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Empowering Communication through Advanced Student Response Systems: Perspectives of Pre-service Mathematics Teachers

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Abstract

Calculators were introduced in the mid-eighties, and since then we have used them for more than quarter of a century in our mathematics classrooms. Many studies have been conducted, especially to understand the effects of calculators on students' mathematical learning and understanding. Literature examining their use in precollege and college levels suggests that calculators can provide more opportunities for students in solving mathematical problems and that their use does not hinder the development of mathematical skills (Ellington, 2003; Reznichenko, 2007). Over time, calculator technology has been enhanced and new features have been added at a rapid rate. A review of the literature suggests that these new technologies can also positively affect students' mathematical learning. One in particular that may have the potential to positively affect students' learning is the TI-Nspire CAS Navigator system. This system allows students to connect their calculators to an instructor-monitored wireless network, which enables students to use their calculators as a Constructed Student Response System. This instructor-monitored environment can provide new learning and teaching experiences to both students and teachers. Access to calculators and their new technologies in classrooms is also on the rise. Therefore, this study was designed to understand the pre-service teachers' perspective on the use of the TI-Nspire CAS Navigator system. It will investigate how the pre-service teachers describe the role of the system in terms of their engagement, communication, and learning.

Keywords

Student Response Systems, Classroom Communication, Pre-Service Teachers

1. Introduction

The *Principles and Standards for School Mathematics* (PSSM) of the National Council of Teachers of Mathematics (NCTM, 2000) states that, "technology is essential in teaching and learning mathematics; it influences the mathematics that is taught and enhances students' learning" (p. 24). One important piece of technology that has been widely integrated into mathematics classrooms is the calculator. The *Report of the 2012 National Survey of Science and Mathematics Education* indicated that over 80% of high school mathematics classrooms have access to graphing calculators and about 58% of them have access to a student response system (Banilower et al., 2013). Literature reviews in precollege and college levels suggested that calculators can provide more opportunities for students in solving mathematical problems, and their use does not hinder students' development of mathematical skills (Ellington, 2003; Reznichenko, 2007).

In recent years, technology around graphing calculators has developed at a rapid rate. As graphing calculators have become more sophisticated and powerful, so have additional features and options. These additional technologies potentially have important effects on both teachers and students. For example, teachers may have to change the way they have been teaching and acquire more knowledge in how to use such technologies effectively in their classrooms. In addition, these new technologies may affect students' learning, dispositions, and experiences in the classroom. The careful study of both these issues provides illumination into the effect of new technologies in both learning and teaching mathematics.

1.1. Graphing Calculators and New Communication Technologies

The past two decades have seen the improvement of graphing calculators and the development of classroom communication technologies, some to be used with graphing calculators. These improvements to calculators include the integration of communication capabilities, Computer Algebra System (CAS) software, dynamic geometry applications, statistical applications, and data acquisition applications. In addition to changes within calculators, a variety of classroom communication technologies have been developed and used within classrooms. In the past fifteen years, we have seen development of wireless networks for use with graphing calculators. This section reviews relevant literature about the impact of some of these improvements and new technologies as well as other relevant literature about the impact of networked classroom communication devices.

Graphing calculators play a major role in today's mathematics classroom all around the world (Dion & Harvey, 2001). A variety of studies shows that graphing calculators can have positive effects on conceptual understanding, active learning, participation, and higher achievement in mathematics (Adams, 1997; Lauten, Graham, & Ferrini-Mundy, 1994; Quaseda & Maxwell, 1994). Meanwhile, networked classrooms seem to be an upcoming technology in mathematics classrooms (Arnold, 2004). Student (or Classroom) Response Systems (SRS/CRS), like Clickers, are a tool that enables teacher and students to communicate in a networked classroom setting. There are two types of SRS, namely Selected SRS and Constructed SRS (Pelton & Pelton, 2006). SSRS allow students to select an answer only from a given list, whereas CSRS allow students to submit their own answers or select an answer from a list. It is important to note that SRS are referred to by different names in the literature, such as, "audience response system" (Kay & LeSage, 2009), "voting machines" (Reay, Bao, Pengfei, Warnakulasooriya, & Baugh, 2005), "wireless keypad response systems" (Burnstein, & Lederman, 2003), "classroom communication system" (Dufresne, Gerace, Leonard, Mestre, & Wenk, 1996), "electronic response system" (Judson, & Sawada, 2002) and "classroom response system" (Fies & Marshall, 2006).

Teachers often find that students do not answer questions aloud in a class (Duncan, 2006). Students may remain silent because of lack of opportunity or socially related fear or anxiety (Dickman, 1993; Reynolds and Nunn, 1997). Literature has suggested the integration of innovative technologies could increase students' participation in mathematics classrooms, and such participation could increase student achievement (Freeman et al., 2014; Hake, 1998; Pratton & Hales, 1986; Roschelle, Penuel, & Abrahamson, 2004). SRS can allow students to respond to questions anonymously, and this could potentially promote their classroom participation. Students showed a higher level of learning in mathematics when they used SRS (Bachman & Bachman, 2011; Bartsch & Murphy, 2011; Brown, 1972; Hegedus & Kaput, 2003; Lucas, 2009; Sinclair, Wideman, & Owston, 2008). Students also developed positive attitudes towards SRS (Herman, Meagher, Abrahamson, & Owens, 2013). A higher level of classroom engagement was also reported when students used SRS (Herman, Meagher, Abrahamson, & Owens, 2013; Sinclair, Wideman, & Owston, 2008). Studies also show that students enjoy answering classroom questions through online polling and SRS (Premadasa, Wijetunge, & Bhatia, 2016; Tremblay, 2010; Zullo, et al., 2011).

In other disciplines such as psychology, students using Clickers showed the greatest learning compared to two other groups (Mayer et al., 2009). In Biology, students who had higher mean participation on Clicker questions attained higher grades (Perez et al., 2010). Similar results were reported with a group of chemistry students (King & Joshi, 2008). However, Morgan (2008) concluded that there was no significant effect for the Clicker treatment on student achievement. This contradicts the above findings, but the author suggested that it was quite possibly due to varied grade distributions among the different disciplines. In Physics (Koenig, 2010) and Chemistry (Hoekstra, 2008) students showed a higher level of interaction and engagement during the lectures when Clickers were used. Sprague and Dahl (2010), Bartsch and Murphy (2011), and Graham, Tripp, Seawright, and Joeckel (2007) also suggested that Clickers can positively influence student engagement. Furthermore, studies in different disciplines including Biology (Preszler, Dawe, Shuster, & Shuster, 2007), Astrophysics, Communication, and Physics (Trees & Jackson, 2007), and Engineering Mathematics (d'Inverno, Davis, & White, 2003) suggested that the use of SSRS can enhance students' engagement and motivation in classroom activities. It is evident that SRS can promote learning when the appropriate pedagogical methodologies are integrated to the classroom instructions (Fies, & Marshall, 2006; Roschelle, Penuel, & Abrahamson, 2004).

The TI-Nspire CAS Navigator system allows students to connect their calculators to an instructor-monitored wireless network, which enables students to use their calculators as CSRS. This instructor-monitored environment can provide new learning and teaching experiences to both students and teachers. Due to the sophisticated features of the calculator one can use in this system, we will define this system as an advanced CSRS. In-service teachers expressed that the TI-Nspire Navigator system helped them with monitoring student activities, offering appropriate teacher intervention, and promoting whole class discourse (Clark-Wilson, 2009). A review by Fies and Marshall (2006) also concluded that there was a greater agreement among researchers that the SRS can promote student learning when supported by appropriate pedagogical methods. Many existing studies about SRS have focused on implementation issues and in-service teachers' perspectives (Clark-Wilson, 2009; Shirley, Irving, Sanalan, Pape, & Owens, 2009, 2011), as well as illustrating student achievements and reactions to SRS. Because this technology has positive influence on students' learning and availability is on the rise, this study will expand the investigation into pre-service teachers' perspectives on the use of SRS while students are learning mathematics. The above discussion illustrates that the use of SRS in a mathematics classroom can develop a better learning environment for both teachers and students. Thus, it is useful to study how aspiring future teachers would react to such technology enriched learning experiences.

2. The Study

This study investigated how pre-service teachers described the role of the TI-Nspire CAS Navigator in terms of their learning, engagement, and communication. The following research questions were addressed during this study:

1) What do pre-service secondary mathematics teachers say about the effects of using the TI-Nspire CAS Navigator system and graphing calculator technologies on their learning, engagement, and communication in the mathematics course for secondary teachers?

2) What do pre-service secondary mathematics teachers say about the benefits and role of the TI-Nspire CAS Navigator and graphing calculator technologies in their future teaching and classroom?

2.1. Theoretical Framework

Vygotsky's sociocultural theory (1978) essentially assumes that primary factors of learning are social and cultural activities. The theory does not ignore the individual element, but it is only a secondary concern. The emergent approach of Cobb and Yackel (1996) suggests that in understanding how individuals learn mathematics, it is extremely important to treat both individual and social dimensions equally. Authors also suggest that neither of these factors are given primacy over the other; rather, these two factors are seen to be reflexively related to each other. They define classroom social norms, socio-mathematical norms, and classroom mathematical practices to explain why collaboration of psychological constructivism (Piaget, 1953) and social interactionism into the emergent perspective is important. Explanations and justifications of solutions, attempts of making sense of others' explanations, and agreement or disagreement indications can be considered as examples of classroom social norms for whole classroom discussions. What counts as a different mathematical solution, an efficient mathematical solution, and acceptable mathematics solutions of a classroom can be considered as examples for socio-mathematical norms (Cobb & Yackel). By using the emergent approach, researchers can analyze how individuals react to different situations. This micro-analysis could help to identify how individuals construct relevant mathematics knowledge as well. Thus, Cobb and Yackel suggest that the emergent approach is helpful and important in classroom based developmental research. When analyzing classroom interactions, classroom communication can play a major role in learning. This study will define classroom communication as classroom discourse that makes students' thinking visible to peers and teacher. In this technology-supported environment, the role of technology in terms of the communication and how pre-service teachers describe it will be exclusively analyzed. In a technology-supported learning environment, it is important to investigate students' interactions with their peers, the teacher, and the technology. Through the lens of the emergent approach, this study will investigate the role of CSRS on those interactions. Additionally, as the participants are aspiring mathematics teachers, the emergent approach can be beneficial in identifying the classroom social norms, socio-mathematical norms, and classroom mathematical practices that may occur in the participants' classroom.

2.2. Methodology

Since the TI-Nspire CAS Navigator technology is a relatively new tool, there is limited shared knowledge available about the role of the system in students' learning. Thus, this study investigates how the pre-service teachers describe the role of the TI-Nspire CAS Navigator in terms of their learning, engagement, and communication. Due to the nature of the research questions, this study is qualitative in nature. The investigators' classroom observational field notes and interviews were used as the data sources for the study. Participants in the study were selected from a course designed to address the teaching and learning of secondary mathematics for pre-service teachers attending a university in the Midwest part of the United States. Students used the TI-Nspire CAS calculators as part of their daily instructions and learning.

One of the investigators taught the course while the second investigator collected data. The non-teaching investigator who attended all the class periods as a nonparticipant observer collected the interview data and field notes. The teaching investigator did not know which students had participated in the study until final grades were submitted. Audio recorded interviews were transcribed verbatim and they were coded using theory-driven and data-driven codes. Analysis and categorization of those codes were used to identify the emerging themes.

2.2.1. Rationale of the Sample

As described earlier, the use of calculator technology in K- 12 and college mathematics classrooms is increasing. In particular, networking capabilities of calculators are improving and becoming more accessible (Banilower, et al., 2013); calculator use in the school system is also improving (Arnold, 2004). Hence, it is important for both in-service and pre-service teachers to have a better understanding of the use of that technology. Early exposure to new technologies and their effective use can have a positive effect on pre-service teachers' ability and willingness to use them in their future classrooms (Mistretta, 2005). Thus, it is important to expose pre-service teachers to educational technologies like SRS in their university mathematics classes.

2.2.2. The Classroom Settings

Each class was 75 minutes long and met two times per week during the fall semester. The observing investigator, the principle investigator, sat in the last row of the class where no students were seated. This investigator did not move about the class nor participate in any classroom discussions or activities. The observing investigator collected the consent forms from the students and kept them in a safe locked drawer in the department of mathematics where only he had the access. Each participant was given a pseudo name and the corresponding interview data were recorded under those pseudo names. The teaching investigator did not have access to any information about the students' participation. The teaching investigator had the access to the interview data only after the final grades of the class were submitted.

Eight participants from the fall semester completed all three interviews (of 13 total students). The teaching investigator had had a lengthy experience in teaching with the CAS graphing calculators combined with the TI-Navigator. Use of an experienced instructor was important because studying a class where the TI-Nspire CAS Navigator was used unsuccessfully would probably only tell us students' negative experiences. Having an experienced teacher can help to reveal both positives and negatives of the use of the system. All students participated in classroom discussion either by asking questions, providing answers, or analyzing each other's responses. Students also discussed their readings from the textbook or articles provided by the teacher. Students used the TI-Nspire CAS calculators from the beginning of the class.

Three rounds of interviews were conducted during the third and fourth weeks, eighth and ninth weeks, and 13 and 14 weeks of the semester. It is very important to make the participants feel comfortable and assure the confidentiality of the interview process in qualitative studies (DiCicco-Bloom & Crabtree, 2006; Douglas, 1985; Farber, 2006; Palmer, 1928). Therefore, the purpose of the first two interviews was to develop a good relationship between the interviewer and the participants. Each of the first two interviews were about 10-15 minutes long. At the end of the first round of the interviews, students were introduced to the TI-Nspire CAS Navigator during their classroom activities. The following figure summarizes the timeline.

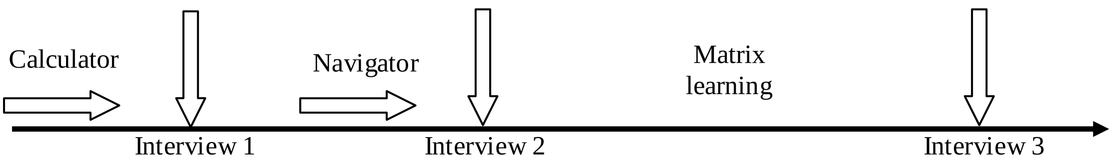

Figure 1. Timeline of the class.

2.3. Data Analysis and Coding

Interview data were analyzed to identify how pre-service teachers describe the role of the CSRS in terms of their learning, engagement, and classroom communication. One of the other goals was to identify the role of the CSRS in shaping their perspectives about future teaching. Coding units were developed mostly based on the interview data. After developing the coding units, we shared them with another doctoral student in the mathematics education program. This student used the codes on a randomly selected interview and then the coding units were adjusted to maintain reliability and objectivity of the coding process (Bogdan & Biklen, 2006; Farber, 2006). After adjusting the coding units, all the remaining interview data were coded. Coding units like NHS (Navigator Help Student) and HNHS (How Navigator Help Student) were used to code interview responses such as, "uhhm, I do not feel like it [referring to the TI-Navigator] hindered at all anything it help it a lot. It would show different ways, like I said, like I did multiple ways to understand something and it allowed it me do it in my own phase." By coding the interview data inductively (Bogdan & Biklen, 2006) we identified coding categories and themes that emerged from the data (Neuman, 2013).

3. Analysis and Discussion

Pamuk and Peker (2009) found that technology-based instruction can positively affect pre-service teachers' attitudes toward using such technologies in their future mathematics classrooms. This study investigated whether the CSRS shaped pre-service teachers' perspective of their future teaching with technology and if it did, in which ways. This section discusses the findings of the above research questions in detail.

The coded interview data identified the following themes: *Instructional Strategies and the CSRS*, *Private Communication in a Public Environment*, and *Future Teaching and the Navigator*.

3.1. Instructional Strategies and the CSRS

People learn in different ways. Some people are very good listeners. Some are visual learners. Some people are good at working collaboratively with others while others are good at working individually. Thus, the use of multiple instructional strategies can be extremely beneficial towards students' learning. If students are given opportunities to learn mathematics in a preferable environment, it can potentially serve as a catalyst for motivation. In *How People Learn: Brain, Mind, Experience, and School*, Bransford, Brown, and Cocking (1999) recommended learner-centered learning environments, formative assessments, and opportunities for community-based learning as important factors of an effective classroom. In promoting learner-centered learning environments, inquiry/discovery-based learning activities can be extremely important.

Students reported that the CSRS supported such instructional strategies. Using the student responses, the following paragraph discusses the role of the CSRS in terms of students' learning. For example, when Fay, one of the pre-service teachers in the study, was asked to describe the use of the CSRS, she responded:

> Uhhm, in this class we used it a lot to discovery based lessons. Like for this matrix one he gave us not like a game, but I feel like a game, you could manipulate matrix and it would manipulate like the unit square. So, we could kind of see as we were doing it. We did not have to graph it out like, because like I scratch down in the paper. For that way you can have see it happening and so we did that for, could of, different things, kind of a like, little inquiry.

Here the student was referring to the matrix transformation activity the class completed using the system. Fay was describing the calculator's mathematical exploration abilities. What is the role of the Navigator in such an activity? For example, through the Screen Capture, students could see how the other students made progress toward the goals of the activity. Thus, they could compare and contrast their own discoveries and progress with the rest of the class. This may have provided them opportunities to explore different solution strategies by themselves.

With the CSRS, the teacher had the opportunity to monitor all the calculator activities simultaneously, enabling the teacher to identify common issues or individual student misconceptions. Through this process, the teacher could address these issues within the lesson that might be an effective way of enhancing students' learning. In continuing the previous response, Fay was also able to identify the supporting role of the Navigator in allowing the teacher to monitor students' work.

> And we also used it as one person can present, it gives [the teacher] a chance to make sure like we all paying attention. Uhhm, you can check and see if everyone is working and it allows you to check for understanding and see if may be one student has not done anything on their calculator. Then you know that they might do not know how to do it.

Dana, another pre-service student in the study, also described the role of the SCRS in allowing the teacher to monitor students.

> Uhhm we used it [Navigator] in the classroom during the activities. So that the professor could see who is doing what and how the students are working on the problems so like he can tell if we were, you know, exploring it in the right way or if we were not doing anything at all.

Gabi also described how they used their calculators to explore mathematical concepts and how such explorations helped them to understand concepts. Further, she described how the peer instructions helped her to keep up with the classroom activities and the role of the Live Presenter in peer instructions.

> Since he is the teacher he knew exactly what button to press and so he could do it faster than I could. Because, sometimes I am a little bit slower with following along with those, because I will be doing

> on my calculator. So when a student is doing it, he was saying exactly how to do it so that the student could do it on the calculator so that I could see what they are doing. So it is little bit slower or at least at an appropriate phase rather than him just pressing buttons.

Fay, Gabi, and Dana described how the CSRS facilitated those instructional strategies, particularly inquiry based activities and peer instructions. The other participants also described how the system helped them to see other student solution strategies and thus learn from their peers. All the eight participants described benefits of screen sharing through the CSRS. All the participants agreed that the Screen Capture could be helpful for students to see other students' solution strategies, while it also helped the teacher monitor student activities. Compared to all the features of the Navigator, the Screen Capture was the most frequently described feature by the participants.

This suggests that the participants of this study identified the CSRS as a supporting tool that could improve the impact of inquiry- or discovery-based activities in a mathematics classroom, particularly through teacher monitoring and peer sharing. All the participants agreed that the use of the system positively influenced them in completing and understanding their activities. Such learning opportunities may have helped them to learn and understand some of the mathematical concepts.

3.2. Private Communication Channels in a Public Environment

Students need to communicate effectively with their peers and teachers to attain higher levels of learning. These communications can happen in a public or a private environment. As mentioned earlier, some students may be comfortable with communicating in public while others may be more comfortable participating in private communication environments. Students' willingness to share their solutions with the class can be negatively influenced by lack of opportunity or socially related fear or anxiety as mentioned earlier.

All the participants identified and described positively the role of the system in terms of their classroom communication. Instead of answering questions publicly by raising their hands or by any other method, students can answer anonymously through the Quick Poll. The evidence, which will be discussed in the following paragraphs, suggested that the TI-Navigator CAS system can strengthen the communication between the teacher and the students. Students can communicate with the teacher what they know or what they do not know by answering through the Quick Poll. Quick Poll answers can be perceived by the students, as a private communication in a public environment. The teacher can get a quick glance at each student's understanding and then provide immediate feedback. This can also be considered an example of effective teacher-student communication. Interview responses of the participants described the way the TI-Navigator positively influences their classroom communication. For example, Kali said:

> uhhm, I think our communication with [the teacher] is uhhh a little different. I mean he is not always at his computer. But you can always go to his computer and see how everybody else is doing. Like the silent communication, you are not necessarily trying to make, but then you are in the sense because he is having screen captures. So uhhm you know he can see if somebody is off track or if they are struggling he could well lecturing or go over there and help or something.

In the above response, Kali described the role of the Screen Capture as a silent communication between the teacher and the students. Silent communication can take place either when the students are working on the activities or when they are answering classroom questions. It is important to note that the TI-Navigator can give a voice to this silent communication. Dan also identified how the tool can positively influence the silent communication between the teacher and a student:

> The teacher to student silent communication uhhh the, the, are you doing the right thing, am I doing the right thing, do I need help, do not I? Teacher can do that without ever actually having uhhm ask or pick somebody out, they can it, may be walking to them and help them. That is nice. I think teacher to student communication is strengthened with it.

The other participants also identified these situations and described how the CSRS can be used to facilitate students' communication in a mathematics classroom. Gabi, Sue, and Macy also described that the Quick Poll was easy and helpful in letting their teacher know what they know and what they do not know. Gabi, Sue, and Macy respectively said that "well through the quick poll and stuff, we are communicating what we knew to the teacher", "uhhm I think the communication with the teacher was easier, communication with each other. There was a lot more communication than the normal class", and "It is an easy way for students to give information to the professor." Fay described how the Screen Capture could help to open up conversations among the students:

> It [Navigator] open ups conversations better because we get like, when he would put screens up then we all could see what each other is doing. You can have like discussions go deeper than they ever would otherwise.

The evidence above suggests that the TI-Navigator CAS system strengthened communication between the student and the teacher and the eight participants were agreeing that the system positively enhanced their classroom communication. The system can be used as a catalyst to bring forward the voices of students who may not speak in public classroom settings. The evidence above further suggests that the system can be used to facilitate students' participation in classroom discussions. Such opportunities can help to create effective learning environments for students. Furthermore, the CSRS can also be used to initiate conversations among students because as described earlier, they can see peers' calculator screens through the Screen Capture.

3.3. Future Teaching and the Navigator

All the participants agreed that they would like to use the system in their future mathematics classrooms. Participants described the ability to monitor students' calculator screens through the CSRS as an important factor. Dana said:

> And there was really hard to get kids like motivated to do it or like answer, things like that and I just kept thinking how nice it would be to have, like everyone have a calculator and then everyone and then I can watch everyone what they are doing and so I think it is like a really good tool to help learning, because it is a way for you to monitor what they are doing.

She described how the system's capacity to monitor student work could be helpful in her future classroom. Gabi, Kali, Dan, and Jack also held similar viewpoints about monitoring student work through the Screen Capture.

After using the CSRS, participants were also able to identify how they could utilize these features to facilitate mathematics teaching in their future classrooms. The participants described the system as an important technology tool that would positively influence their future teaching. For example, participants said, "it gives the teacher a chance to make sure like we all paying attention. And that is definitely how I will use it if I have a chance in a class" (Fay) and "Activities are good but then this makes one step better, because now not only they are working on the activity, but you are watching them work on the activity" (Dana).

The findings of previous sections along with the data presented here suggest that the pre-service teachers believed the CSRS can help to facilitate or enhance students' learning. The data above suggests that all the participants talked positively about their intentions for future use of the tool in a mathematics classroom. The participants talked about the Screen Capture and how it can be used to monitor calculator based activities. Furthermore, they described how such monitoring capabilities could help them, as teachers, to provide necessary scaffolding for students. Furthermore, these findings of the study strengthen the previously mentioned findings of Pamuk and Peker (2009).

3.4. Research Questions, Themes, and Findings

In the previous sections, emerging themes from the data provided a detailed description about the participants' perspectives about the CSRS. Participants were able to identify key features of the system and define the role of those features in terms of their learning and future teaching. The relationship between emerging themes and the research questions will be discussed in this section.

3.4.1. RQ 1 and Findings

The first research question examined how pre-service teachers described the role of the CSRS in terms of their own learning, engagement, and communication. The data presented previously suggested that all the eight pre-service teachers identified that the system provided more learning opportunities for them and allowed them to communicate with their peers and the teacher more effectively. During the third interview, participants were asked to describe the role of the system in terms of their learning. All the participants reported that the system did not hinder their learning. The participants described how the use of the system helped them to compare their work to that of others and that helped them to keep up with the work. In the lens of the theoretical framework this study adopted, the system facilitated the development of positive classroom norms in communicating between teacher and student and between students.

In the section of Instructional Strategies and the CSRS, Fay and Gabi described how the use of different instructional strategies helped them to learn and understand classroom activities. Fay described how the system helped them to make their own discoveries. Gabi described how the system facilitated her learning from the peer instructions. Furthermore, Gabi described how the Quick Poll feature helped them learn classroom materials. It provided opportunities for them to communicate with the teacher what they know and what they do not know. Participants also described the benefits of the features Live Presenter and Screen Capture in terms of their learning. As seen above, pre-service teachers described how the different features of the tool helped their own leaning.

Another important part of the first research question was the relationship between student engagement and the system. The participants described the ability to monitor students' calculator screens as extremely important and beneficial for both students and teachers. As previously mentioned, the participants identified that the system can be used to motivate students to engage with classroom activities.

The participants also described ways the system can positively influence their classroom communication. They identified that it can especially strengthen silent communication between students and teacher. What is meant by silent communication? As mentioned earlier, there can be many reasons students do not respond to a teacher's questions aloud. Anonymity of their responses through the system reduced or perhaps removed the effect of those factors which prevented them from answering classroom questions otherwise. The section Private Communication Channels in a Public Environment provided strong evidence to suggest that the system can positively influence students' classroom communication. A strong majority of pre-service teachers agreed that the system can strengthen communication between student and teacher. Participants also described the importance of features like Quick Poll and Live Presenter in terms of students' communication.

3.4.2. RQ 2 and Findings.

The second research question investigates what pre-service secondary mathematics teachers say about the benefits and role of the CSRS in their future classrooms. All the participants identified the system as an important piece of technology that can be used in their future mathematics classrooms. As described in the section Future Teaching and the Navigator, the participants described how the different features of the system could play an important role in future teaching.

Specifically, the data shows participants believed monitoring capabilities, formative assessment options, and communication opportunities of the tool would be beneficial in their future teaching. All the pre-service teachers were very aware of the monitoring capabilities of the tool. The participants predicted that through the monitoring function, they could make better decisions about when and how to make meaningful teacher interventions. Furthermore, they affirmed that students recognized the benefits of monitoring in motivating their engagement with the classroom activities. The Quick Poll can be used to check students' understanding during a lesson. Pre-service teachers deeply valued the anonymity of participation in Quick Poll questions. They were strong proponents of using the anonymity to motivate and increase students' participation in classroom activities. As described in the Private Communication Channels in a Public Environment section, participants endorsed the importance of Live Presenter and Quick Poll in terms of classroom communication.

Overall, this study provides strong evidence to conclude that pre-service teachers developed positive attitudes towards possible use of CSRS in their future classrooms. They identified how such tools play an important role in promoting learning, engagement, commutation, and motivation in their future mathematics classrooms.

3.5. Limitations of the Study

The small sample size is a limitation of the study in generalizing the findings to a broader population. However, previous studies revealed little about interactions between the CSRS and pre-service teachers. It was extremely important to investigate how students identified the role of the system in terms of their learning and teaching and a small sample size enabled close analysis of interview data in finding evidence to answer research questions.

4. Conclusions

The presented qualitative evidence shows how pre-service secondary mathematics teachers describe the role of the CSRS in terms of their learning, engagement, and communication in a mathematics classroom. Specifically, based on the analysis in the previous chapter, this study can conclude that the participants agreed the Screen Capture could motivate students to actively engage in classroom activities in different ways. First, knowing that the teacher can see each calculator screen can hold them accountable for what they are doing on the calculator. Second, knowing the teacher can help them as needed during an activity, fosters a safe environment to engage in the activity. Third, students' ability to compare themselves to the rest of the class can further motivate them to continue with an activity. The participants also described that anonymous participation in classroom question and answering sessions through the Quick Poll can reduce anxiety and thus increase their participation.

Students' engagement and effective classroom communication can positively affect their learning. The data supports the conclusion that the pre-service secondary mathematics teachers' learning was positively affected by the CSRS. In addition, the participants described positively their willingness to use the tool in their future mathematics classrooms because of perceived positive effects on students' engagement, communication, and learning.

Finally, the pre-service teachers described the features Screen Capture, Quick Poll, and Live Presenter as important in promoting the engagement and communication that can enhance students' learning. This study provides an initial framework that recommends the inclusion of the following aspects when investigating CSRS such as: public and private (silent) communication, students' engagement, students' motivation, formative assessments, instructional strategies, and students' learning.

5. Future Work

Pre-service teachers may be more conditioned to take a teachers' perspective compared to some other student groups with other career perspectives. During the interviews, some participants described themselves as belonging to a more motivated student group since they were seniors and aspiring teachers. Thus, it may be valuable to investigate how the students in introductory or other mathematics courses would identify or describe the role of the Student Response Systems. Those students' perspectives about the classroom communication and engagement could be helpful in developing and implementing more effective pedagogical strategies. Thus, it could be beneficial to investigate if these findings also hold for other groups of students, such as those who do not plan to be teachers or those who do not enjoy mathematics.

Learning how various aspects of the TI-Nspire Navigator and other CSRS might influence students' participation, engagement, and learning could be helpful in developing effective or enhancing classroom activities and instructions. For example, participants often mentioned and held the view that the monitoring capabilities of the CSRS can motivate students' participation in classroom activities. Thus, it may be important to investigate the effects of these monitoring capabilities in more detail among a diverse student population. In addition, pre-service teachers described that screen-sharing capabilities of SRS can provide opportunities for students to learn from their peers, self-evaluate their learning, and start mathematical conversations. This may mean that SRS can provide opportunities for students to learn as a community and future research could examine the effects of the classroom communities.

Some participants self-identified themselves as motivated to learn, participate in classroom activities, and communicate with the class regardless of the presence of technology. Perhaps these communication technologies have different impacts on such learners. Future questions could include: Will this technology help students with a variety of learning styles and students of other ages? How would this technology help students labeled at-risk or gifted and talented? Answers to such questions can help to develop effective classroom activities and classroom practices. It is our hope that these and other questions will be addressed in the future.

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