troubleshooting, but the others were able to quickly fix problems.

As last year, our observations showed that LearningCheck and Quick Poll were the most commonly used applications; the observed teachers usually prepared their own worksheets and Quick Poll questions; however, there was some sharing of materials within schools and all teachers made use of activities demonstrated or mentioned at the inservice (PD) sessions.

Although teachers were encouraged at the PD sessions to incorporate physical objects, and tools other than graphing calculators (e.g., compasses) into their lessons along with technology, we did not observe any manipulative use by students – even in a lesson on surface area and volume of 3D shapes. However, two teachers used a TI-Navigator activity in which students sent quadratic functions to match arches in projected photographs. These virtual objects engaged students and provided a link to real-world applications.

Analysis of this year's observations showed that a) there were far fewer technical problems than in the implementation year, and b) teachers had begun to incorporate some changes in their pedagogy around use of TI-Navigator. In particular, we found that the observed teachers, to varying degrees, were using TI-Navigator to move towards a pedagogy associated with classroom connectivity (Hegedus & Kaput, 2002). They were using student responses as cues for making decisions about the direction of subsequent work, had students working together in pairs or groups, and were beginning to engage students in analysis of errors. We also noticed an increased effort on the part of all four teachers to involve the students in mathematical investigations. For example: Teacher A3 who was still somewhat tentative about the technology was one of those who used photographs to work on transformations of a parabola. This type of lesson is well known, but the teacher's decision to try it – and her attempts to get the students involved in discussing the mathematical ideas (while not completely successful), indicated a willingness to adopt a new teaching approach.

Control. Although they were not expected to use technology, both teachers did use graphing calculators at least once during the observed lessons and were comfortable doing so. In using technology the observed teachers followed their usual approach - fairly traditional, teacher-directed, focused on eliciting next steps in procedures and (to a lesser degree) getting students to explain the steps that they were taking or had taken in solving problems. Key mathematical points were reviewed along the way – e.g., difference between 3x and $3x^2$ and how to interpolate a root by thinking of boundaries. As usual, students, working in pairs or groups, then had time to complete assigned questions from their text or a worksheet while the teacher circulated and addressed individual student difficulties.

As in the case of teachers at the experimental schools, neither of the control teachers used manipulatives in connection with technology during observed sessions. In one session in which technology was not used, a student teacher used algebra tiles for part of the lesson.

4.1.2 Use of other demonstration/recording methods

Observers recorded how teachers used methods other than the TI-Navigator to demonstrate and record mathematical ideas, and commented on the relationships between the methods where appropriate.

Experimental. In the experimental classes, three of the observed teachers used the blackboard to record key ideas, sketch a graph or diagram, and to review procedures (e.g., isolating a variable); they occasionally had students write solutions on the board. In particular, as last year, Teacher B2 set up questions, and empty tables of values on the board before class; he also used Smartview on a regular basis. The fourth observed teacher had a Smartboard in her class and used it in preference to the blackboard.

Unlike last year, observers found that most teachers could proficiently move between use of board and TI-Navigator and were more likely to move around the class during the lesson.

Control. In the control classes the board was used for the same purposes as in the experimental classes. Teachers had students come to the board to write solutions – and then went over the work with the class. They drew sketches and diagrams to illustrate concepts, and recorded definitions and key ideas for students to copy.

4.1.4 Student engagement

Experimental. Students in both academic and applied classes were engaged at least part of the time but there were differences between students at School A and School B. The following are a few examples of observer comments on engagement. Teacher ID and course level are indicated.

- [Students are] a little chatty but they are all talking about their parabolas (B1 - academic)
- Students are into it…they want to know who submitted what. (B1 - academic)
- Students very involved in answering the quiz. Students very concerned about getting the right answers. They are working so hard they don't even notice that it's time to stop. (B2 - applied)
- Boys are more actively engaged; girls work quietly. All are quite focused on the tasks and interested in whether they got an answer right. (B2 - applied)
- During quiz students work quietly and individually; during take up many don't pay attention (A3 - academic)
- [Students] relatively engaged, discuss amongst themselves as they try to solve review question but lots of off task talk as well (A3 - academic)
- Lots of off topic chatter. During activities students do the work. Teacher doesn't demand attention. (A4 - applied)
- Most students pay attention when teacher is talking; the rest of the time there is constant chatter. (A4 - applied)

The difference in amount of off-topic chatter between classes in Schools A and B could be related to individual class management approaches or possibly a general expectation by students at School A that such talk is permitted -- last year we did notice that students at School A (with other teachers) were quite talkative. At the same time, as noted in other sections of this paper, teachers B1 and B2 had made noticeable progress in building class participation in TI-Navigator activities.

As mentioned last year, students quickly became disengaged if the teacher was required to spend more than a few minutes trouble-shooting technical problems. This year, it was mainly a problem in the classroom of Teacher A3 who was still quite slow in working with technology and who (as seen in the first excerpt below) did not, as a rule, assign work while troubleshooting technical problems.

- [Students] totally off task while teacher deals with technical issues; they aren't given anything to do. (A3 – academic)
- [Students are] relatively engaged when solving problems but get into off task talk when teacher is dealing with technical issues or entering the next question. (A3 – academic).

Control. As in the experimental classes, most students were engaged for at least part of each lesson. They were attentive during directed activities, and teaching sessions, but there was off-topic chatter to varying degrees during seatwork time.

4.1.5 Links to other strands/subjects

Experimental. The observed lessons focused on a variety of algebraic topics – linear relations (intersection points, slope), solving linear systems, multiplying binomials, factoring (common factoring, factoring binomials including difference of squares), solving problems involving quadratic equations, and analyzing parabolas. There were also a few sessions connected to trigonometry (symmetric triangles, trigonometric ratios) and one on finding surface area and volume of three dimensional figures.

During these lessons, teachers made connections to previous work – reminding students of related concepts, reviewing terminology and procedures. In most cases, connections were "within-strand," (e.g., within the algebra strand); however, in one observed lesson Teacher A4 modified an activity to link work on ratios of sides of similar triangles (part of the trigonometry strand) to previous work on linear relations. [The teacher mentioned that he had only realized the connection as he prepared the lesson.] This teacher designed an activity in which students used a unique number to set the ratio between a pair of similar triangles (see example, Figure 1). Students then sent their number (y) and the length of the missing side (x) as an ordered pair. The first three diagrams were set so that the students' points formed a straight line. As the class worked through the examples the teacher reviewed the concept of slope and then linked it to the ratio lesson. In the next case the unknowns were not lengths of corresponding sides. As a result, the onscreen image was a hyperbola. The students were quite surprised but unfortunately there was no time left in that class to analyse the result.

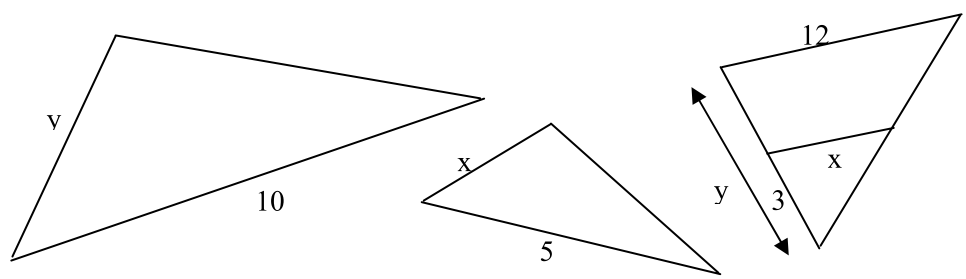

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Figure 1. Examples of triangle pairs in a class activity. The variable x represents the missing number. The variable y represents the student's unique number (i.e., it is known).

In a few cases, teachers developed links outside mathematics. As mentioned earlier, two teachers used photographs to develop the idea of parabola transformations, and one teacher used 'taking off/putting on shoes and socks' to illustrate the flow-chart method of solving linear equations.

Control. Findings in the control classes were similar. During observed classes teachers regularly reviewed previous work but made few connections between mathematics strands or to situations outside of mathematics.

4.1.6 Mathematical discussions

In this project, we are interested in whether use of the TI-Navigator supports dialogue in the classroom. Thus, a focus of our observations was the level of mathematical discussion in the classes.

Experimental. Although the year two PD sessions explicitly focused on the development of rich class discussions (especially around mistakes/misconceptions), most talk during whole class time was in the form of teacher question and brief student answer. This may be related to student expectations i.e., that the teacher does the explaining in a math class. However, brief answers – if they are part of whole group participation and not simply vehicles for one or two students to show the teacher what they know – may be evidence of growing participation in a new *discourse*.

Sfard (2007) contends that learning mathematics is equivalent to learning a (new) discourse. That is, learning the words of that discourse (or different meanings for old words), learning how to use the visual mediators of that discourse (e.g., formulae, diagrams), learning the "endorsed narratives" of the discourse (e.g., (a+b)^2 = a^2+2ab+b^2), and the routines of the discourse, i.e., the "well-defined repetitive patterns in interlocutors' actions" (p. 572).[1] Sfard points out that "even the first step in a new discourse is, by definition, already the act of participation in this discourse," (p.583); thus, at first, students may not be able to formulate full statements on a particular topic on their own. According to Sfard, one of the teacher's tasks is to get students to use the words, narratives and routines of the discourse even before they may have a full sense of the concept at hand.

It would seem that in the process of learning the discourse of mathematics, students would benefit from contributing to and talking about shared objects (whether concrete or virtual). Certainly, our observations provide some evidence that, especially in the two classes observed at School B, classroom conversation had started to develop around TI-Navigator displays. Although full discussions were not held, there was a sense in which students were actively and collectively involved in the task at hand. There was a palpable energy in many of the sessions – fuelled by teachers' expectations and by students' competitive spirit, but tempered by students' sense of responsibility (obviously encouraged by the teacher) for one another's understanding. Some observer comments:

- Teacher says "ok, we started slow but we should be getting faster." ….she asks "what if I translate this grid to here?" She moves the axes down…. she says "thank you very much" and stops the activity. All students get it right. (B1 - academic)
- Students are a little chatty but they are all talking about their parabolas….. They seem to be having fun today. Teacher is showing high proficiency with the calculators and TI … highlighting curves using colours that she is choosing … moving quickly from one activity to the next. (B1 - academic)
- Students who got the right answer go around to help those who got a wrong answer. There is quite a bit of discussion and students appear to enjoy the process. (B1 - academic)
- In the activity there were various errors - same intercept but opposite slope, same slope but different intercept, same intercept but different slope. Teacher went through each answer and why it was wrong. Teacher expects students to respond fairly quickly but doesn't rush - class moves at students' pace. (B2 - applied)

[1] Note: Sfard does not consider mathematics a language. Discourse also includes nonverbal forms of communication of a particular community.

- Listening, working, very quiet. …..One student gets up to show another how to input the equation. (B2 - applied)
- Much improved student attention when doing the activity on sending the graphs - they do some talking to one another, are concerned if they make an error, pay attention when teacher takes up answers. Clearly interested in doing this matching game. (B2 - applied)

At School A there was less focused whole class attention to the shared image. In particular, teacher A3 was quite slow at carrying out procedures and frequently stopped to troubleshoot minor problems; this disrupted the flow of the lesson and curtailed the energy that might have developed. Active student participation was evident in some observed sessions of teacher A4. For example, an observer wrote:

- Same equation – now send a perpendicular line. ….Out of 4 answers only one is right – students keep trying. Many are forgetting to put x. Students try resubmitting. Teacher tells students who got it right so far and others try to fix theirs. One student says "This is so cool – I want to send more" so he grabs his neighbour's calculator and puts another equation in. (A4- applied)

However, "conversation" was usually between one individual and the teacher (or between student partners.)

Control. Both observed teachers of control classes used the traditional question and answer format to review ideas or take up solutions.

4.1.7 Focus on Teacher B2

A more complete analysis of Teacher B2's development follows. Teacher B2, while still far from being an expert user of TI-Navigator, made remarkable progress during the two years of the study in incorporating technology into his teaching; and we contend that the pedagogical changes have had a positive effect on his ability to engage students.

At the start of the study Teacher B2 had four years of teaching experience. He had entered teaching after a number of years in industry in another country. His knowledge of mathematics was very strong. He was keen to share his enjoyment of mathematics with his students and was frustrated at their lack of enthusiasm. In both years we observed his teaching of applied classes, which lead to community college rather than university. Teacher B2's teaching style was very traditional – in general, he explained the topic for the day and pointed out important ideas. Many students did not participate. Teacher B2 asked questions of a small number of students and if a response was correct he moved to the next point. He spent most of his time at the front of the class, seldom engaging students at their desks.

Teacher B2 began using the TI-Navigator at the summer week-long session before the first year. He was very nervous about using technology in the mathematics classroom. Although he had used graphing calculators with his classes, this was mainly to satisfy the curriculum requirements; our observations showed that initially he was unaware of many of the features of a graphing calculator.

In the first semester of year one, Teacher B2 struggled with technical issues. Classes were often delayed while he attempted to help a student login or send data. Nevertheless he noticed that students enjoyed using the system, so he agreed to have in-class help. The coach (a teacher, expert in TI-Navigator) recognized immediately that there were two problems – lack of confidence with the technology, and a very teacher-centered pedagogical style. The coach taught a number of lessons in which he modeled engaging students in discussion of the mathematics, and helped Teacher B2 with various technical issues. Subsequent observations revealed that Teacher B2 was more comfortable with the technology; times to set up and troubleshoot were greatly reduced and Teacher B2 was more familiar with calculator commands and with TI-Navigator programs such as Learning Check. Although Teacher B2 was not yet getting students involved in class discussions he was moving around the classroom to check on their progress. Students were more involved than at the beginning of the semester.

From the start of year two there was a noticeable difference in tempo. The class moved at a quick pace with very little time wasted on technical issues. Over the course of the six observed classes Teacher B2 combined board work, calculator work, and TI-Navigator work with some skill. An observer wrote:

- Teacher beginning to use [technology] casually …. Throws in reminders (e.g., the negative sign on the calculator is different than the subtraction sign); knows the commands; able to troubleshoot; uses the TI-84 poster to remind students what they need to do; aware of keeping the grid square [on the NAV display]. (Teacher B2's class, 11/13/07)

During technology activities students were very engaged – they were less so when the teacher was "lecturing". An observer noted at one class:

- Teacher goes around and talks to student, looks at their work, interacts with them. Students are ready to roll as soon as a graph is shown. Someone says "I get it!" Another, "Oh I got it now sir!" (Teacher B2's class, 10/29/07)

There were still no class discussions; however, Teacher B2 used his observations of student work to review/reteach certain points.

Although Teacher B2 did not use the TI-Navigator every class, he mentioned its usefulness: for quizzes, for engaging the students, and for allowing him to bring interesting mathematical ideas into the class. During a lesson on solving systems of equations he had the students "make stars"; students added multiples of two linear equations and sent their answers. Students saw that their line graphs went through the intersection point created by the graphs of the initial two, and the teacher pointed out that as a result you could use a carefully chosen combination of multiples to solve a system of equations.

Discussions with Teacher B2 showed that he is thinking about new ways to use TI-Navigator. He mentioned that he had suddenly recognized that he could work on quadratic expressions on the TI-Navigator by entering them as quadratic functions. He was very pleased with the subsequent lesson in which students factored quadratics and sent answers in the form of functions (e.g., y=(x+3)(x-1). [He mentioned this to the department head who said "Oh, I always do that!" but this didn't dampen his enthusiasm for the idea.]

Thus, although Teacher B2 had considerable mathematics knowledge, he was initially constrained by inexperience with (and fear of) technology, and lack of strategies for engaging students. In the first year he was constrained by inexperience with the equipment, frustrated at losing class time to troubleshoot problems, and often found that he didn't "cover" as much material during the class as he would have without technology. Although Teacher B2 received significant support from his department head and from the PD sessions, he was not able to successfully integrate the technology into his teaching until he received onsite help. Subsequently, this year's PD sessions, which focused more on pedagogy than technical skills, supported Teacher B2 in learning to use the technology as one of many tools, and in responding more skilfully to student responses and needs.

4.2 Student focus group responses

The three focus groups were held in mid-May; each involved 4-6 students and lasted approximately half an hour. Two groups involved students from academic classes; the other drew students from an applied class.

In all three groups students revealed that they used technology both at home and at school. In particular, for projects in history, science, and English, they used the Internet and word processing programs. Students also mentioned using spreadsheets in business classes, draw programs, photo imaging software, and devices such as CD players, iPod's and cell phones. A few students mentioned using graphing calculators in science, but only as aids for calculating; i.e., probes were not used.

In regard to mathematics, graphing calculators and the TI-Navigator were the main types of technology used. Although the curriculum requires use of geometry software, students in one group had not used Geometer's Sketchpad (which is licensed for use in Ontario schools) and no one mentioned use of other mathematical software.

Drawing on our observations and the technology-use data we categorized the teachers of the focus group students with respect to TI-Navigator use; teacher B1 was ranked High because of frequent use and high competence; teacher A4 was ranked Medium because of moderate use (with the observed class) and very good competence, and teacher A3 was ranked Low because of moderate use and fair competence. Student focus group comments supported our conclusions.

For example, with respect to how TI-Navigator was used, teacher A3's students noted:

- [The teacher] doesn't really know how to use TI-Navigator

- It takes a long time to set up
- It doesn't usually work out
- [The teacher] mainly uses Quick Poll

On the other hand, teacher A4's applied students offered:

- [We have] questions, polls … like y = x, functions, we would put that in and graph it
- He would send us homework and then we do it and send it back
- And we get tests

In this class, students are quite clear about the varied uses of TI-Navigator in their lessons and they mention taking questions (i.e., LearningCheck questions) home on their calculators.

The academic students of teacher B1 said:

- [We do] sketching functions …..and sending our answer to the teacher
- We've had quizzes – we get the questions on the calculator – she collects it
- You have to put the answer, give the equation …… then we can see the graph
- Well, we use [the TI-Navigator] a lot

These student comments suggest that teacher B1 is using much of the functionality of the TI-Navigator – including collecting and marking answers – on a regular basis.

Student answers gave us additional insight into some of the pedagogical approaches used by the teachers. Note: the teacher of the quoted student is included for reference.

- [The teacher] usually moves on; she doesn't usually stop to talk about mistakes (A3)
- Like say, if you don't really know the answer and someone else has the right answer then the teacher will talk about it. Then we will understand it more. (A4)
- I think it's made it easier because when he teaches us he asks us a question about it so then people answer so if we don't really understand and we got a wrong answer he'll go through it again cuz like he knows everyone's not ready. He shows us again how to do it. (A4)

According to these student reports we can see that unlike teacher A3, teacher A4 is comfortable in using student responses and errors to guide the progress of the lesson.

Many of the focus group students liked being able to see one another's answers but they had different reasons.

[I] like seeing other people's answers. It helps me see if I did something wrong - that I'm not the only one. (A3)

- Now when we see other's answer, then we talk about [it] and it's like "wow, that's your answer" (B1)

- We like it because they don't really know who you are, if you get the wrong answer they won't know who you are or anything (A4)
- They won't make fun of you because they don't know who you are (A4)

These comments reveal that some students like the anonymity afforded by TI-Navigator, while others appreciate analyzing and talking to one another about their answers.

And finally, students shared their overall feelings about use of TI-Navigator. There were some negative comments, mainly concerned with the fact that use of TI-Navigator is time consuming; otherwise students were generally positive about the technology.

- [It's] not necessary - but fun (A3)
- Um, somewhat it's better for me, I understand math more easily now. (A4)
- I think it makes more people work harder so cuz they see that, this problem is on the overhead or projector and then people want to do the next question to see if they get it right or wrong…… it just makes it easier….cuz everyone can answer the question at the same time and we can compare our answers. (A4)
- It's different … it's faster (B1)
- It's very progressive … it's very interesting (B1)
- The graphs are much better, it's more accurate (B1)

Although this is a very, very small sample it is interesting to note that the applied students emphasized that TI-Navigator makes it easier to do/understand mathematics, while the academic students focused on fun/interest, speed, and the accuracy of graphs.

4.3 Teacher interview data

4.3.1 Experimental schools

Interviews at the experimental schools were held at the end of the year. At School B, individual interviews were conducted with the three study teachers (one of whom was the department head). At School A teachers asked to have a group discussion, thus, the interview involved the five study teachers, including the department head.

Overall, the eight teachers said that they enjoyed using the TI-Navigator. Most of their reasons revolved around the students. All agreed that using TI-Navigator to do quick checks helped them determine whether the students understood the material. Several mentioned how the instant feedback got students involved, and one commented that TI-Navigator increased interactions between the teacher and the students. Other teachers talked about how the opportunity for students to answer anonymously increased the participation of particular students, and one added, "it's student-centered… [it] gets kids discussing the ideas."

Two teachers who were interviewed individually mentioned the idea of competition. One compared TI-Navigator work to computer games; he said that some students find math dry but that this gave them the opportunity to do something – to show that they were faster or more knowledgeable; the other reported that students were more engaged – that they tried to be the fastest and the best.

Teachers also found TI-Navigator particularly helpful in introducing topics – especially quadratics, trigonometric graphs, intersections of lines, and transformations of parabolas. One offered that technology activities let her focus on meaning at the beginning of a unit so that students get the 'big picture.' Another found that it took time away from teaching basic concepts but that it helped because students needed to think in order to produce, for example, correct graphs.

Several teachers mentioned the visual connection. One offered that the TI-Navigator supports the development of visualization skills and another said that it helps students learn to visualize quickly "even the hardest functions," and a third commented that activities with visuals make students eager to do more. From a slightly different angle, one teacher contended that one of the most important features of the TI-Navigator is that "students can see everything;" that is, students can see which mistakes occur and can focus on the visual display as the errors are analysed.

Teachers had fewer technical problems this year, but several complained about faulty hubs/wires and all agreed that the set up of TI-Navigator by teachers who are required to move between classes is a very time consuming process. In addition, there were problems with forgotten calculators and dead batteries. [Note: we purchased batteries for the schools at the start of the year. The board agreed to provide funds for replacement batteries; however, in practice, the department heads had difficulty accessing the funds.]

When asked about pedagogical challenges one teacher mentioned the difficulty of contending with technical problems while teaching a lesson, and another talked about the problem of waiting for students who are slow to send their responses, but a third brought up a more fundamental issue. He said that in teaching with the TI-Navigator he needs to have a very structured lesson plan (that is, he needs to prepare carefully). This comment draws attention to the fact that teaching with technology is demanding. In the traditional classroom, teachers can sometimes avoid problem situations by ignoring students who don't participate or who offer unusual solutions; however, in the TI-Navigator classroom "kids can't 'opt out'" (Teacher A6). Dealing with a wide range of student responses requires deep knowledge of the subject matter. As one of the department heads noted: "If you don't have the background, technology can't help. You're watching something beautiful but you're not making the connections."

4.3.2 Control school

An interview was conducted with the department head at School C to review the year and provide an opportunity to discuss future plans. The department head reported that there had been no particular problems this year. Most teachers used a traditional approach and as noted in the technology section, no one had used TI-Navigator and use of graphing calculators had been sparse except in one class.

5. Concluding Remarks

In this second year of the TI-Navigator study we focused on helping teachers in the experimental schools extend their implementation especially in terms of holding class discussions.

By the start of year two, seven of the eight study teachers at the experimental schools had relatively strong technological backgrounds. All teachers gained additional confidence during the year; however, one was still tentative about general use and troubleshooting by the end of the year.

Several of the observed teachers who had followed a traditional pedagogy, showed some movement towards a more open classroom; although they did not hold full class discussions, they did engage students in analysing projected responses, and considering the source of errors. LearningCheck and Quick Poll were the most commonly used applications but all participating teachers used activities recommended by colleagues or shared at the PD sessions.

While teachers were very positive about the effects on students – noting that students enjoyed TI-Navigator activities and were motivated to participate – the ANCOVA results show that the treatment had a significant effect only in the case of the academic classes. Despite the fact that there was no significant effect in the case of the applied classes, we contend that applied students did benefit from the use of TI-Navigator. Students in the two observed applied classes were actively involved in the mathematics activities, and applied students in the focus group interview indicated that they enjoyed the technology and particularly appreciated being able to share answers anonymously. Academic students who participated in focus group interviews also reported that they enjoyed using TI-Navigator. In addition, we found that students in the observed academic classes were engaged by the activities and that in one of the academic classes, student participation was accompanied by a noticeable energy.

Several teachers at the experimental and control schools have agreed to be part of the study in September as we follow some of the students into Grade 11, and we look forward to continuing our work with them.

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Appendix A – Observation Form

(Spaces removed where possible)

Pre-observation questions:

1. What are you planning to do when I observe your class?
2. What will the students be doing?
3. How does this lesson relate to the rest of your work in mathematics? (Which strand or unit does it connect to? Does it continue work from the previous day?)
4. Will you be using technology? If yes, how will you use it?
5. What will students to for homework?
6. EXPERIMENTAL: Will students use their graphing calculators to complete their homework?

Mathematics Lesson Observation Form

SITE	DATE
TEACHER	OBSERVER
Time : Begin _________ End___________	Total length : ______hrs. ______min.

Classroom

A. Walls:

- rules of behavior posted _____
- cooperative learning rules posted _____
- student math tests _____
- student math projects _____
- posters on math concepts _____
- number line _____
- graphs or charts _____
- other: _____

B. Classroom resources in view

- Manipulatives ________________________________
- Computers (working) #_____
- Other ________________________________

1. Students (shaded sections – first visit)Total number			ESL			Girls	
Total present			Special Needs			Boys	

Seating Arrangement :

- students have assigned seats _____
- seating appears to be random _____
- desks arranged in single rows _____
- desks arranged in paired rows _____
- desks arranged in clusters of: 3 4 5 mixed

2. Lesson overview

Topic:
Textbook: (incl pg # if app)
Worksheets: (desc.)
Description
3. Technology use

Technology used (check all that apply)	Calculator		CBL/CBR	
	Graphing Calculator		Software:	
	Navigator		Other	

4. Observation notes (If possible, use the following headings to organize field notes.)

Use of technology
Use of sketches/diagrams/models (e.g., on chalkboard, via software, manipulatives)
Student engagement/time on task
Links – to other strands, to real life applications, to prior knowledge
Mathematical discussions – depth, breadth, student participation in, student initiated
Other

Post-Observation Prompts

1. How did you feel that particular lesson went?
    - Did you accomplish what you had expected?
    - Were you trying anything new?
    - Where did your ideas come from?
2. Was this session typical of what you're doing in mathematics these days?

    If yes: Did you do anything special because you knew I would be here?

    If no: How was today's session different from usual?
    - Have you tried to implement any ideas from workshops?
    - What did you try? How did it work out? Would you try it again?
3. Are there any comments that you'd like to add on this lesson?

Appendix B – Focus Group Questions

Please tell me about your mathematics experiences in elementary school. (*Possible themes*)

- math class as a place for exploration/investigation
- math class as a place for being told how to do math
- individual/paired/group work
- sharing/not sharing ideas and results
- use of manipulatives
- use of computers/calculators
- math homework
  - types of questions,
  - amount of homework,
  - difficulty with
  - textbooks/worksheets

1. With regard to technology.
   a. Where have you used technology?
      i. At home?
      ii. At school?
   b. What types of technology do you use regularly?
   c. Have you used technology for school work?
      i. Which subjects?
      ii. Which topics?
   d. Which types of technology have you used for school work?
      - Word processing programs
      - Scientific calculators
      - Graphing calculators
      - Geometer's Sketchpad
      - Spreadsheets
      - Drawing/AutoCAD type programs
      - Other ____

2. With regard to the Navigator, would you comment on the following:
   a. How you have used the equipment thus far in your program.
   b. How/whether it has affected your mathematics class.
   c. How/whether it has affected your understanding of math ideas.

3. With regard to the Graphing calculators, would you comment on the following:
   a. How you have used the calculators thus far in the program.
      i. At school
      ii. At home
   b. Have you used the calculators when you were not required?
      i. For what purpose?
      ii. In what subject area?

Appendix C – Teacher Interview Questions

Q1 - What did you like about using TI Navigator this year in your classroom?

Q 2 – What were some of the technical challenges?

Q 3 – What were the pedagogical challenges using the technology and integrating it with the curriculum?

Q 4 – What do you think the impact is on student learning?

Q 5 - Do you have any suggestions for how we can work better together next year?

Appendix D – Technology Use Log Form

Date	**Topic/text page/comments**	**Technology Used**	✓	**# min. (approx)**
		None		
		Graphing calculators alone		
		LearningCheck		
		Quick Poll		
		TI-Navigator Activity		
		Other ______________		
Date	**Topic/text page/comments**	**Technology Used**	✓	**# min. (approx)**
		None		
		Graphing calculators alone		
		LearningCheck		
		Quick Poll		
		TI-Navigator Activity		
		Other ________________		
Date	**Topic/text page/comments**	**Technology Used**	✓	**# min. (approx)**
		None		
		Graphing calculators alone		
		LearningCheck		
		Quick Poll		
		TI-Navigator Activity		
		Other_______________		
Date	**Topic/text page/comments**	**Technology Used**	✓	**# min. (approx)**
		None		
		Graphing calculators alone		
		LearningCheck		
		Quick Poll		
		TI-Navigator Activity		
		Other ______________		
Date	**Topic/text page/comments**	**Technology Used**	✓	**# min. (approx)**
		None		
		Graphing calculators alone		
		LearningCheck		
		Quick Poll		
		TI-Navigator Activity		
		Other ______________		