College of Staten Island: Development of Inquiry Based Mathematics Content by Teachers and Students with TI-Nspire for Mathematics Teaching and Learning

(Texas Instruments – Early Stage Research on Instruction with the TI-Nspire Handheld. Phase I - Final Report, June 30, 2008)

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Introduction

TI-Nspire™ represents not only a new generation of graphing calculator technology, but also an advance in the capabilities of a low-cost personal computing device that is reliable and easy-to-use, supporting a broad range of instructional models and advanced modes of assessment for teaching mathematics. TI-Nspire™ incorporates two new capabilities not available previously:

a. The ability to display multiple representations which are connected and in a single plane. That is, the multiple representation capability dynamically links graphical curves, axes, equations and tables in simultaneous displays, such that a change in one representation is transmitted to the others. This feature allows teachers to design new tasks for their students to address the NCTM standards focusing on connections between algebraic and geometric representations, on inquiry-based approaches to teaching and learning mathematics, etc.
b. The ability to document content. This document-based content system is an organized presentation of multiple screens of mathematics, which can be saved, shared, annotated, and revisited, giving teachers new ways of assessing their students' understanding of mathematics and technology.

In the past decades graphing calculators have been widely used in mathematics teaching. Past studies demonstrated that the use of graphing calculators increased students' computational and procedural skills in mathematics learning (Harskamp, Suhre, & van Struen, 2000; Hong, Toham, & Kiernan, 2000). However, past studies have provided a mixed picture regarding the influence of graphing calculators on students' deeper conceptual understanding of mathematics (Hong, Toham, & Kiernan, 2000; Thompson & Senk, 2001). Researchers argued that for the cases that graphing calculators failed to improve students' conceptual understanding of mathematics, the reason came from the pedagogy of using calculators (Kastberg & Leatham, 2005). In these cases, the calculators were often used as an add-on to traditional teaching rather than in a more integrated way (Kastberg & Leatham, 2005). The calculator-based technology used in an inquiry-based learning environment is capable of involving students in collecting real time data, generating hypotheses, analyzing data, and drawing conclusions (Lyublinskaya, 2003a & b). These student-centered activities increase students' understanding of mathematical concepts and methods (Niess, 2001). Research indicates that it takes a great deal of education and experience to achieve a comfortable level of expertise in the use of technology as a teaching tool for helping students to learn (Fleener, 1995; Thomas & Cooper, 2000). Thus, when new technology such as TI-Nspire™ is introduced to the teachers, a great need exists for addressing the pedagogical issues surrounding the use of this technology by providing teachers a forum to examine their pedagogical perspectives for using this technology in teaching and to explore when and how to use it in the classroom.

With the fast pace of emerging technologies for teaching mathematics, few teachers have experienced learning mathematics with technology. They lack key learning experiences in their teacher preparation programs. Current mathematics teachers need professional development opportunities to guide the development of the knowledge needed for teaching with technologies.

They need opportunities designed specifically to develop their technological, pedagogical, and content knowledge (TPCK), guiding them in thinking strategically in planning, organizing, implementing, critiquing results and abstracting plans for integrating technologies in guiding student learning with specific mathematics content and for meeting the diversity of student needs (Niess, 2008).

Early studies (Niess et al., 2005) on continuing in-service professional development described five developmental levels of teachers' TPCK for teaching mathematics with appropriate technologies using ideas from Rogers' (1995) five levels:

1. *Recognizing* (knowledge) where teachers are able to use the technologies and recognize alignment of the capabilities of the technologies with mathematics content.
2. *Accepting* (persuasion) where teachers form a favorable or unfavorable attitude toward teaching and learning mathematics with appropriate technologies.
3. *Adapting* (decision) where teachers engage in activities that lead to a choice to adopt or reject teaching and learning mathematics with appropriate technologies.
4. *Exploring* (implementation) where teachers actively integrate teaching and learning of mathematics with appropriate technologies.
5. *Advancing* (confirmation) where teachers evaluate the results of the decision to integrate teaching and learning mathematics with appropriate technologies.

The professional development designed for the teachers in this project recognized the developmental process that teachers need to engage in as they develop the strategic thinking and knowledge needed for integrating TI-Nspire™ in their mathematics curriculum. Shreiter and Ammon (1989) argue that teachers' adaptations of new instructional practices are a process of assimilation and accommodation that results in changes in their thinking. But what does this process mean for developing TPCK for teaching mathematics? Any response requires a more in-depth description of TPCK.

Three important layers provide the research basis for the use of TI-Nspire™:

1. *Effectiveness.* TI-Nspire™ enhances strong research findings: Graphing calculators enhance student learning (Ellington, 2003; Khoju, Jaciw, & Miller, 2005). Incorporating formative assessment into everyday teaching practice is highly effective (Shepard, 2000, p. 10). When integrating TI-Nspire™ learning handhelds into their practice, teachers can draw insights from a rich literature substantiating effective use of graphing calculators and formative assessment in mathematics classrooms.
2. *Enhanced representation and communication of important mathematics.* TI-Nspire™'s linked representations help teachers to focus students' attention on the relationships among multiple representations, such as algebraic equations, geometric constructions, graphs, and tables of data.
3. *Deeper opportunities to learn.* Using the new document and networking features of TI-Nspire™, teachers can develop classroom practices that increase the time students spend doing mathematics in an environment that has the ingredients for success: increased support for mastering difficult concepts and skills; high student participation; and tools for reflective practice.

Opportunity for improvements of mathematics learning comes from the benefits of having capabilities that extend beyond the familiar graphing calculator. For example, teachers have new opportunities to differentiate instruction. Additional instructional models allow teachers to support project-based learning, engage in participatory simulations, and encourage students to build mathematical models. There is a need to build cumulatively on our existing understanding of teaching secondary mathematics with graphing calculators, by developing professional development programs concentrated on instruction and assessment to exploit the advances in the state of the art offered by TI-Nspire™ and to concentrate on developing additional instructional models for differentiated instruction and collaborative learning.

Examining the impact of this new technology on teachers and students' thinking about mathematics content, teaching/learning processes, and personal confidence is equally important. Current research shows that teachers' understanding of mathematics content, beliefs about learning and instruction, and confidence in new teaching techniques, all play a vital and integrated role in influencing what students actually learn and how they feel about their learning ability and about math or technology in general (Killion, 2002; Santa, 2004). These multiple layers of pedagogical learning must be added to mastering the technologies such as TI-Nspire™. Moreover, a research focus on patterns and strategies for such a professional development becomes particularly important.

References

Ellington, A. J. (2003). A Meta Analysis of the Effects of Calculators on Students' Achievement and Attitude Levels in Precollege Mathematics Classes. *Journal for Research in Mathematics Education*, 34(5), 433-463.

Fleener, M. J. (1995). A survey of mathematics teachers' attitudes about calculators: The impact of philosophical orientation. *Journal of Computers in Mathematics and Science Teaching,* 14, 481-498.

Grossman, P. L. (1989). A study in contrast: Sources of pedagogical content knowledge for secondary English. *Journal of Teachers Education, 40*(5), 24-31.

Grossman, P. L. (1991). Overcoming the apprenticeship of observation in teacher education coursework. *Teaching and Teacher Education, 7,* 245-257.

Harskamp, E. G., Suhre, C. J. M., & van Struen, A. (2000). The graphics calculator and students' solution strategies. *Mathematics Education Research Journal, 12,* 37 -52.

Hong, Y., Toham, M., & Kiernan, C. (2000). Supercalculators and university entrance calculus examinations. *Mathematics Education Research Journal*, *12*, 321 -326.

Kaput, J., Noss, R., & Hoyles, C. (2002). Developing new notations for a learnable mathematics in the computational era. In L. D. English (Ed.), *Handbook of international research on mathematics education* (pp. 51-75). Mahwah, NJ: Lawrence Earlbaum Associates.

Kastberg, S., & Leatham, K. (2005). Research on graphing calculators at the secondary level: Implications for mathematics teacher education. *Contemporary Issues in Technology and Teacher Education*, *5*(1), 25-37.

Khoju, M., Jaciw, A., & Miller, G. I. (2005). *Effectiveness of graphing calculators in K-12 mathematics achievement: A systematic review*. Palo Alto, CA: Empirical Education, Inc.

Killion, J. (2002). What works in the high school: Results-based staff development. Oxford, OH: National Staff Development Council. Retrieved March 22, 2003 from http://www.nsdc.org/connect/projects/hswhatworks.pdf

Lyublinskaya, I. (2003a). Connecting Mathematics with Science: Experiments for Precalculus. Emeryville, CA: Key Curriculum Press.

Lyublinskaya, I. (2003b). Connecting Mathematics and Science: Experiments for Calculus. Emeryville, CA: Key Curriculum Press.

Niess, M. (2001). A Model for Integrating Technology in Preservice Science and Mathematics Content-Specific Teacher Preparation, *School Science and Mathematics, 101*(2), 102-109.

Niess, M. L. (2005). Preparing teachers to teach science and mathematics with technology: Developing a technology pedagogical content knowledge. *Teaching and Teacher Education, 21*(5), 509-523.

Niess, M. L. (2008). *Mathematics Teachers Developing Technology, Pedagogy and Content Knowledge (TPCK).* Paper presented at the annual meeting of the Society for Information Technology and Teacher Education (SITE), Las Vegas, NV, March.
Niess, M. L., Suharwoto, G., Lee, K., & Sadri, P. (2006). *Guiding Inservice Mathematics Teachers in Developing TPCK*. Paper presented at the American Education Research Association Annual Conference, San Francisco, CA, April.
Roschelle, J., Pea, R., Hoadley, C., Gordin, D., & Means, B. (2000). Changing how and what children learn in school with computer-based technologies. *The Future of Children, 10*(2), 76-101.
Rogers, E. (1995). *Diffusion of Innovations.* The Free Press of Simon and Schuster Inc.: New York, NY.
Santa, C. M. (2004). Project CRISS: Evidence of Effectiveness. Kalispell, MT. Retrieved March 9, 2004 from http://www.projectcriss.com/projectcriss/pages/research/media/R-Evidence.pdf
Shepard, L. A. (2000). The role of assessment in a learning culture. *Educational Researcher, 29*(7), 4-14.
Thompson, D. R., & Senk, S. L. (2001). The effects of curriculum on achievement in second-year algebra: The example of the University of Chicago School Mathematics Project. *Journal for Research in Mathematics Education*, 32, 58-84.
Thomas, J. A., & Cooper, S. B. (2000). Teaching technology: A new opportunity for pioneers in teacher education. *Journal of Computing in Teacher Education, 17*(1), 13-19.

Project Background

This project established the following research questions:

1. To which degree teachers will be able to use TI-Nspire features, such as document-based content and the ability to display multiple representations which are connected and in a single plane, in order to develop inquiry based activities for teaching mathematics.
2. How progression of teachers' content creation tasks affects students' understanding of mathematics as demonstrated by students' performance.
3. What is the process of students' use of content creation capabilities of TI-Nspire and how does that affect students' understanding of mathematics.

The goals of the project are as follows:

(a) **to improve teacher quality** through 3-day summer professional development training with TI-Nspire specialists, weekly curriculum workshops throughout the school year, and classroom teaching experiences. The expected outcome of this goal is that all 5 participating teachers will complete one year project; demonstrate proficiency in the classroom use of TI-Nspire; and produce at least 8 TI-Nspire classroom tested activities that demonstrate progressively higher skill level and ability in using document-based content and the connected multiple representations features of TI-Nspire in order to develop inquiry based activities for teaching "higher order" understanding and problem solving.

(b) **to promote use of technology** in the mathematics classrooms for investigation and inquiry for underserved and underrepresented students in order to increase these students' achievement in the areas of mathematics and technology through implementing TI-Nspire technology in mathematics curriculum materials in the classrooms. The expected outcomes of this goal are that students taught by teachers participating in the project will improve their performance on mathematics assessments compared to the control group in similar classes that did not use this technology, and that students will start creating their own content using TI-Nspire handheld devices in order to develop deeper understanding of mathematics.

What has been accomplished over the grant period:

1. Five high school mathematics teachers from Curtis High School, including Mathematics Assistant Principal, participated in the 3-days TI-Nspire workshop held at College of Staten Island in August 2007.
2. One retired AP Math and currently NYC Board of Education mentor, who serves as a facilitator of the curriculum development workshops at Curtis High School has participated in 3-days TI-Npsire workshop on Staten Island and 2-days TI-Nspire workshop in Edison, NJ.
3. Dr. Irina Lyublinskaya, project PI, has been an instructor for both workshops.
4. Five teachers were selected as control group – all teaching the same subject, freshmen integrated algebra (formerly NY Math A) as experimental group. As of December 2007, one teacher from experimental group and one teacher from the control group dropped out of the program, so 4 teachers were participating in each group until the end of the project.
5. The number of experimental sections was 5 with the total number of students 131 during registration. The school is Title I school, the mobility and drop out rate is very high. Based on the report cards submitted by the teachers, the number of students in the experimental group at the end of the fall semester was 105 and at the end of the spring semester 107. The breakdown of the classes is following
   - Code F, regular freshmen integrated algebra, students performed at the grade level (levels 3 and 4 on the 8^{th} grade math city exams) – 1 section
   - Code A, this is a repeater section of integrated algebra for students who did not pass Math A Regents exam as freshmen[1] – 1 section
   - Code R, this is a reduced size freshmen integrated algebra for students who performed below grade level (levels 1 and 2 on the 8^{th} grade math city exams) – 3 sections.
6. The experimental group included teachers of various backgrounds
   a. Teacher A had 3 years of experience and was very intimidated with the TI-Nspire technology for most of the academic year. She never used View Screen panel. When she finally decided to use it in class in March, she did not plug it in to the power outlet and commented "I knew it would not work". However, she got very excited about grab and drag feature of the TI-Nspire when developing lesson about the effect of lead coefficient of quadratic on properties of parabola. She even invited us to see the lesson while before she was dreading using the TI-Nspire in class and dreading our visits. By the end of the school year she became much more positive and excited about TI-Nspire technology. Total teaching load – 5 sections, 2 of them were experimental.
   b. Teacher B was in her 1^{st} year of teaching. She was a confident person and a risk-taker. She started to use TI-Nspire since early October with most applications. Example of her risk-taking: she was working with the students in Data and Statistics application. She had a scatter plot on the screen with movable line and decided to see if she can put a function on the screen to model the scatter plot. She never tried that before. Despite that she went to the menus and found an option

[1] Starting 2007 – 2008 New York State introduced new mathematics curriculum, the sequence of Math A and Math B (each of 3 semester) was replaced by sequence of three year-long courses: integrated algebra, geometry, and algebra 2.

Plot Function right in front of her students. As a first year teacher she was under a lot of pressure, and felt burnt down by the end of the year, although still positively inclined and interested in using TI-Nspire in her classroom. Total teaching load – 5 sections, 1 of them was experimental.

   c. Teacher C had 7 years of experience, was confident as an individual user, but not with the students. She had classroom management problems and did not manage well classroom time. For a long time she refused to use View screen panel, but finally agreed to use it and loved it – she let students to come to the panel to hook up their handhelds to show their work and could not believe how many kids wanted to do the work and to show their work. In her own words: she never had such a great class participation. She was a very creative and constructivist teacher but she needed to learn how to better implement her ideas into the classroom environment. Total teaching load – 2 sections, 1 of them was experimental. Teacher C was a mathematics coach of the department.
   d. Teacher D had 10 years of experience. He considered himself a tech guru, but did not put time into learning technology or planning, thus many ideas fell through the cracks. He mainly relied on his partners to get all the ground work done, thus he did not really know all the needy greedy details of the work of the software or handheld. Thus in the classroom he could not help students when they were stuck. He also did not follow along with the students and as a result students were usually confused or lost and the lesson's objectives were not accomplished. Total teaching load – 1 section. Teacher D was department chair and school math assistance principal.

7. The number of control sections was 9. There were total of 2 R sections, 3 A sections, and 4 F sections in the control group. During registration there were total of 227 students in these sections. At the end of the fall semester there were 178 students in the control group and at the end of the spring semester there were total of 171 students.
8. Both groups of teachers, experimental and control, met weekly for curriculum development workshops to develop inquiry based lessons. During spring semester both groups met 13 times for 3 hours each time.
9. The experimental group developed the following lessons:
   a. Writing Function Rule (written by whole group - Oct. 22, 2007)
   b. Similar Figures (written by whole group - Nov.5, 2007)
   c. Solving Equations Graphically (written by whole group – Dec. 3, 2007)
   d. Modeling with Real Function Rule (written by teachers B, C – Feb. 11, 2008)
   e. Finding Rate of Change – (written by teachers A, D – Feb. 11, 2008)
   f. Predicting Using Trend Lines – (written by teachers B, C – Mar. 10, 2008)
   g. Using the Line of Best Fit to Make Predictions – (written by teachers A, D – Mar 10, 2008)
   h. Discovering Exponential Functions – (written by teachers B, D – Mar 31, 2008)
   i. Exploring Leading Coefficient of Quadratic Graphs – (written by teachers A, C – Mar. 31, 2008)
   j. Discriminant (written by teachers B, D – Apr. 28, 2008)
   k. Axis of Symmetry, Parabola (written by teachers A, C – Apr. 28, 2008)
   l. What are trigonometry ratios (written by teachers B, D – May 19, 2008)
   m. Discovering Trigonometry Ratios (written by teachers A, C – May 19, 2008)
10. Each lesson was first presented during PD group meeting, and revised upon the comments from the peers, facilitator and PI and then taught to the students in the classroom while observed by the PI and the facilitator. The first three lessons were

developed by the experimental group as a whole. Starting in the spring semester teachers in the experimental group developed lessons in pairs. The pairs changed as it is shown above. Total of three lessons per teacher were observed, one in December, one in February and one in March

List of collected data

Quantitative data from teacher participants:

1. Initial survey on attitudes towards TI-Nspire – after summer 3-days PD, October 2007
2. Final surveys on attitudes towards TI-Nspire – May 2008
3. Self-Assessment on TI-Nspire Proficiency - May 2008

Qualitative data from teacher participants:

4. Teacher Reflection journals
   a. After each lesson in which TI-Nspire is used.
   b. After each observed lesson.
5. Developed lesson plans
6. Developed activities files for TI-Nspire™ handheld/software

Data from classroom visits and presentations at PD

7. Observation Protocols for observed lessons on use of TI-Nspire (quantitative)
8. Rubrics on instructional practice for observed lessons (quantitative)
9. Narrative descriptions of the lessons (qualitative)
10. Narrative descriptions of the group presentations of the lessons (qualitative)

Quantitative data from the students in the experimental group:

1. Pre-test – mathematics content, September 2007
2. Post-test – mathematics content, January 2007
3. Fall 2007 semester grades
4. Spring 2008 semester grades
5. Self-Assessment on TI-Nspire Proficiency - May 2008
6. Attitude Survey towards TI-Nspire – May 2008

Qualitative data from the students of the teacher participants:

7. Reflections after each class in which TI-Nspire is used
8. Reflections after each class when developed lessons are used

Quantitative data from the students in the control group:

1. Pre-test – mathematics content, September 2007
2. Post-test – mathematics content, January 2007
3. Fall 2007 semester grades
4. Spring 2008 semester grades

Data Analysis and Relation to Research Questions

In this report only analysis of quantitative data is presented. The large amount of qualitative data requires much larger amount of time to transcribe and analyze it. Thus,

1. The research question #1, “To which degree teachers will be able to use TI-Nspire features, such as document-based content and the ability to display multiple representations which are

connected and in a single plane, in order to develop inquiry based activities for teaching mathematics." has not been addressed in this report since it requires analysis of qualitative data such as teacher developed content and teacher reflections, although all necessary data were collected in order to address this research question.

2. Since research question #2 "How progression of teachers' content creation tasks affects students' understanding of mathematics as demonstrated by students' performance." can be addressed based on quantitative data collected in this study, results and new questions raised by the analysis are provided in this report.

3. During one year of study students never reached the point of creating their own content, thus the research question #3 "What is the process of students' use of content creation capabilities of TI-Nspire and how does that affect students' understanding of mathematics." cannot be addressed in this current study.

Professional Development Intervention Model

In this study we developed and used an intervention model of teacher professional development to provide 4 teachers of various background and experience with the opportunity and support in creating their own content in the TI-Nspire environment. In the experimental group, two were new teachers and two were experienced teachers. This model involved teachers meeting weekly in a series of PD workshops facilitated by the expert master teacher in a following sequence: a) working as a whole group (at the beginning of the project) or working in pairs (toward second half of the project) to review curriculum sequence for the next two weeks, to select topic of the lesson, lesson's objectives, and to brainstorm lesson's activities appropriate for the TI-Nspire environment; b) meeting together for developing a lesson plan and TI-Nspire documents for the lesson – putting together work developed by the teachers outside the meetings; c) presentation of the lesson and activity at the PD meeting with demonstration of the TI-Nspire activity to the group, facilitator and PI for peer review and critique – followed by necessary modification/revision of the lesson plan and .tns documents; d) teaching the lesson in class by all teachers during the same week – observed by facilitator and PI, followed by post-observation discussion.

The analysis of the observed lessons is presented below, the quality of the use of TI-Nspire technology in these lessons as well as quality if instructional practice is analyzed over time for 3 observed lessons for each teacher. Lesson plans and TI-Nspire documents are collected over a period from October 2007 – May 2008. Detailed analysis of these lesson plans and TI-Nspire documents have not yet been prepared and will be provided later.

We observed that when teachers create their own materials, they feel more comfortable in the classroom teaching it to the students. They are also learning new technology in a "need-based" basis, discovering specific skills and applications that would allow them to accomplish the objectives of the lesson. In our view this is a constructivists approach to learning technology for the teachers. We also observed that teachers did not retain most of the skills that they learned during 3-days summer institute that they took prior to the school year, but working with the lessons for their own students helped them to retain particular skills used in these lessons. Thus we think that document creation (meaning very simple documents) is the best method to introduce teachers to TI-Nspire technology, when these documents are relevant to their teaching. This, of course raises question if this will work for teachers of all levels. We found that our teachers were very intimidated to work individually, but when given an option to work as a group they felt comfortable. Maybe not all teachers will be comfortable to start with document creation, but as a group exercise, I think it will be a good introductory level skill for all teachers.

Suggested model of professional development needs to be tested more before we can state if it is an effective intervention for the teachers to incorporate their own content into the classroom. Due to intensive nature of this model, teachers were able to create limited number of lessons that were peer-reviewed and tested in the classroom. How much did it affect their use of TI-Nspire technology during other lessons? Did they use TI-Nspire technology and how it was used? Did they use pre-made materials? In our study teachers had to deal with new curriculum that was introduced for the first year as well as with integration of new technology. How much impact that had on their ability to fully devote time to learning new technology? How much burden new technology was for the new teachers in our group? All these questions could be studied in a larger scale study.

Teacher's Attitudes and Proficiency

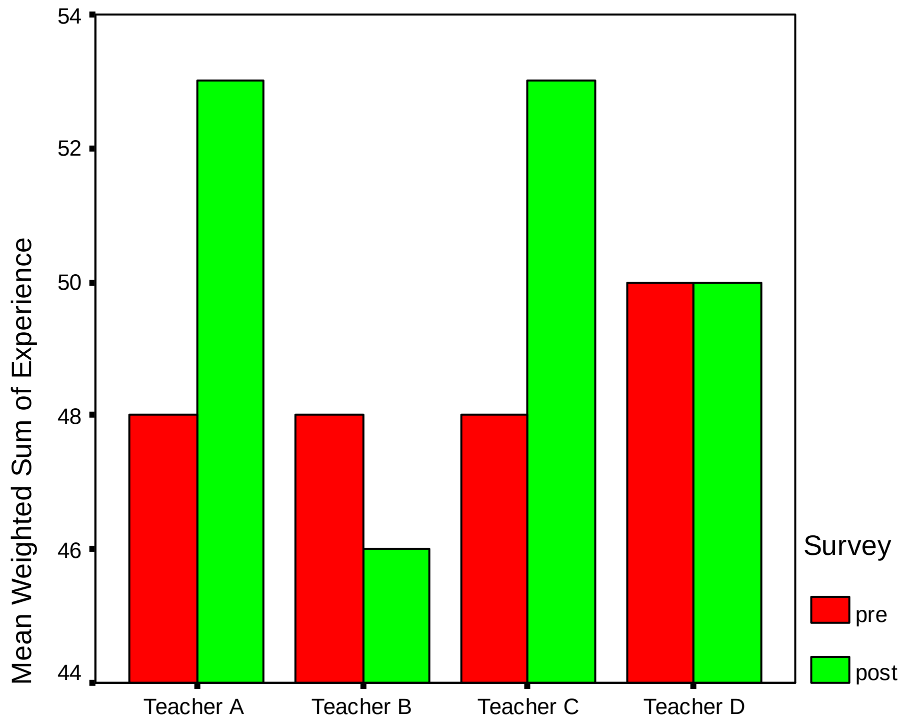
Pre-surveys and post-surveys had the same set of questions (the survey is given in Appendix 1). The pre-survey was conducted in September after teachers completed 3-days summer institute. The post-survey was conducted in May.
Questions 1 – 7 reflect experience on the scale 1 – 2 (disagree – agree); questions 8 – 13 reflect comfort on the scale 1- 5 (strongly disagree – strongly agree), and questions 14 – 18 reflect skills about use in teaching on the scale 1- 5 (strongly disagree – strongly agree). Last two questions were open ended essays that are not analyzed in this report. In order to analyze changes in teachers' attitudes and perspectives, composite experience, comfort, and teaching scores were constructed as weighted sums of corresponding scores. The ranges are 28 to 56 for experience, 21 to 105 for comfort, and 15 to 75 for teaching. Table 1 provides descriptive statistics for these three values.

Table 1. Descriptive Statistics for Teachers' Attitudes

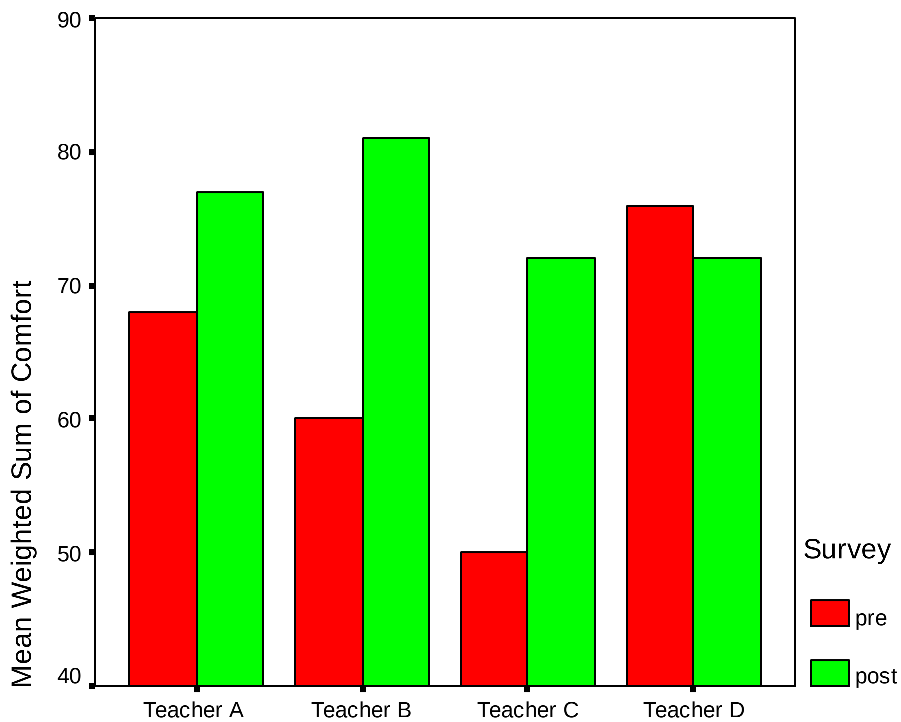
Survey		N	Minimum	Maximum	Mean
Pre	experience	4	48	50	48.50
	comfort	4	50	76	63.50
	use in teaching	4	43	63	52.75
Post	experience	4	46	53	50.50
	comfort	4	72	81	75.50
	use in teaching	4	46	52	49.25

As we can observe from the table, while the comfort and experience with TI-Nspire increased, the teacher's attitudes towards their abilities to use TI-Nspire in teaching decreased. This could be explained by the fact that teachers learned more about potential of this technology and realized that they need more time and more practice with TI-Nspire technology in order to implement it into the classroom more effectively.

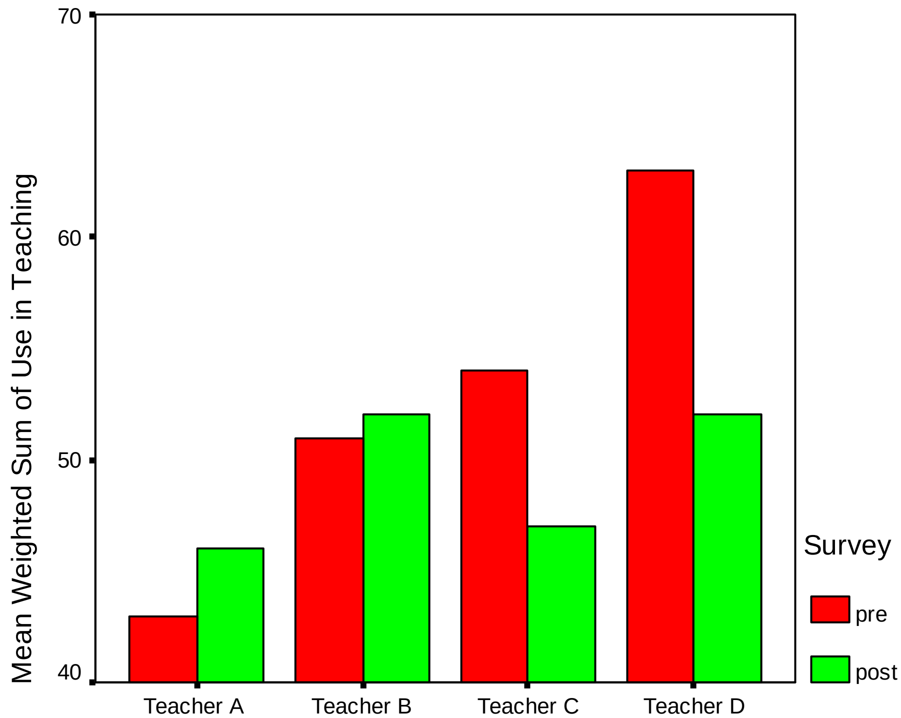
Individual teachers' perceptions towards their experience with TI-Nspire technology are shown on Figure 1a), their comfort level with TI-Nspire is shown on Figure 1b), and their attitudes towards their ability to use TI-Nspire in teaching are shown in Figure 1c).



a) Perceptions towards experience with TI-Nspire



b) Comfort level with TI-Nspire



c) Attitudes towards TI-Nspire use in teaching
Figure 1. Teachers' Attitudes and Perceptions Towards TI-Nspire Technology

Closer look at teachers individually shows an interesting dynamics in teachers' attitudes and perceptions. From Fig. 1a) it is seen that Teachers A, B and C had initially the same perceptions of their experience. The perceptions improved for teachers A and C, who used TI-Nspire technology approximately every other week as reported by their students (see Fig. 5 below) in two sections for teacher A and in one section for teacher C. On the other hand, perceptions of the experience for the teacher B who used TI-Nspire once-twice per week, worsened. This could be explained possibly by the fact that Teacher B was 1st year teacher dealing with many aspects of teaching profession, such as classroom management, learning new curriculum, etc. on top of integrating new technology into the classroom. This might have led her to the lower perceptions of her own experience with the technology compared to her colleagues. Teacher D had higher perceptions to start with, but with very infrequent classroom use of about once per month, his perceptions of experience did not change. Analyzing Fig. 1b) shows that teachers A, B, and C all demonstrated increase in comfort level while teacher's D comfort level decreased, which is also consistent with frequency of classroom use. Teacher B demonstrated the highest comfort level, and both, teachers B and C showed about the same increase in comfort level over the grant period. The changes in attitudes of teachers towards their abilities to use of TI-Nspire in teaching can be observed from Fig. 1c). Initially Teacher D had highest attitude, followed by teacher C, then teacher B, and the lowest attitude for teacher A. After one year of using TI-Nspire in the classroom teacher B attitudes about her abilities to use TI-Nspire in teaching slightly increased, reaching highest score in the group. Teacher A's attitudes increased as well, but for teachers C and D the score went significantly down. This is again correlated with the frequency of classroom use reported by the students in the students' post-survey.

Next we considered quality of classroom instruction and technology use based on classroom observations (see Appendices 3 and 4 for rubrics and protocol of observations).

Classroom Observations of Lessons Taught by the Teachers

Each teacher was observed by two observers three times. Rubrics consisted of 14 questions was used to evaluate quality of instructional practice. Composite score on instructional practice was calculated as the average score, with range 0 to 3. The quality of the use of technology was evaluated using observation protocol. The composite score on the use of technology was calculated based on specific questions of the observation protocol as the average of scores on questions 4a-c and 6 which are scored on scale 1 – 5, and sum of scores from questions 3 and 7 that scored on scale 0 to 1. The range for the technology score is 0 to 5.

First, consistency of observations between two observers were checked, using t-test (p = 0.919 for technology score and p = .778 for instructional score). Thus, the averages of two observations were used for each teacher to calculate the mean scores for each observation.

The question was if quality of instructional practice with technology and use of technology are improving with consequent observations that were approximately 1.5 months apart. The following graph shows the changes in the scores for each individual teacher:

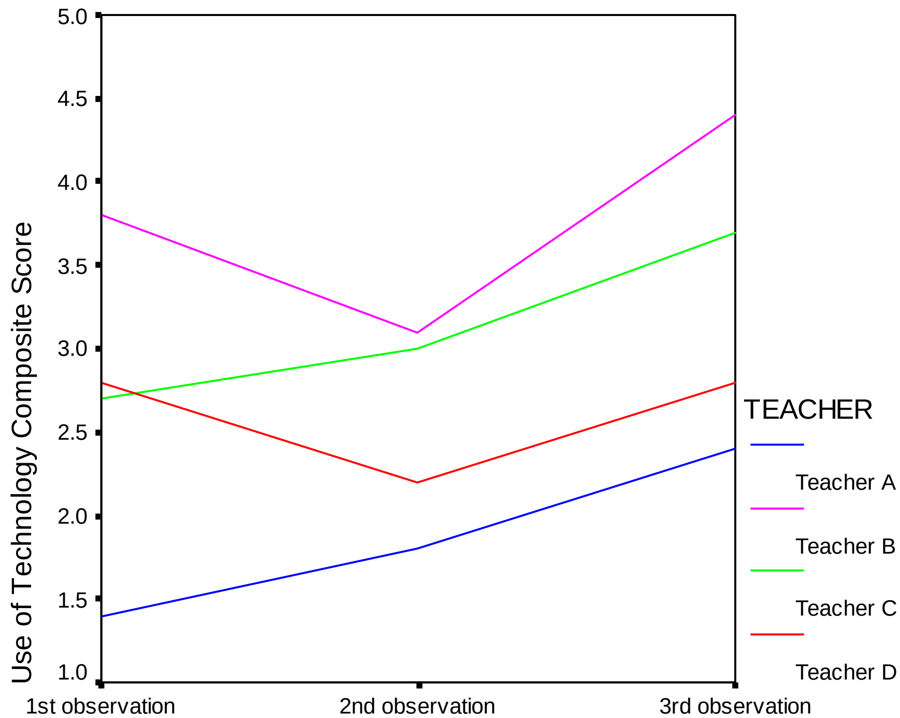


Figure 2. Changes in Quality of Use of TI-Nspire Technology

All teachers, but teacher D, demonstrate general improvement in quality of use of technology by the end of the academic year with teacher B showing highest score followed by teacher C, then teacher D and then teacher A. The largest improvement is shown by the teachers A and C.

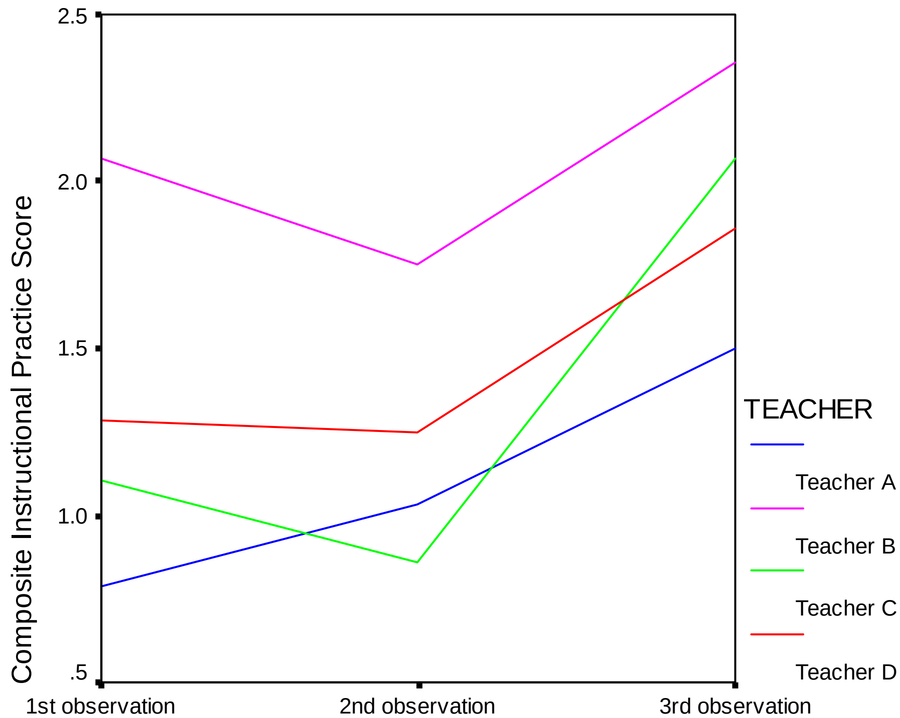


Figure 3. Quality of Instructional Practice with the TI-Nspire Technology

The quality of instructional practice in general is consistent with quality of use of technology.

Comparison of attitudes and perceptions with quality of lessons shows that Teacher B who had highest comfort level with the TI-Nspire technology and highest attitudes towards use of TI-Npsire in teaching also had the highest quality of instructional practice in general and highest quality of use of TI-Nspire technology in her lessons by the 3rd observed lesson (mid-March). At the same time her perception of her experience was not that high. It is an interesting fact that this was 1st year teacher. From personal communication with the teachers, only teacher B had technology integrated methods courses in her teacher preparation program. Did that affect her ability to embrace the challenge of integrating TI-Nspire technology at higher level than other teachers? How much teacher preparation program affect teacher's ability to successfully integrate new technology into the classroom? What are other factors that affected the changes in the quality of instructional practice and quality of use of technology by the teachers over the time? Based on comparison of Figure 1 with Figures 2 and 3, there is a complex relationship between teachers' attitudes and perceptions and the quality of their teaching, which is another question that needs to be studied with larger group of teachers.

Some of these questions might be addressed after we analyze the qualitative data.

The next question is how the teacher's attitudes and perceptions, proficiency in the use of technology, as well as quality of instructional practice might impact students' attitudes and perceptions, proficiency in the use of TI-Nspire technology, and performance.

Students Pre-Post Tests

All students in F, A, and R courses in school were given algebra readiness test in September. This was multiple-choice content test developed by the school, researcher did not have access to the test, only to the grades. For the students in control and experimental group this test was used as pre-test. The test was administered only to students attending school on the day when this test was given. The post-test was administered in January at the end of the fall semester.

Independent samples t-test were run for each level of courses on each group, control and experimental to compare the means on pre and post tests. The results are given in the tables below for each group.

Table 2. Control Group
134 students took pre-test, 135 students took post-test.

Class Level	Test	Number	Mean Score	St. Dev	T	P
R	Pre	37	31.95	20.73	-1.258	.212
	Post	34	39.00	26.37		
A	Pre	44	44.30	20.70	-1.321	.190
	Post	45	54.96	19.74		
F	Pre	53	59.34	21.40	-1.153	.252
	Post	54	63.87	19.21		

Table 3. Experimental Group
95 students took pre-test, 98 students took post-test.

Class Level	Test	Number	Mean Score	St. Dev	T	P
R	Pre	51	45.22	16.49	-1.244	.216
	Post	58	49.26	17.30		
A	Pre	18	47.72	17.64	-.534	.597
	Post	15	52.60	12.17		
F	Pre	26	62.88	18.26	-2.657	.011
	Post	25	74.76	13.14		

Test scores went up in both groups. There were no significant changes in control group in all three levels of integrated algebra. However, in the experimental group while the changes in the lower level classes were insignificant, the changes in the upper level classes were significant. These results could be attributed to the effect of integrating TI-Nspire into the integrated algebra classes. The learning curve with such complicated technology as TI-Nspire could be pretty long. This technology has not been integrated in the experimental classes until late October. For weaker students it was not long and frequent enough to become comfortable enough with the technology to see any effect on their performance in mathematics. However, for high achieving students for whom learning curve is much shorter, the technology impact on the mathematics performance could appear much sooner.

Due to early administration of post-test by the school, there were no data showing difference in teacher's attitudes, skills, and quality of instructions to consider relationship between these factors and changes in pre-post tests described above.

Students' Proficiency and Attitudes

The students' proficiency and attitudes survey was conducted to students in experimental group in May (see Appendix 5). There were total of 76 students who answered the survey. In this group 40% were male and 60% were female, 23% were white, 40% African-American, 20% Hispanic, 7% Asian, and 10% marked "other". Students' age ranges from 12 to 16 with 58% of students being 14 and 33% of students being 15. 73% of students owned graphing calculator and 27% did not own graphing calculator.

The part 1 of the survey dealt with students' self-assessment of their proficiency with the TI-Nspire technology. The survey had 25 questions with Likert-like scale from strongly disagree assigned value 1 to strongly agree assigned value 5. In order to analyze these data, 6 composite scores were created: general skills (average of scores for questions 1 through 5), calculator app (average of scores for questions 6 through 8), graphs & geometry app (average of scores for questions 9 through 15), lists & spreadsheets app (average of scores for questions 16 through 19), notes app (average of scores for questions 20 through 22), data & stats app (average of scores for questions 23 through 25). Table 4 shows overall descriptive statistics for the proficiency composite scores:

Table 4. Overall Proficiency Scores for Experimental Group

	N	Min	Max	St.Dev.
general skills (average 1-5)	79	1	5	3.24
calculator app (average 6-8)	79	1	5	3.41
graphs & geometry app (average 9-15)	83	1	5	3.06
lists & spreadsheets app (average 16-19)	76	1	5	3.03
notes app (average 20-22)	76	1	17	3.02
data & stat app (average 23-25)	76	1	13	3.36

As it was expected based on teacher and students responses students most often used calculator application and showed highest proficiency level in this application. It is also clear from the table that teachers preferred to use data & statistics applications to lists and spreadsheets applications. This could be explained by the fact that data & statistics app is much simpler and provides faster access to various StatPlots. More detailed analysis of skills in relation to various factors is provided below.

<u>Students' Proficiency vs. Demographics</u>

One-way ANOVA test results showed that there is no significant difference in TI-Nspire proficiency gained by students of different race. Independent samples T-test was run to compare mean scores for all composite skills scores to test if there is a difference in TI-Nspire proficiency by gender. The t-test results show no significant difference in proficiency between boys and girls. T-test was run to compare students' proficiency with TI-Nspire depending on the ownership of graphing calculator. The proficiency scores were statistically the same for students who owned and did now own graphing calculator. Thus, results of this study show that students' proficiency with TI-Nspire technology is independent from students' demographics.

The question of gender, race, and socio-economic status is an important question to ask in any study that considers technology and should be tested for a large scale study. It is reasonable to expect that after considerate time using technology effectively in the classroom, there should be no demographics differences.

The other researched factors were how students' proficiency skills depended on the course level, and then more specifically on the teacher. One-way ANOVA test showed that there were no significant difference between skills gained by the students from different level courses. However, one-way ANOVA test comparing skills by teacher showed significant difference in general skills (F = 4.002, *p* = 0.011), lists & spreadsheets app (F = 2.948, *p* = .038), and notes app (F = 4.053, *p* = 0.10). Further research showed the significant difference in these skills between the following teachers (Table 4)

Table 4. Students' Proficiency Skills by Teacher – Results of Independent Samples T-test

	Teacher	Number	Mean Score	St. Dev	T	P
general skills (average 1-5)	Teacher A	43	3.07	.921	-2.746	.008
	Teacher B	16	3.76	.649		
notes app (average 20-22)	Teacher A	43	2.61	.931	-3.078	.003
	Teacher B	14	4.48	3.686		
General skills (average 1-5)	Teacher B	16	3.76	.649	3.247	.003
	Teacher C	10	2.82	.829		
lists & spreadsheets app (average 16-19)	Teacher B	14	3.40	.804	2.356	.028
	Teacher C	10	2.65	.728		
general skills (average 1-5)	Teacher D	10	3.58	.757	2.155	.045
	Teacher C	10	2.82	.829		
lists & spreadsheets app (average 16-19)	Teacher D	9	3.53	.905	2.340	.032
	Teacher C	10	2.65	.728		

Due to small sample size, we cannot rely on the statistical significance of the results. However, the trends in the students' proficiency skills can be observed. For more visual representation, these results are also illustrated on Figure 4 below:

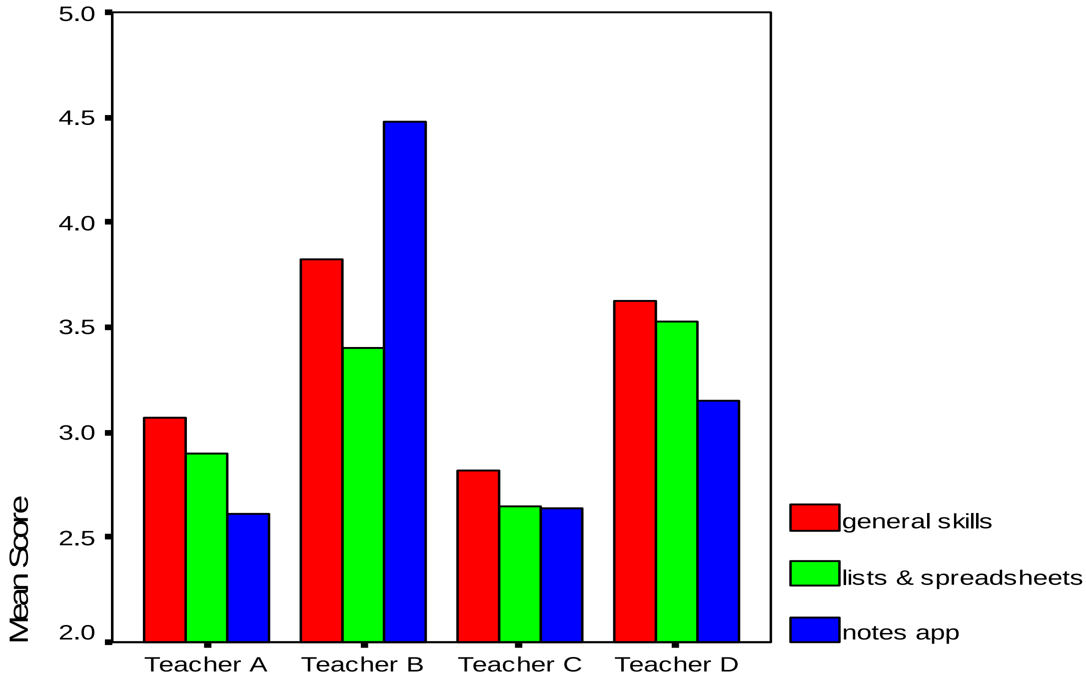


Figure 4. Students' TI-Nspire Proficiency Skills by Teacher. Scale: from 1 lowest to 5 highest

As it is seen from the graph, students in Teacher's B class became more proficient in the use of TI-Nspire in specific applications that have been used in the classroom. This result corresponds to the earlier results that Teacher B had higher comfort level and attitudes towards using TI-Nspire in teaching. She also had higher quality of instructional practice and use of technology based on classroom observations. When compared to the frequency of the technology use in the classroom (see Figure 5), this result also correlates with the frequency of technology use by the teachers.

Due to the fact that a lot of various factors interact, it is much harder to analyze relationships between students' proficiency in other teachers' classes, since they showed much larger variability between attitudes, skills, quality of instruction and frequency of technology use. The data suggest that when teacher uses technology on a regular basis and effectively, within instructionally sound practice, their proficiency is improving, which affects teacher's attitudes and comfort level which become consistent with their practice and their students' proficiency skills.

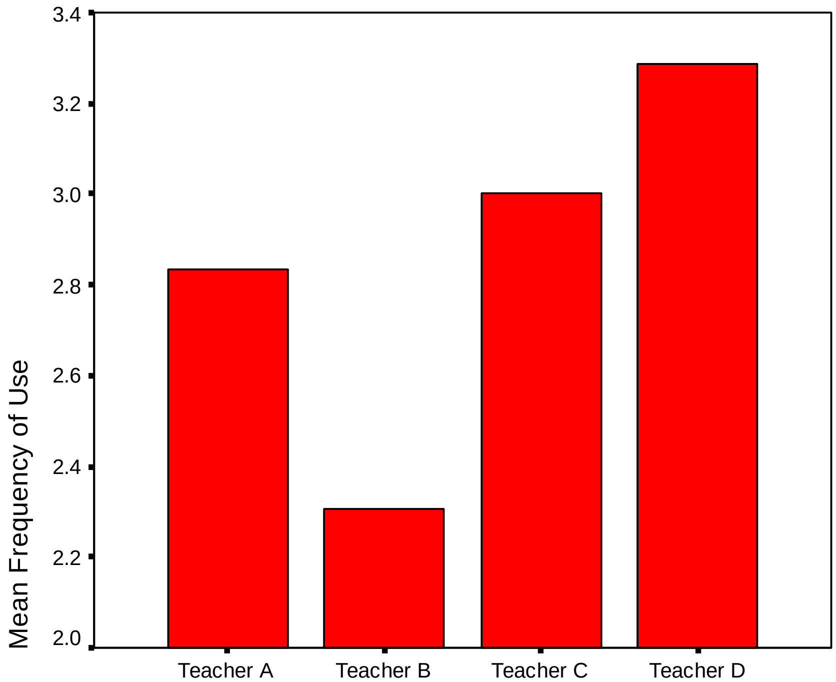


Figure 5. Frequency of TI-Nspire Use.
Scale: 1-every class; 2-once-twice per week; 3-once-twice per month; 4-once-twice per semester

The part 2 of the survey dealt with students' attitudes towards TI-Nspire technology. There were total of 13 questions with Likert-like scale from strongly disagree assigned value 1 to strongly agree assigned value 5. First 7 questions addressed students experience with and views of TI-Nspire technology at the moment of taking survey and the next 6 questions addressed students' comfort level using TI-Nspire technology. Two composite scores have been created to analyze students' responses. Composite experience score was constructed as weighted sum of experience scores, ranging from 28 to 56 and composite comfort score was constructed as weighted sum of comfort scores ranging from 21 to 105. Table 5 provides descriptive statistics for these two values.

Table 5. Descriptive Statistics for Experience and Comfort Scores

	Variable	N	Min	Max	Mean	St.Dev.
Overall	Experience	73	28	56	44.22	8.561
	Comfort	72	21	94	65.12	16.090
Course Level F	Experience	20	28	56	44.10	9.808
	Comfort	18	36	87	67.11	15.373
Course Level A	Experience	22	28	53	40.09	8.124
	Comfort	23	21	79	55.35	15.593
Course Level R	Experience	31	29	54	47.23	6.849
	Comfort	31	48	94	71.23	13.652
Teacher A	Experience	42	28	56	42.00	9.082
	Comfort	41	21	87	60.51	16.404
Teacher B	Experience	12	39	53	48.75	5.065
	Comfort	13	54	93	77.46	13.017

Teacher C	Experience	10	29	54	44.40	8.618
	Comfort	10	48	76	62.90	10.482
Teacher D	Experience	9	33	53	48.33	6.500
	Comfort	8	51	94	71.50	13.990

Students' attitudes by demographics factors were compared. No difference was found as a factor of gender, race, or if students owned graphing calculator. Comparison of students' attitudes by teachers is shown on Figure 6. Again, the highest scores are achieved for students in the Teacher's B classes. Analysis of students' attitudes as a factor of course level and teachers is shown in the Table 6.

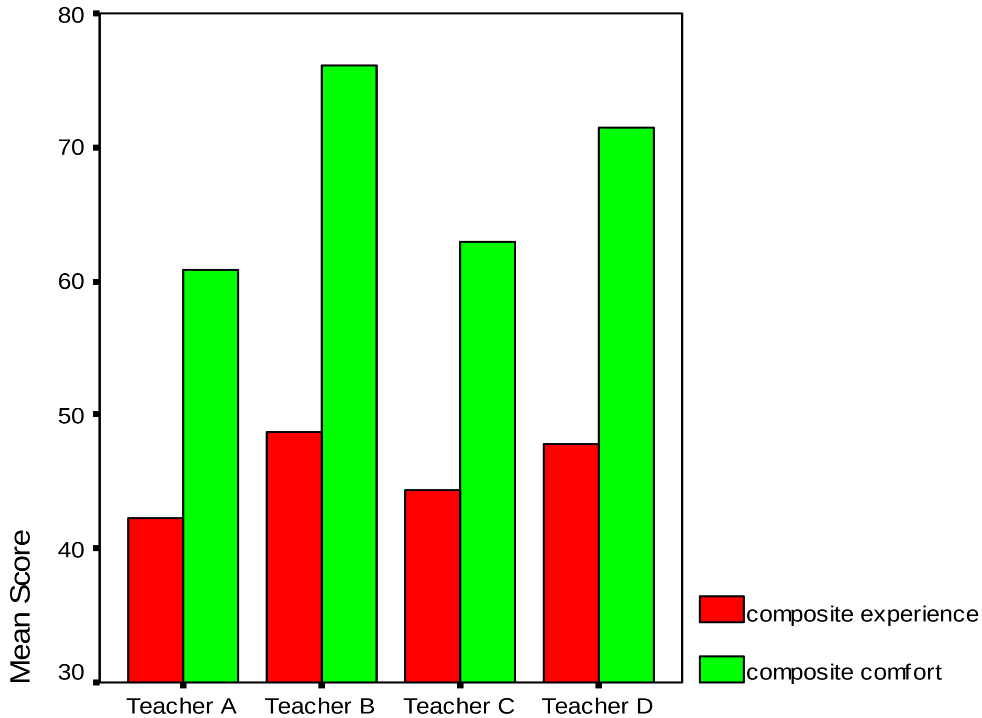


Figure 6. Students' Attitudes by Teachers.

Table 6. Students' Attitudes by Course Level and Teachers – Results of ANOVA

By Course Level	F	Sig.	By Teacher	F	Sig.
Composite Experience	4.964	.010	Composite Experience	2.983	.037
Composite Comfort	7.896	.001	Composite Comfort	4.824	.004

The ANOVA test shows there is a significant difference between comfort level and experience as a factor of course level and teacher. Further statistical analysis using independent samples t-test showed that the following results were significant:

Table 7. Students' Attitudes by Teacher – Results of Independent Samples T-Test

	Teacher	Number	Mean Score	St. Dev	T	P
Composite experience	Teacher A	42	42.00	9.082	-3.333	.002
	Teacher B	12	48.75	5.065		
Composite experience	Teacher A	42	42	9.082	-2.454	.026
	Teacher D	9	48.33	6.500		
Composite comfort	Teacher A	41	60.51	16.404	-3.394	.001
	Teacher B	13	77.46	13.017		
Composite comfort	Teacher B	13	77.46	13.017	2.886	.009
	Teacher C	10	62.90	10.482		

Once again, there is a strong relationship between students' comfort and experience and frequency of technology use by the teacher in the classroom and quality of instruction. Further studies on a larger scale are needed to research interaction of these factors deeper.

Analysis of attitudes as a factor of students' course level demonstrated that there is no relationship between students' mathematics abilities and previous preparation and their attitudes and perspectives. The experience and comfort scores are shown on Figure 7. Students in the lowest level integrated algebra course had the highest level of comfort and experience. Independent samples T-test results are shown in the Table 8.

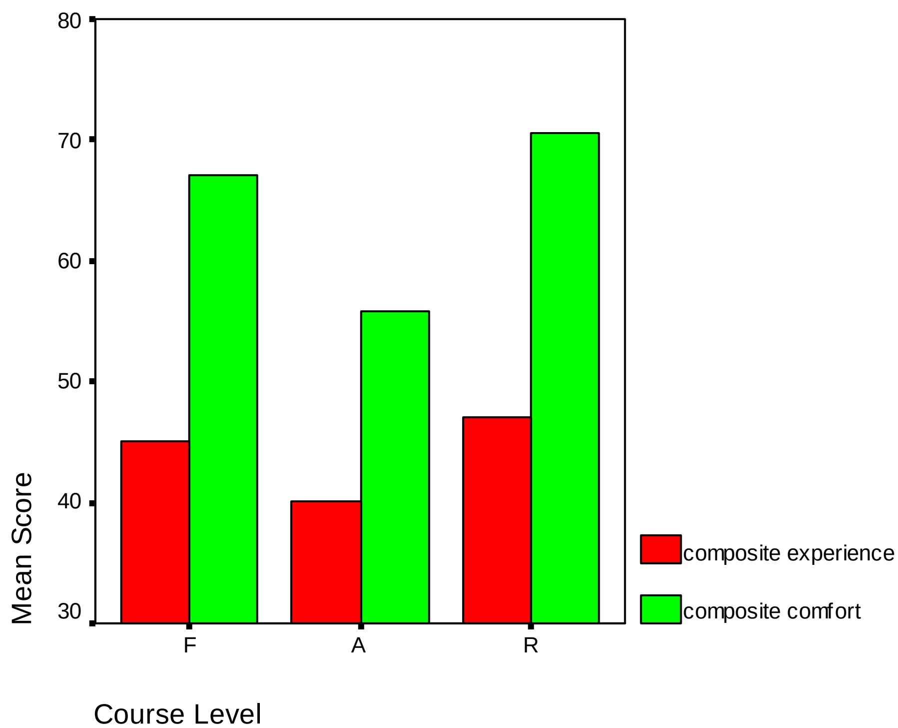


Figure 7. Students' Attitudes by Course Level.

Table 8. Students' Attitudes by Course Level – Results of Independent Samples T-test

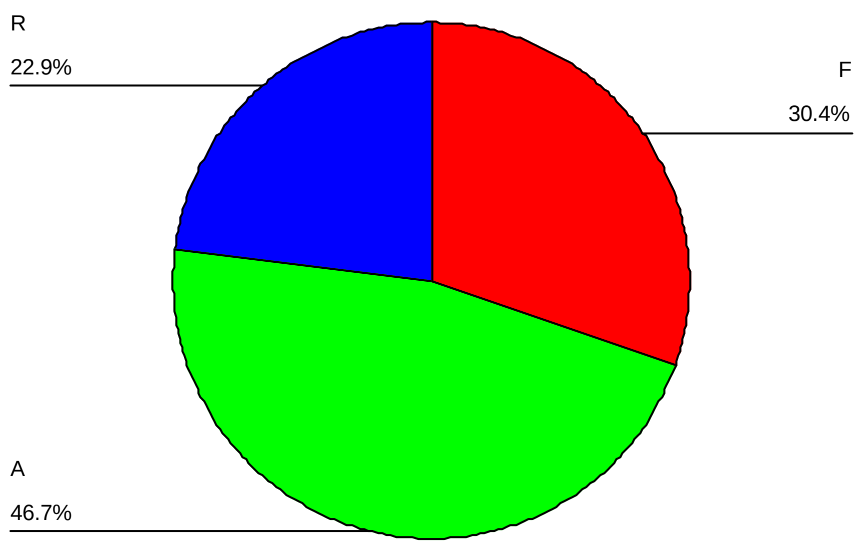
	Course level	Number	Mean Score	St. Dev	T	P

Composite comfort	Level F	18	67.11	15.373	2.416	.021
	Level A	23	55.35	15.593		
Composite experience	Level A	22	40.09	8.124	-3.458	.001
	Level R	31	47.23	6.849		
Composite comfort	Level A	23	55.35	15.593	-3.978	.000
	Level R	31	71.23	13.652		

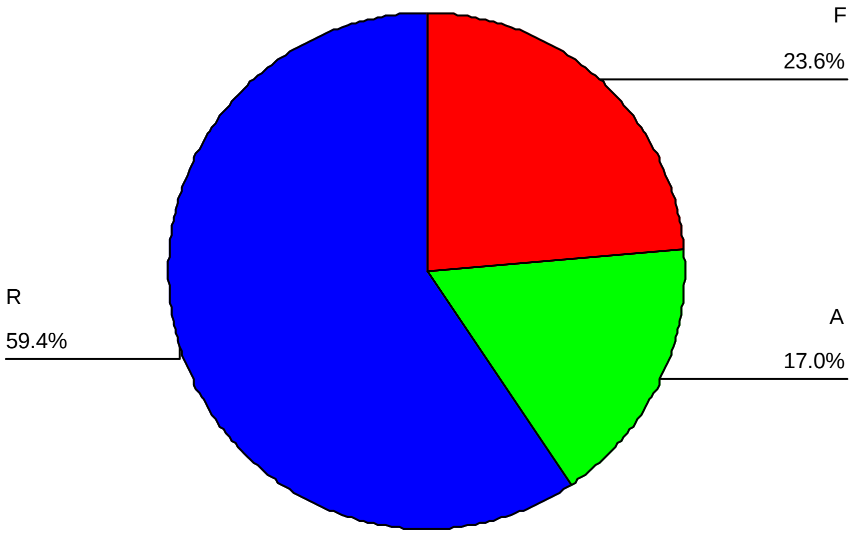
The question that should be raised is how these differences are related to the teacher's attitudes, skills, and quality of instruction. Due to strong ineraction between these factors and small sample size, this analysis was not possible; however, further analysis of qualitative data might be able to answer some of these questions.

Students' Grades

The composition of control and experimental groups based on report cards used for grades analysis is shown on Figure 8. The percentage of higher performing students (course level F) was about the same in both groups, however the percentage of students performing at the lowest level (course level R) was much higher in the experimental group.



a. Control group (N = 178)



b. Experimental group (N = 105)
Figure 8. Composition of Participants Based on Course Level

The overall statistics and comparison of grades between control and experimental groups is provided below in Table 9. The grades were calculated as average of fall and spring semester grades. The independent samples t-test showed that experimental group had significantly higher average grades than control group despite the fact that it had larger number of lower performing students (T = - 4.238, *p* = 0.000).

Table 9. Comparison of Average Grades Control vs. Experimental

Group	N	Minimum	Maximum	Mean	Std. Deviation
control	349	31	100	61.28	14.055
experimental	212	40	97	66.33	13.079

Further analysis of students' performance by course level revealed that higher performing students in course level F had significantly higher grade average in experimental group than in control group (T = -4.509, *p* = 0.000), but in courses A and R while averages in experimental groups were higher, the difference was not statistically significant (T = -1.711, *p* = 0.090 and T = -0.20, *p* = .984). The descriptive statistics by course level is shown in Table 10.

Table 10. Comparison of Average Grades by Course Level

Course Level	Group	N	Mean	Std. Deviation
F	control	106	66.90	13.116
	experimental	50	77.02	13.072
A	control	163	56.20	13.929

	experimental	36	58.89	6.773
R	control	80	64.19	11.816
	experimental	126	64.22	11.948

There could be various factors that could attribute to the differences found in students' grades. Due to experimental design all sections had the same curriculum sequence monitored by the school's mathematics assistant principal. Students were evaluated and placed in courses based on the city placement test results. School's policy is to maintain a racial, gender, and socio-economic balance between sections of the same level. Thus, the major difference between the sections is the teacher and teaching practice that is incorporated into the lessons. The teachers in the experimental group were a representative cross-section of the larger group of mathematics faculty of the school. Based on these conditions, it is reasonable to suggest that the difference in students' performance could be partially attributed to the integration of the TI-Nspire technology, as it was a major difference between the experimental and control groups.

In order to analyze students' progress over the year, we isolated a group of students that stayed with the project throughout a whole year and excluded all other students. There were total of 152 such students in control and 98 such students in experimental group. The graph below shows composition of control and experimental groups by course level:

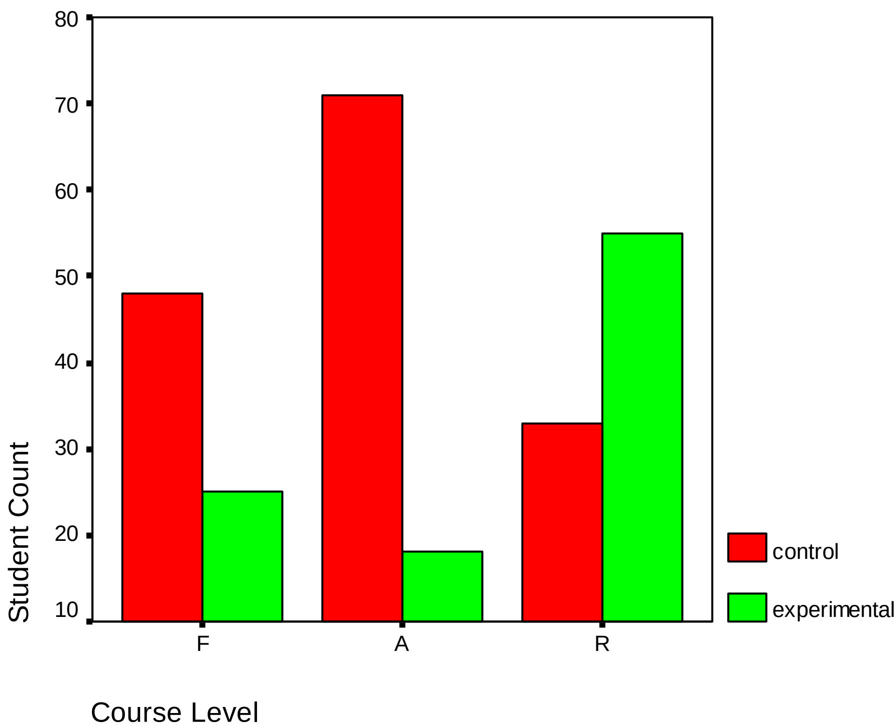


Figure 9. Composition of Research Subgroup by Course Level

Nonparametric related samples test was used to compare changes in grades from fall 2007 to spring 2008 between control and experimental groups, first overall and then by course level. The results of the test are shown in Table 11. The test results are significant for both groups, control group: Z = -5.177, p = .000, experimental group: Z = -3.893, p = .000, Z-values are based on positive ranks.

Table 11. Wilcoxon Signed Ranks Test for Analysis of Grade Change - Ranks

Group			N	Mean Rank	Sum of Ranks
Control	spring grade - fall grade	Negative Ranks	82[a]	67.23	5512.50
		Positive Ranks	37[b]	43.99	1627.50
		Ties	32[c]		
		Total	151		
experimental	spring grade - fall grade	Negative Ranks	54[a]	38.08	2056.50
		Positive Ranks	19[b]	33.92	644.50
		Ties	25[c]		
		Total	98		

a spring grade < fall grade
b spring grade > fall grade
c fall grade = spring grade

The unfortunate results are that grades significantly decreased in both groups, however, as it is seen from Table 11, the decrease in grades is much more dramatic in control group. We broke this down by course level to see how integrating TI-Nspire might have contributed to the difference between control and experimental groups based on students' tracking. The results are shown in Tables 12 and 13.

Table 12. Wilcoxon Signed Ranks Test for Analysis of Grade Change by Course Level – Ranks

Group	Course level			N	Mean Rank	Sum of Ranks
Control	F	Spring grade - fall grade	Negative Ranks	23[a]	23.76	546.50
			Positive Ranks	20[b]	19.98	399.50
			Ties	5[c]		
			Total	48		
	A	Spring grade - fall grade	Negative Ranks	41[a]	29.49	1209.00
			Positive Ranks	11[b]	15.36	169.00
			Ties	18[c]		
			Total	70		
	R	spring grade - fall grade	Negative Ranks	18[a]	13.81	248.50
			Positive Ranks	6[b]	8.58	51.50
			Ties	9[c]		
			Total	33		
experimental	F	spring grade - fall grade	Negative Ranks	17[a]	12.82	218.00
			Positive Ranks	4[b]	3.25	13.00
			Ties	4[c]		
			Total	25		
	A	spring grade - fall grade	Negative Ranks	4[a]	4.13	16.50
			Positive Ranks	5[b]	5.70	28.50

			Ties	9[c]		
			Total	18		
	R	spring grade - fall grade	Negative Ranks	33[a]	21.82	720.00
			Positive Ranks	10[b]	22.60	226.00
			Ties	12[c]		
			Total	55		

a spring grade < fall grade
b spring grade > fall grade
c fall grade = spring grade

Table 13. Wilcoxon Signed Ranks Test for Analysis of Grade Change - Test Statistics

Group	Course Level		spring grade - fall grade
Control	F	Z	-.895[a]
		Asymp. Sig. (2-tailed)	.371
	A	Z	-4.785[a]
		Asymp. Sig. (2-tailed)	.000
	R	Z	-2.820[a]
		Asymp. Sig. (2-tailed)	.005
experimental	F	Z	-3.567[a]
		Asymp. Sig. (2-tailed)	.000
	A	Z	-.716[b]
		Asymp. Sig. (2-tailed)	.474
	R	Z	-2.992[a]
		Asymp. Sig. (2-tailed)	.003

a Based on positive ranks.
b Based on negative ranks.

In order to better understand results, new composite variable was created as difference between fall and spring grades, and independent samples t-test was run to compare the means between control and experimental groups by course level. The results of the test confirmed preliminary findings above:

Table 14. Comparison of Grade Differences by Course Level (Fall – Spring)

Course Level	Group	N	Mean	Std. Deviation	T	P
F	control	48	.8333	7.47857	-3.385	.001
	experimental	25	7.0000	7.33712		
A	control	70	5.4286	8.09289	3.022	.006
	experimental	18	-1.6667	9.07485		
R	control	33	4.9394	10.86261	0.992	.326
	experimental	55	2.7818	7.97378		

As it is seen from the data in Table 14, while there was no significant change in spring grades compared to fall grades in control group in highest level courses, the spring grades for same level students in experimental group significantly decreased. For the lowest level courses grades decreased similarly in both groups. The intermediate level courses is where experimental group showed increase in semester grades, and although this increase was insignificant, control group showed significant decrease in semester grades creating statistically significant difference between two groups. One more analysis of grade difference by teacher was performed for future comparison with teachers' data.

Table 15. Grade Difference by Teacher and Course Level - Descriptive Statistics

Teacher	Course Level	N	Minimum	Maximum	Mean	Std. Deviation
Teacher A	F	25	-5.00	20.00	7.0000	7.33712
	A	18	-25.00	15.00	**-1.6667**	9.07485
Teacher B	R	21	.00	17.00	5.6667	4.90238
Teacher C	R	18	-28.00	10.00	**-1.8889**	9.77325
Teacher D	R	16	-5.00	16.00	4.2500	6.96180

The changes in the mean grade differences for classes where spring grades were higher than fall grades are shown in bold.

Except for the fact that experimental group performed better than control group, there is no clear relationship between students' performance in mathematics and their attitudes towards TI-Nspire or proficiency in using TI-Nspire. There is also no clear pattern between students' grades changes and teachers' attitudes, skills, and quality of instruction. Due to the fact that each teacher has different grading policy, the grades do not necessarily represent actual students' performance. The better representation of students' performance in this case would be standardized test scores that will be collected upon approval from the NYC Board of Education.

Results and Discussion

Due to small scale of this study most of the results of this study raise new questions rather than provide definite answers to the questions that were originally raised.

It is definite that there is learning curve in using TI-Nspire for both, students and their teachers, and the time that it takes before the effect of TI-Nspire integration affects students' attitudes, proficiency skills, and performance depends on many factors, including their own level of performance in STEM content, and attitudes and proficiency level of their teachers. It is also affected by their teachers' quality of instructional practice and quality and frequency of technology use in the classroom.

The results that affected teachers are definitely dependent on the intervention model of the professional development implemented in this project. Further study of this model is necessary to understand its effect on teacher's TPCK and performance in the classroom. There is a definite relationship between teachers' attitudes, proficiency, frequency of technology use in the classroom, and quality of instruction with technology. There is a definite trend between good practice in general and good use of technology. As data suggests, the teacher who achieved higher comfort level and higher attitudes towards using TI-Nspire in teaching also had higher self-reported proficiency skills, higher frequency of using TI-Nspire technology reported by students, and higher quality of instructional practice in general and specifically for the use of technology in her lessons based on classroom observations. However, this relationship becomes more complex when teachers are not consistent across various factors. Teacher's comfort level is not necessarily consistent with teacher's perceptions of their experience with technology. Even the best teachers may feel negative about their experience due to many factors that are not necessarily related to this study, as we observed with the case of Teacher B, who felt overwhelmed and burned down by the end of the spring semester when she was working with teacher D and had to pull a whole load for the group. On the other hand, working with a great partner and developing one great lesson could change teacher's perceptions towards their experience a lot. Teachers A and C worked together on the last 3 lessons and felt really good about their experience and the lessons they developed, so their perceptions about their experience with TI-Nspire and their comfort level had increased a lot. This helped teacher A to come around from completely negative attitude and lack of confidence. It also helped her to improve the quality of her instructional practice, although she remained to be weakest teacher in the group. Teacher C was the second strongest teacher in terms of instructional practice with technology, but her lower attitudes towards using TI-Nspire technology in the classroom led to lower frequency of using this technology in the classroom.

As we see from the data, although there are general trends, each case is individual, and with only 4 teachers in the study, it is hard to make general statements with so many different factors. Large scale study is necessary to analyze correlations between these various parameters. The further qualitative data of teacher developed content will also help to analyze if use of technology affected teacher's pedagogy and math content knowledge.

The students' attitudes and performance in mathematics are always of interest to research. In this small scale study students' performance was compared between control and experimental groups of approximately similar compositions. In both groups students were taking exactly the same course at three different levels of tracking. The first comparison was done between pre and post tests offered in September and January, respectively. Between pre and post tests TI-Nspire technology was used occasionally over a period of 2 months. The only significant increase in post-test scores was observed in the upper level classes of experimental group. These results could be attributed to the effect of integrating TI-Nspire technology. The further question is how different is the learning curve with TI-Nspire technology for students with different level of performance in mathematics? Is there a period of time when this technology could be a distraction for low performing students and could worsen their performance in mathematics before it creates a positive impact? How frequent should students of different level use TI-Nspire technology in the classroom in order to shorten the learning curve and to see the impact of this technology on their mathematics achievement earlier in their mathematics courses?

The second comparison was performed between fall and spring semester grades on control and experimental groups. By the spring semester students in experimental group have experienced TI-Nspire technology on average 2-3 times per month. The average grades for the experimental sections were significantly higher than for the control sections, and although the grades dropped from fall to the spring, the decrease in grades for experimental sections was much less compared to the decrease in grades in control groups. There are a lot of factors that affect students' performance in mathematics classes; however, due to the fact that composition of the groups was similar and experimental group of teachers was a representative cross-section of the mathematics faculty, it is reasonable to suggest that these changes could be attributed to the use of TI-Nspire technology in experimental group. There is a need for more detailed analysis of students' performance depending on students' level and teacher's quality of instruction, as well as frequency of technology use. The standardized scores are being requested to have more objective data on students' performance. As soon as these data are acquired, further analysis will be performed.

Analysis of students' attitudes showed that there is no relationship between students' performance in mathematics and their attitudes towards TI-Nspire or proficiency in using TI-Nspire. There is also no clear pattern between students' grades changes and teachers' attitudes,

skills, and quality of instruction. However, data suggest that there is strong relation between students' attitude and proficiency with TI-Nspire and teachers' attitudes, proficiency and frequency of technology use. In addition, there is a strong relationship between students' comfort and experience with TI-Nspire and quality of instruction with use of technology.
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In conclusion, this project raised several important questions that need further research on a larger scale. There is still abundance of qualitative data that are being currently analyzed and that will add to this analysis and will clarify some of the questions and will probably raise additional questions. NSF ITEST application has been submitted to seek funding to continue this study.

Appendix 1.

Stages of Adoption - High School Teacher
Final Survey on Attitudes on TI-Nspire Technology

EXPERIENCE. Characterize your current experience with and views of TI Nspire technology by circling the one response (Disagree or Agree) to each statement that comes closest to your view.

1. I have little or no knowledge of the TI-Nspire technology	DISAGREE	AGREE
2. I am aware that TI-Nspire technology exist, but I have not used one.	DISAGREE	AGREE
3. I am currently trying to learn the basics of TI-Nspire technology.	DISAGREE	AGREE
4. I am beginning to understand the process of using TI-Nspire technology.	DISAGREE	AGREE
5. I am proficient in using a TI-Nspire technology to solve problems.	DISAGREE	AGREE
6. I can think of specific tasks in which using a TI-Nspire technology might be useful	DISAGREE	AGREE
7. I view the TI-Nspire technology as a tool to help me solve problems.	DISAGREE	AGREE

COMFORT. Characterize your current comfort level with TI-Nspire technology by circling the one response to each statement that comes closest to your view.

SD = Strongly Disagree, **D** = Disagree, **U** = Undecided, **A** = Agree, **SA** = Strongly Agree

8. I avoid using TI-Nspire technology.	**SD**	**D**	**U**	**A**	**SA**
9. I am nervous about the prospect of using TI-Nspire technology.	**SD**	**D**	**U**	**A**	**SA**
10. I have used a TI-Nspire technology, but I am usually frustrated in doing so.	**SD**	**D**	**U**	**A**	**SA**
11. I am gaining a sense of confidence in using the TI-Nspire technology for specific tasks.	**SD**	**D**	**U**	**A**	**SA**

12. I have confidence in my ability to use the TI-Nspire document capabilities.	**SD**	**D**	**U**	**A**	**SA**
13. I have confidence in my ability to use the TI-Nspire linked multiple representations capabilities	**SD**	**D**	**U**	**A**	**SA**

USE IN TEACHING. Characterize your current skills by circling the response that comes closest to your view.

SD = Strongly Disagree, **D** = Disagree, **U** = Undecided, **A** = Agree, **SA** = Strongly Agree

14. I am able to use the TI-Nspire technology as an instructional aid in my classroom.	**SD**	**D**	**U**	**A**	**SA**
15. I can integrate the TI-Nspire technology into the school curriculum	**SD**	**D**	**U**	**A**	**SA**
16. I am comfortable to use pre-developed materials as an instructional aid.	**SD**	**D**	**U**	**A**	**SA**
17. I can develop my own materials for the TI-Nspire technology to use as an instructional aid	**SD**	**D**	**U**	**A**	**SA**
18. I can help students to develop their own materials for the TI-Nspire technology	**SD**	**D**	**U**	**A**	**SA**

****

BRIEF ESSAYS. (Use back of page, if needed.)

19. Please describe your best lesson using TI-Nspire technology in your classroom. Why was it the best?

20. Please describe your worst lesson using TI-Nspire technology in your classroom. Why was it the worst?

21. What were the advantages and challenges you experienced while using TI-Nspire technology in teaching and learning?

Appendix 2.

Teacher Survey
TI Nspire Proficiency Self-Assessment and
Attitude Towards TI Nspire

This survey has three parts and will take you about 15 minutes to complete. Please answer all questions on pages 1-4. Thank you!

Date __________**Course:** _______________ **Teacher:** _________________________________

Gender: ①Male ②Female **Age:** ____

Race: ①White/Caucasian ②Black/African American ③Hispanic/Latino ④Asian ⑤Other

Do you have a TI-Nspire at home? ① No ②Yes

Do you have access to the World Wide Web at home? ①No ②Yes

Instructions: Select one level of agreement for each statement to indicate how you feel.
SD = Strongly Disagree, D = Disagree, U = Undecided, A = Agree, SA = Strongly Agree

Part 1. TI-Nspire Proficiency

I feel confident that I could...	**SD**	**D**	**U**	**A**	**SA**
1. Navigate between documents in My Documents folder.	①	②	③	④	⑤
2. Open and Save documents. Create and delete documents.	①	②	③	④	⑤
3. Navigate between pages and problems in a document. Insert and delete pages and problems.	①	②	③	④	⑤
4. Change page layout	①	②	③	④	⑤
5. Change document settings	①	②	③	④	⑤
Calculator Application					
6. Perform basic computations on the screen	①	②	③	④	⑤
7. Use Menu to perform various operations (for example, delete variable, insert comment, factor, numeric solve, etc.)	①	②	③	④	⑤

	I feel confident that I could...	SD	D	U	A	SA
8.	Insert expressions and symbols	1	2	3	4	5
	Graphs & Geometry Application					
9.	Graph functions, grab and move plots of the functions, use trace feature	1	2	3	4	5
10.	Change windows settings through menu and by grab and drag	1	2	3	4	5
11.	Set up and display scatter plots	1	2	3	4	5
12.	Use Text and Calculate tools	1	2	3	4	5
13.	Use Attributes to hide/show and animate objects	1	2	3	4	5
14.	Choose between plane geometry and analytic views	1	2	3	4	5
15.	Use geometry tools, such as Points &Lines, Measurement, Shapes, Construction, and Transformations	1	2	3	4	5
	Lists and Spreadsheets					
16.	Resize, insert, delete, and move columns in the table	1	2	3	4	5
17.	Generate sequence, use Fill Down or Data Capture options	1	2	3	4	5
18.	Use Stat Calculations options to find regressions	1	2	3	4	5
19.	Use Function Table	1	2	3	4	5
	Notes Application					
20.	Choose between different text templates (Q&A, Proof, or Default)	1	2	3	4	5
21.	Insert expressions, shapes or comments in the text	1	2	3	4	5
22.	Change format of the text (bold, italic, super and subscript)	1	2	3	4	5
	Data and Statistics Application					
23.	Set up and display STAT PLOTS (histograms, line plots, scatter plots, box plots, dot plots)	1	2	3	4	5

I feel confident that I could...	**SD**	**D**	**U**	**A**	**SA**
24. Change window settings, use ZOOM features	①	②	③	④	⑤
25. Add lines and functions to the stat plot	①	②	③	④	⑤
Handheld and Software Connectivity; Presentations					
26. Transfer files between handheld and computer	①	②	③	④	⑤
27. Transfer files between two handheld units	①	②	③	④	⑤
28. Use View Screen panel with handheld unit	①	②	③	④	⑤
29. Use Presentation and Handheld View modes of computer software	①	②	③	④	⑤
30. Use TestGard to prepare handheld for standardized testing	①	②	③	④	⑤

Thank you for your time.

Appendix 3.

CLASSROOM VISIT FORM
Rubrics on Quality of Instruction

Teacher's Name:____________________________ School:________________________

Subject Class: __________________ Period: ________________ Date: _______________

Topic of Lesson: ____

	OBSERVED STUDENTS BEHAVIOR	H	M	L	N/A	COMMENTS
1.	Focused on task(s)					
2.	Responsiveness exhibited					
3.	Engaged in hands on activities					
4.	Participated in skills development					
5.	Participated in small groups					
6.	Constructive noise level					
7.	Used technology and/or media					
8.	Exploration of ideas occurred					
9.	Enthusiasm exhibited					
10.	Students and teacher interacted					
11.	Exchange of ideas among students occurred					
12.	Engaged in analytical thinking					
13.	Applied knowledge learned					
14.	Students reflected upon and shared knowledge gained					

Prepared by: ____

Appendix 4.

TI-Nspire Early Stage Phase I
2007-2008
Observation Protocols

Teacher Name: _____________ Observation date: _____________________

Subject: _______________ Grade: _____________

1. What concepts or topics does the teacher use TI-Nspire technology to teach?

2. What type of TI-Nspire technologies does the teacher use?
   a. Handheld with the view screen panel
   b. Computer software with projection
   c. Both

3. How does the teacher use TI-Nspire technology? Please provide details in a narrative format about the teaching process that involves the use of technology. This should cover how and when the teacher starts to introduce technology, what activity/ies the teacher and students do with technology, how the class uses technology as a tool to construct or apply knowledge.

   There are four different ways to use technology:
   a. Use technology for demonstration (learn new knowledge)
   b. Use technology for hands on activity (learn new knowledge)
   c. Use technology to apply learned knowledge
   d. Use technology to assess student learning

For each type use of technology, please provide your observation notes as suggested above

Use technology for demonstration (learn new knowledge)

Use technology for hands on activity (learn new knowledge)

Use technology to apply learned knowledge

Use technology to assess student learning

Please answer the following questions based on your observation

4. The technology has been used by teachers in different way. Some teachers use technology as an add-on to their traditional teaching. Some teachers use technology in a more constructive way, which means that the technology is synergistically integrated into his or her planning and teaching.

a) How do you view the use of technology by the teacher you are observing in the continuum from add-on to constructive way?

1	2	3	4	5
Add on				Very constructive

b) The teacher is enthusiastic about using technology

1	2	3	4	5
Not at all enthusiastic	Slightly enthusiastic	Somewhat enthusiastic	Enthusiastic	Very much enthusiastic

c) The teacher is proficient in using technology

1	2	3	4	5
Not at all proficient	Slightly proficient	Somewhat proficient	Proficient	Very much proficient

5. How do students respond to the use of technologies? Please record the interaction between the teacher and students, students' reaction, engagement, enthusiasm or hesitance about the use of technology. Some typical episodes in classroom are most welcome.

Please answer the following question based on your observation

6. Students enjoy using technology

1	2	3	4	5
Not at all enjoy	Slightly enjoy	Somewhat enjoy	Enjoy	Very much enjoy

7. Was the activity used with the TI-Nspire a discovery activity? Y N
   Please provide brief description of the activity

8. Any reflection you may have

Appendix 5.

High School Students Survey
TI Nspire Proficiency Self-Assessment and
Attitude Towards TI Nspire

This survey has three parts and will take you about 15 minutes to complete. Please answer all questions on pages 1-4. Thank you!

Date __________Course: _______________ **Teacher:** _________________________________

Grade Level: ① 9th ② 10th ③ 11th ④ 12th

Gender: ①Male ②Female **Age:** ____

Race: ①White/Caucasian ②Black/African American ③Hispanic/Latino ④Asian ⑤Other

Do you have a graphing calculator at home? ① No ②Yes

Do you have access to the World Wide Web at home? ①No ②Yes

Instructions: Select one level of agreement for each statement to indicate how you feel.
SD = Strongly Disagree, D = Disagree, U = Undecided, A = Agree, SA = Strongly Agree

Part 1. TI-Nspire Proficiency

I feel confident that I could...	SD	D	U	A	SA
1. Navigate between documents in My Documents folder.	①	②	③	④	⑤
2. Open and Save documents. Create and delete documents.	①	②	③	④	⑤
3. Navigate between pages and problems in a document. Insert and delete pages and problems.	①	②	③	④	⑤
4. Change page layout	①	②	③	④	⑤
5. Change document settings	①	②	③	④	⑤
Calculator Application					
6. Perform basic computations on the screen	①	②	③	④	⑤
7. Use Menu to perform various operations (for example, delete variable, insert comment, factor, numeric solve, etc.)	①	②	③	④	⑤
8. Insert expressions and symbols	①	②	③	④	⑤

	I feel confident that I could...	SD	D	U	A	SA
	Graphs & Geometry Application					
9.	Graph functions, grab and move plots of the functions, use trace feature	①	②	③	④	⑤
10.	Change windows settings through menu and by grab and drag	①	②	③	④	⑤
11.	Set up and display scatter plots	①	②	③	④	⑤
12.	Use Text and Calculate tools	①	②	③	④	⑤
13.	Use Attributes to hide/show and animate objects	①	②	③	④	⑤
14.	Choose between plane geometry and analytic views	①	②	③	④	⑤
15.	Use geometry tools, such as Points &Lines, Measurement, Shapes, Construction, and Transformations	①	②	③	④	⑤
	Lists and Spreadsheets					
16.	Resize, insert, delete, and move columns in the table	①	②	③	④	⑤
17.	Generate sequence, use Fill Down or Data Capture options	①	②	③	④	⑤
18.	Use Stat Calculations options to find regressions	①	②	③	④	⑤
19.	Use Function Table	①	②	③	④	⑤
	Notes Application					
20.	Choose between different text templates (Q&A, Proof, or Default)	①	②	③	④	⑤
21.	Insert expressions, shapes or comments in the text	①	②	③	④	⑤
22.	Change format of the text (bold, italic, super and subscript)	①	②	③	④	⑤
	Data and Statistics Application					
23.	Set up and display STAT PLOTS (histograms, line plots, scatter plots, box plots, dot plots)	①	②	③	④	⑤
24.	Change window settings, use ZOOM features	①	②	③	④	⑤

I feel confident that I could...	SD	D	U	A	SA
25. Add lines and functions to the stat plot	①	②	③	④	⑤

Part 2. Attitudes Towards TI Nspire

EXPERIENCE. Characterize your current experience with and views of TI Nspire technology by circling the one response (Disagree or Agree) to each statement that comes closest to your view.

1. I have little or no knowledge of the TI-Nspire technology DISAGREE AGREE
2. I am aware that TI-Nspire technology exist, but I have not used one. DISAGREE AGREE
3. I am currently trying to learn the basics of TI-Nspire technology. DISAGREE AGREE
4. I am beginning to understand the process of using TI-Nspire technology. DISAGREE AGREE
5. I am proficient in using a TI-Nspire technology to solve problems. DISAGREE AGREE
6. I can think of specific tasks in which using a TI-Nspire technology might be useful DISAGREE AGREE
7. I view the TI-Nspire technology as a tool to help me solve problems. DISAGREE AGREE

COMFORT. Characterize your current comfort level with TI-Nspire technology by circling the one response to each statement that comes closest to your view.

SD = Strongly Disagree, **D** = Disagree, **U** = Undecided, **A** = Agree, **SA** = Strongly Agree

8. I avoid using TI-Nspire technology. **SD D U A SA**
9. I am nervous about the prospect of using TI-Nspire technology. **SD D U A SA**
10. I have used a TI-Nspire technology, but I am usually frustrated in doing so. **SD D U A SA**
11. I am gaining a sense of confidence in using the TI-Nspire technology for **SD D U A SA**

specific tasks.

12. I have confidence in my ability to use the TI-Nspire document capabilities.	**SD**	**D**	**U**	**A**	**SA**
13. I have confidence in my ability to use the TI-Nspire linked multiple representations capabilities	**SD**	**D**	**U**	**A**	**SA**

Part 3. Brief open-ended questions

1. On average how often did you use TI-Nspire in your class this year (circle one)

Every class   1-2 times per week   1-2 times per month   1-2 times per semester

2. Please describe your best learning experience with TI-Nspire in this class. Why it was the best?

3. Please describe your worst learning experience with TI-Nspire in this class. Why it was the worst?

Thank you for your time.