ELECTRONIC AUDIENCE RESPONSE SYSTEM IN THE SECONDARY MATHEMATICS CLASSROOM TO ENGAGE STUDENTS

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Wendy Lara Bradley
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Examining Committee Members:

Dr. Kristie Jones Newton, Advisory Chair, Department of Teaching and Learning
Dr. Julie L. Booth, College of Education, Department of Psychological, Leadership, and Organizational Studies
Dr. Catherine Schifter, College of Education, Department of Psychological, Leadership, and Organizational Studies
Dr. Carol Brandt, College of Education, Department of Teaching and Learning
Dr. John Kerrigan, External Member, West Chester University

ABSTRACT

There is a current push for students to reach higher levels of achievement in mathematics in order to compete in today's technologically changing world—a push that is being led by the Common Core Standards Initiative (CCSI) and the National Council of Teachers of Mathematics (NCTM). The issue with this new push, however, is that most students are disinterested in mathematics, resulting in them choosing to not participate in class. Active participation is a form of behavioral engagement that can lead to cognitive engagement and higher achievement. To improve participation, the expectancy-value theory suggests that the perceived benefit of participation needs to be increased while the cost reduced. Electronic audience response systems (EARS) have the potential to accomplish this, and they have begun to be implemented at the college level with primarily positive results.

The purpose of this study is to examine if EARS can similarly improve student participation and achievement in the secondary geometry classroom. Using a quasi-experimental design, this study compared students' participation using hand raising versus EARS devices in the classroom and found that student participation increased significantly when using EARS. To look at achievement, a treatment and comparison group design was used, and despite that no statistically significant difference was found, the results do support EARS' potential to improve achievement. Lastly, this study looked at student and teacher perceptions of using the EARS in the classroom, and found mixed results.

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CHAPTER 1
INTRODUCTION

A recent study by Cooper (2014) found that the majority of high school students report being bored in school. This is not surprising given that the current generation of students has grown up with technology that allows them to interact whenever they want and receive instant results or information. Such instant gratification is very different from what students encounter in the mathematics classroom. According the National Center for Educational Statistics (NCES, 2003), mathematics classes are typically taught by the teacher doing most of the talking and using tools such as a textbook, workbook, chalkboard or overhead projector, and pencil and paper. Students view these tools as antiquated—therefore, adding to their boredom in the classroom.

A secondary factor that may contribute to students' boredom is the lack of interaction in the typical mathematics course. The primary interactions that occur in the classroom take place in the format of question-and-answer interactions prompted by the teacher (NCES, 2003). Often times, these interactions are fairly short and only involve one or two students, leaving the rest of the class disengaged and uninterested (Black & Wiliam, 1998; Plisko, 2003). The lack of opportunities for students to engage in interaction is a growing concern, especially because it has been found that students who do participate are actively engaged in the learning process (Boylan, 2010; Lave & Wenger, 1991).

In an effort to improve all students' opportunities to become engaged in the classroom, some educators have turned to technologies, such as the electronic audience response system (EARS; Beatty & Gerace, 2009; Bruff, 2009). The EARS, a commonly used technology in universities, provides all students with the opportunity to participate during question-and-answer interactions with a more game-like feel. This active participation by the student is a form of behavioral engagement that can lead to a deeper understanding of the material (Fredricks, Blumenfeld, & Paris, 2004).

To better frame the potential of the EARS in the classroom, I will first situate the issue of non-participation in the context of learning and engagement to provide a basis for the need to improve student participation. Next, I will provide a brief overview of audience response systems (ARS). Using the expectancy-value theory and research on formative assessment, I will then provide a theoretical basis for EARS' ability to improve participation and achievement. Then, I will discuss the current literature pertaining to ARS. Finally, I will address the current gaps in the literature that this study attempts to address before introducing the methodology and results of the current study.

Context of the Problem

According to the National Council of Teachers of Mathematics (NCTM), in order for our youth to compete academically and keep up with changing technology, there is a need for a stronger mathematical foundation (2000). The Common Core Standards Initiative (CCSI, 2014) and the NCTM (2000) suggest students take four years of mathematics in high school and reach a level beyond algebra 2 in order to be adequately prepared for college. In addition to the push for achieving a higher level of mathematics, students are also being encouraged to gain a deeper understanding of the concepts, beyond rote memorization and procedural knowledge (CCSI, 2014; NCTM, 2000). Unfortunately, an analysis of U.S. mathematics classrooms shows that the majority of classroom time is spent reviewing material and procedural knowledge, with little time devoted to discussion (NCES, 2003). To meet the CCSI and NCTM Standards, the teacher must go beyond reviewing material and instead engage students in conversations and discussions on new concepts. In order for this to occur, the students need to retain the knowledge they have already learned and the teacher needs to be able to accurately determine what previous concepts need to be reviewed.

Adding to this challenge is that by the time students reach high school, many have developed disinterest in, lack of confidence with, and low motivation toward mathematics. These factors contribute to students' avoidance, and therefore, lack of engagement (Graham, Tripp, Seawright, & Joeckel, 2007; Singh, Granville, & Dika, 2002; Wigfield & Meece, 1988). Fredricks et al. (2004) defined three different types of engagement in education: behavioral, cognitive, and emotional. Behavioral engagement involves the actions students take in the classroom, such as participating in class discussions, being attentive during lectures, and putting forth effort in an activity. Cognitive engagement involves students being engaged in an activity for the purpose of learning. Emotional engagement is the connection that students feel to the content, classroom, and the teacher. Studies have shown these types of engagement are positively correlated to achievement (Christle & Schuster, 2003; Fredricks et al., 2004; Prince, 2004).

It is not only the engagement itself, but also the students' motives that can have an effect on how they participate and what they learn (Roth, Lee, & Hsu, 2009). A student engaged insofar as to simply find an answer will learn less than someone engaged in questioning, analyzing, and reflecting on their understanding (Engeström, 2001;

Fredricks et al., 2004). With the pressure to pass mandated tests to graduate and be accepted into college, some students' motivations seem to be limited to grades or passing exams rather than understanding the material. To move students to higher level of cognitive understanding, they need to take on a more active role in the classroom, including participating in question-answer interactions, class discussions, and being engaged in learning (Lave, 1997; Lave & Wenger, 1991).

A recent study by Cooper (2014) looked more closely at student engagement with respect to three categories of teaching practices: connective instruction, academic rigor, and lively teaching. In connective instruction, the individual student is emphasized, creating emotional engagement for the student. In academic rigor, the academics of the classroom are emphasized, providing opportunities for cognitive engagement. Lively teaching incorporates the use of games, projects, and other activities to provide active learning opportunities for students that lead to behavioral engagement. Students in the study rated the level of teaching practices across a variety of subjects, and mathematics classrooms were rated as having a significantly higher level of academic rigor than other subjects. The study also found that when lively teaching was used in classrooms with high academic rigor, engagement improved (Cooper, 2014). Because mathematics classrooms were viewed as being of high academic rigor, this suggests that incorporating lively teaching in the mathematics classroom has the potential to improve student engagement.

A concept often associated with lively teaching is active participation. Active participation involves the teacher consciously creating opportunities for students to participate in class (Pratton & Hales, 1986). Research has shown that classrooms using active participation have significantly higher achievement than those that do not (Haydon, MacSuga-Cage, Simonsen, & Hawkins, 2012; Pratton & Hales, 1986; Prince, 2004). One suggested technique to incorporate active learning includes breaking up lectures with opportunities to respond using choir responses (the whole class answers at once) in addition to individual responses (Haydon et al., 2012; Prince, 2004). This provides all students with the opportunity to respond and prevents lag time between concepts where students can lose interest and become disengaged (Haydon et al., 2012; Prince, 2004).

However, when using choir response, a shy or quiet student's response can be easily lost in the crowd or students may copy others' replies. An additional flaw in choir responses is that it can be difficult for the teacher to quickly gauge what misconceptions students have, thus making it hard for the teacher to provide appropriate feedback, which some students prefer (Jansen, 2008). Yet, allowing students to respond with traditional hand raising also has its flaws. Asking individual students for a response can be perceived as threatening to some students and only provides the teacher with one perspective (Haydon et al., 2012; Jansen, 2008). Teachers tend to have differentiated expectations of students, which can affect their calling pattern and consequently, a student's participation (Turner & Patrick, 2004).

The implementation of the EARS in a classroom can potentially eliminate these flaws. EARS allow all students to participate simultaneously, providing the teacher with a more accurate gauge of students' understanding. The anonymity that EARS offers may also alleviate some of the anxiety and fear that students have concerning participating.

To better understand the potential of EARS devices in the classroom in regards to participation, I turn my attention to a general description of audience response systems.

Introduction To Audience Response Systems

Audience Response Systems (ARS) have been available since the 1960s (Bruff, 2009). These devices originated as response cards (Christle & Schuster, 2003) or flashcards (Lasry, 2008), consisting of small, pre-printed responses as well as blank cards students could write on using dry erase markers (Bruff, 2009; Christle & Schuster, 2003; Lasry, 2008). Students would hold up the cards to share their response with the teacher and class. More recently, however, electronic devices have found their way into the classroom. These devices go by various names, including classroom response systems, electronic voting systems, and clickers (Kay, Lesage, & Knaack, 2010). Regardless of the name, an EARS provides students with a hand-held device that allows them to submit answers to a posed question (Kay et al., 2010). The teacher can then display the results to the class instantaneously.

Some of the key differences amongst the various available devices are in the hardware and software features. For hardware, each system has a central hub or computer that collects the data from the students. Most of the devices use Wi-Fi or radio frequencies to achieve this, but some of the older systems are hardwired into the central hub (Bruff, 2009; Caldwell, 2007). Each student has his or her own hand-held device to respond to a question. The hand-held device typically has four buttons to answer multiple-choice questions, and some also have numeric or text entry capabilities (Bruff, 2009; Caldwell, 2007). There are also applications and Internet-based programs that allow phones, computers, or tablets to be used as the clicker device (Bruff, 2009; Engel & Green, 2011).

Regarding software, a majority of the devices allow the results to be aggregated and displayed anonymously to the class, and some have the capability of recording individual responses for the instructor to review later on (Bruff, 2009; Caldwell, 2007). Some programs allow students to change or resubmit an answer and track the progress of the class' response over a period time for a particular question (Bruff, 2009). Other devices also provide opportunities to use the EARS for quizzes and will even grade the students' submissions (Bruff, 2009). This is just a brief overview of the different options and capabilities of devices currently available. Some newer EARS that use tablets or phones as the hand-held device now also allow students to show their work by using the touch screen features of the devices. As technology advances, the capabilities of these devices are likely to expand even further.

Theoretical Perspective

Expectancy-Value Theory

To increase student participation, an instructor must take into account the possible reasons for a student's reluctance to participate. Student participation in this context is defined as the willingness of a student to voluntarily answer a question. The expectant-value theory helps to explain students' reluctance. Atkinson (1957) looked at the motivation of students to perform a task as a function of the task's motive, expectancy, and incentive as perceived by the student. He defines expectancy as the "cognitive anticipation … that performance of some act will be followed by a particular consequence" (Atkinson, 1957, p. 360). The incentive is the "relative attractiveness" (Atkinson, 1957, p. 360) of performing the act.

Eccles and Wigfield (2002) expanded on this by stating that a person's choices about completing a task are influenced by both positive and negative task characteristics and every task has a cost associated with it. They found that each task has a perceived expectancy and value that are influenced by perceptions about success, level of difficulty, and individual goals. The expectancy is difficult to alter in the math classroom because it is tied into a student's past experiences, outside influences, and their own perception (Eccles, 1983; Eccles & Wigfield, 2002).

Eccles (1983) stated that the value of a task for a student is "inversely related to [a] cost/benefit ratio" (p. 93). The cost of a task is the considered the negative aspects of the task such as the amount of effort and time necessary to succeed and what it means to fail (Eccles, 1983, Eccles & Wigfeld, 2002). The benefit includes the interest in the task and the value it has for future goals (Eccles, 1983; Eccles & Wigfield, 2002). In order to increase the students' motivation to participate in question-answer interactions, the cost needs to be reduced and the benefits increased. To examine how this can be done using an EARS, we first need to look more closely at the costs and the benefits of participating.

Cost of Participation

Using traditional hand raising, a teacher can call on only one student at a time. This often results in a few students tending to dominate the discussions, causing other students to see little value in participating (Bojinova & Oigara, 2011; Fies & Marshall, 2006; Zhu, 2007). The difficulty of the task can also affect the effort—tasks that students consider to be easy can cause them to lose interest and become disengaged. Tasks that are too difficult can have similar results, especially when students perceive they will most likely fail, and thus see little value in putting forth effort (Eccles, 1983).

An additional cost is the risk perceived by the students. When a student raises his or her hand and is called on, the class is focusing on that particular student (Christle & Schuster, 2003). This situation creates risk for the student because if the student responds incorrectly, they may be embarrassed in front of their peers (Bojinova & Oigara, 2011; Jansen, 2008; Popelka, 2010; Wigfield & Meece, 1988). Some students also perceive participation, in particular critiquing others' responses, as inappropriate behavior (Jansen, 2008). These negative views about participating will often result in the students avoiding participation (Eccles, 1983).

Another cost of hand raising participation is time. Students tend to reach an answer at different paces, and this can result in some students having an expectation that they will not be able to get an answer before the teacher calls on someone else. Besides the time needed to complete a task, students also view time as a commodity that is not to be wasted. Therefore, if they take the time to do a problem and are not called on to respond, they may have less time to do another activity that is more interesting or engaging to them (Eccles, 1983).

Students who perceive the cost as too high will not be actively engaged in a lesson. This is a concern because participation is a form of behavioral engagement, which is linked to cognitive engagement. To decrease the risk of participating, instructors have to provide opportunities for all students to contribute to class discussions, to be successful, and to focus on their own understanding rather than that of their peers (Bembenutty, 2012; Turner & Patrick, 2004).

EARS can decrease the risk of participation by providing the opportunity for all students to anonymously participate, reducing the risk of embarrassment in front of their peers (Fies & Marshall, 2006; Stowell & Nelson, 2007). Displaying students' responses can be delayed for a period of time, providing all students with the opportunity to try a task, potentially increasing the students' effort in the task. The EARS, therefore, has the promise of reducing the students' perceived cost of participation.

Benefits of Participation

To increase students' perceived value of participation, a teacher can incorporate formative assessment in the classroom. Formative assessment involves the conscious effort by a teacher to provide feedback to students and opportunities for students to monitor their own learning without the pressure of grades (Black & Wiliam, 1998; Sadler, 1989). A formative assessment task allows students to determine what the key concepts are, where they are in relation to the learning goal, and how to potentially close this gap (Black & Wiliam, 1998; Black & Wiliam, 2009; Nolen, 2011; Sadler, 1989).

EARS can be used to tally students' responses and display the results to the class. This provides the opportunity for a student to self-monitor their progress during the lesson by comparing their knowledge with that of their peers, without the risk of failure (Sadler, 1989). At the same time it provides the teacher a quick way to gauge students' understanding, which allows the teacher to adjust their lesson accordingly. This in turn provides students an opportunity to close the gap between their understanding and the learning goal, which can improve their achievement level (Bembenutty, 2012; Black & Wiliam, 1998; Black & Wiliam, 2009; Bojinova & Oigara, 2011; Bruff, 2009; Sadler, 1989; Zhu, 2007). Some EARS can save the students' submissions for the teacher to review later. The teacher can use this information to provide targeted feedback and suggestions for improvement to the individual student (Bruff, 2009; Sadler, 1989).

A few EARS also allow students to show the work they did to arrive at their answer. A teacher can then use a student's work as an example to show the class what is expected (Sadler, 1989). Displaying students' work can also provide the opportunity to open a discussion since students often times feel more comfortable evaluating others' work as they are less emotionally attached to it (Sadler, 1989). These discussions can help students self-monitor their own work by seeing and hearing about other ways to do the problem, as well as possible improvements to these methods. At the same time, discussing the reasoning behind the procedures, not just the steps that were executed, can provide a deeper understanding of mathematics that goes beyond rote memorization and procedural knowledge (NCTM, 2000).

Formative assessments can be used to create classroom discussions, enrich student understandings, clear up misunderstandings, and adjust lessons (Black & Wiliam, 2009). In particular, it has been found that the difference between low and high achieving students is reduced in classes that use formative assessment (Black & Wiliam, 1998; Yin et al., 2008). Incorporating the philosophies of formative assessment with question and answer interactions can add value, potentially increasing student participation.

To increase student participation in class, the risk of participation must be minimized and the gains maximized. The EARS has the potential to reduce risk by taking away some of the fears associated with hand raising. At the same time, it increases the value to both the teacher and student by providing instant insight into the student's understanding, as well as potential ways to close the gap between expectations and current standing. This combination of limited risk and high value associated with the EARS means that it has the potential to improve students' desire to participate in class, which in turn can improve their achievement.

Pilot Study

I conducted a pilot study that looked at the effect of the method of response on high school geometry students' voluntary participation. The study looked at three different method of responses, hand-raising, flashcards (small index size cards with pre-printed choices), and an EARS device. The study was conducted over a fourteen week time period across two sections of a Geometry class that I taught. A quasi-experimental design was used with students (n = 27) in each class altering the method of response across twelve lessons. The two sections of the class during the same lesson sometimes used the same method of response and other days varied in the method of response. A video camera was used to record the participation during hand-raising and flashcards. Participation was considered an attempt to answer the question by holding up a flashcard or raising their hand. For the EARS the program saved the data to be analyzed at a later date. How often a student participated during the lesson was recorded along with the total number of possible responses and a participation rate was calculated for each student, the number of responses divided by the total number of possible responses, for each method of response.

A repeated ANOVA was conducted on the participation rate across the three methods of response and a significant effect was found (F[2, 52] = 97.269, MSE = 19665.60, p = .00, η^2 = .789). The EARS showed the most participation (M = 94.25, SD = 1.52) flashcards came next (M = 68.97, SD = 4.02) and hand-raising had the least participation (M = 40.311, SD = 2.761). Students also provided some informal feedback and they preferred the EARS to the flashcards and some felt uncomfortable with the camera in the classroom.

Research Questions

Building off of EARS' potential to reduce the costs and increase the benefits of participation and my results from the pilot study, this study aimed to answer the following research questions:

1) When responding to questions, how does student participation using an EARS compare to participation using traditional hand raising?

2) How do scores on a unit test after learning with EARS compare to scores after learning with hand raising?

3) What are teachers' perceptions and attitudes toward using an EARS in the classroom?

4) What are students' perceptions toward using an EARS in the classroom to participate?

CHAPTER 2

LITERATURE REVIEW

The expectancy-value theory states that a student's perception of the cost and benefits of a task is a contributing factor to their willingness to perform that task (Eccles, 1983). In order for the EARS to improve students' participation and achievement in class, students must have a positive perception about using the devices. Research has found that the majority of students enjoy using EARS in the classroom (Bojinova & Oigara, 2011; Caldwell, 2007; d'Inverno, Davis, & White, 2003; Draper & Brown, 2004; Fies & Marshall, 2006; Freeman & Blayney, 2005; Kay et al., 2010; Liu & Stengel, 2009; Titman & Lancaster, 2011). In this section, I analyze the literature on students' perceptions of using EARS in the classroom. I then look at the effect EARS has had on students' achievement and provide suggestions for the effective implementation of EARS in the classroom. Finally, I will show how the current study attempts to address some of the gaps in the literature.

Student Perceptions of EARS

Benefits Related to Engagement

A common theme that has emerged in the literature is engagement (Bojinova & Oigara, 2011; Fies & Marshall, 2006; Freeman & Blayney, 2005; Kay et al., 2010). Bojinova and Oigara (2011) conducted a study the college level in two different courses that had students using an EARS device during review and practice sessions of the class, not during the actual lesson itself. The research found that the majority of students felt more engaged in the classroom when using EARS (Bojinova & Oigara, 2011). Kay, Knaack, and Lesage (2010) conducted a study at the secondary level across various disciplines and teachers. Students used an EARS device for one month and at the end completed a survey. The study found that students enjoyed using the EARS and felt more engaged (Kay et al., 2010). However this study did not collect data on how the EARS were actually implemented by the teachers.

A similar study was conducted by Draper & Brown (2004) that looked at how students perceived the use of EARS when implemented across various college level classes. Students felt that EARS requires them to think about the material and concentrate, thereby improving their cognitive engagement (Beekes, 2006; Bojinova & Oigara, 2011; Draper & Brown, 2004). A study by Titman and Lancaster (2011) focused in on the use of EARS in a college level Statistics class of 12-15 students. Students used the devices to answer questions during the lecture and at the end of the course answered a questionnaire about using an EARS. The students primarily had positive impressions of the EARS and felt it broke up the lecture and kept them motivated to pay attention. Other studies have noted similar results when using an ARS (Conoley, Moore, Croom, & Flowers, 2006; Marmolejo, Wilder, & Bradley, 2004).). Students felt that EARS requires them to think about the material and concentrate, thereby improving their cognitive engagement (Beekes, 2006; Bojinova & Oigara, 2011; Draper & Brown, 2004). Some studies have also noted that EARS helped students improve their attention (Conoley, Moore, Croom, & Flowers, 2006; Marmolejo, Wilder, & Bradley, 2004; Titman & Lancaster, 2011). However, a study by Bartsch and Murphy (2011) disputed these findings. In their study, students were asked to attend a short lecture on an unfamiliar topic, with one group using EARS during the lecture and the other using traditional hand raising. At the end of the lecture, students answered questions about their engagement, and no improvement was found when using EARS compared to traditional hand raising. However, that students volunteered to participate and were only required to attend a short lecture, compared to a traditional class, these factors may have impacted this finding.

A study by Bunce, Flens, and Neiles (2010) further supports students' perspectives of being more attentive and engaged in lessons when using EARS. During a lecture chemistry class, students volunteered to use an EARS to record every time their attention waivered from the lecture and for approximately how long. The results showed that during the demonstration and clicker question segments of the lecture, the students' attention was higher than in the traditional lecture segments.

Benefits Related to Participation

Engagement is a broad term that can involve cognitive, behavioral, and emotional elements. Participation is particular type of behavioral engagement that involves a student actively answering a question, which is the primary focus of this study. The expectancy-value theory suggests that participation will improve with EARS, and research confirms this (Bojinova & Oigara, 2011; Freeman & Blayney, 2005; Kay et al., 2010).

In their study, Bojinova and Oigara (2011) used EARS in two undergraduate college courses and had the students complete a survey at the end of the course. On the survey, students were asked to rate their agreement with the statement, "I am more likely to participate in class with clickers compared to hand raising" (Bojinova & Oigara, 2011, p. 176). Over 93% of the students agreed or strongly agreed with this statement. Graham et al. (2007) conducted a study during a voluntary college-wide pilot implementation of an EARS system to look a the impact on EARS on engagement and the teaching strategies that students felt were most beneficial when an EARS was used. They found similar results, with 89% of the students stating that EARS helped them participate in class. The study by Kay et al. (2010) at the secondary level found a slightly lower percentage of 55% agreeing they would participate more with clickers—however, only 15% stated they disagreed.

These studies show that, from the students' perspective, EARS helps them participate in class, but actual quantitative data on participation is lacking. However, it should be noted that in these studies the students used EARS in a variety of classrooms, so there is a possibility that the class, pedagogical approach, or teacher could have also contributed to the positive perception. A study by Freeman and Blayney (2005) examined this possibility more closely by having students in the same class switch between EARS and hand raising to respond to questions. At the end of the course the students were surveyed, and 68% stated that the EARS increased their level of interaction in the class. These results suggest that it is in fact the EARS, and not just the class or teacher, that results in the students' perception of increased participation when using EARS.

Unfortunately, these studies used surveys to determine level of participation and did not directly investigate students' actual participation in the class. Nonetheless, studies have been conducted on response cards—a similar method of response—that did look directly at student participation. Christle and Schuster (2003) studied five students in a mathematics classroom and found that, with the exception of one student, all of the students' participation increased when using response cards compared to hand raising. The one exception participated equally when using hand raising or response cards. Even though Christle and Schuster's (2003) was a small study, similar results have been found across other disciplines and levels, in that student participation increases over hand raising when using response cards (Gardner, Heward, & Grossi, 1994; Marmolejo et al., 2004).

Due to the similarity between the two response methods, it is feasible to consider that if response cards improve student participation, then EARS should, as well. However, EARS have a key advantage over response cards in that they offer anonymity. In the literature, anonymity has often been cited as a contributing factor to students' preference of EARS (Bojinova & Oigara, 2011; DeBourgh, 2007; Draper & Brown, 2004; Caldwell, 2007; Fallon & Forrest, 2011; Freeman & Blayney, 2005; Graham et al., 2007; Popelka, 2010). Students felt less risk was involved when using anonymous EARS, since the rest of the class would not know who had the wrong answers (Bojinova & Oigara, 2011; Caldwell, 2007). Anonymity, as well as its other features, leads to most students enjoying using EARS in the classroom (Caldwell, 2007; d'Inverno et al., 2003; Draper & Brown, 2004; Liu & Stengel, 2009; Titman & Lancaster, 2011). Students' perspectives regarding EARS and participation provide evidence that the EARS can improve students' actual participation in the classroom when compared to traditional hand raising.

Benefits Related to Formative Assessment

DeBourgh (2007) conducted a study implementing EARS in a nursing course in conjunction with formative assessment techniques. Questions were presented to the students and they were given a time limit in which to respond using their EARS device. At the end of allotted time, all students' answers were displayed to the class. If the majority answered a question correctly, the teacher then moved on to a follow-up reasoning question. If there was a split in the class between a right and wrong answer, or if the majority of the class selected an incorrect answer, the teacher promoted peer discussion in the class to try to eliminate possible answers. At the end of the course, students completed a survey about their experience with EARS. Based on these surveys, students were "highly satisfied with both operational aspects and instructional aspects of using the technology" (DeBourgh, 2007, p. 83). Students felt that the immediate feedback provided about their answers was useful (DeBourgh, 2007). Overall, the students felt that using the EARS with formative assessment helped support their understanding and enabled them to focus on the larger concepts (DeBourgh, 2007). Even though these results show promise toward raising a student's understanding, no achievement data was collected to support the students' perceptions about the benefits.

A study by Bojinova and Oigara (2011) corroborate these findings—students' most enthusiastic responses in their study occurred when EARS were used for formative assessment. It appears that students like using EARS to check their understanding (Bojinova & Oigara, 2011; Draper & Brown, 2004; Graham et al., 2007; Kay et al., 2010). Some students claim that they concentrated more on the lesson and are better able to reflect on the material when using EARS (Beekes, 2006; Draper & Brown, 2004).

Another contributing factor is that students like to see how they are doing compared to their peers (Bojinova & Oigara, 2011; Draper & Brown, 2004; Kay et al., 2010). Students also feel these interactions break up the lecture and provide an element of fun (Beekes, 2006; Conoley et al., 2006; DeBourgh, 2007; Fies & Marshall, 2006; Freeman & Blayney, 2005; Popelka, 2010; Zhu, 2007).

Some may criticize students' attitudes about EARS, claiming student enthusiasm could merely be a result of the novelty of the device. A study by Landrum (2013) considered this possibility and accounted for it by asking students about their perception of EARS at various points throughout the semester. Landrum (2013) found that there was a significant decline in participation and understanding of the material over the course of the semester. However, by the end of the course, 83% of students still stated they participated more with clickers, and 77% felt clickers helped them understand the material. This suggests that even though there may be a slight novelty effect, the overall encouraging perspectives about using EARS is due to more than its newness.

Negative Perceptions

Though much research has pointed to positive reactions to EARS, this is not to say that all responses to EARS have been positive. The majority of negative comments about using EARS have revolved around cost and technical problems (Caldwell, 2007; Freeman & Blayney, 2005; Graham et al., 2007). At the college level, many students are required to purchase the device—however, with new apps that allow phones and tablets to be used as EARS devices, this cost can be reduced. In regards to technical issues, proper training and support can help reduce these issues.

Some students have felt rushed and anxious when using the EARS to respond to teacher questions (Caldwell, 2007; Draper & Brown, 2004; Kay et al., 2010). These types of comments have been more common when the EARS were used for grading. In the current study, the EARS were used for formative assessment—because this does not contribute to grades, it eliminates this potential negative reaction.

Another negative perception of EARS is related to the time involved to use the devices. In some studies, students felt it broke up the flow of the lecture and took away time for other examples or information to be presented (Freeman & Blayney, 2005; Kay et al., 2010; Lambert, Cartledge, Heward, & Lo, 2006). For classrooms that are not consistently using EARS, it may also take time out of class to get the devices set up and put away at the end of the class. It also takes more time for the teacher to pose a question, wait for all students to respond, and then provide the appropriate feedback. Negative comments related to time were primarily seen in college level classes involving lectures where there is typically little interaction involved. At the high school level, this may not be as much of an issue since students are usually expected to interact in a smaller setting.

Despite that the EARS has some perceived negative attributes, a majority of students feel the advantages of EARS outweigh the disadvantages (Draper & Brown, 2004). Thus, the literature supports that EARS has the potential to increase students' participation in the classroom by reducing the perceived costs and increasing the perceived benefits.

Effects of EARS on Achievement

Because EARS improves student engagement and engagement is linked to improved achievement, it seems plausible that EARS can also improve achievement. Unfortunately, the literature regarding this is mixed—only some studies have demonstrated improved achievement (Bartsch & Murphy, 2011; Caldwell, 2007; Conoley et al., 2006; Kennedy & Cutts, 2005; Liu & Stengel, 2009; Lucas, 2009; Marmolejo et al., 2004; Mayer et al., 2008, Premuroso, Tong, & Beed, 2011), while others found no significant difference when using EARS (Bojinova & Oigara, 2011; Martyn, 2007; Nightingale, 2010). To better understand this disparity, it is necessary to take a closer look at these studies.

Effects on Assessment Scores

The literature on EARS' effect on student achievement on final exams, tests, and quizzes is inconclusive, but does provide support for the potential of EARS to improve achievement. Gardner et al. (1994) implemented response cards in an elementary science classroom. The students switched between using hand raising and response cards for each lesson. The following day after a lesson, students were provided a short quiz on the material from the previous day. The study found that students performed better on the quiz after the response card lessons. At the end of unit, a review test was given, and questions regarding material taught during response card lessons had higher accuracy then questions covered during hand raising lessons. A study by Christle and Schuster (2003) found similar results, with most of the students' quiz scores improving when the content was covered using a response cards compared to traditional hand raising. In

Christle and Schuster's (2003) study only five students were included and one student did not have a change in their quiz score, but this student received over 95% on the quiz regardless of the method of response. This suggests that EARS can improve test scores for average and low-performing students without hurting higher performing students. Marmolejo et al. (2004) supports this finding by showing improved quiz scores for students who used response cards and noting this improvement was the most pronounced for low-performing students. For this study students in college level Psychology course were given true-false or multiple-choice questions to answer during a lecture. At the end of the lecture students were given a quiz on the material covered in the lecture that contained true and false and multiple-choice questions. During each lecture students alternated between using response cards and hand-raising.

The studies above suggest that EARS can improve test scores for average and low-performing students without hurting higher performing students, but they only used response cards and primarily asked multiple-choice and true false questions. Fallon and Forrest (2011) compared response cards to EARS during review sessions by altering the methods across two sections. The study found that, overall, students did not show a significant difference on their test scores between using EARS compared to response cards. One thing to note in this study, however, is that the devices were not used in the actual class, but in review sessions that were optional to attend.

Lasry (2008) found a similar result when he compared the use of EARS and response cards in conjunction with Peer Instruction (PI). One section of the class used response cards while the other used EARS. There was no significant difference found between the sections on beginning and end of the semester exams. These findings, along with Fallon and Forrest, imply that using an EARS or response cards may have similar effects on students' overall achievement.

Liu and Stengel (2009) implemented EARS in two college-level quantitative courses. In one section of the course, the instructor incorporated EARS by posting multiple-choice questions, displaying the results of the students' responses, and then based on the class' answers, reviewing or continuing on with the lecture. The students in the EARS class were not required to use an EARS device since they had to purchase them, but they were encouraged to do so with an incentive: the ability to drop a low grade. This additional motivating factor, as well as that not all students used the devices, may have impacted the results of this study. The researchers found that on most exams, students in the EARS class performed better than the regular class. The one exception was on an exam involving more complex solutions that the authors noted tended to not be easily addressed with multiple-choice questions, revealing a possible limitation to the EARS. Using a newer EARS that allow students to type in or draw answers allowing students and teachers to incorporate more complex mathematical symbols and notations may reduce this limitation.

Nightingale (2010) performed a comparable study in college business classes. Three professors agreed to teach one section of their class without using EARS but to treat everything else the same. Students' final exam scores were compared across the sections, and no significant difference was found between the two groups. Martyn (2007) and Bojinova and Oigara (2011) found similar results when comparing classes who used EARS to those not using EARS. A study by Premuroso et al. (2011) contradicts these findings, however. In Premuroso et al.'s (2011) study, students who used EARS had significantly higher final exam scores than those who used hand raising in a college-level class. These studies offered little detail about the actual implementation of the devices in the classroom. Additionally, these studies (Bojinova & Oigara, 2011; Martyn, 2007; Nightingale, 2010; Premuroso et al., 2011) only compared students' final exam scores, whereas Liu and Stengel (2009) compared unit tests.

Bartsch and Murphy (2011) attempted to remove the variables that occur in the classroom setting and affect EARS' effectiveness by having students volunteer to attend a lecture given by the same professor. One group of students used EARS while the other students used hand raising to answer questions. The study found that students in the EARS grouped had significantly higher scores on a quiz given at the conclusion of the lecture. Overall, the literature provides evidence that EARS can potentially improve student achievement on unit test or quizzes, which is the focus of this study.

Correlation to Achievement

The literature is not definitive in regards to EARS improving achievement, but it does show that using EARS in conjunction with formative assessment can be used to predict student achievement. Premuroso et al. (2011) performed an experimental study to compare student performance in a college accounting course of students who used EARS to students who did not. A multiple regression model was used that took into account GPA, gender, major, online homework average, and EARS averages. The EARS average was calculated based on the number of correct answers students submitted. The results showed that students' EARS average significantly contributed to their exam scores.

Lucas (2009) conducted a study using Peer Instruction (PI) as the pedagogical approach with the aid of EARS in his college-level calculus class. PI involved presenting students with a concept question, revealing the class' answer choices, having students discuss the answers and question in small groups, and then re-voting. Students were given points for correct responses and submitting an answer during the PI sessions, though this did not contribute to their overall class grade. Lucas (2009) found a positive correlation between the students' overall average grade and their average score from the PI sessions. He noted that the PI participation scores "closely parallels homework as a possible predictor of student performance " (Lucas, 2009, p. 222). Lucas (2009) and Premuroso et al. (2011) found a positive correlation between using EARS and student achievement using different pedagogical approaches. It should be noted that it was not just the use of the EARS device itself, but also the students' scores when answering questions using the EARS that correlated to achievement. This implies that teachers using EARS with formative assessment techniques may be able to predict students' overall grades in a mathematics course.

Looking across the abilities of students, researchers have found that the variance in exam scores for students in classes that use EARS were less than those that did not (Bojinova & Oigara, 2011, p. 179). Several studies have noted that classes that use EARS have less students with final grades of Ds or Fs, and fewer students who withdraw (Caldwell, 2007; Premuroso et al., 2011). Kennedy and Cutts (2005) looked more closely at the connection between the use of EARS and the ability to successfully answer questions on exams in a college computer science class. The students were divided into four clusters: low EARS users with moderate success, high EARS users with low success, low EARS users with low success, and high EARS users with high success. Comparing these clusters' performance on a class test showed that students who were high users of EARS and moderately successful scored significantly higher than the remaining clusters (Kennedy & Cutts, 2005, p. 266). These research findings reveal the potential of the EARS to close the achievement gap for students in the mathematics classroom without lowering the achievement of high-ability students.

Implementing EARS

Research has suggested that it is not merely the presence of EARS, but rather the implementation that is important (Beatty & Gerace, 2009; Draper & Brown, 2004; Zhu, 2007). EARS can be used in the classroom for summative assessments, formative assessments, opinion polls, and attendance records. One of the prominent suggestions when implementing EARS is to explain the purpose of using the device to students, as well as expectations (Bruff, 2009; Caldwell, 2007; Draper & Brown, 2004; Kay et al., 2010; Zhu, 2007).

This study aims to investigate using EARS to enhance formative assessment, which is a preferred use of EARS (Kay et al., 2010). Research by Beatty and Gerace (2009) supports that technology-enhanced formative assessment (TEFA) can be effective in high school classrooms for improving engagement. These researchers provide four key principles for implementing TEFA in the classroom: using question-driven instruction, promoting discussion, being flexible, and discussing ways for the student to become engaged in learning. This section of the literature review will briefly summarize best practices and suggestions for incorporating EARS for formative assessment in the context of these four key principles.

Implementing Question-Driven Instruction

The first step in incorporating TEFA is to use question-driven instruction to spotlight and motivate student learning of key concepts (Beatty & Gerace, 2009; Blood & Gulchak, 2013). A teacher can use EARS to pose questions and provide an opportunity for all students to participate (Blood & Gulchak, 2013; Graham et al., 2007). Research suggests giving an appropriate time limit in which to allow students to answer the question—so that students have adequate time to ponder the question but know when to submit their answers by (Beatty & Gerace, 2009; Cline, 2006; Martyn, 2007). If the time limit is too short, it can be stressful for students, adding to the cost of participating (Kay et al., 2010). In addition, questions that use EARS response should be scattered throughout the class to break up the lesson (Bruff, 2009; Martyn, 2007; Zhu, 2007). The questions should also primarily be created before class to save time (Bruff, 2009; Caldwell, 2007). Most systems, however, allow a teacher to implement an impulsive question, as well (Bruff, 2009).

Bruff (2009) suggests that when using EARS, multiple-choice questions are best. Even though many EARS programs do have the capability to allow for free text responses, the software has difficulty displaying these in a useful graph since an additional space or decimal place could be interpreted as a different answer. To incorporate free-response with EARS, Bruff (2009) suggests having students provide a few possible answers, and then have the class vote on these.

Creating Questions

It is not only the act of questioning, but also the structure of the question that can affect the success of EARS in the classroom (Caldwell, 2007; Titman & Lancaster, 2011). When writing multiple choices, the literature suggests keeping the answer choices to five or below (Caldwell, 2007; Martyn, 2007). Providing an answer choice such as "I don't know" or "Unsure" is a way to prevent guessing and provide teachers with a clearer picture of understanding (Beatty & Gerace, 2009; Bruff, 2009; Caldwell, 2007). The answer selections should also highlight common errors or misconceptions by providing choices that would be chosen if one of these errors were made (Caldwell, 2007; Sullivan, 2008; Titman & Lancaster, 2011). The answers should also be placed in a logical order and be independent of each other (Sullivan, 2008).

For the question itself, Titman and Lancaster (2011) suggest using the same scenario for multiple questions in order to reduce the time it takes students to process the content. A second suggestion is to provide students with different scenarios or graphs and ask a question requiring them to compare and contrast the scenarios. These types of questions tend to reach a higher cognitive level and draw students to the differences (Sullivan, 2008).

The EARS questions should not be used for longer procedural problems but rather for smaller steps within the procedure (Caldwell, 2007; Titman & Lancaster, 2011). Students preferred when the questions were not used to introduce a new topic, but rather review topics or discuss a topic they have been taught (Titman & Lancaster, 2011).

Lastly, when creating questions it is important to avoiding negative connotations in the questions so as to not try to trick or confuse students (Sullivan, 2008).

Promoting Discussions

The second principle encourages using these questions to invoke discussion in the classroom (Beatty & Gerace, 2009; Caldwell, 2007; Martyn, 2007). One option is to reveal the correct answer and then, as a class, discuss possible errors or misconceptions that led to the wrong answers (Beatty & Gerace, 2009; Bruff, 2009). A second approach is to simply reveal the results and then have the class discuss, as a whole group or in small groups, the question further and resubmit an answer before revealing the correct choice (Bruff, 2009; Caldwell, 2007; Lucas, 2009). A mix of the two involves revealing students responses and then discussing the different answers as a class to slowly eliminate incorrect answers until the correct answer is revealed (Bruff, 2009; Caldwell, 2007). Regardless of approach, however, the key aspect in this step is to elicit discussion, which will allow students to move beyond rote memorization and procedural knowledge to reasoning and logic (Beatty & Gerace, 2009; Caldwell, 2007).

Being Flexible

The third principle calls for the teacher to use students' responses to alter their teaching decisions (Beatty & Gerace, 2009; Caldwell, 2007). EARS can be used to perform regular checks of students' understanding throughout the lesson (Blood & Gulchak, 2013; Bruff, 2009; Caldwell, 2007). The teacher needs to use the data gathered to adjust lessons, create new questions as needed, or review concepts (Beatty & Gerace, 2009; Blood & Gulchak, 2013; Bruff, 2009; Zhu, 2007). This can be perceived as a benefit to students as it provides them with the opportunity to correct their misunderstandings before a major assessment.

Discussing Ways for Students to Become Engaged in Learning

Lastly, students should be encouraged to talk about learning the content and how they can actively engage and participate in the learning process. Displaying EARS results provides students with instant feedback, which can be used by students to reflect on their learning with respect to the expectations of their peers (Blood & Gulchak, 2013; Bruff, 2009; Draper & Brown, 2004; Graham et al., 2007). EARS results can also be saved and reviewed to gain a more accurate image of an individual student's progress (Blood & Gulchak, 2013). This feature can be helpful when using an exit ticket in the classroom. An exit ticket is usually a few quick questions at the end of a lecture that students must answer before leaving (Bruff, 2009; Caldwell, 2007). The teacher can then provide feedback to individual students on their progress so they can work toward closing the gap between their knowledge and the class expectations, a key element of formative assessment (Black & Wiliam, 1998).

Additional Considerations

These are just a few of the tips provided in the literature about how to effectively implement EARS and formative assessment in the classroom. Before deciding to use EARS devices, instructors should try the devices themselves and show students how to use them (Bruff, 2009; Caldwell, 2007). This can help reduce some of the technical issues that can lead to students' negative perceptions of EARS.

Another consideration teachers should take into account is the time it takes to implement EARS (Caldwell, 2007; Draper & Brown, 2004; Titman & Lancaster, 2011). Outside of the classroom, it will take time to create and structure questions to use during the lectures, and the teacher has to also be willing to go back and revise them as needed (Sullivan, 2008). Even though many EARS systems can automatically grade responses, the teacher will still have to spend time reviewing this data. Lastly, it can take time in class to pose the question and gather all of the students' responses, which may result in getting through less material (Caldwell, 2007; Draper & Brown, 2004; Titman & Lancaster, 2011). If TEFA is implemented properly it can lead to meaningful discussions and a deeper understanding, making up for the loss in material and time. The teacher must take these factors into consideration when lesson planning and be willing to adjust their lessons to make the TEFA beneficial for everyone (Titman & Lancaster, 2011).

Gaps in the Literature

The majority of prior research that looks at EARS has done so at the college level. A primary reason for this appears to be the cost of the equipment (Bojinova & Oigara, 2011; Zhu, 2007). To address this, some colleges pass the cost of the devices on to the student, making buying a clicker a course requirement (Landrum, 2013; Liu & Stengel, 2009). Other studies have purchased devices that could be set up in a lecture hall, providing access to the devices by multiple classes and disciplines (Draper & Brown, 2004; Mayer et al., 2008; Titman & Lancaster, 2011). Some of these studies were done in large lecture style classes (Caldwell, 2007; DeBourgh, 2007; Draper & Brown, 2004; Kennedy & Cutts, 2005; Mayer et al., 2008, Premuroso et al., 2011), while others only implemented EARS during review sessions (d'Inverno et al., 2003; Fallon & Forrest, 2011).

Yet, there is a little research that looks at EARS in a high school classroom, which differs from a college class. In the high school mathematics classroom, the student expects the teacher to review material—while in college the professor expects students to seek help during office hours to review material they do not understand (Gehrke, 2012). In college students are expected to do the work to learn the material without getting credit for it, while in high school students expect to receive credit for all assignments including homework (Gehrke, 2012). Another difference is the structure of a class itself. High school classes typically range from 25 to 35 students and are usually every day of the school week, while college classes can range in size from small discussion classes to large lecture style classes, and often times there may be large gaps of time between classes (Gehrke, 2012). These differences have the potential to influence students' engagement and achievement in the mathematics classroom; therefore, findings at the college level using an EARS should not be generalized to a high school classroom. This study aimed to fill this gap by directly looking at a typical high school mathematics classroom

Another gap in the literature involves how participation has been measured. Prior research on EARS used surveys to determine whether EARS improved students' participation. The studies did not directly compare students' participation in the class setting when using EARS to hand raising. This study attempted to address this gap by comparing actual class participation rates when using EARS to hand raising during question-answer interactions. If this study demonstrates that EARS improves students' participation, then EARS may be used by teachers to behaviorally engage students in their classroom. This information will be valuable given that research has shown the majority of students are not engaged in the average classroom (Cooper, 2014; Singh et al., 2002). In addition, because engagement is linked to higher achievement, this study aimed to not only investigate participation but also to determine how EARS might improve student achievement (Christle & Schuster, 2003; Fredricks et al., 2004; Prince, 2004).

Research on EARS' effect on achievement has produced mixed results, implying that it may not be just the devices but rather the implementation that affects achievement (Bojinova & Oigara, 2011; Landrum, 2013; Premuroso et al., 2011). The studies that found a correlation between using an EARS and achievement did not simply take into account the use of an EARS, but the answer that was submitted. In the current study, the teacher used formative assessment techniques in the classroom. Another unique aspect of the current study is that students were able to submit text-based answers, diagrams, and were able to show their work for the teacher to analyze later by using an IPad as the clicker device. In the literature, an EARS has primarily been used to answer multiple-choice or true-false questions (Caldwell, 2007; Freeman & Blayney, 2005). By using alternative forms of responses, a teacher may have more options for their question-answer interactions and thus, may offer more opportunities for students to actively participate. This can lead to a deeper understanding of the material (Fredricks et al., 2004). Such a deeper, higher level of understanding is required to meet the current mathematics standards (CCSI, 2014; NCTM, 2000).

The majority of the studies looked at the EARS from the students' perspective. Whether through observations or surveys, the data only allowed for the students' viewpoints. The studies tended to not discuss the teacher's perspective about using the devices in regards to achievement, engagement, or implementation.

The current study aimed to determine if EARS can be used to improve student achievement by increasing student engagement through participation in a high school geometry classroom. Students using EARS were directly compared to students using hand raising in a quasi-experimental study. Use of hand raising and of EARS were the independent variables, and students' participation and achievement scores were the dependent variables. This study aimed to go a step further by also considering the teacher and student perspective of using the EARS devices. The details of this study are further discussed in the next section.

CHAPTER 3

METHODOLOGY

The purpose of the current, quasi-experimental study was to answer the following research questions:

Q1) When responding to questions, how does student participation using an EARS compare to participation using traditional hand raising?

The review of the literature revealed that students are likely to participate more when using EARS. In studies comparing the use of an ARS to hand raising, students participated at a higher rate when using ARS compared to traditional hand raising (Christle & Schuster, 2003; Freeman & Blayney, 2005; Gardner et al., 1994). Based on these previous findings, the following hypothesis was formed in relation to this research question:

H1) A student using EARS will have a significantly higher participation rate than when the student uses hand raising.

Q2) How do scores on a unit test after learning with EARS compare to scores after learning with hand raising?

Prior research has shown that some students' achievement improves when using EARS. In particular, achievement scores improved on quizzes and small unit tests when using an ARS compared to hand raising (Christle & Schuster, 2003; Liu & Stengel, 2009). Based on these findings, the following hypothesis was formed in relation to this research question:

H2) Students using EARS will have significantly higher achievement scores than students using hand raising.

Q3) What are teachers' perceptions of and attitudes toward using an EARS in the classroom?

The research revealed little information about teachers' perspectives in regards to using an EARS. This question aims to address this gap by determining how teachers perceive using the devices.

Q4) What are students' perceptions toward using an EARS in the classroom to participate?

The expectancy-value theory states that students' perceived costs and benefits of a task is a determining factor in their decision to perform the task (Atkinson, 1957; Eccles, 1983, Eccles & Wigfield, 2002). Students often perceive participation as having a high risk and low benefit (Bojinova & Oigara, 2011). This question aims to gain a better understanding of this by looking at students' perception of participating in the mathematics classroom with and without an EARS.

Participants

Students

Participants of the current study were students enrolled in a geometry class at a public high school that encompasses ninth through twelfth grades and is located in a suburban setting. The majority of the student body at this school is middle-class and Caucasian. The district in which this school resides transitioned to the state standards, which are similar to Common Core Standards (CCSI, 2014). The district currently has three high schools, two of which are traditional public schools. The third high school is a STEM academy set up for students interested in science, technology, engineering, and mathematics. Students interested in attending the STEM school apply for a limited number of slots that are available.

At this public high school, most mathematics classrooms use technology such as calculators, the teacher's computer, projectors, and a Smart Board. Recently, a cart of IPads was purchased for the department, but it is rarely being used. Students are also permitted to bring their own personal technology devices to use at the teacher's discretion. The mathematics teachers in this study do not allow students to use their own devices nor any technology other than a calculator and the classroom Smart Board. As a teacher in the school district, I have access to the administration, teachers, and students. To minimize my impact on the study, only sections that I do not teach were included in this study.

Students at the school study site are required to complete at least three years of mathematics, one of which must be geometry, in order to graduate. Geometry is only offered at the high school, and there is both a regular and an honors level. The geometry class is taken primarily by ninth and tenth graders, in addition to a handful of upper classmen. Students must complete algebra 1 to be eligible to take geometry. Typically, several ninth graders in the class have also completed algebra 2 before enrolling in the geometry class.

As a required course in the school with only two levels available, the geometry courses tend to have more diversity in terms of different grade and achievement levels. Research has shown that ninth and tenth graders, the primary population who enroll in geometry, tend be less engaged than upperclassmen (Cooper, 2014). The diverse population as well as the prevalence of underclassmen is the rationale for choosing students in the geometry classes for the sample. Geometry teachers were asked if they were willing to assist with the study, and only students in the sections taught by the participating teachers were included in the sample.

A total of sixty- two participating students out of 157 from the regular geometry classes at the high school taught by the participating teachers agreed to be participate in the study. Students were informed about what the study entails in regards to their participation and that it is completely voluntary. Students who agreed to participate were provided an assent form to sign, and their parents were provided a consent form. Basic demographic information about the students, including gender, and grade-level was also collected.

Teachers

Four geometry teachers agreed to be part of this study, and they each were asked to sign a consent form. All four teachers have been employed at the school for at least two years and have taught geometry before. Two of the teachers have used flashcards in the classroom, but none have used an EARS. Three of the teachers have access to a SmartBoard in the classroom. One teacher floats between classrooms, and the remaining three have their own classroom. Two of the teachers had two sections of geometry students that were part of the study, and the rest had only one section.

The teachers with the two sections of geometry were the only ones required to use the EARS devices. Prior to the implementation of the devices, these teachers were provided training on the technical aspects of using the EARS for an hour and half initially and then a follow up fifteen minute training was provided to each teacher. In addition the teachers were trained on how to implement the EARS and incorporate formative assessments based on the suggestions from the literature.

Data Instruments

Measure for Participation

The participation rate of the students was determined by using a participation proportion. A participation proportion is defined as the actual number of attempts to respond divided by the total number of possible responses per a student. Students were not required to participate in class, nor did participation have a direct effect on their grade. If a student was absent the proportion was calculated based only on the days they were present.

To determine the participation proportion during hand raising lessons, observers were used. Each observer was provided a chart on which they marked each time a student responded to one the formative assessment questions. The observers also noted if any of the students were not present during the observation. The observers tallied the number of responses per each student to the formative assessment questions posed by the teacher. During the hand raising lessons, raising one's hand or calling out an answer was considered an attempt to respond, regardless if that student was called on. Only attempts to respond for the initial posing of a question were counted—no responses to repeats of the same question counted. When possible the tallies by two observers in the same section on the same day were compared to determine inter-rater reliability. For tallies that varied, the average was used as the official count. For the EARS lessons, EARS software was used to record the students' responses to questions. A response was defined as using the EARS to submit a possible answer to a posed question. The number of responses by each of the students to the formative assessment question was counted. The counts were also only collected for the initial posing of a question. Any student who was absent during the data collection was noted.

EARS Device

The EARS device used in this study was an IPad equipped with a free app called TAPit from Answer Pad. The app only works on the IPAD to take advantage of the larger screen. To create and pose questions, the teacher used the corresponding website, The Answer Pad. The program is free and a teacher can create an account for free or pay a premium for additional features. Once the account is set up, the teacher can create a group for the students. The teacher can then choose to enter each student and create their password and user name or allow the students to self-register. Once the students are registered, they can use the app on their IPad to log in and establish a connection with the teacher. Since each student has a particular log in and password students cannot pretend to be someone else, which I found happened in the pilot study.

The teacher has two main options for sending questions to the students. The Go Interactive feature allows the teacher to send students multiple choice, true-false, fill in, slider, free response, and a few other template style questions. However, this feature does not allow the teacher to type in the question or answers; rather, it provides the students a specific format for which to answer the question. The teacher receives a display of all students' responses, as well as a bar graph of responses for multiple choice or true-false questions that shows overall how many students responded with a particular answer (see Figure 2). A bar graph or analysis is not provided for free-response or other graphical templates that require students to draw on their device to submit an answer (see Figure 3). The teacher can send questions to the students throughout the lecture, and students can submit answers as they are received. The teacher can save the students responses using an option called capture for each question to review later on. This feature is the one that was used for this study.

Figure 1. Example of student's IPad app for a multiple-choice question.

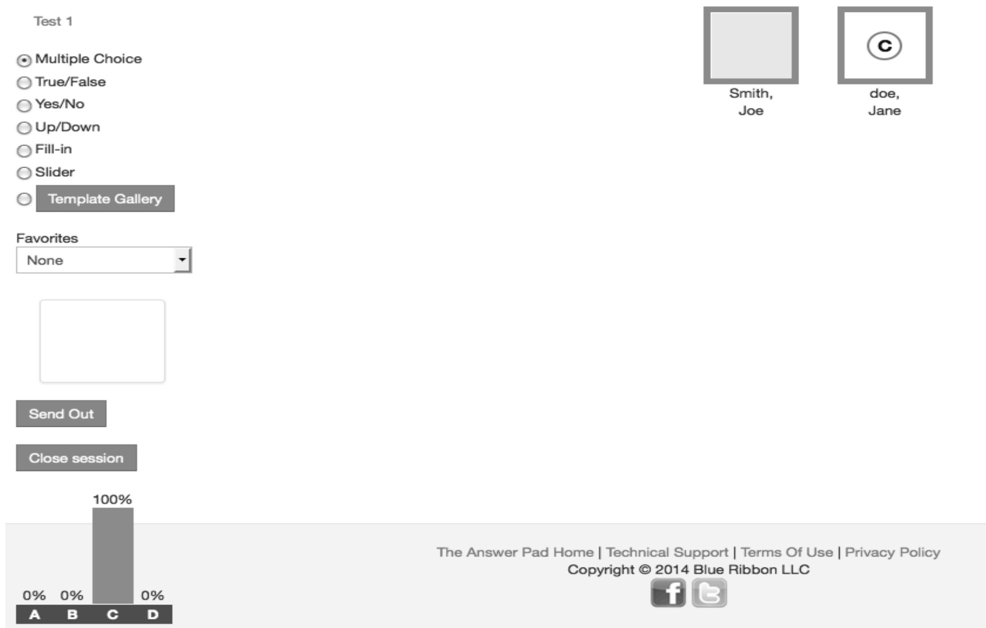

Figure 2. Teacher's display when using the Go Interactive feature with multiple-choice.

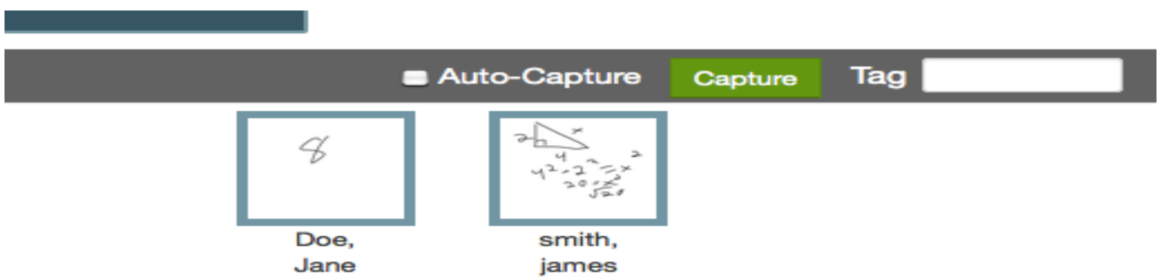

Figure 3. Teacher's display when using the Go Interactive feature with free-response.

As a second option, the teacher can create a pre-fabricated test or quiz to submit to students. Using The Answer Pad webpage, the teacher sets up an answer sheet specifying the type of question to be asked—multiple choice, fill in, etc.—and the correct answer to the question (see Figure 4). The teacher does not type in the actual questions or answers, but instead uploads a pdf file of the test. The teacher can then specify at what time the test should become available and a time limit, if desired. The program provides the teacher with an access code that he or she shares with the students. Using the app, the students access the test and submit their answers, as well as their work, to the teacher. The teacher can then look at various reports on the students' submissions. If given the option by the teacher, the student can re-enter the system to access the test after they have submitted to see which problems they had right or wrong. This feature was not used in this study.

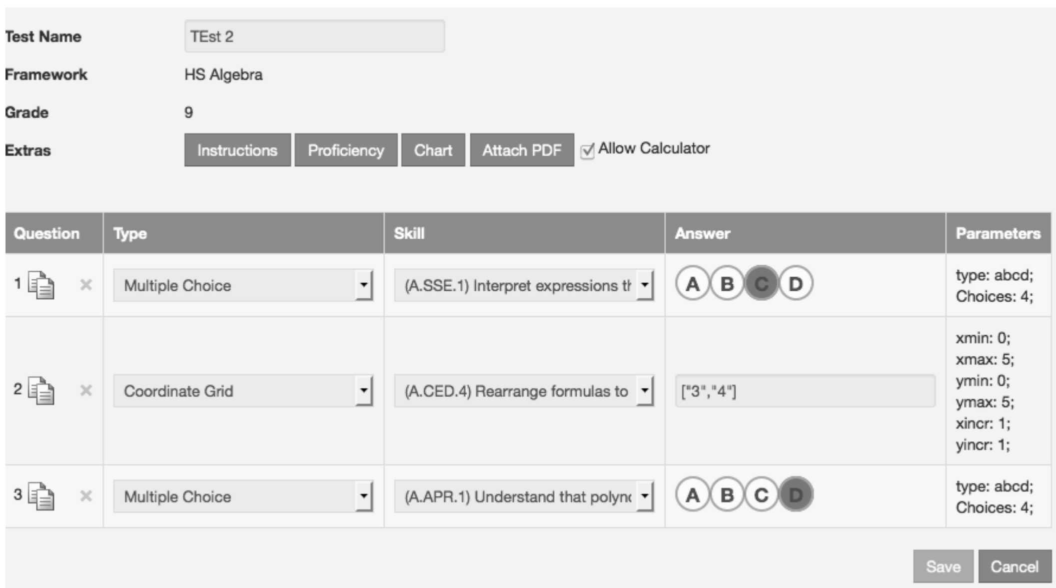

Figure 4 Example of the answer sheet editing process.

Achievement Measures

Two tests were used for this study: a midterm and a unit test on right triangles. The midterm is a common summative assessment that is used by all teachers of regular geometry classes. The midterm contains 42 multiple-choice questions and two open-ended questions, one of which is a fill in the blank proof and the other is to find a missing angle and show the work. The midterm covers material from the beginning of the year to the end of the second marking period. All students are required to take the midterm and students' midterm score is averaged with their final exam score to form a fifth grade that is averaged with the four marking periods' grades to determine students' final grade for the course.

The unit test on right triangles is a common summative assessment that is used by all geometry teachers. The test has four multiple-choice questions and 15 short response questions. Short response questions require students to show their work as well as provide the correct answer. This unit test covers materials on right triangles, including the Pythagorean theorem, special right triangles (45-45-90 and 30-60-90), and trigonometry. The literature showed improved achievement on quizzes when using an EARS at the college level (Liu & Stengel, 2009). A unit test at the high school level is similar to that of a college quiz, so it was chosen to measure student achievement in the current study.

The test scores that were used to determine achievement levels in this study were the participants' scores on the midterm and the unit test, resulting in two test scores per student. Each test score was a percentage, determined by the number of points earned by a student over the total number of possible points. Thus, the possible test scores ranged from 0 to 100%, excluding extra credit.

Perception Measures

Two surveys were used in this study to determine students' and teachers' perceptions of using an EARS device in the classroom. The teacher survey (see

Appendix A) was created based on the negative and positive perceptions commonly noted in the literature. The student survey (see Appendix B) was adapted from the ARS Attitude Survey for Students (Kay et al., 2010), with permission from the author. Additional questions were added based on the literature on the perceived risk and value of participating. Both surveys consist of a series of questions that are answered with 5-point scale responses, as well as one additional open-ended question in which respondents may write any additional comments. Students using the EARS anonymously completed the survey at the conclusion of the study. Teachers completed the survey at the end of the unit.

Research Design

Procedural Design

Two different style experimental designs were used for this study. Both designs are a quasi-experimental design, since the students were not randomly assigned to a particular section of the course. For the first question comparing participation using an EARS to hand raising, an AB design was used across four of the sections, with the A condition involving hand raising and the B condition being using the EARS during class question-answer interactions. To answer the second question, which asked how students' test scores using an EARS compared to hand raising, a treatment-comparison design was used. The study was conducted over the same unit on right triangles that took from four to five weeks, depending on the teacher.

Research Questions 1, 3, and 4

Two of the participating teachers had two sections of geometry that participated in the study: Ms. Doe and Ms. Smith. To answer research questions 1 and 4, only students in Ms. Doe and Ms. Smith's classes were used for the data collection. In each of the sections, a random sample of at most 10 participating students was selected. The number ten was chosen because it was a reasonable amount for the observers to watch and still provided a sufficient sample size. The observers thus only recorded participation tallies for these student participants in each class to calculate the participation proportion. Prior to the intervention of the EARS, these students were observed during a typical lesson taught by the teachers. Using the data collected from this lesson, a participation proportion baseline was established for the students.

The students in Ms. Doe's and Ms. Smith's classes were introduced to the EARS prior to data collection. The students were shown how to use the devices, including how to log in, submit answers, and submit work. During the intervention phase, students were taught content from the unit on right triangles. A series of formative assessment questions were created for each topic (see Appendix C for examples). All four teachers were requested to incorporate at least four of the questions within a lesson as a way to gauge students' understanding and break up the lessons. The questions were a mix of multiple choice and free response. Ms. Doe was asked to incorporate the same four questions across her two sections during the same lesson, but often at least one question differed. Ms. Smith was asked to do the same, but was permitted to use a different set of questions than Ms. Doe. Ms. Smith did not differ in the four key questions she used across the two sections.

For the hand raising lessons when asking a multiple-choice question, the teacher was to poll the students by asking how many think the answer is A, B, C, and so forth. If a question needed to be repeated, only the initial time the question was asked was used for data collection. The pre-selected students who raised their hand during any of the answer choices were counted as participating in that question. For free-response questions, the teacher asked students to raise their hand to provide a response. The pre-selected students who raised their hand or called out an answer were counted as participating. Follow-up questions were not recorded as part of the participation count—the teacher used students' votes on the free response question and their polled responses to the multiple-choice questions to gauge student understanding only. If a majority of the students appeared to have the wrong answer, the teacher was asked to review the concept before continuing with the lesson. Follow-up questions or other questions asked during the lesson were not a part of the data collection as a way to control for the format of the questions as much as possible when comparing the students' participation. All the teachers were required to use the same techniques during their lessons and the observers recorded how the technique was implemented (see Appendix E). Observers in Ms. Doe and Ms Smith's class also recorded student participation for the pre-selected students.

For the EARS, the computer program was used to count the number of responses. Students logged into the system at the start of class, and the teacher then began the lesson. The teacher asked the pre-fabricated questions during lesson and asked students to submit answers using their EARS. For multiple-choice questions, the teacher was to provide a wait time and then display a bar graph depicting the class' responses. The teacher saved the responses, and this data was used to determine the number of students who participated for that question. For free response questions, students submitted their answers using their EARS devices. These submissions were saved and used to calculate the participation proportion. The teachers were trained to take several of the more common answers and asked the students to vote on them using the EARS, but this rarely occurred due to time issues. Any follow-up questions, discussions, or other questions asked were not included as part of the data collection in an effort to control for the questions as a possible factor contributing to the participation rate of students. For both types of questions, the teacher used the data collected by the EARS to gauge students' understanding. If a majority of the students appeared to have the wrong answer, the teacher was to review the concept further before continuing the lesson. During these lessons, the observer noted how the EARS were implemented by the teacher using a pre-fabricated check list (see Appendix D).

For the first two observed lessons, students in Ms. Doe's section A used an EARS, while students in section B used hand raising. For the next three observed lessons, the method of response was switched, with section A students using hand raising and section B students using an EARS device.

For the first observed lesson of Ms. Smith's class, students in section A used an EARS and students in section B used hand raising. For the next lesson, the sections switched their response method, so that section A used hand raising and section B used EARS. The method of response switched back and forth for each lesson after that, with section A observed using hand raising two times and using EARS four times, while section B used hand-raising four times and EARS two times. At the conclusion of the study all of the participating students in Ms. Doe and Ms Smith's class responded to the survey on their perceptions about using the EARS in the mathematics classroom to answer research question 4.

Research Question 2

To answer question 2, a comparison treatment group design was used. Prior to the implementation of the EARS, the midterm was used to establish a baseline of the students' achievement levels. For the second achievement measure of the unit test, the students were grouped into two groups. The students across Ms. Doe's and Ms. Smith's classes were collapsed to form the treatment group because they used the EARS devices. A comparison group was created from the students in Ms. Right's and Mr. Trig's classes, as they never used the EARS.

All participating teachers incorporated the pre-established formative assessment questions during a unit on right triangles. Mr. Trig and Ms. Right used hand raising, while Ms. Doe and Ms. Smith used a mix of EARS and hand raising during the unit, as noted above. At the conclusion of the unit on right triangles, all student groups took the same unit test on right triangles.

Analysis of the Data

The data collected were used to test two hypotheses: one related to the participation rate and the other to achievement. Before testing the hypotheses, I first established that there was no significant difference between the students in regards to participation or achievement. To establish this, I used the data collected for the baseline: the midterm scores and the baseline participation rate. Using an $\alpha = .05$, I tested the null hypotheses: 1) there is no significant difference between the students participation rate, and 2) there is no significant difference between the students midterm grades.

Research Question 1

To determine whether to accept or reject the null hypothesis that there is no significant difference in participation across the sections, two-way ANOVA (teacher; section) was run using the baseline participation proportion. Ms. Doe's two sections were then collapsed into one set of data that included the participation proportion when using an EARS and the proportion when using hand raising. Similarly, the data collected for Ms. Smith's two sections were collapsed. A repeated measure ANOVA was run using the teacher and method of response as the grouping factor. A repeated ANOVA is needed since the data was collected from the same students over a period of time (Huck, 2012).

Research Question 2

To test the null hypothesis that there is no significant difference in achievement across sections, the baseline midterm scores were used. Students' midterm test scores in the treatment and comparison group were compared using an independent *t*-test, as there were two independent groups being compared (Salkind, 2011). An ANCOVA was run, using the midterm scores as a covariate to control for any differences in achievement prior to the implementation of the EARS (Huck, 2012).

Research Question 3

The responses to the survey for Ms. Doe and Ms. Smith were reported for the scaled items. For the open-ended question, the results were analyzed using qualitative analysis that categorized comments into positive and negative aspects. The findings are reported based on this analysis in the results section.

Research Question 4

To determine students' perception of using EARS, the percent of students who selected each response was calculated and reported. Based on students' open responses, a coding scheme was developed categorizing the comments into positive and negative aspects and then looking for themes similar to that found in the literature and any that differed from previous literature findings. The findings are reported based on this analysis in the results section.

Timing

I held an initial meeting with all geometry teachers at the high school in December. During this initial meeting, I discussed the purpose of the study and began training on the use of the technology. I met with the teachers again in January to obtain consent, go over the details of the study, and review the formative assessment questions. At this time, I also provided the teachers with tips on how to best use the EARS, based on the literature.

The teachers gave students an introduction to the study and its procedures in early January. At this time, the students were given permission forms and informed that the purpose of the study is to determine how methods of response affect classroom interactions and achievement. They were not specifically told that participation rates were being collected as data so as to limit the Hawthorne effect (James & Vo, 2010). The treatment group began using EARS devices during lessons at this time in addition to traditional hand raising to familiarize them with the two methods of responses.

The observers were recruited in December and January and introduced to the study and data instruments they were to use. The observers were over 18 and had the proper clearances to be in the school. The observers began observing classes in late January to practice the data collection procedures and for the class to become familiar with their presence. During the actual data collection, the observers checked in with me at the start and conclusion of each day and submitted all data collected.

Midterm exams occurred in January and the student's scores were recorded by their perspective teacher. The intervention began in February after midterms were completed, and lasted until early March. During the actual data collection, I provided the teachers with technology assistance and answered any questions that they had. I also checked in with the teachers at least once per week throughout the active data collection. At the conclusion of the data collection, I met with the teachers to thank them for their participation.

Ethics

The current study was conducted within the school district at which I am currently employed. I am a teacher within this school district and therefore have a power-based relationship with the students, in which I have power over the students. I attempted to reduce the effect of this relationship by only using sections that I do not teach and limiting my contact with the student participants.

The observers had all proper clearances and were trained in conducting a study before coming in to collect data. The observers also turned over all data information collected directly to me.

The data collected for this study was kept in a secure location with limited access. Upon completion of the study, the results were shared with the teachers. Students interested in the results of the study are permitted to contact me, and I will share the results with them, as well. Two years after completing the study, all collected data will be destroyed.

CHAPTER 4

RESULTS

Overview

In this chapter I will present the results from the data collection in order to answer the research questions. First, I will present the overall information about the population and sample used for this study. Next, I will present the quantitative data analysis to look at the effect EARS had on participation and engagement. I will then present the qualitative data on teacher and student perceptions about using these devices. Finally, during the observations the observers recorded information about the implementation of the questions, which will be presented in the last section.

Sample Characteristics

Demographics of Teachers and Classes

For this study, students in four different teachers' classrooms were asked to participate. Teachers and students voluntarily consented to participate in the study. Two of the teachers, Ms. Doe and Ms. Smith, each taught two sections of geometry. The other two teachers, Ms. Right and Mr. Trig, each taught only one section of geometry. Table 1 presents basic information about the teachers. Table 2 shows demographic information about each section.

Table 1

Instructor Demographics

Teacher	Gender	Number of Years Teaching	
		Teaching Overall	Teaching Geometry
Doe	F	16	14
Smith	F	7	3
Right	F	17	14
Trig	M	10	7
Average		12	9

Table 2

Class Demographic Information

Teacher	Section	(N)	Gender %		Grade %			
			Female	Male	9^{th}	10^{th}	11^{th}	12^{th}
Doe	A	(27)	44.4	55.6	55.6	37.0	3.7	3.7
Doe	B	(26)	38.5	61.5	42.3	53.9	3.8	0.0
Smith	A	(27)	51.9	48.1	44.4	44.4	7.5	3.7
Smith	B	(20)	35.0	65.0	40.0	50.0	5.0	5.0
Right	A	(28)	50.0	50.0	39.3	46.4	10.7	3.6
Trig	A	(29)	44.8	55.2	37.9	62.0	0.0	0.0
Total		(157)	44.6	55.4	43.5	49.0	5.0	2.5

Demographics of Student Sample

Out of all of the 157 students the six sections, 62 students consented to be included in the study. One student in Ms. Smith's class was removed from the study because they withdrew from school while the study was in process. One student from Ms. Doe's class was removed from study due to excessive absence that resulted in data not being able to be collected. These two students were removed at the conclusion of the data collection, resulting in a final sample size of 60 students. Achievement data was collected for each of these students but only a subgroup was used for the participation data, see Figure 5. Demographic information was obtained about all the students and can be found in Table 3.

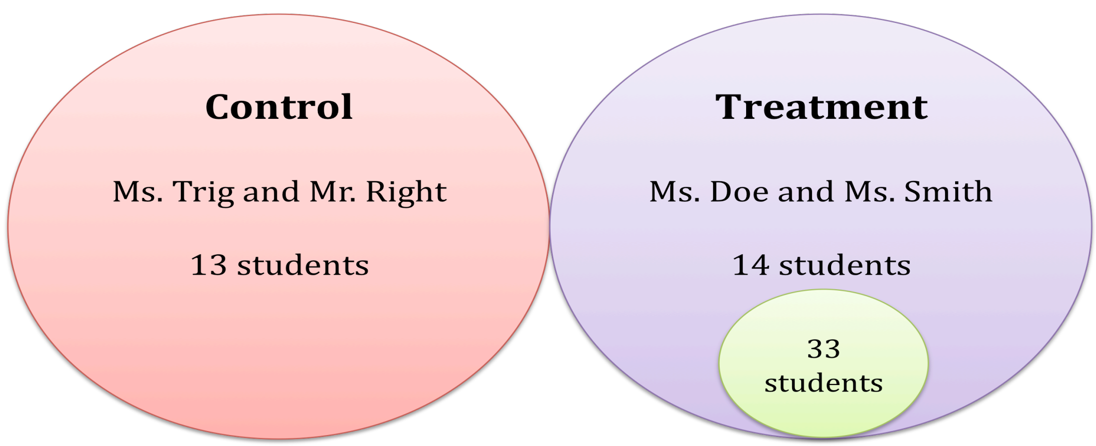

Figure 5: A visual representation of the student participation groups.

Ms. Doe and Ms. Smith's classes were chosen to use the EARS devices in the classroom because they each taught two sections. A random selection of ten students was chosen to create a treatment subgroup for each section. Ms. Doe's section A only had six students consent to be in the study, so random selection was not required for this section. The subgroups contained the students for whom participation data was collected. Any student whose absences resulted in no data being collected during at least one of the methods of response, hand raising or EARS, was removed from the subgroup. As a result, two students in Smith's class were removed only from the subgroup. This left a sample size of 33 students for which participation data was collected (see Table 3).

Table 3

Sample Characteristics

Teacher	Section	(n)	Gender %		Grade %			
			Female	Male	9th	10th	11th	12th
			Treatment Group					
Doe[a]	A	(6)	50.0	50.0	66.7	33.3	0.0	0.0
Doe	B	(12)	66.7	33.3	33.3	58.4	8.3	0.0
Doe subgroup[a]	B	(10)	70.0	30.0	40.0	60.0	0.0	0.0
Smith	A	(15)	73.3	26.7	46.7	46.7	0.0	6.6
Smith subgroup[a]	A	(8)	75.0	25.0	37.5	50.0	0.0	12.5
Smith	B	(14)	42.9	57.1	42.9	50.0	7.1	0.0
Smith subgroup[a]	B	(9)	66.7	33.3	33.3	55.6	11.1	0.0
Total		(47)	59.6	40.4	44.7	48.9	4.3	2.1
Subgroup		(33)	63.6	36.4	42.5	51.5	3.0	3.0
			Comparison Group					
Right	A	(8)	75.0	25.0	50.0	37.5	0.0	12.5
Trig	A	(5)	80.0	20.0	60.0	40.0	0.0	0.0
Total		(13)	76.9	23.1	53.8	38.5	0.0	7.7
Overall Total		(60)	63.3	36.7	46.7	46.7	3.3	3.3

Note. This table does not include demographics on students that were removed from the study.

[a]The subset of students out of the corresponding section that participation data was collected on.

Data Results

Research Question 1

Research question 1 of this study is the following: When responding to questions, how does class participation using an EARS compare to participation using traditional hand raising? To answer this question, only the students in Ms. Doe and Ms. Smith's subgroups were used because these teachers had two sections of the class.

In order to establish whether there was a significant difference in participation between response methods, a baseline participation rate was established for each of the subgroups prior to the implementation of EARS. Two observers were used to tally student responses during a typical lesson, which resulted in an inter-rater reliability coefficient of .97. The participation proportion (total number of responses per student divided by number of possible responses) was then calculated for each student. One student was absent in each section of Ms. Doe's class during the baseline participation collection, but they were still included in the remainder of the study.

A two-way ANOVA was conducted on baseline participation and showed that there is no significant main effect of teacher on baseline participation using hand raising (F [1, 27] = 0.57, MSE = 67.38, p = .458, η^2 = .02); there is a no significant main effect of section on baseline participation (F [1, 27] = 0.85, MSE = 100.95, p = .365, η^2 = .03); and there is no significant interaction of teacher and section on baseline participation (F [1, 27] = 1.76 , MSE = 209.27 p = .195, η^2 = .06). Based on these results, the null hypothesis that there is no significant difference in participation across sections and teachers prior to implementing the EARS was accepted. Accepting this hypothesis allows us to establish that the section and teacher are not contributing factors to any differences that may be found in participation when looking at the data collected during the implementation of the EARS (Salkind, 2011).

Because it was found that the section a student was in did not contribute to differences in participation, each teacher's two sections were collapsed to create one group for each teacher. Despite that the baseline analysis also revealed that the teachers did not contribute to differences in participation, the sections were not collapsed across teachers. The rationale for this was that each teacher used a different set of questions within their two sections. For example, Ms. Doe asked the same questions across her two sections, but Ms. Smith asked a different set of questions for each of her two sections. Grouping them by the teacher can potentially account for the questions asked being a possible contributing factor to any differences found in participation proportions. The teachers themselves may have implemented the EARS devices slightly differently, and grouping the students by teacher will allow this to be considered as a possible contributing factor.

To test the research hypothesis that student participation improves when using an EARS compared to hand raising, a participation proportion was calculated for each student using each method of response. For hand raising, observers tallied students' participation during the lesson. Due to scheduling conflicts, two observers were only present during one day during data collection in each section, with an inter-rater reliability coefficient of 1.0. The data collection was conducted over a four-week time period.

A repeated ANOVA was conducted on participation, showing that there is a significant main effect of the method of response on students' participation (*F* [1, 31] = 90.42, *MSE* = 25370.57, *p* = .000, η^2 = .75) and no significant main effect of interaction between teacher and response method on participation (*F* [1, 31] = .91, *MSE* = 236.40, *p* = .348, η^2 = .03). In addition, the significant difference shows that when using the EARS, participation portion (*M = 88.35, SD* = 13.89) is higher than when using traditional hand raising (*M* = 50.39, *SD* = 21.99). These results support the hypothesis that student participation is higher when using an EARS compared to hand raising.

Research Question 2

The second research question for this study is the following: How do scores on a unit test after learning with EARS compare to scores using only hand raising? For this question, students across all sections and teachers were used. Each student took the same midterm and unit test on Right Triangles. One student in Ms. Doe's class was removed from this data analysis because they missed the Unit test on right triangles test. Collapsing all the sections that used EARS into one group formed a treatment group of 47 students. The students in the two sections that did not use the EARS were collapsed to form the comparison group of 13 students.

An independent *t*-test conducted on the baseline showed a significant difference between the comparison and EARS group on midterm scores (*t* [57] = 3.25, *p* = .002, *d* = 1.11). The treatment group showed lower achievement (*M* = 73.04, *SD* = 12.65) compared to the control group (*M* = 85.38, *SD* = 9.61). The null hypothesis that the groups had no significant difference in achievement levels was rejected. After adjusting for achievement by covarying baseline scores, a one-way ANCOVA was conducted, showing no significant difference in the unit test on right triangles scores between the EARS and comparison group (F [1, 56] = .019, p = .891, η^2 = .00).

To look more closely at whether EARS had an effect on students' achievement, a repeated ANOVA comparing midterm scores and Unit test on right triangles test scores was used. Since this involved comparing across two different tests, I first had to standardize the scores between the tests by finding the Z-score for each student on the midterm and Unit test on right triangles test scores (Salkind, 2011). A repeated ANOVA showed no significant effect of test time between the midterm and Unit test on right triangles test (F [1, 57] = .80, p = .376, η^2 = .014) and no significant interaction between method of response and test time on scores (F [1, 57] = 2.55, p = .116, η^2 =.04).

The comparison group had two low scores on the Unit test on right triangles test and the EARS group had one low score on the Unit test on right triangles test, and these were marked as outliers in SPSS. However, after removing these three data values, a repeated ANOVA still showed no significant effect of test time between the midterm and Unit test on right triangles test (F [1, 54] = .15, p = .699, η^2 =.003); and no significant interaction between the method of response and test time on scores (F [1, 54] = 2.96, p = .091, η^2 = .05). Even though these results are not statistically significant for the set α = .05, the non-significance is still fairly low ($p < .10$) and the effect size is medium. Taking this into account I am not going to reject or accept the research hypothesis that student achievement improves when using an EARS compared to hand raising at this time.

Along with overall achievement the prior research showed that there is a correlation between EARS and achievement (Lucas, 2009; Premuroso et al., 2011). These studies did not just look at student's participation with EARS but also considered the answers submitted by the students. For this study the answers that were submitted using an EARS were not considered, only that a student submitted an answer. To determine whether participation with an EARS can predict achievement a correlation was run on the students EARS participation rate and Unit test scores. The correlation was not significant for use of the EARS predicting achievement test (r [32] = .14, p = .44). A secondary correlation was run on students hand-raising participation and Unit test scores. The correlation was not significant for hand-raising predicting achievement on the test (r [31] = .03, p = .87).

Research Question 3

The third research question for this study was the following: What are teachers' perceptions and attitudes toward using an EARS in the classroom? To answer this question, Ms. Doe and Ms. Smith were asked at the end of the study to complete a survey about using the devices (see Appendix A). The teachers answered the questions using a 1 to 5 scale, with 5 being strongly agree and 1 strongly disagree. The results are shown in Table 4.

Ms. Doe and Ms. Smith were asked to share any additional comments or thoughts they had on the use of the EARS. Ms. Smith chose to not add any additional comments. Ms. Doe stated that due to the students not having their own devices, it took too much time to distribute and collect the EARS during each class. Informally, both teachers expressed negative comments about the EARS during the study, especially in regards to the time it took to use them and issues with Wi-Fi that resulted in delays in sending and receiving students' responses.

Table 4

Teacher Perception Survey

Question	Doe	Smith
Difficulty using IPads	4	3
IPAD took too much time	5	4
Rather use traditional hand-raising	4	3
Enjoyed having students answer questions with the IPad	3	4
Students did not appear to enjoy using the IPad	2	2
Felt students more engaged with IPad*	4	4
IPad more informative to gauge student understanding	3	4
Using IPad helped me adjust my teaching to student's needs	2	3

* *Note*. Teachers were comparing the IPad to traditional hand raising when rating these questions. The rating is 1 strongly disagree and 5 strongly agree.

Research Question 4

This study also examined the students' perceptions of using an EARS in the classroom. The students in Ms. Doe and Ms. Smith's class were asked to complete a survey after using the EARS (IPads) intermittently during a the key unit of study (see Appendix B). Students rated their responses using a 1 to 5 scale with 1 representing not willing or disagree and 5 strongly agree or willing. Students across the four sections were collapsed into one group, and the results are displayed in Table 5.

Of the students, 36% wrote additional comments with respect to their experiences with the IPad devices. These comments were categorized into positive and negative feedback about the use of the IPad. Overall 59% of the comments were positive and 41% were negative.

The positive comments all fell under the categories of enjoyment and helping with learning. One student commented, “I like using the IPads more than raising my hand,” and another stated the IPads “make class a lot more fun.” A student commented they liked using IPads because “some people are scared to ask questions.” Expanding on this, a different student wrote, “I personally like answering questions on them because if the rates are low she does the problem and the person doesn’t have to admit needing help in class.” Other students commented how, with the IPads, “everyone [was] involved and added less pressure or stress,” and “it wasn’t the same 4 people answering all the questions.”

A few of the negative comments revolved around the time it took out of the class and specific features about the application. One student noted that “the eraser doesn't work too well” and it was difficult to show work using the draw features. Even with these drawbacks, this student noted it “wasn’t bad though.” A different student felt “it kind of forced the students who don’t participate to participate.” Two students commented that the IPads were anti-social. One wrote, “The classroom is very boring, and no one will socialize.” Another student wrote the following:

> Students are commonly afraid to answer questions or speak up during class. Using IPads may be an advantage to having them answer questions, because it influences them to given an answer virtually and not orally. I believe that students should develop their social skills and answer these

> questions for all to hear. It does not help the class to have them lose these skills or leave them unused. … While I don't mind using them, I do feel it will take away from some of the values of an actual classroom.

These are a sample of the overall comments that were left by students with most other comments being similar to those stated here.

Table 5

Student Perception Survey Responses

Question	% Answered for each scale				
	1	2	3	4	5
Willing to voluntarily participate in math	12.8	10.6	27.2	19.1	29.8
Willing to volunteer with IPad[a]	6.4	4.3	27.2	21.2	40.4
How do you feel if a teacher calls on you to answer	6.4	10.6	21.3	36.1	25.5
Using IPad how do you feel about answering[a]	6.4	2.1	21.3	29.8	40.0
Worried you have the wrong answer if called on	32.0	23.4	23.4	10.6	10.6
Worried submit wrong answer with IPad[a]	40.4	27.2	19.1	8.5	4.3
How useful is participating in math help with understanding?	6.4	10.6	10.6	32.0	40.4
How useful IPads to help with understanding[a]	14.9	14.9	32.0	17.0	21.2
How useful is participating to help you stay focused	8.5	8.5	14.9	25.5	42.6
How useful are IPads to help you stay focused[a]	4.3	17.0	31.9	31.9	14.7
Expect to do better on test questions on material IPad was used for	0.0	0.0	59.6	23.4	17.0
Liked seeing student responses with IPad	2.1	8.5	21.9	25.6	31.9
Liked the anonymity IPad offered	2.1	4.3	31.9	12.8	48.9
IPads add an element of fun	4.3	8.5	19.1	25.6	42.6

Note. Unless the IPad is specifically mentioned, questions were in relation to using traditional hand raising. The rating scale was 1 disagree and 5 agreed.

[a] Students answered these questions in comparison to hand raising.

Treatment Fidelity

Along with the primary data used to answer the research questions, the observers recorded information about the implementation of the four formative assessment questions (see Appendix D and E). Table 6 presents how often a particular type of question was asked and if the question was asked as part of a lesson or as a review or warm up activity.

During the training period, the teachers were taught to use specific techniques that were supported by the literature during both hand raising and EARS. For both response methods, teachers were to provide a time limit and review the concept if approximately 40% of the students had the wrong answer. During hand raising, when using multiple-choice, teachers were to poll the students, and for open-ended questions, teachers were to request a few answers and create a poll based on those answers. Table 7 shows the percentage of how often the teachers implemented the techniques for the hand raising questions.

Table 6

Question Analysis on EARS and Hand-Raising

Teacher	Multiple-Choice %	Open-End%	Lesson %	Warm/Review %
Doe	47.62	52.38	80.95	19.25
Smith	66.67	33.33	66.67	33.33
Right	57.14	42.86	55.55	44.44
Trig	56.25	43.75	25.00	75.00

Note. This data is based on the days the observers were present, not the entire unit.

For the EARS, the teachers were to display a bar graph of the results for multiple choice and hide student names. For open-ended questions, teachers were to make a new multiple-choice question from the submitted answers. If over 40% students had the answer wrong, the concept or question was to be reviewed. Table 8 shows the break down of how often the teachers followed this protocol during the implementation of the EARS. Note that a few of the techniques were often not implemented.

Table 7

Hand Raising Implementation of Questions

Teacher	Time Limit %	Poll %	Create-Poll %	Review Concept%
Doe	100.0	100.0	37.5	85.0
Smith	100.0	95.8	0.0	83.3
Right	100.0	100.0	49.5	66.7
Trig	100.0	66.7	0.0	75.0

Note. For the review concept the observers did their best to estimate when most of the class appeared to have the wrong answer and the concept needed to be reviewed. This table only reflects data collected on the observations days, not the entire unit of study.

Table 8

EARS Implementation of Questions

Teacher	Time Limit %	Bar Graph %	New Poll %	Hide Names%	Review %
Doe	100.0	83.0	50.0	100.0	62.5
Smith	100.0	100.0	20.0	60.0	100.0

Note. The bar graph was not always displayed, but if the teacher stated the results this was counted as a bar graph. A few of the observation days were shortened periods, and as a result, the teacher did not always have time to make a new poll from the open-ended problems. This table only reflects data from the days observers were present, not for the entire unit of study.

Validity

Due to the small sample size, the results of this study should only be generalized to similar groups. To assist with this, basic demographic information about the participants were collected and included in the findings. To improve the external validity, various sections of geometry were investigated to determine if the same effects could be found, regardless of the teacher.

In terms of internal validity, conducting the study over the same time period between the two groups reduced the history and maturation effect. The same tests were also used for the two groups to limit the influence of the tests and unit of study. Because the groups were not randomly created, the participation rates and test scores were compared between the two groups prior to the intervention and accounted for in the data analysis.

To reduce the influence of an observer on student behavior, the observers were in the classroom for several days prior to the start of data collection. Students became accustomed to their presence in the classroom, thereby reducing the influence on students' behavior.

CHAPTER 5

DISCUSSION

Overview

The NCTM (2000) and the CCSI (2014) have redefined the nation's mathematics standards to encourage a deeper understanding of concepts and a higher level of mathematical knowledge. In order to achieve this, students need to be actively engaged in learning. Unfortunately, by the time most students reach high school, they are often disinterested in mathematics, often resulting in avoiding or disengaging from the learning process (Signh et al., 2002). In an effort to engage students in learning, EARS have been implemented in many college-level classes with positive results of increased interest, engagement, and achievement (Bartsch & Murphy, 2011; Bojinova & Oigara, 2011; Caldwell, 2007; Draper & Brown, 2004). This study aims to add to the research by examining EARS at the secondary level in the geometry classroom. This study used a quasi-experimental design to determine whether EARS has an effect on participation and achievement in the geometry classroom.

Effect of EARS on Participation

With regard to engagement, the majority of the literature on EARS shows that students' participation improves when using an EARS device (Bojinova & Oigara, 2011; Freeman & Blayney, 2005). Based on this, this study posed the hypothesis that student participation is higher when using EARS over hand raising in the secondary geometry classroom. To test this hypothesis, students in this study switched between using an EARS and hand raising during the data collection period. For each student, a participation proportion was calculated for each of the two methods of response. A baseline participation was also established across groups prior to EARS, and no significant difference was found between the groups. The participation rates using the two methods of response and the teacher as the dependent variables was compared using a repeated ANOVA and a significant difference was found for the main effect of method of response. No significant difference was found on the interaction of teacher and method of response, reducing the possibility that the question format or teacher contributed to the difference in participation.

Looking more closely at the results showed an increase in participation rate and a lower standard deviation when using an EARS compared to hand raising. The method of response not only revealed a significant difference, but also a practical significant difference. Effect size shows 75% of the variance in participation is accounted for by the method of response. These results are in line with those by Freeman and Blayney (2005) who found students in the same class preferred EARS to hand raising. One thing to note in this study was that there were some technical glitches that resulted in students not being able to submit answers, and as a result they were tallied as not responding, yet there was still a significant increase in participation found.

This study went beyond actual participation to look at students' perception of using the EARS. Based on student responses to a survey it was found that 49% students felt comfortable voluntarily participating with hand raising, and 62% felt comfortable participating with an EARS. There were 32% who were uncomfortable voluntarily participating with hand raising, but only 11% who were uncomfortable using the EARS. These results are in accordance with the quantitative analysis that shows an increased participation when using an EARS.

To better understand the increased participation when using EARS, we can turn to the expectancy-value theory, which states that a student's willingness to engage in an activity, such as class participation, is based on their perceived benefit and cost of such action (Eccles, 1983, Eccles & Wigfield, 2002). Participating can be perceived as risky to students due to they potential embarrassment of having a wrong answer and being in the spot light (Christle & Schuster, 2003; Wigfield & Meece, 1988). Students also at times do not see the value in participating when using hand raising, since often a few students tend to dominate the discussion (Bojinova & Oigara, 2011; Fies & Marshall, 2006).

The survey looked more closely at the students' perceived cost of participation. When using hand raising, 17% students were uncomfortable with a teacher calling on them and 62% were comfortable with it. When using the EARS, only 9% were uncomfortable submitting an answer and 70% were comfortable. With hand raising, 20% worried about having a wrong answer and 55% did not. With EARS, 13% worried about having wrong answers and 68% did not. Students were only introduced to the devices a few times prior to the start of the study and therefore unfamiliarity with the EARS could have resulted in an increased worry about submitting a wrong answer. The survey found that EARS appeared to decrease the perceived risk of participation.

One student did note that they felt pressure to participate, so the EARS may have increased anxiety regarding participating for some students. The existing literature has found similar results, with some students feeling anxious or rushed when using the EARS (Caldwell, 2007; Draper & Brown, 2004; Kay et al., 2010). However, another student also noted they felt less pressure and stress when using the EARS.

Several students did not like the technology problems as well as the time EARS took away from class, which is in line with the literature (Caldwell, 2007; Freeman & Blayney, 2005; Kay et al., 2010). The teachers had similar views of the cost, as both noted they found it difficult to use the EARS in the classroom and the EARS took too much time. The time needed to use the EARS could be reduced if students were able to use their own devices. For this study, the students had to use a cart of IPads and thus, time was lost during class for handing out, collecting, and logging on to the devices

A surprising cost to participating found in this study but not previously noted in the literature is a lack of social interaction due to the use of EARS. One possible reason this has not been mentioned previously is the existing literature on EARS primarily examined them at the college level in lecture-style classes where teacher-student interactions are more limited. In the secondary classroom, the students are in classes with familiar faces so tend to be more social with each other and the teacher. A potential way to overcome a lack of social interaction when using EARS is to use the students' revealed answers as a platform to discuss the problems in small groups or as a whole class (Bruff, 2009; Caldwell, 2007; Lucas, 2009). This technique was suggested to the teachers during training, but appeared not to occur based on the miscellaneous data collected—this may have been due to a lack of time.

Even with reduced costs, students still must see the benefits of participating in order to actively engage in the act. Based on the survey, the students showed an interest in using the EARS, with 68% finding it added an element of fun. The students also liked to see each other's responses with 57% stating they agree or strongly agree. In addition, 62% agreed or strongly agreed to liking the anonymity it had to offer. The literature showed similar findings of students' enjoyment of using EARS outweighing the negative aspects (Draper & Brown, 2004).

The literature also showed that EARS helped improve student attention (Conoley et al., 2006; Titman & Lancaster, 2011). The survey from the current study also asked about attention and found 68% of students agreed that participation helped them stay focused, while 17% did not agree. When comparing using the EARS to hand raising, 46.7% agreed EARS was more helpful and 21% did not agree. A possible reason for the large percentage who felt the EARS did not help them focus may be that IPads were used as the EARS devices and they had other applications that could cause students to become distracted. Another benefit noted by a few students was that the whole class was involved, not just a few. The two teachers who used the EARS saw similar benefits for the students. Both noted that they felt students were more engaged when using the EARS and that students appeared to enjoy using the EARS.

Overall, the students appeared to enjoy using the EARS devices in the classroom more so than traditional hand raising. The teachers, on the other hand, preferred hand raising to using the EARS. Based on informal discussion, some reasons for this preference included the time the EARS took to set up during class and frustration with the technology glitches. Despite the negative comments, the data reveals the EARS devices can increase student participation by reducing the perceived risk and increasing the benefits.

Effect of EARS on Achievement

Students who are actively participating in the classroom are behaviorally engaged in the learning process. Research has shown that engagement is positively correlated to achievement (Christle & Schuster, 2003; Fredricks et al., 2004; Prince, 2004). These findings led to the second aim of this study, which was to determine if EARS can improve student achievement.

In this study, the achievement of students who used EARS were compared to students who never used the EARS. Students were compared prior to the implementation of EARS using a midterm test as a baseline, and a significant difference was found between the comparison and EARS group. To account for this difference, students' midterm and Unit test on right triangles test scores were standardized using z-scores and a repeated ANOVA was used to compare these scores across the two groups. No significant difference was found for the main effect of the test scores or the method of response. Even though there was no statistical significant difference, the effect size revealed that 4% of the variance between the midterm and Unit test on right triangles test could be accounted for by the method of response. Furthermore, when removing a few outliers from the data, 5% of the variance could be accounted for by the method of response. The large effect size shows the potential of EARS to improve student achievement.

One possible reason why this study did not find a difference in achievement is the unit that was used for data collection. Unit test on right triangles involves solving right triangles, including trigonometry and Pythagorean theorem. From past experiences, the students tend to do fairly well on this chapter compared to other units of study in the curriculum.

Along with implementing an EARS device in the classroom, this study also had teachers use formative assessment techniques. Research has shown that when EARS are used in conjunction with formative assessment, students believe it helps them understand the material (DeBourgh, 2007, Draper & Brown, 2004; Graham et al., 2007). The teachers in the comparison group and in the EARS group both implemented formative assessment techniques, which could contribute to the lack of difference in test scores. The students in the EARS group also did not use the EARS devices on a daily basis but only a few times throughout the unit. These results are in line with the literature, which had mixed results on the effect of EARS on achievement, as some studies found improved scores and others found no difference (Bartsch & Murphy, 2011; Bojinova & Oigara, 2009; Caldwell, 2007; Nightingale, 2010).

The quantitative analysis was slightly contradicted by some of the survey results. The survey shows that 62% felt participating in math was useful in helping them understand the material. Comparing EARS to hand raising, 38% thought that EARS was more useful toward helping them understand than hand raising. When considering the content that was covered, 40% stated they thought they would do better on EARS questions on the test and 60% were neutral. These results suggest that students did see the potential of EARS to improve their achievement, but it did not occur.

A possible contributing factor to this outcome may be the teachers' views of the EARS. The teachers did feel that the EARS helped them better gauge students' understanding so they could review concepts as needed. Interestingly, neither teacher felt that the EARS helped them to adjust their teaching to meet the students needs. Thus, teachers may have not adjusted their teaching based on students' responses to EARS questions. These findings suggests that simply implementing an EARS into the classroom without adjusting teaching style may not result in improved achievement, but the potential is there with proper implementation and adjustments.

Effect of EARS on Teachers

This study asked for the teacher's perspective about using the devices. The study found that the teachers felt the EARS helped to engage the students in the classroom and therefore provide them a better gauge of their understanding. Even with these comments though the teachers would prefer not to use the devices and instead wanted to stay with the traditional hand raising techniques. A primary reason for this appeared to be the time taken out of the classroom to pass out and collect the devices. The teachers saw this time as commodity that was being lost and it outweighed the improved engagement the EARS provided by the students. This implies that if EARS are to be implemented properly into the secondary classroom the time lost needs to be considered or overcome by providing students with their own devices to use.

Limitations

This study did have few limitations that need to be considered before drawing any conclusions. The first limitation that needs to be considered is the sample itself. The sample only consisted of students in a geometry mathematics classroom and was primarily made up of ninth and tenth graders. The students were already pre-determined to be in a certain class section, and although baselines were used to try and minimize the impact of this on the overall results, it still may contribute to the findings. The students were also not randomly assigned to be in the EARS or control group, rather only students from particular sections were randomly chosen. The students voluntarily agreed to be in the study. As a result those who felt more comfortable with the teacher, mathematics class, and participation in general were more likely to choose to be part of the study. Some students never handed back the forms and as a result could not be included in the study. These factors along with the small sample size may limit the generalizability of the results.

Another limitation is the length of this study. The students were presented with the EARS prior to the unit of study, but due to scheduling conflicts this did not occur as many times as was originally planned. Students were not use to using any technology besides a calculator in the classroom. The implementation of the EARS on fly took place during one unit, lasting from four to five weeks. During this time, students switched back and forth between EARS and hand raising so the devices were only sporadically used. This lends itself to the possibility that the improved participation could be due to the novelty of the device, an effect which may decrease over time. Research by Landrum (2013) considered this possibility and found that even though the effects were reduced, it was not enough to discount the EARS as a way to increase participation.

Another limitation is the implementation of the devices using formative assessment techniques. The teachers were provided with some basic training about the devices and suggestions on how to use formative assessment. Unfortunately, this training did not seem sufficient for the teachers. The miscellaneous data showed that new questions were often not created from open-ended questions. The formative questions were also not spread out throughout the lecture, but instead at times used as a review or warm up. This failure to properly implement EARS could contribute to the lack of progress in achievement scores and negative perceptions of students. Prior research has suggested that proper implementation is a key factor to consider when using an EARS (Beatty & Gerace, 2009; Draper & Brown, 2004; Zhu, 2007).

Lastly even though this study looked at participation and achievement of the EARS using participations rates, test scores, and survey results, these are all quantitative methods. By not considering a qualitative approach that looked at the same phenomenon the corroboration between the survey results and other data analysis is limited by the possible bias and flaws in the quantitative method (Greene, Caracelli, & Graham, 1989). To reduce this a mixed-method approach should be considered with the purpose of triangulation that uses different methods to offset each other's limitations to increase the validity of the results (Greene et al., 1989).

Future Research

The current study provides a valuable contribution to the ongoing literature on EARS in the classroom. Before any conclusions can be drawn about the contributions EARS may offer in regards to participation and achievement in the secondary mathematics classroom, more research is needed.

Future research and professional development in this area should look across other mathematic courses such as Algebra or Pre-Calculus. Doing so would expand the results over other grade levels as well as mathematical content. Researchers should also consider the different levels of the courses to see if the effect of using an EARS differs across level.

The timing of this study is one of the limitations that should be considered in future research. The EARS were only used intermittently during one unit of study. Future research should have students use EARS for an entire marking period, semester, or even year. By doing so, the novelty effect of the devices is reduced so that any findings on participation and achievement can be contributed to the device, not just the newness of the device.

The teachers were asked to implement both multiple-choice and open-ended questions when using the EARS devices. The prior literature on EARS primarily implemented multiple-choice questions only. Since this particular program can save all the students results a closer look at the effect of open-ended questions with EARS should be looked at. Such things as the type of responses the students provide, is there a difference in the participation rate when looking at the type of question across the methods, and the perceptions of students and teachers in regards to these questions and an EARS.

This study only examined students' overall achievement between the treatment and control group. The treatment group did not use the EARS throughout the unit but rather a mix of EARS and hand-raising. Students may have performed better on the assessment questions that contained content that was covered when the EARS than the content covered during hand-raising and should be considered in future research.

When reviewing the student perceptions of using the EARS a few interesting comments came up about the social aspects of the EARS in the classroom. Future research should look more closely at this by considering how the implementation of EARS changes the social interactions in the classroom. Another aspect to consider is if the addition of the device to the students makes them feel like they are being forced to participate rather than given a choice.

Conclusion

Even though the finding that showed no difference in achievement is disappointing, this study still contributes to the growing research on EARS by looking at a high school geometry classroom, which prior research has not considered. The student perceptions and quantitative data analysis supports the claim that EARS devices can increase participation in the secondary mathematics classroom. If a teacher uses the results from the EARS to adjust their teaching and create discussions that engage students in learning, this may improve student achievement (Black & Wiliam, 2009; Yin et al., 2008). Therefore, it is only reasonable to predict that if EARS are implemented with the proper formative assessment techniques, it is possible to see improved achievement and participation levels in the secondary mathematics classroom.

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APPENDIX A

TEACHER PERCEPTION SURVEY

Please rate the following statements using the provided 5-point scale.

5= strongly agree, 4= agree, 3= neutral, 2= disagree, 1= strongly disagree.

1. I found it difficult to use the IPads as clickers in the classroom.

5 4 3 2 1

2. I enjoyed having students answer questions using the IPad.

5 4 3 2 1

3. Using the IPad took up too much time out of the class.

5 4 3 2 1

4. I felt using the IPad caused students to be more engaged in the lesson.

5 4 3 2 1

5. Using the IPad was more informative then traditional hand raising to gauge students' understanding.

5 4 3 2 1

6. Students did not appear to enjoy using the IPad

5 4 3 2 1

7. Using the IPad along with formative assessment helped me to adjust my teaching to the students' needs better than traditional hand raising.

5 4 3 2 1

8. I'd rather use traditional hand raising then an IPad or clicker device.

5 4 3 2 1

9. Any additional comments or concerns with using the IPad as a clicker compared to traditional hand raising?

APPENDIX B

STUDENT PERCEPTION SURVEY

The following questions ask you to rate on a scale of 1 to 5 your perceptions toward participating in the math classroom. Answer each question by circling the number that best describes your view. There is no right or wrong answer.

1. In math class, how willing are you to voluntarily participate to answer a question?

   Not willing 1 2 3 4 5 Willing

2. Comparing hand raising to the IPads, how willing are you to voluntarily participate to answer a question in math class?

   I am a lot less willing with the IPad 1 2 3 4 5 I am a lot more willing with the IPad

3. How do you feel about a teacher calling on you to answer a question?

   Uncomfortable 1 2 3 4 5 Very Comfortable

4. Compared to hand raising, when using the IPad how do you feel about submitting an answer?

   A lot more uncomfortable 1 2 3 4 5 A lot more comfortable

5. When called on by the teacher, how much do you worry that you will say the wrong answer?

   Not at all 1 2 3 4 5 Very much

10. Compared to hand raising, how much do you worry that you will submit the wrong answer when using the IPad?

   Much less worried1 2 3 4 5 Much more worried

11. How useful is participating in math class with helping you understand the material?

Not at all 1 2 3 4 5 Very useful

12. Compared to hand raising, how useful is using the IPads to help you understanding the material?

Not at all useful 1 2 3 4 5 Very useful

13. How useful is participating in math class to help you stay focused during the lesson?

Not at all useful 1 2 3 4 5 Very useful

14. Compared to hand raising, how useful are IPads to help you stay focused during the lesson?

With IPADs it is Not at all useful 1 2 3 4 5 With IPads it is very useful

15. Comparing the concepts you learned while using the IPad to that when raising your hand how well do you expect to do on the test questions?

Worse on IPad material questions 1 2 3 4 5 Better on IPad material questions

16. I liked seeing other students' responses when using the IPad.

Strongly Disagree 1 2 3 4 5 Strongly Agree

17. I liked the anonymity the IPad offered.

Strongly Disagree 1 2 3 4 5 Strongly Agree

18. IPads add an element of fun to the classroom.

Strongly Disagree 1 2 3 4 5 Strongly Agree

Please add any additional comments you have about using the IPad in class, likes, dislikes, observations, etc…

APPENDIX C

Examples of Formative Assessment Questions

I. Pythagorean Theorem

II. Trigonometry

III. Inverse Trigonometry

IV. 45-45-90 triangle rules

V. 30-60-90 triangles rules

Not possible

1. If you are only given one side of an isosceles right triangle, what can be used to find the other sides?
   a. I, III, and IV
   b. I, II, V
   c. I, II, IV
   d. II, IV
2. If you are given a scalene right triangle and told the length of one side and an angle of 55°, what can be used to find the other sides?
   a. II, V
   b. III, V
   c. VI
   d. II

3. The triangle with the sides of 10, 9, and 13 is

   a. acute

   b. right

   c. obtuse

   d. I don't know how to do this

4. The leg of an isosceles right triangle is $\sqrt{7}$, what is the hypotenuse?

5. A jogger runs 8 miles north, 9 miles west, and then 15 miles back to the starting point in a southeast direction. If the jogger plotted out their path what type of triangle would that make?

6. Which of the following could be sides of a 45-45-90 triangle?

   a. 6; 6; 12

   b. 6; 8; 10

   c. $6\sqrt{2}$; 12; 12

   d. $6\sqrt{2}$, $6\sqrt{2}$, 12

APPENDIX D

HOW DID THE TEACHER IMPLEMENT THE EARS

Question	1	2	3	4	5
What question format was used?	Multiple-Choice Fill In Blank Other:_____	Multiple-Choice Fill In Blank Other:_____	Multiple-Choice Fill In Blank Other:_____	Multiple-Choice Fill In Blank Other:_____	Multiple-Choice Fill In Blank Other:_____
Did the teacher provide a time limit to students before displaying results?	Yes No	Yes No	Yes No	Yes No	Yes No
For multiple-choice questions did the teacher display the bar graph to the students?	Yes No	Yes No	Yes No	Yes No	Yes No
For open-ended style questions did the teacher take the responses and create a new multiple-choice question based on them?	Yes No	Yes No	Yes No	Yes No	Yes No
For questions that at least 10% of the class had incorrect answers did the teacher go over the question?	Yes No	Yes No	Yes No	Yes No	Yes No
For questions that at least 10% of the class had incorrect answers did students explain the answer or possible mistakes students may have made?	Yes No	Yes No	Yes No	Yes No	Yes No
For questions that over 40% of the class had the wrong answer did the teacher go back over the concept?	Yes No	Yes No	Yes No	Yes No	Yes No

APPENDIX E

QUESTION IMPLEMENTATION WITH HAND RAISING

Question	1	2	3	4	5
What question format was used?	Multiple-Choice Fill In Blank Other:_____	Multiple-Choice Fill In Blank Other:_____	Multiple-Choice Fill In Blank Other:_____	Multiple-Choice Fill In Blank Other:_____	Multiple-Choice Fill In Blank Other:_____
Did the teacher provide a time limit to students before requesting answers?	Yes No	Yes No	Yes No	Yes No	Yes No
For multiple-choice questions did the teacher poll students on each possible response?	Yes No	Yes No	Yes No	Yes No	Yes No
For open-ended style questions did the teacher take multiple responses and create a new multiple-choice question based on them?	Yes No	Yes No	Yes No	Yes No	Yes No
For questions that at least 10% of the class had incorrect answers did the teacher go over the question?	Yes No	Yes No	Yes No	Yes No	Yes No
For questions that at least 10% of the class had incorrect answers did students explain the answer or possible mistakes students may have made?	Yes No	Yes No	Yes No	Yes No	Yes No
For questions that over 40% of the class had the wrong answer did the teacher go back over the concept?	Yes No	Yes No	Yes No	Yes No	Yes No

APPENDIX F

IRB APPROVAL

TEMPLE UNIVERSITY®

Office for Human Subjects Protections
Institutional Review Board
Medical Intervention Committees A1 & A2
Social and Behavioral Committee B
Unanticipated Problems Committee

Student Faculty Conference Center
3340 N Broad Street - Suite 304
Philadelphia, Pennsylvania 19140
Phone: (215) 707-3390
Fax: (215) 707-9100
e-mail: irb@temple.edu

Certification of Approval for a Project Involving Human Subjects

Protocol Number:	22653
PI:	NEWTON, KRISTIE
Review Type:	EXPEDITED
Approved On:	22-Dec-2014
Approved From:	22-Dec-2014
Approved To:	21-Dec-2015
Committee:	B BEHAVIORAL AND SOCIAL SCIENCES
School/College:	EDUCATION (1900)
Department:	EDUCATION:TEACHING & LEARNING (19020)
Sponsor:	No External Sponsor
Project Title:	Electronic Audience Response systems in the secondary mathematics classroom to engage students.

The IRB approved the protocol 22653.

If the study was approved under expedited or full board review, the approval period can be found above. Otherwise, the study was deemed exempt and does not have an IRB approval period.

If applicable to your study, you can access your IRB-approved, stamped consent document or consent script through eRA. Enter the relevant approved submission (for example, Modifications Required to Secure Approval) and open the stamped documents by clicking the View icon next to each document. The stamped documents are labeled as such.

Before an approval period ends, you must submit the Continuing Review form via the eRA module. Please note that though an item is submitted in eRA, it is not received in the IRB office until the principal investigator approves it. Consequently, please submit the Continuing Review form via the eRA module at least 60 days, and preferably 90 days, before the study's expiration date.
Note that all applicable Institutional approvals must also be secured before study implementation. These approvals include, but are not limited to, Medical Radiation Committee ("MRC"); Radiation Safety Committee ("RSC"); Institutional Biosafety Committee ("IBC"); and Temple University Survey Coordinating Committee ("TUSCC"). Please visit these Committees' websites for further information.

Finally, in conducting this research, you are obligated to submit modification requests for all changes to any study; reportable new information using the Reportable New Information form; and renewal and closure forms. For the complete list of investigator responsibilities, please see the Policies and Procedures, the Investigator Manual, and other requirements found on the Temple University IRB website: http://www.temple.edu/research/regaffairs/irb/index.html

Please contact the IRB at (215) 707-3390 if you have any questions

APPENDIX G

PARTICIPATION RAW DATA

Teacher	Section	Baseline	IPAD	Hand Raising
Doe[a]	A	0	Absent	Absent
Doe	A	0	83.33	25
Doe	A	42.31	100	87.5
Doe	A	19.23	100	50
Doe	A	0	91.66	0
Doe	A	0	75	75
Doe	A	Absent	91.66	75
Doe	B	12.5	100	53.85
Doe	B	Absent	66.67	61.54
Doe	B	8.33	100	69.23
Doe	B	0	71.43	30.77
Doe	B	0	85.71	46.15
Doe	B	0	85.71	61.54
Doe	B	0	100	61.54
Doe	B	4.17	100	53.85
Doe	B	4.17	75	76.92
Doe	B	0	100	53.85
Smith	A	3.92	72.73	12.5
Smith	A	0	90	37.5
Smith	A	0	100	25
Smith	A	0	92.86	25
Smith	A	3.92	100	37.5
Smith	A	15.69	90	25
Smith	A	1.96	100	75
Smith	A	5.88	92.86	62.5

Smith[a]	A	1.96	92.86	Absent
Smith	B	0	87.5	50
Smith	B	0	100	37.5
Smith	B	2.94	62.5	62.5
Smith	B	0	100	62.5
Smith	B	2.94	50	25
Smith	B	41.18	100	81.25
Smith	B	2.94	100	81.25
Smith	B	0	62.5	31.25
Smith	B	0	87.5	50
Smith[a]	B	5.88	68.75	Absent

[a]Removed from participation subgroup

APPENDIX H

ACHIEVEMENT RAW DATA

Comparison Group

Teacher	Section	Midterm	Ch7Test	Response
Trig	1.00	62.00	56.00	.00
Trig	1.00	86.00	90.00	.00
Trig	1.00	84.00	94.00	.00
Trig	1.00	95.00	75.00	.00
Trig	1.00	78.00	93.00	.00
Right	1.00	77.00	51.00	.00
Right	1.00	88.00	93.00	.00
Right	1.00	85.00	81.00	.00
Right	1.00	95.00	99.00	.00
Right	1.00	80.00	85.00	.00
Right	1.00	93.00	96.00	.00
Right	1.00	90.00	83.00	.00
Right	1.00	97.00	94.00	.00

EARS Group

Teacher	Section	Midterm	Ch7Test	Response
Smith	1.00	77.00	83.00	1.00
Smith	1.00	67.00	90.00	1.00
Smith	1.00	92.00	96.00	1.00
Smith	1.00	78.00	93.00	1.00
Smith	1.00	76.00	93.00	1.00
Smith	1.00	78.00	85.00	1.00
Smith	1.00	84.00	93.00	1.00
Smith	1.00	62.00	53.00	1.00
Smith	1.00	59.00	48.00	1.00
Smith	1.00	84.00	62.00	1.00
Smith	1.00	71.00	6.00	1.00
Smith	1.00	46.00	72.00	1.00
Smith	1.00	83.00	90.00	1.00
Smith	1.00	74.00	69.00	1.00
Smith	1.00	82.00	81.00	1.00
Smith	8.00	71.00	58.00	1.00
Smith	8.00	53.00	31.00	1.00
Smith	8.00	88.00	95.00	1.00
Smith	8.00	55.00	63.00	1.00
Smith	8.00	57.00	60.00	1.00
Smith	8.00	91.00	73.00	1.00
Smith	8.00	71.00	70.00	1.00
Smith	8.00	81.00	78.00	1.00
Smith	8.00	66.00	80.00	1.00
Smith	8.00	59.00	70.00	1.00
Smith	8.00	89.00	96.00	1.00

Smith	8.00	52.00	59.00	1.00
Smith	8.00	69.00	47.00	1.00
Smith	8.00	76.00	72.00	1.00
Doe	1.00	94.00	96.00	1.00
Doe	1.00	56.00	54.00	1.00
Doe	1.00	75.00	90.00	1.00
Doe	1.00	91.00	77.00	1.00
Doe	1.00	62.00	84.00	1.00
Doe	1.00	83.00	60.00	1.00
Doe	8.00	56.00	78.00	1.00
Doe	8.00	50.00	85.00	1.00
Doe	8.00	78.00	73.00	1.00
Doe	8.00	70.00	93.00	1.00
Doe	8.00	90.00	98.00	1.00
Doe	8.00	87.00	95.00	1.00
Doe	8.00	80.00	81.00	1.00
Doe	8.00	72.00	91.00	1.00
Doe	8.00	76.00	85.00	1.00
Doe	8.00	72.00	77.00	1.00
Doe	8.00	77.00	81.00	1.00