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Barriers to technology implementation in community college mathematics classrooms

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Abstract

Algebra has been called the gatekeeper to higher level mathematics, college success, and higher wages, but many community college students struggle to pass college-level mathematics courses. The National Educational Technology Plan for higher education (U.S. Department of Education 2017b) calls for the integration of technology, such as real-time formative assessments, to support student learning. Community college faculty, however, struggle to implement technology to support student learning. The purpose of this ethnographic study is to describe barriers to technology implementation from the perspectives of mathematics community college instructors. A rural community college in the southeastern United States had a goal of increasing student success rates in developmental and college algebra courses by engaging in professional development to incorporate classroom connectivity technology, the Texas Instruments Navigator system coupled with the Nspire calculator, within their algebra sequence. Over the course of 3 years, mathematics faculty participated in 27 professional development days, provided input for lesson creation and revision, and had ongoing classroom support. Faculty interviews were conducted postintervention and analyzed using a grounded theory approach (Charmaz 2006). Barriers to the implementation of classroom connectivity technology at the instructor level included faculty beliefs about mathematics teaching and learning and about students' abilities. Other findings included lack of time for planning, inadequate technical support, lack of agency related to the college's quality enhancement plan, and the perception of misalignment between the activities and the state-mandated curriculum. Implications for supporting technology implementation in higher education will be discussed.

Keywords Classroom connectivity technology · Technology integration · Community college · Mathematics · Discourse · Professional development

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The U.S. Department of Education (U.S. DOE 2017b) argues that technology should be used in higher education to provide a "more integrated experience for students" (p. 74), but few community college faculty report consistent use of educational technology to support student learning (Daher and Lazarevic 2014). This lack of consistent use of technology has been called the "digital use divide" according to the recent National Educational Technology Plan (U.S. DOE 2016), which has supplanted the traditional inequities of the digital divide, or differential computer access and skills across groups of students or the differences in access between home and school (Groff and Mouza 2008; Wood et al. 2005). Accordingly, the divide today lies in the opportunity to use technology to enhance or transform learning versus passively completing traditional learning activities with an electronic device. This divide, combined with students' motivation and willingness to participate in classroom activities, can play a role in technology implementation (Lee et al. 2012), which is especially evident in higher education (Daher and Lazarevic 2014). Technology use in higher education that is based on real-world application, however, can provide students with multiple means of representation, expression, and engagement, thus increasing students' interest and motivation (U.S. DOE 2017b).

The effective implementation of classroom connectivity technology (CCT) to support student learning of mathematics has been documented (e.g., Irving et al. 2016; Pape et al. 2013). CCT such as the Texas Instruments (TI) Navigator system allows teachers to communicate wirelessly with students to increase the potential for formative assessment as well as active engagement with classroom content. Explorations of similar technology coupled with student-centered learning strategies resulted in increases in student attendance (Burnstein and Lederman 2001; Fortner-Wood et al. 2013), participation and engagement (Burnstein and Lederman 2001; Fortner-Wood et al. 2013; Hassanin et al. 2016; Oigara and Keengwe 2013), comprehension (Preszler et al. 2007), class satisfaction (Chuang 2014; Fortner-Wood et al. 2013; Irving et al. 2016; Oigara and Keengwe 2013), and achievement (Hassanin et al. 2016; Irving et al. 2016; Pape et al. 2013). Within a 3-year randomized control trial, for example, student achievement in Algebra I classrooms was significantly improved with effect sizes ranging from 0.19–0.37 (Irving et al. 2016; Pape et al. 2013).

Based on an examination of data for accreditation, a community college in the southeast United States determined that they would implement CCT, the TI Navigator coupled with the Nspire graphing calculator, to enhance their mathematics instruction. The goal of this project was to increase student retention and success rates within their mathematics course sequence. To do this, the department embarked on a 3-year professional development (PD) program to support their mathematics faculty to integrate this technology within their instruction. Although there was considerable success in moving the faculty toward the use of these tools, significant resistence was evident throughout the project. The purpose of the present study was to describe instructors' perceived barriers to the implementation of CCT within their mathematics instruction at this community college.

Community college students, mathematics learning, and technology

The undergraduate student population in the United States is typically nontraditional (e.g., first-generation college student attending part time), creating challenges in "navigating unfamiliar systems and institutional processes" (U.S. DOE 2017b, p. 7). In addition, community college students are typically underprepared for college coursework and take several developmental courses before enrolling in the required algebra sequence (Edwards et al. 2015; Fike and Fike 2008). For example, in a multistate longitudinal study of over 250,000 community college students, 59% were referred for developmental mathematics courses and 19% were placed three or more levels below college-level algebra (Bailey et al. 2010). Those enrolled in developmental mathematics are more frequently African American or Hispanic, low-income students, first-generation students, and female (Chen 2016). More concerning, only 30–40% of students enrolled in developmental mathematics courses complete the required sequence (Bailey et al. 2010). These enrollment and completion data are supported through several investigations of the contexts of developmental mathematics engagment and undergradutate student success (e.g., Attewell et al. 2006; Chen 2016).

The 2017 supplement to the National Education Technology Plan specifically focuses on the role of technology in higher education and calls on higher education instructors to use real-time formative assessments that would provide feeback on the effectiveness and relevance of activities, allowing them to better support student learning (U.S. DOE 2017b). Few studies, however, have examined technology implementation at the community college level. One recent study at a Midwest community college found that approximately 16% of instructors integrated Web 2.0 applications in their instruction (Daher and Lazarevic 2014).

Among the ten principles that should guide higher education stakeholders in expanding technological systems is the collection and use of real-time data to aid in instruction (U.S. DOE 2017b), such as audience response systems for formative assessment. Audience response systems allow students and teachers to exchange information electronically. Students use a handheld device (e.g., a "clicker") to send data—typically answers to multiple choice questions—to the teacher's computer, which records and aggregates individual student responses. The audience response system used in this study, TI-Nspire Navigator system, is a type of CCT: a wireless communication system that connects instructors' computers to students' graphing calculators (see Fig. 1). These CCT systems provide a space in which students' mathematical thinking may be projected for whole class exploration. Similar to audience response systems, the *Quick Poll* feature of the TI-Nspire Navigator system allows teachers to ask a question to determine students' present understanding and a *Quiz Document* can be sent to review several questions at once. These components provide powerful formative assessment capabilities that enable teachers to gauge prior learning before a lesson or knowledge acquired during a lesson. The TI-Nspire Navigator system also has several components that exceed the capabilities of typical audience response systems. Using *Screen Capture*, the teacher can take a screen shot and anonymously display the students' calculator screens for

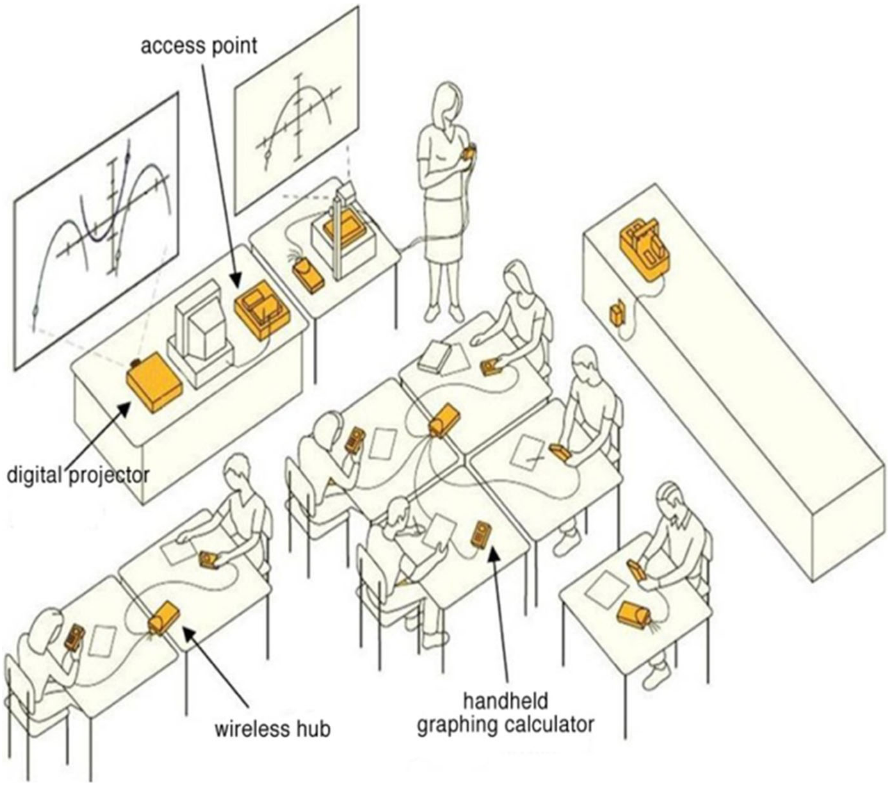

Fig. 1 Representation of the connected classroom. Teacher's computer is connected to a projector to project images of students' mathematical representations. In the version depicted here, the teacher's computer wirelessly communicates with the students' graphing calculators through a hub to which students' calculators are connected. Later versions of the technology allowed wireless communication with students' calculators without being connected to the hub. Adapted from "Classroom connectivity in Algebra I: Results of a randomized control trial," by S. J. Pape, K. E. Irving, D. T. Owens, C. K. Boscardin, V. A. Sanalan, A. L. Abrahamson, S. Kaya, H. S. Shin, and D. Silver, 2013, *Effective Education*, *2*, p. 2. Copyright 2013 by Taylor and Francis

examination and discussion (see Fig. 2). Finally, *Activity Documents* provide an interactive file and activity sheet to support student inquiry and concept development.

There are several important features of this technology that have been shown to impact student achievement in algebra classrooms (Pape et al. 2013). The TI-Nspire Navigator system allows for close integration of multiply linked, dynamic (e.g., changes in the position of a line are linked to changes in its equation or values of points in a table), and publically displayed representations that provide teachers and students opportunity for productive classroom discourse (Hegedus and Moreno-Armella 2009; Roschelle et al. 2003; Shirley and Irving 2015). Thus, CCT provides a space in which students' mathematical thinking may be explored and provides for immediate feedback to teachers and students (see Fig. 2).

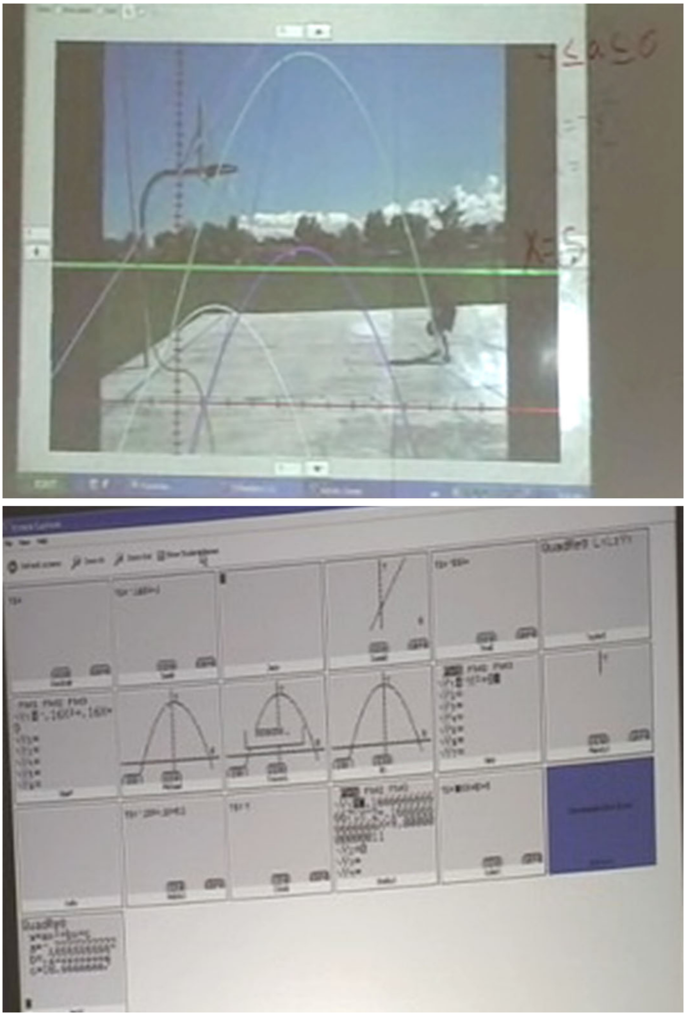

Fig. 2 Screen shots of student work displayed by the teacher using screen capture

Institutions of higher education should incentivize teaching with technology and instructional designers should collaborate with instructors to create effective research-based activities (U.S. DOE 2017b). The National Technology Plan supplement recommends that instructors increase their digital literacy so that they can create "compelling learning activities" to improve assessment and practice (U.S. DOE 2017a, p. 40). Several factors that promote the likelihood of high level technology integration include ample time—both within and outside of the school schedule—to integrate the technology into instructional activities (Kopcha 2012; Thomas and Hong 2013; Vannatta and Fordham 2004), PD training (Ertmer 2005; U.S. DOE 2016; Vannatta and Fordham 2004), and a risk-taking attitude (Vannatta and Fordham 2004). PD with "very specific, task-relevant, and classroom applicable experience” has been shown to have a significant effect on the successful integration of technology with secondary teachers (Mueller et al. 2008, p. 1532).

Factors related to technology implementation

There have been many theoretical and empirical discussions of the barriers teachers face when implementing technology. Many first-order barriers, or external barriers (e.g., cost, Internet access), have diminished, while second-order, or internal, barriers (e.g., teachers’ instructional and assessment practices) persist (Ertmer 1999; U.S. DOE 2016). These factors may be considered from an ecological systems perspective (Zhao and Frank 2003) as embedded levels of influence (Fig. 3). The inner circle includes teacher-level factors, or the teacher as the innovator, with the innovation and context surrounding the teacher’s efforts to implement the technological innovation (Zhao et al. 2002). Various other models have specifically included student factors (e.g., Groff and Mouza 2008; Wood et al. 2005), which may be thought of as an additional contextual layer close to the classroom context, and broader factors such as legislation that may or may not be informed by research (Groff and Mouza 2008).

For a number of years, educational research has focused on the teacher-level factors that play a role in the degree of technology adoption. A review of the literature supports the four subcategories for teacher-level issues found by Wood et al. (2005): philosophical and pedagogical issues, skills and characteristics, curriculum, and digital divide. Beliefs about teaching and learning, as well as attitudes toward technology, are the most common philosophical and pedagogical

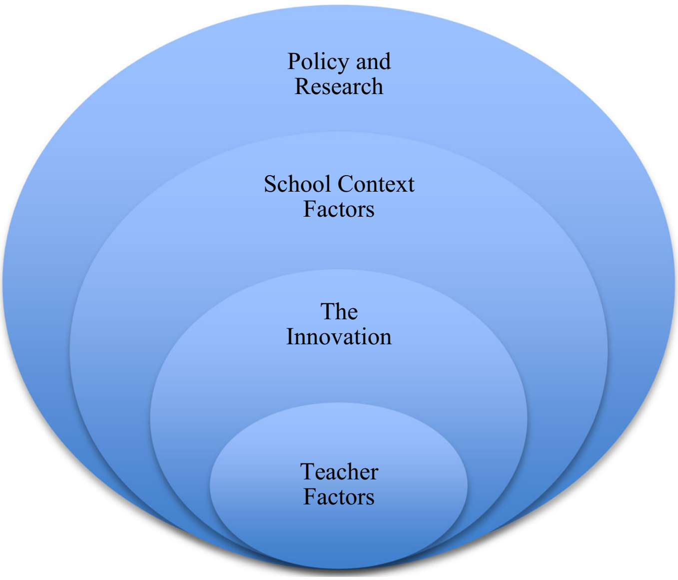

Fig. 3 Model of factors influencing technology implementation

barriers (Ertmer 1999; Ertmer et al. 2012; Goos and Bennison 2008; Hew and Brush 2007; Kopcha 2012; Lee et al. 2012). The most commonly addressed factors related to skills and characteristics were the amount of experience with technology and the lack of ability to identify appropriate supports when technological issues arose (Butler and Sellbom 2002; Groff and Mouza 2008; Mueller et al. 2008; Wood et al. 2005). Curriculum-related barriers to technology integration focused on concerns about pressure to get through the curriculum in the allotted time and the extra time needed to develop questions specific to the technological integration (Lee et al. 2012; Pierce and Ball 2009). The digital use divide manifested as the teachers' lack of familiarity with the basic technology or the knowledge of how to appropriately implement technology as an instructional tool (Groff and Mouza 2008; Mueller et al. 2008; Wood et al. 2005).

At the innovation level, according to Zhao et al. (2002), substantial barriers to successful implementation include the distance from the school culture, available resources, and the innovator's current practice, as well as the degree of dependence on others. That is, the greater the distance from present culture and practice and the greater the innovation depends on others, the less likely that the innovation will be successful. Many school contextual factors abound; however, two aspects have been most identified in the literature. Almost every study found that the unreliability of technology and lack of institutional resources to support the technology were the largest hindrances to successful uptake in the classroom (Butler and Sellbom 2002; Groff and Mouza 2008; Wood et al. 2005). Other factors included access to the technology, access to appropriate PD, the lack of ability to keep up with technological trends (Ertmer 1999; Goos and Bennison 2008; Hew and Brush 2007; Lee et al. 2012; Wachira and Keengwe 2011), and effective pedagogy, such as taking up students' incorrect and correct responses (Lee et al. 2012). The lack of institutional support, through providing the time needed to learn the new technologies, was also a concern (Pierce and Ball 2009).

The outer circle acknowledges policy and research as influential, yet very few studies address the role of these areas. Groff and Mouza (2008) posit that the lack of cohesive and relevant research has led to an unclear picture of how to best measure the effectiveness of technology in the classroom and illustrate how legislative press for technology has been inconsistent and not tied to student outcomes. The political world in which education is situated has been in flux for a number of years, which has resulted in very little clear direction and "many educators do not feel they have the ability to develop rigorous, integrated, technology based projects while still working toward the goals of annual state testing" (p. 25). At the community college level, faculty frequently feel mandated to "cover" the state curriculum. Recent policy states, however, that students should be engaging in more critical thinking, problem solving, and communication (Johnson et al. 2015; Partnership for 21st Century Learning 2016), skills that can be supported by technology-enabled learning activities (U.S. DOE 2016, 2017a).

Method

The present study, part of a larger 3-year undertaking, was situated in a rural community college in the southeastern United States. Prior to beginning Southern Association of Colleges and Schools accreditation, an examination of 2 years of success and retention data showed that low success rates in mathematics (i.e., College Algebra = 56.75%; Intermediate Algebra = 52.3%) warranted a focus on the algebra course sequence. The goal of the college's Quality Enhancement Plan (QEP), therefore, was to increase student success rates through increasing student engagement, confidence, and mathematical understanding. The department chair determined that the department would use the TI-Nspire Navigator system as a mechanism for changing instruction through classroom dialogue and frequent formative assessment.

Eight mathematics faculty at the community college engaged in 3 years of PD during which they engaged in 27 full-day (e.g., approximately 9:00 AM–3:00 PM) PD sessions. Our work together started with instruction on classroom interactions including questioning techniques and classroom instructional practices that support self-regulated learning (4 days). Next, a TI trainer provided training focused on the components of the TI-Nspire Navigator system (5 days). The PD then focused on connecting discourse theory and the pedagogy of the connected classroom (3 days). During the following summer, several instructors and graduate students worked to develop and/or revise lessons because the faculty was not satisfied with the lessons available through the TI website. During the second year, 5 days of PD included professional learning opportunities related to classroom interactions in conjunction with CCT, classroom instruction video sharing and discussion, and curriculum redesign. The PD during Year 3 focused on updated software (3 days) provided by a TI trainer and individualized feedback (7 days).

Participants

All eight full-time mathematics instructors participated in this study. Three instuctors were male, and five were female. Four of the participants had a master's degree in mathematics, one held a master's in mathematics teaching, two held bachelor's degrees in accounting, and the final participant held a doctorate in mathematics education. They had taught for approximately 5.5 years on average (SD = 4.5 years) with a range from 1–15 years of experience.

Procedure

We used an ethnographic approach to explore and describe the perceptions of this rural community college mathematics department faculty, which was viewed as a single case. Ethnographic studies seek to describe a culture, rely on interviews and observations as main data sources, and have reserachers who are knowledge producers and active participants (Koro-Ljungberg et al. 2009). Ethnography is marked by prolonged field engagement, which also aids in trustworthiness and credibility (Flick 2009). We conducted semistructured interviews to capture instructors' perceived barriers to technology implementation. Although the primary data source for this article was semistructured individual interviews, classroom observations, field notes, student focus groups, and document analysis were conducted as part of the larger study.

Two individuals not related to the intervention conducted the anonymous semistructured interviews. Questions focused on several aspects of the PD. Participants were asked to report on the most and least helpful components, components that supported their students' learning, their own experiences implementing the technology within their mathematics instruction, successes and barriers to implementation, frequency and purposes of technology use, their typical use of the technology to support student learning, and their perception of students' learning and engagement generally. Example questions included: (a) What parts of the professional development have helped you support your students to learn? (b) What does it mean for you for your students to be actively involved in this class? (c) How often have you used the technology this semester? (supported with specific examples) and (d) What barriers to implementing or difficulties using the technology have you experienced? These open-ended questions were designed to elicit teachers' beliefs about teaching and learning with technology, breadth and depth of experience with CCT, and concerns with technology implementation, which align with the teacher- and innovation-level barriers found in the review of literature. Contextual and policy factors were not a focus, but themes became apparent through the participants' repsonses.

Data analysis

The interviews were transcribed verbatim and member checks were conducted to ensure accuracy. Using Charmaz's (2006) approach to coding in grounded theory, we followed a constant comparative method (Glaser and Strauss 1967). A research team read each transcript together during team meetings and discussed coding while taking notes of sample codes with definitions and examples. All transcripts were then coded line-by-line, separately, by two individuals. Data were then reduced by the two individuals, jointly, during focused coding according to Charmaz's (2006) protocol. Focused codes were discussed by the research team resulting in code refinement as necessary until saturation was achieved. Analyst triangulation enhanced trustworthiness and credibility (Patton 2002). Final coding was entered in NVivo, and themes were examined within and across categories.

Findings: barriers to technology implementation

In this section, we examine four levels of barriers that emerged in the literature (i.e., teacher, innovation, school context, and policy) as voiced by community college faculty. Throughout, we work to investigate the interaction between these factors.

Teacher factors

Faculty interview responses related more to philosophical beliefs and pedagogy than skills and characteristics, curriculum, or a digital use divide.

Instructor beliefs about mathematics teaching and learning

Although the instructors found the PD elements (e.g., classroom discourse supported through CCT) to be important to their practice, several instructors' beliefs about mathematics teaching and learning impeded their implementation of the pedagogical aspects that were central to the technology implementation. The TI-Nspire Navigator was introduced as a tool to make students' mathematical thinking an object of discourse to be unpacked in the classroom. Classroom interaction was indicated by participants as an advantage resulting from the use of the technology, but several individuals did not see a place for an emphasis on language in a mathematics classroom. One professor proclaimed, "[The] PD is more emphasis in the English than the math. I don't see it. It's a math class…. That's not the point… in my point of view it's not…. It's not an English class…" Another faculty member felt similarly: "That's what the problem is…. It's not that I'm against math education, but most of the people in math education is more on emphasis on English than math. Use the education to put emphasis on math, not take away from math and introduce the language." These statements reflected the mathematics instructors' beliefs that language was not important to the learning of mathematics concepts. Their statements reflected a belief that these areas of learning were separate and bringing them together would be detrimental to the learning of mathematics content.

Another manifestation of instructors' beliefs about mathematics and mathematics teaching and learning was a difficulty with the idea of being asked to teach toward big ideas rather than the traditional conceptualization of mathematics as discrete concepts determined by the textbook. For example, "[the students are] more accustomed to seeing maybe two or three concepts and then practicing them over and over maybe ten to fifteen problems for each concept." This statement provides evidence of several instructors' beliefs that mathematics is made up of discrete topics that should remain separate. Related to both the instructors' beliefs about their role as mathematics instructors and their feelings of time constraints (see discussion below) was that they did not see value in taking up student responses for discussion during class time. Although the PD emphasized facilitating student examination of their own and their classmates' mathematical thinking, many teachers felt it was their role to explain all the answers that the students had submitted and further that it was more efficient for them to do so. "English don't have a place; I'm sorry. [English] Has a place in some things but not to be the center of the class; the center of the class is the application of the math." One faculty member was adamant that he would not reveal students' answers, even anonymously, because this might embarrass a student who responded incorrectly. This practice limited the potential of the class to learn from each other's errors through classroom discourse.

Instructor beliefs about students

The instructors indicated several areas of concern related to their students. First, the complexity of the technology "scared students…. I think a lot of students see the calculators and it's very intimidating at first, and, you know, we don't even use the calculators to their full extent…. So, I try to dispel the fear of this scary piece of technology that has a hundred buttons for them to press, you know, but I still think a few of them are intimidated by it." This fear was shared by several of the instructors who related negative feelings about the technology to their students, particularly with nontraditional students. "I have a few of the older students that really struggle using it. I had one student who pretty much every day… I'd have to explain to her how to change pages and how to answer questions, every day without fail and it was just a struggle to get her to catch on."

Second, because the focus of the PD was to use the technology to make students' mathematical thinking an object of discourse, the instructors noted the students' lack of mathematical understanding and inexperience with providing explanations of their mathematical thinking were substantial barriers to changing their instructional practices. "They're already struggling to understand the material, they already don't have a good background like I said." The instructors perceived the students' limited mathematical knowledge, expectations for engagement, and lack of comfort with classroom interactions as impediments.

Innovation factors

At the level of the innovation itself, time was also reported as a barrier in terms of planning for instruction. One professor proclaimed, "Time, time is the biggest barrier, getting through the material. I'm behind in all my classes most of the semester and then had at some point to stop [using the technology] and rush to catch up." This response also related to the instructor's belief that didactic instruction was more productive for learning than providing context in which students explored mathematics concepts and developed mathematical understandings. Anonymous submission of student responses was identified as a positive aspect of the technology, but time constraints due to curriculum pacing resulted in limited use of this component of the technological system or discussion of student responses for some instructors. Another dimension of time was related to the time to find appropriate materials to use with the technology. One instructor lamented, "I had trouble finding… I found some activities that I liked but typically the graphing ones were the best; the most visual ones worked the best. Some of the other ones I felt like… you know, I just wasn't impressed with what was already there and I didn't have time to create anything that I felt comfortable with." These statements reflected a general underlying concern that the materials offered with the TI-Nspire Navigator system were either too difficult for the students or the students were not equipped to learn from their mathematical behavior.

Technical support was initially another substantial barrier, as the computers in the classrooms erased all information, including class lists, when the class session was terminated. There was initial reluctance to make changes to alleviate this issue, which became a resource issue because the college had to procure a laptop for each instructor so they could save the information necessary to use the system. This, in turn, introduced a time issue because the faculty had to connect their laptop to the system and projector at the beginning of every class period. The technology was seen as using up valuable instructional time.

Contextual and policy factors

In this study, the contextual factors were complex. The faculty was involved in determining the focus of the QEP, but some of the faculty felt that they "don't think they had a choice." This statement likely refers to the fact that the department chair determined the nature of the instructional changes to support student learning. The college supported the instructors' efforts through the purchase of ample technology as well as PD and release time to participate in the project. The faculty, however, were consistently asked to take on more class sections due to the limited number of instructors. During one semester, the death of a faculty member resulted in several faculty teaching six and seven sections, exacerbating time constraints for instructional planning. The following excerpt exemplifies the complex issues the faculty experienced:

> This semester I'm not using it because we only had so many classrooms with the equipment and we have to keep them for QEP mainly and I'm teaching Statistics, which would be a great class to use them in. I walked into that statistics class like six weeks into the semester so students were very apprehensive, they didn't want to use them… so we didn't use them and I feel like if I had been able to use them in that class for the entire semester…. I feel that my students would have done much better this term. I really do; I think it was a big detriment that we weren't using them.

At the policy level, the state-mandated curriculum included many discrete topics, which the faculty indicated as a substantial barrier to technology integration. "You know I have the test schedule to where we have time to get through the material because… they're going to take College Algebra so the material has to be covered. I mean there's no way I can go around that." Another faculty member stated that "No, I mean I don't think it's a problem, really the problem is the curriculum, it's not the computer; we have to teach so much." During the second year of the PD, we set out to examine the course syllabi in relation to the state-mandated curriculum and began to discuss the notion of teaching toward big ideas. Contrary to the PD content, the instructors perceived the curriculum as discrete sections in the textbook and expected their students to learn discrete topics followed by practice. They, therefore, were unable to redesign the curriculum sufficiently to leave space for teaching differently. The important point here is that they came to this QEP because of low success rates in these courses but were unable to make the necessary changes to fully implement the technology.

Discussion

Despite 3 years of continual PD, the barriers tended to be insurmountable for many of the instructors. Understanding the multiple factors that serve as barriers to technology implementation is critical given the recent focus on teaching 21st century skills (International Society for Technology in Education 2016; Partnership for 21st Century Learning 2016; U.S. DOE 2016, 2017a), continued lack of appropriate technology implementation (U.S. DOE 2016, 2017a), and large number of community college students who need to take developmental coursework (Bailey et al. 2010; Fike and Fike 2008). The barriers to implementation of CCT included teacher factors such as their beliefs about mathematics teaching and learning as well as beliefs about students' ability to learn through their own activity such as problem exploration and solution. At the innovation level, the technology required faculty to open the learning context to exploration and discourse, which was very distant from their present practice.

Even though the faculty had administrative support and PD that paired pedagogy with a technology tool (Daher and Lazarevic 2014), there was some question about whether the faculty had buy-in to the innovation, which likely increased the distance they felt between their present practice and the innovation. Several participants noted that the innovation was imposed upon them, which is a contextual factor. Finally, the state-mandated curriculum seemed to corroborate the instructors' beliefs about mathematics and teaching mathematics. They felt that the curriculum was to be delivered to students in discrete chunks and these chunks mandated by the state were too numerous to be delivered through exploration of mathematical concepts and teaching toward big ideas.

The faculty members who participated in this PD program were required to have substantial graduate-level mathematics coursework. Although graduate coursework may not be aligned with teaching algebra, we assume that their mathematics content knowledge was substantial. Their conception of mathematics and teaching and learning mathematics, however, made their implementation of the technology problematic. The faculty perceptions of their students' limited knowledge and inexperience with explanations and their perceptions of students' and teachers' roles precluded exploration and explanation that is central to the pedagogy of the connected classroom. Finally, the interaction between the time constraints, state-mandated curriculum, and the notion of mathematics as discrete topics (i.e., teacher and policy factors) further conflated to impede implementation.

There are several important implications for practice from this 3-year study. To foster the faculty members' knowledge of how to implement the TI-Nspire Navigator, or any other technological tool, PD needs to be multifaceted including attending to both faculty beliefs about learning and about mathematics, such as discourse and effective instructional strategies with technology to support mathematics conceptual development. The faculty members' perceptions of the state-mandated curricula served as a barrier to re-examining the curriculum and teaching toward larger content areas versus individual, discrete sections and topics. Thus, instructors need to be supported to examine and reflect on the curriculum to build larger conceptual chunks, such that learning can be focused on mathematics concepts as conceptual wholes rather than in discrete topics. There was also a perceived misalignment between TI activities and college curriculum that created an additional barrier: time to prepare lessons. Instructors should be provided the time to develop lessons based on the present instruction and to explore how technology such as CCT may fit within their curriculum.

Additionally, when the CCT was used, it was not used to build students' conceptual understanding. This mimics the widespread concern of students using technology merely as tools to replace pencil-and-paper tasks, or the digital use divide, rather than in ways that transform their learning (U.S. DOE 2016). Thus, PD needs to support community college instructors to experience learner-centered instructional practices as a vehicle for supporting them to engage learners in this way within their classes. Faculty and students may need more experience supporting learner-centered instruction with graphing calculators prior to adding the connectivity component of CCT. Students' use of "technology-as-partner in the learning process" instead of "technology-as-teacher" precedes meaningful learning; meaningful learning focuses on active, constructive, authentic, intentional, and cooperative activities (Jonassen et al. 2008, p. 7). Further research is needed regarding PD to support community college faculty members' knowledge of effective instruction with CCT or any other technological tool, specifically related to teachers' beliefs. An additional suggestion is to asses instructors' beliefs prior to the PD to help tailor the resources to facilitate change (Ertmer et al. 2012).

There is much to be encouraged by this 3-year PD program. Instructors took up the work to engage their students but perceived many barriers that were reflected in both the amount and manner in which the technology was used meaningfully to support student success rates. CCT has the potential to increase student engagement, confidence, and mathematical understanding—and in some cases accomplished this goal (Irving et al. 2016; Pape et al. 2013). Although some of the community college faculties were resistant to this innovation, others were more willing to work toward the goal set forth in the National Technology Plan (U.S. DOE 2016) supplement's recommendation of increasing instructor's digital literacy. The recommendations set forth here for both practice and research can move us forward toward reducing the digital use divide.

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