A Case Study of Investigating Preservice Mathematics Teachers' Initial Use of the Next-Generation TI-Nspire Graphing Calculators with Regard to TPACK

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Abstract: As many researchers have studied, calculators may not be appropriate for all educational situations or all mathematical subjects. However, Ellington (2003) reported that the improvement to problem solving skills was most significant when (a) special curriculum materials were designed for use with the calculator and (b) the type of calculator used was the graphing calculator. The purpose of the study was to identify strengths and limitations in how prospective mathematics teachers use the graphing calculator in teaching mathematics concepts and procedures. This study included both quantitative and qualitative data collection and analysis methods, providing an opportunity for presenting a greater diversity of views. , discussion thread and essay data were qualitatively analyzed in the context of the TI-Nspire study in search of recurring themes, informed by the Technological Pedagogical Content Knowledge (TPCK) framework (Niess, 2008).

Introduction

Pre-service teachers' education is important because it prepares new teachers and, as such, they are future instructional leaders. Teachers have to be well prepared for changing learning and instructional environments. Today's schools require teachers who have knowledge of effective teaching strategies and technologies so all students need can be met. Therefore, pre-service teacher' education programs should prepare future teachers to use technology effectively in their classroom.

Graphing calculator is just only one of enhanced interactive handheld device for supporting mathematics. Since the advent of graphing calculators in the mid-1980s, there has been a growing volume of literature on the use of graphing calculators in mathematics instruction. In this brief review, it summarizes recent research findings and meta-analyses.

Hembree and Dessart (1992) reviewed 79 reports on the use of calculators in mathematics instruction, revealing a scenario of uncertainty and conflicts. On the one hand, there seemed to be large potential benefits from the hand-held devices; while on the other, there had been little actual change in the mathematics curriculum. The authors found strong research evidence in favor of calculator use in instruction. From arithmetic performance, problem solving, to students' attitudes toward mathematics, calculators were found to be playing significant roles. Pedagogically, calculators were used primarily for familiarization, checking, and problem solving in the early grades. In the secondary grades, calculators were more often used as computational tools and reference. However, there were few empirical studies on how to integrate calculators into the learning processes.

The same conflicting scenario may have remained in the 1990s. In a survey study involving 146 middle and high school algebra teachers, Milou (1999) investigated their use of and attitudes toward graphing calculators, finding that the use of graphing calculators was still controversial among algebra teachers and the majority tended to think of graphing calculators as a motivational tool. Adding to the evidence for the use of graphing calculators in algebra classes, Milou's data confirmed that graphing calculators have little negative effect on student performance and do not cause deterioration of students' algebraic skills. Noticeably, algebra teachers are uncertain about the instructional use of graphing calculators. Milou reiterated the need to consider the curricular implications of graphing calculators (cf. Burrill, 1992).

More recent research on the use of graphing calculators has sought to examine students' experience and its impact on the instrumentalization (Trouche, 2005b) of the calculator as well as the social and cultural aspects of such tools (Doerr & Zangor, 2000). In a study of secondary students' conception of variables, Graham and Thomas (2000) found that the graphing calculator helps students construct a versatile view of variables through tool-based mathematical experience. The graphing calculator proved to be an instrument for students' algebraic thinking in terms of variables, which is previously a difficult strand of algebra. Graham and Thomas's study also underlines the significance of redesigning curricular component to provide students with meaningful learning experiences with technology.

Along the social and cultural dimension, Doerr and Zangor (2000) examined the meaning-making process of students and teachers with respect to the use of graphing calculators in mathematics learning in a class-based qualitative study. The researchers studied how the classroom community constructed meaning for the tool and further how the tool assisted students to construct mathematical meaning in learning tasks. Doerr and Zangor identified five themes of graphing calculator use in classroom mathematical practice. The graphing calculators were being used as computational tools, transformational tools, data collection and analysis tools, visualizing tools, and checking tools. Underlying the emerging tool use, the researchers suggested, were teachers' mathematical knowledge and beliefs, their pedagogical role, and the nature of mathematical tasks. Interestingly, they found that the calculator, when used as a personal device, could inhibit communication in small group settings. When used as a shared social device, the calculators tended to support mathematical discourse in the classroom learning community.

Teachers' beliefs about mathematics and mathematics instruction are fundamentally related to their teaching practice, including their use of new technology. New ideas and technologies tend to be shaped and reshaped by teachers' beliefs and established practices (Thompson, 1992). Based on a survey of 800 mathematics teachers across the elementary, middle and high school levels, Brown and colleagues (2007) identified four factors that account for teachers' belief and practices regarding their calculator use: catalyst beliefs, teacher knowledge, crutch beliefs, and teacher practices. The researchers suggest that mathematics teachers at all levels should be provided intellectual and technical support, with the focus on influencing their beliefs, mathematical knowledge, and pedagogical skills. In particular, "pre-service teachers could be more effectively supported in the integration of calculators in their mathematics instruction through the methods courses for preservice teachers" (p. 113). Mishra and Koehler introduced the Technological Pedagogical Content Knowledge (TPACK) as a way of thinking about the knowledge teachers need to understand to integrate technology effectively in their classrooms. They argue that TPACK comprises knowledge of content, pedagogy, and technology, as well as understanding the complex interaction between these knowledge components.

TI-Nspire, the next-generation handheld calculator from Texas Instruments, featuring simultaneous multiple linked representations and enhanced interactivity was released in Fall 2007. TI-Nspire offers a new instructional tool to support mathematics instruction and to engage pre-service secondary teachers of mathematics in exploring new ways of mathematics teaching.

In summary, there is substantial research evidence for the use of graphing calculators in mathematics instruction, in spite of the fact that teaching with technology is a complex process involving a range of social, cultural, and technical variables. There has been a repeated theme in the research findings that the mere addition of calculators to the existing curriculum will not fully realize the potentials of the new technology, and the integration of calculators as well as other technologies in mathematics instruction calls for the reconsideration of the whole mathematics curriculum (Burrill, 1992; Heid, 1997). Further, there has been a consensus that preservice mathematics teachers should be provided with rich experiences in the use of new technology in a mathematics education program in order for them to develop technology-related pedagogical content knowledge (Mishra & Koehler, 2006).

Methods

The purpose of the study was to identify strengths and limitations in how prospective mathematics teachers use the graphing calculator in teaching mathematics concepts and procedures. This study included both quantitative and qualitative data collection and analysis methods, providing an opportunity for presenting a greater diversity of views. Then inferences will be completed on the basis of data sources. This project was put into practice with an undergraduate class during Fall 2007 and based on lessons learned from that implementation with a second class during Spring 2008 in the Department of Middle and Secondary Education.

Context

Participants in the study were pre-service mathematics teachers taking MAE4657 (Using Technology to Teach Mathematics) in Fall 2007 (n=23) and Spring 2008 (n=12). MAE4657 is a required methods course for the middle grades mathematics and secondary mathematics tracks in teacher preparation. While the course is intended to be taken in the first semester of the teacher preparation program (junior year) the pre-service teachers were at various stages in their preparation (e.g., some juniors and others seniors). There was also considerable variation in their mathematics knowledge and technology fluency. Participants in the course are engaged in exploring a comprehensive list of topics in algebra, geometry, probability and data analysis, discrete mathematics, and calculus using a variety of technologies, including graphing calculators. The course has a component that addresses new technologies. Thus, the TI-Nspire project was incorporated into the course as an integral component with the approval of the program coordinator. An initial survey on participants' background, particularly, their attitude' toward calculator use in teaching and learning mathematics and their attitude toward mathematics was administered early in each semester.

Procedure

Team members attended summer workshops to become familiar with TI-Nspire, the newest graphing calculator from Texas Instruments. Following the workshops lessons were conceptualized that would be developed and taught with the class over a period of four weeks for eight 75-minute class periods. Based on their review of the computational and pedagogical features of TI-Nspire, the project team decided to focus on a few big ideas of secondary mathematics as opposed to tackling traditional problems using the new technology. Operating under the theoretical framework of Model-Facilitated Learning (MFL) (Milrad, Spector, & Davidsen, 2003), the team developed a series of five instructional units to engage pre-service mathematics teachers to readdress their own mathematics content knowledge, to learn about the new graphing handheld, and to further reflect on its implication for mathematics teaching and learning. Specifically, the project was designed in a way to foster the development of preservice mathematics teachers' technological pedagogical content knowledge or TPACK (e.g., Mishra & Koehler, 2006) while promoting deep understanding of big ideas of mathematics as opposed to re-addressing routine problems using new technology.

The research team selected five worthwhile topics from number theory, financial literary, trigonometry, statistics, and physics, and developed instructional tasks for each topic, taking advantage of the multiple representations and manipulative tools of TI-Nspire. Each lesson started with a realistic scenario that was deemed familiar and interesting to the participants. The informal scenario was further mathematized through small group work and whole-class discussion under guidance of the instructor, and investigated by participants at an increasing level of complexity using resources of the TI-Npsire. The mathematical models developed on the TI-Nspire were ultimately used by participants for holistic reasoning and judgments with respect to the initial situations. The instructional purpose of these lessons was to engage preservice mathematics teachers in reconnecting and expanding their own existing mathematical knowledge, and mindfully reflecting on the implications of the new technology for their pedagogical methods. Lessons are provided in Appendix A of the report.

From the onset, the research team chose to focus on integrating the exploration of mathematical ideas with the introduction of the new technology. Instead of teaching the use of TI-Nspire first and then using it for problem solving, they treated the new technology as a way to tackle challenging mathematical problems, each feature of the new technology being introduced wherever and whenever they came in handy. This proved to be an effective strategy in that many of the participants could navigate through the TI-Nspire menu system, search for tools, and discover their own way of using TI-Nspire with no prior keyboard training. What made the key combinations meaningful was in fact the mathematical situations, although certain just-in-time support from the instructor was constantly provided.

For each lesson, the class was divided into five groups of four or five students according to the instructor's perception of their performance in the class. All of the students were loaned a TI-Nspire for use inside and outside the classroom. While the instructor was implementing each lesson, two research team members observed target group activities and their interactions. After each class period, participants were asked to leave on the university's online course site their reflections regarding the mathematics content, the use of technology, and the relevance of the lesson to their future job as a mathematics teacher.

Toward the end of each semester, participants were asked to design their own lesson plans featuring the use of TI-Npsire, which led to a collection of over 30 lesson plans. They also were asked to write their responses to an imaginary teaching scenario in which they were offered the new technology and were required by their future employer to incorporate it into their mathematics teaching. These responses led to 35 essays, each about 300 words. Selected participants were also interviewed by the research team members about their month-long experience using TI-Nspire.

Data Sources

Data were gathered from students' lesson plans, interviews, discussion threads (through online course website), an initial questionnaire, and response to a hypothetical teaching scenario. The team analyzed students' journals, homework assignments, lesson plans, and field notes in search of repeated themes regarding participants' learning experience using the new TI-NSpire graphing calculator.

Interviews: As the Nspire was the final unit of the course, these interviews were administered at the end of the semester for both the fall and spring semesters. During the fall semester, students were interviewed in groups by two team members. During the spring semester the students answered the interview questions by participating in a Blackboard discussion group, where each pre-service teacher was asked to answer the interview questions as well as to respond to other student's posted comments. The same interview questions were used for both groups.

1. State your demographic background: major, grade, experience of teaching, internship.
2. What is your prior experience related to calculator use (class or high school, calculator version)?
3. How and what was helpful to understanding mathematics problems when you used TI-Nspire?
4. How and what was not helpful to understanding mathematics problems when you used TI-Nspire?
5. If you have struggled with using TI-Nspire, what and why was the problem?
6. What do you think about technology integration for math education?
7. As a pre-service teacher, will you use the calculator for your teaching in the future?
8. What do you think about the instruction which presents a problem scenario first?
9. How can this course be improved?

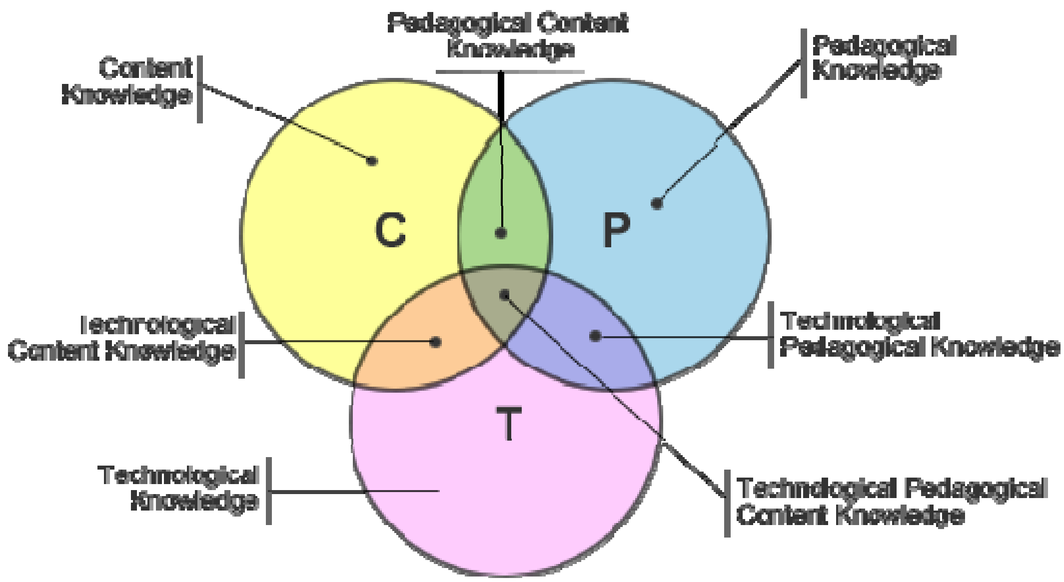
Discussion board threads: Discussion board threads focused the pre-service teachers' experience with the TI-Nspire in the three areas of technical issues, personal beliefs, and content knowledge

Essay Paper: Toward the end of the TI-Nspire sessions both in Fall 2007 and Spring 2008, all participants were asked to respond to a hypothetical teaching scenario that involved the use of the TI-Nspire. The purpose was to gather data about their overall instructional inclinations when TI-Nspire was available for classroom use.

Observations: Team members were participant observers within the classes taking field notes. When appropriate following class sessions team members would use data from observations to make informed decisions regarding instruction for subsequent classes.

Data Analysis

Interview, discussion thread and essay data were qualitatively analyzed in the context of the TI-Nspire study in search of recurring themes, informed by the Technological Pedagogical Content Knowledge (TPCK) framework (Niess, 2008). TPCK builds on Shulman's idea of PCK, and attempts to capture some of the essential qualities of knowledge required by teachers for technology integration in their teaching, while addressing the complex, multifaceted and situated nature of teacher knowledge. At the heart of the TPCK framework, is the complex interplay of three primary forms of knowledge: Content (CK), Pedagogy (PK), and Technology (TK).



Using WEFT software for qualitative data analysis, data sets were inputted and categorized using the TPCK framework. To ensure credibility of data coding team members independently coded passages and then compared the coding. Discrepancies between the assigning of codes were discussed until consensus was reached. The discussions on discrepancies allowed the researchers to refine the categories and descriptions of each whereby subcategories emerged.

Findings

Across the data sources there were five major themes identified in the participants' responses: TI-Nspire as a pedagogical tool, the tension between textbook constraints and teacher's design initiatives, the tension between traditions and innovations, teachers as learners, and personal beliefs and experiences. For the data sources a description of the findings as they relate to the evident themes are provided.

Technical Issues

Preservice mathematics teachers made both positive and negative comments on the same features of the calculator mostly depending on their familiarity with the calculator. For example, some students were fascinated with having two different graphs on the same screen while on the other hand, for some the feature was a source of frustration.

One of the major complains about this new technology was the contrast level of the screen which was asserted as a drawback for the people who had trouble eyesight difficulties, and the placement of the numbers and letters. Some suggested that "it would be really neat if the letters were put on perpendicularly to the numbers and the keypad swiveled out and the letters were aligned like a keyboard".

It was observed that most of the complaints resulted from not having enough experience with the calculator. As the pre-service teachers became more familiar with the features of the calculator with increasing use of with it, their frustration tend to disappear.

Personal Belief

Pre-service teachers aligned themselves in one of two camps about the new calculator: full support for the use of it in class recognizing its benefits for students' learning and concern about students loosing focus of the topic whereby the focus becomes more on a procedural use of the calculator. The interview responses also evinced that similar beliefs were prevalent among the pre-service teachers. First, multiple students believed that the calculator should only be used after students have learned "by hand". The second belief which had fair representation in the interviews was that students needed to know how to use the calculator. Because technology in the classroom is becoming more customary, some pre-service teachers did not discuss the usefulness of the calculators as mathematical aids, but simply as technology that should be learned.

Content Knowledge

In discussion threads, students reflected on certain activities focusing on gravitational force, central tendency of a data set, piecewise function, integral applications, prime numbers and Fibonacci sequence. The discussions provided enough evidence that preservice teachers were familiar with the concepts mentioned above. In the interviews, when the pre-service teachers were asked if they would use the calculator in their future teaching, they generally shirked from discussing the Nspire in relation to any specific content. They had broad ideas of whether technology and specifically calculators were helpful, and they stuck to asserting only these general principles. Two students did allude to the fact that it would be better not to introduce the Nspire to middle school students as they thought it would be too complicated for those students.

Essay Papers:

Toward the end of the TI-Nspire sessions both in Fall 2007 and Spring 2008, all participants were asked to respond to a hypothetical teaching scenario that involved the use of the TI-Nspire. The purpose was to gather data about their overall instructional inclinations when TI-Nspire was available for classroom use.

The prompt and questions are as follows:

Imagine the following situation. You have been just hired by a high school, and the school has been awarded a grant from a generous company for you to teach Algebra I/II using TI-Nspire or similar technologies. All of your students will have access to a TI-Nspire at home and in class. Further, you have the full support of the principal. Work out a plan to teach mathematics using the technology you are offered. Please address as many as you can of the following questions:

How are you going to use the current textbook, which is not written for the use of the new technology?
How are you going to plan classroom learning activities?
How are you going to assign homework?
How are you going to assess students' performance?
How are you going to deal with unexpected questions and other issues in the classroom?
Why are you teaching the way you propose to teach?
Other thoughts you may have regarding your assignment.

Participants brought their own beliefs and experiences to the TI-Nspire project, which affects the instructional flow and the classroom interactions. However, their experience with the TI-Nspire and the activities also affected their beliefs and decision-making or, at least, created dissonance in their belief system. Therefore, careful planning and design seem to be essential in taking full advantage of the features of TI-Nspire in future endeavors, including strategies to address their prior knowledge and attitudes.

Conclusions

First, the effective use of TI-Nspire lies in the resequencing and reorganization of traditional mathematical topics, i.e., it is essentially an instructional design issue. Under sound instructional principles such as those of MFL, the new technology affords students opportunity to model and explore a variety of mathematical ideas at increasingly complex level and ultimately develop a holistic view of the mathematics in terms of their multiple connections and representation (NCTM, 2000, 2003). Second, the new technology plays the roles of cognitive amplifiers and organizers (Heid, 1997) in support of students' mathematical problem solving. Third, the new technology stands as a challenge to collaborative learning in small group. The project team's initial findings are consistent with those of Doerr and Zangor (2000).

Through multiple experiences including a hypothetical teaching scenario involving TI-Nspire, class reflections, and lesson plans participants responded to a variety of aspects of teaching with technology. The initial analysis of their responses unveiled five major themes. First, the new technology served as a tool or stimulator in fostering pedagogical reflection among the participants. Second, faced with the challenges and alternatives of the new technology, participants experienced the tension between traditional curricular materials (e.g., the textbook) and the need to recreate their instructional tasks. Third, the new technology stands as a challenge to the traditional paper-n-pencil approach to school mathematics, causing a tension or, at times conflicts between participants' traditional view of mathematics teaching and their awareness of innovative alternatives. Fourth, the new technology stimulated among the participants a willingness to learn on their own and with their students. There is evidence that the new technology might have fostered the emergence of certain openness in their approach to teaching. They explicitly identified the need for further support, training and peer assistance. Fifth, participants' beliefs and prior experience played an important role in their justification of their proposed ways of teaching and assessment. Their beliefs shaped their learning experiences on the TI-Nspire project, which further challenged their beliefs.

Teachers in general are not well prepared to take advantage of technologies such as the graphing calculator to support mathematics education. Deficiencies are not easily categorized and seem to involve what is now being called technological pedagogical content knowledge (TPCK) (AACTE Committee on Innovation and Technology, 2008). Deficiencies with regard to TPCK have not been addressed by traditional teacher preparation or professional development. Rather than support teachers, the graphing calculator in many cases makes it evident that teachers lack the appropriate TPCK.

According to Mishra and Koehler (2006) effective technology integration for pedagogy around specific subject matter requires developing sensitivity to the dynamic, transactional relationship between all three components. The expertise demonstrated by a teacher capable of negotiating these relationships represents a form of expertise different from, and greater than, the knowledge of a disciplinary expert (say a mathematician or a scientist), a technology expert (a computer scientist) and a pedagogical expert (an experienced educator). Furthermore, the incorporation of a new technology (e.g., TI-Nspire calculator) suddenly forces teachers to confront basic educational issues because this new technology reconstructs the dynamic equilibrium among the elements of technology, pedagogy and content. Through the design of effective learning tasks utilizing technology integration teachers are confronted with new decisions about the content and pedagogy.

Future studies need to further examine the dynamic interplay between elements such as connections, interactions, and constraints between and among content, pedagogy, and technology. The identification of centrally held beliefs about the nature of mathematics and the learning of mathematics in contexts involving the use of technology for teaching mathematics is another area that merits further examination. Finally, curriculum development leading to units of content that are supported by NSpire are needed to examine the effectiveness of the use of the calculator learning different levels of mathematics and the interplay of multiple representations in the learning process.

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