TEACHING AND LEARNING CALCULUS II WITH THE TI-NAVIGATOR SYSTEM AND THE TI-NSPIRE CX CAS

Christal Schoen
Stephen F. Austin State University
P.O. Box 12041, SFA Station, Nacogdoches, TX, 75962
Christal.Schoen@SFASU.edu

Abstract: Many educational mathematicians believe conceptual development can be enhanced when students use technology in the classroom to collaborate and actively inquire about mathematical phenomena. Despite this, some mathematics students may be reluctant to adopt new technology. This paper focuses on the use of the TI-Navigator System and TI-Nspire-CX CAS handheld graphing calculators as teaching and learning tools in an active-learning Calculus II class. The class was taught by a mathematics education researcher who is an expert on technology in the mathematics classroom. The interaction between the professor, technology, and the students was examined through classroom observation and interviews. Student attitudes towards and proficiency with the technology varied greatly, as did benefits gained from utilizing technology. While some students believed that using the calculators helped them to complete problems without doing much mental work, test scores and the quality of their work suggest that such assumptions needed to be more accurate. Other students believed that the technology helped them master conceptual material, with one student claiming that the calculator helped him become more proficient with symbolic manipulation. In interviews, students with negative attitudes about technology frequently referenced previous educators who frowned upon calculator use.

Introduction

When I was a kid, my elementary teachers said, "You are not always going to have a calculator in your pocket," which sounds amusing today. The statement was intended to motivate students to become proficient in arithmetic, and it worked (for me). As an upper elementary school student, one of my teachers introduced activities designed to be completed with a calculator. I told my grandparents about the new activities, and my grandfather was not impressed, as he worried that the technology would replace the act of learning procedures. His reaction troubled me, even as a child, because I looked up to him and hoped to be as bright as he was one day.

However, even in my grandfather's school days, teachers used technology. Some common examples of educational technology include chalk, slate, pencil, and paper. Students may also have used physical manipulatives to visualize problems, such as an abacus or slide rule. As human beings and their societies have advanced, new educational technologies have been invented. Times change as they always have, which means education will also change.

When I was an undergraduate mathematics student, some professors allowed handheld calculators, and some did not. A popular calculator among students at my institution was the TI-89, a graphing calculator made by Texas Instruments with computer algebra capabilities. The computer algebra system (CAS) can be defined as mathematical software that can perform symbolic manipulations on expressions and equations.

In conversations with other educational mathematicians, I have occasionally been asked, "Why are you still discussing graphing calculators? Isn't that topic settled?" While I understand where the question is coming from (since so much has been published about using calculators in mathematics education), I still see a need for discussion. In my own life, I have encountered mathematics teachers and professors who are adamantly against adopting such technology. Further, while there are exciting, free online tools like Desmos that educators can adopt as teaching tools, they are only available to some. For example, in many rural communities, WI-FI and internet services are not strong enough to support multiple users (or sometimes a single user). Also, the calculator provides in-class test security that online applications and software running on computers cannot provide.

Background:

Though many mathematics educators advocate for using technology in the classroom, some still prefer to instruct all students using a chalkboard, chalk, paper, and pencils. (Though chalk, pencils, paper, and chalkboards are examples of technology invented by humans, "technology" here refers to devices that require electricity.) Some mathematicians believe that since they were able to learn mathematics that way, everyone else can, too. This avoidance of modern technology is not new. For example, it was once thought that "the abacus corrupts the teaching of arithmetic" (Monagan et al., 2016, p. 306).

In 1986, Hembree and Dessart conducted a meta-analysis using 79 mathematics education articles that discussed calculators in the classroom. They concluded that learning with a calculator did not hurt students' ability to perform calculations using paper-and-pencil methods in kindergarten through twelfth grade except for in fourth grade (when students were likely learning their multiplication tables). In fact, some students who learned with calculators outperformed their peers in mathematics, and those who learned with calculators tended to enjoy math more than those who learned via other methods. The authors posit that the students benefitted from the use of calculators (Hembree & Dessart, 1986).

A few years later, a seminal study was published by Heid (1988) that examined the use of Computer Algebra Systems in applied calculus. Two experimental sections were taught in which students used a computer with CAS capabilities during the first 12 weeks (about three months) of the term, and one control section was taught using traditional methods. Heid's method avoided an abundance of emphasis on skills so that more time could be dedicated toward mastering concepts. In her study, she found that students who learned with computer algebra systems had a significantly higher level of conceptual understanding, and one experimental group outperformed those taught using conventional methods on the skills test. She concluded that "compressed and minimal attention to skill development was not necessarily harmful, even on a skills test:" (1988, p. 22).

When Tokpah wrote his Ph.D. dissertation, countless studies were conducted about calculators in mathematics education and CAS in the mathematics classroom. His dissertation, "The Effects of Computer Algebra Systems on Students' Achievement in Mathematics," was a Meta-analysis of previously conducted studies. From his work, Tokpah determined that students who ordinarily scored around the 50th percentile in math would instead perform at around the 65th percentile if they had been taught with CAS. The result was so strong that 11,749 studies with non-significant results would be needed to contradict the findings of his meta-analysis (Tokpah, 2008).

The above sources are a few of the countless studies about computing technologies conducted in mathematics education. More are cited in the full dissertation, and I would be happy to share sources with anyone reading and also to learn about articles you have found.

Study:

My dissertation is titled "The Role of the Use of Technology and Social Media within the Dynamic of an Active Learning Calculus Classroom." I discussed active learning, collaborative group work, social media for educational purposes, technology, and how various teaching strategies interact. However, in this paper, we will restrict our discussion to the acts of teaching and learning with the TI-Nspire CX CAS (a handheld graphing calculator with CAS capabilities) and teaching/learning with the TI-Navigator System (software and modem that links the handhelds with the instructor's computer). The study was qualitative. I chose to conduct a qualitative study because research literature often represents what works in the classroom, but it usually does not explain how or why techniques work. For instance, I believe the researchers who concluded that learning with calculators and computer algebra systems can benefit concept development when I read their work. Still, I want to understand why using such technologies works well for students deeply. Designing a qualitative study allowed me to probe the data to try and determine the whys and how. Also, it was important for me to understand the students' learning experience with the discussed technologies since the literature often addresses what researchers have observed without getting at student attitudes. I am curious about what students think.

Data for this study were collected from January to June of 2019. The study took place at a mid-sized doctoral university with higher research activity (R2) in the midwestern region of the United States, and the participants included members of a Calculus II class taught by an expert in active learning and teaching with technology in the mathematics classroom. The classroom where the course was taught included nine stationary labs for student seating and a professor's workstation in the center. There were wall-mounted screens at the head of each lab station and larger screens on three of the four walls. Two cameras that the instructor could control were mounted on the ceiling. Classwork was completed in groups at the lab stations. During various class sessions, the instructor projected images from the cameras, his laptop, the document camera, a desktop computer, and student handheld calculators on the screens around the room.

Data analyzed for the study included field notes taken during 24 of the 26 class session meetings held during the semester. Notes were written about the professor, his students, student-student interactions, and teacher-student interactions. Student and professor interviews, journal entries created by the professor, student work, the professor's gradebook, and Facebook interactions were also part of the data collection and analysis. I interviewed 14 of the 37 students in the class, and each student was interviewed multiple times. The first solo interview with each student allowed me to collect background information on each interviewee and provide a baseline for observation. The second was a group interview in which participants were assigned to 1 of 3 groups in which they attempted to solve a problem and answered questions after their attempt. I asked clarifying questions about previous interview responses during the third interview (the Second Solo Interview in my dissertation). I focused the questions on the TI-Nspire CX CAS and the TI-Navigator System. For the Final (Solo) Online Interview, I checked in with each student to ensure my interpretation of their responses was accurate. This allowed them to correct my misconceptions and ensure that their point of view was represented as accurately as I reasonably could.

To analyze the wealth of data collected, I used the Constant Comparative method of Qualitative analyses (Glaser & Strauss, 1967). This method means that data collection and analysis occur together so that analysis informs further data collection and vice versa. For example, initial analysis led to the generation of interview questions for future interviews. This method was chosen because I did not know what to expect from the data. Using constant comparison allowed me to look at the students' words and honor their lived experiences.

Once student and instructor interviews had been transcribed, transcriptions were uploaded to NVivo Qualitative Analysis software. As I read transcripts, I looked for patterns in the words used by my subjects. Patterns I observed would be described by a word or two, and the words chosen had been spoken by the participants. As an example, a word students frequently used was "force," as in features of the course "forced" them to learn, so the word "Force" became a code that was assigned to pieces of data. Whenever a student felt compelled to work to learn mathematics, the "Force" code was applied. Once codes had been assigned, another mathematics education researcher re-coded a data sample to ensure the analysis's reliability.

Results:

Analysis of 24 class sessions and over 42 student interviews demonstrated various student attitudes toward learning with the TI-Nspire CX CAS and TI-Navigator system. Some participants had strong positive feelings about working with the devices, while others had negative. For example, one participant, referred to as Burt in the dissertation, really enjoyed using the handheld devices. He had attempted Calculus II the prior semester when he took the class from a professor who primarily used lectures throughout the class. According to Burt, his first professor taught a class built mostly on procedures. In contrast, the professor he had taught for the study used active learning methods and was interested in teaching concepts and procedures. Though Burt initially thought that the Nspire would make mathematics exceedingly easy, he changed his mind before the end of the semester. While he claimed he could have easily worked through problems from his previous calculus class with the handheld, the more conceptual questions his Calculus II professor asked were not quickly addressed by punching buttons. He said that it was helpful to have the handheld to record his ideas into, but that the device could not complete his test for him.

> Interviewer: *How did the calculator inhibit your learning?*
> Burt: *I guess I do not think it did….*
> Interviewer: *….I just wanted to get your ideas on that.*
> Burt: *Yeah, no, I never remember thinking, like, "Oh, I have the calculator, so I don't have to learn this at all," you know? (Schoen, 2021, p. 78)*

Here, Burt addresses the conceptual nature of some ideas in the class and concludes that the calculator would not be a substitute for learning.

Some participants were not as optimistic as Burt was about using the calculator. One student, whom I called Michael, had negative feelings about using the calculator as a learning tool. Michael said of the TI-Nspire CX CAS, "The thing still kinda feels like a magic box…" (Schoen, 2021, p. 91). He also referred to himself as a person who was not tech-literate, and he did not feel comfortable using computers for anything besides gaming. According to Michael, this adversely affected his learning, and he wished that technology were not a part of the class. He did as much as he could with paper-and-pencil methods, but in the end, he felt he could not keep up.

Despite some students' negative feelings toward modern technology, removing tech from the classroom may be harmful. Some students may not enjoy working with calculators or computers, but that does not change the fact that they are necessary in the modern world. In fact, the Mathematics Association of America has a statement regarding technology in the classroom lthat was written by their Committee on the Undergraduate Program in Mathematics that is accessible on their website. It reads:

> "Employers want graduates to have experience with technology, be it programming or using software applications. Using an appropriate tool to solve a problem is a universally-valued skill. Effective communication of ideas often requires technology for images, data representations, and notation. Most important, for professional and personal needs, students need the ability to learn to use emerging technologies. We therefore have a responsibility to encourage and enable our students to learn technologies alongside their mathematics" (Zorn, 2015, p. 86).

As shown in the above quote, one of the most prominent professional organizations for mathematicians in the United States recommends technology use in the mathematics classroom because employers expect their workers to be able to learn new technologies. Technology will continue to evolve as time passes, so there may be benefit in expecting students to adapt to technology as part of the educational experience.

Some students had feelings about calculators that could not be classified as positive or negative, as they were much more nuanced than could be represented by a simple binary. To illustrate this point, consider the student I called "Molly." It was determined through observation that she was proficient on the calculator and used it frequently, but she seemed to feel guilty for using it. Below is an excerpt from an interview with Molly.

> *Molly:* *….I like it because I feel like it's more real-world, ‘cuz I feel like, in the real world, you just pull out your calculator and do it, kind of, but I feel like I'm…not losing my math skills, but I feel like I'd like them a little sharper than they are now.*
> *Interviewer:* *Okay. How come?*
> *Molly:* *I don't know….in elementary school, we did those tests, and your brain is smarter than the calculator. It can do things faster… I've carried that throughout… middle school and high school. I didn't really use my calculator. And then, they kind of introduced the calculator more, and like, "Use this! Use this," sort of deal, but even before that, I did… I've had a lot of experience doing things by hand, and I kind of liked that because I feel like if I'm ever without a calculator, I wouldn't be stranded and not know how to do something, and I just kind of like being prepared.*
> *Interviewer:* *Okay. Do you think that as an engineer, you'll be doing things without the use of software?*
> *Molly:* *Um…I think it depends on what kind of engineering I go into (Schoen, 2015, p. 81).*

Molly took Calculus I at the same institution during the previous semester from a professor who used lectures as the sole means of lesson delivery. This professor did not allow calculators whatsoever and, according to one student, made derogatory remarks about teaching and learning with calculators. It is possible that this professor's attitude affected Molly's initial impression of her Calculus II professor and course.

An issue experienced by multiple participants concerns the gap between their opinions about calculators and the reality of what happens in the classroom. A student I called "Jessica," for instance, believed that the calculators made mathematics far too simple, but her grade indicated otherwise. The following excerpt is from Jessica's Final Online Interview.

> *Jessica:* *I feel like sometimes, it [TI-Nspire CX CAS] kind of let me cheat my way through a problem….I could not, like, actually try that hard.*
> *Interviewer:* *Okay. How is that cheating?*
> *Jessica:* *I don't know. {Subject laughs} But it makes me feel bad if I'm not actually doing it by hand (Schoen, 2021, p. 83).*

Although Jessica thought using the handheld was "cheating," she earned 40% on the Final Exam (the mean score was 63.3%), and her overall grade was a D+. Tests and the Final Exam for this course were split into two parts. In the first part of the test, students were not allowed to use their calculators. Most of the problems presented on this part of the test were procedural. After handing in the first part of the exam, students were given the second part and permitted to use a calculator to complete it. Questions on the second part of the exam were more conceptual.

Another participant who did not like using the calculator was a young man I called Seth. He was worried that if he began to rely on the calculator, he might forget how to perform computations. Thus, instead of learning to explore concepts using the calculator (as the instructor intended), Seth solved problems using paper-and-pencil methods as often as possible. In the following excerpt from his Final Online Interview, Seth discusses the Final Exam.

> *Interviewer: So, which part [of the Final Exam] was easier and harder?*
> *Seth: Easier? The by-hands portion [the non-calculator part].*
> *Interviewer: Why do you suppose that was?*
> *Seth: A lot of thinking of, like, how to solve equations in math, I understand completely, and I can do it in my head faster than…the theory behind the math (Schoen, 2021, p. 87).*

Here, Seth admits that he struggles with conceptual understanding. I could not help but wonder if he would have grown to understand concepts more deeply if he had given the technology a chance. It should be noted that Seth's previous instructor has a negative attitude toward teaching and learning with graphing calculators and that he made this clear to his class (according to student participants).

While Seth had been worried about potentially forgetting how to use paper-and-pencil methods to solve calculus problems, another student, whom I called Quincy, found that he had improved his techniques for symbol manipulation. He enjoyed working with technology and would frequently solve a problem by hand, then check his work using the TI-Nspire CX CAS, read the symbolic output, and finally try to prove to himself that his symbolic answer meant the same thing as the symbolic answer provided by his handheld device (Schoen, 2021, p. 51). If Seth had engaged in this practice, perhaps he could have benefited similarly.

The professor utilized the TI-Navigator System to help facilitate classroom involvement. This system linked individual handheld devices with the instructor's laptop so that he could monitor what students were doing on their calculators. He could then call on a student to discuss calculator output with the class and project their calculator screen to the wall-mounted monitors around the room. This way, he could start classroom discussions and invite people into the conversation. During Group Interviews, students shared that their awareness that they could be called upon to present using their calculator displays kept them focused and on task. They reported feeling compelled to learn because they did not want to disappoint their class or professor by being unprepared to speak about their work.

Another feature of the TI-Navigator System is that it can be used like a clicker system to send Quick Polls that students respond to on handheld devices, a feature the professor used in class. This allowed introverted students who may be reluctant to participate in a whole-class discussion to contribute quietly. Navigator was also used to take attendance quickly, , and send active learning calculus lab files directly to student handhelds. The students and professor found the system to be convenient and organized, and the speed with which the electronic files were distributed helped the class flow smoothly.

Conclusion and Recommendations:

“Although it carries few intrinsic biases of its own, electronic technology has enormous power to intensify and reinforce almost any bias the user or designer brings to it." (Kaput & Thompson, 1994, p. 680).

We all have different ideas about how to teach our students best. Still, we need to remember to keep an open mind about new technologies that may enter the educational space. Though we may prefer one type of technology over another, we need to maintain a professional and optimistic demeanor in the presence of our students. In this study, it was observed that students who had teachers and professors who denigrated calculator use in mathematics education tended to have negative feelings about using such devices in their Calculus II course. In some cases, this harmed student outcomes. We should act to improve student outcomes at our institutions, whether we are the instructors of record or not, so we need to be supportive of one another as we try teaching with different technologies.

It was observed in this study that student perceptions can vary significantly from what is observed by instructors. Many students in this study who believed that the calculator made the course “too easy” struggled to understand concepts and theories. Some earned low grades, demonstrating that the course was not, in fact, “too easy.” When we overhear students complaining about our colleagues’ choices, possibly even proclaiming that the course is overly simplistic because of said choices, we need to understand that there may be more to the story. Students do not always know how they best learn. Rather than patting ourselves on the back and believing that we are better than the other instructors, we may consider coaching the students to look for the benefits they may obtain from trying new technology.

Frankly, Teaching mathematics is hard enough as it is. We need to support one another for the sake of our students and the discipline’s future. This author looks forward to meeting with you at our next ICTCM in 2025 that you email her if you have any questions, comments, or suggestions.

Sources:

Heid, M. K. (1988). Resequencing skills and concepts in applied calculus using the computer as a tool. Journal for research in mathematics education, 19(1), 3-25.

Hembree, R., & Dessart, D. J. (1986). Effects of handheld calculators in precollege mathematics education: A meta-analysis. Journal for research in mathematics education, 17(2), 83-99.

Kaput, J. J., & Thompson, P. W. (1994). Technology in mathematics education research: The first 25 years in the JRME. Journal for research in mathematics education, 25(6), 676-684.

Schoen, C. (2021). The Role of the Use of Technology within the Dynamic of an Active Learning Calculus Classroom. [Doctoral dissertation, Central Michigan University].

Tokpah, C. L. (2008). The effects of computer algebra systems on students' achievement in mathematics (Doctoral dissertation, Kent State University).

Zorn, P. (Ed.). (2015). *2015 CUPM curriculum guide to majors in the mathematical sciences*. Mathematical Association of America.