Using an Interactive Response Collection System to Increase Classroom Formative Assessment in an

Effort to Improve Student Self-Efficacy in Mathematics in Limited Resource Environments

A Master's Research Project Presented to

The Faculty of the College of Education

Ohio University

In Partial Fulfillment

of the Requirements for the Degree

Master of Education

by

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June, 2010

This Master's Research Project has been approved

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Abstract

The purpose of this research was to examine the relationship between changes in self-efficacy towards mathematics and increased use of formative assessment in the classroom. A Smart Senteo Interactive Response System was introduced into a math class of 14 high school students studying Ohio 10th grade standards. Lessons using traditional lecture were compared to lessons using the response system to collect and share formative assessment. Students were given self-efficacy surveys and quizzes to monitor changes in efficacy and achievement. This study attempted to link improvements in achievement to changes in student self-efficacy. Based on the self-efficacy surveys, the formative assessment of student performance provided through the use of the response system improved the students' perceptions of their level of enjoyment and reduced feelings of helplessness or avoidance. Students' perceptions of ability were relative to their achievement earned on quizzes for each lesson. Utility and general attitudes towards mathematics were the least influenced by increased use of formative assessment.

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Recent educational initiatives have recognized a need for better math performance and higher educational levels of math for successful transition into post-secondary options. However, struggling students and students with disabilities often develop a poor self-efficacy regarding their ability to succeed in math. The problem is often exaggerated after several years of poor math development and school failure in the subject. More than any other subject, mathematics relies on a careful progression of developmental skills that allow learners to move through instructions that are concrete, representational, symbolic, and finally abstract (Maccini, Mulcahy, & Wilson, 2007).

Students in elementary and middle school might be successful in other content area subjects, but fail to achieve the needed mastery levels of important developmental math skills. They are often passed from one grade to the next, continually being exposed to a level of math that is deemed gradelevel appropriate without having achieved the necessary prerequisite skills. As they advance into secondary school, they become exposed to more abstract representations of math concepts. However, if they have never developed an understanding of the concrete and mental representations, this information will only frustrate them. These students will shut down and often develop learned helplessness and work avoidance. The struggling student will go through the motions of following steps and instructions, but will not have any real level of conceptual understanding.

Ohio State achievement testing confirms math and science are often the lowest scoring academic areas (Ohio Department of Education, 2009). With the increasing technological demands of careers in society, it is imperative to make real world connections for practical applications and improve mathematical understanding. Studies show that student's base their perceived ability in math on how well they complete and master the tasks given to them in class (Chouinard, Karsenti, & Roy, 2007; Siegle & McCoach, 2007; Usher & Pajares, 2009). Effective instruction must address ways to improve student self-efficacy towards math to increase student achievement.

Literature Review

Self-Efficacy and its Effect on Student Understanding

Much research has been done regarding the relationships between self-efficacy and learning. Self-efficacy research in education references the work of Albert Bandura. Bandura (1993) discusses self-efficacy as "people's belief about their capabilities to exercise control over their own level of functioning and over events that affect their lives" (p. 18). Efficacy beliefs effect how people feel, think, motivate themselves and behave through the four major areas of cognitive, motivational, affective, and selection processes.

Studies have shown that perceived self-efficacy has greater influence on positive attitudes toward mathematics than actual ability level. In Maccini et al. (2007)'s review of mathematics interventions for students with learning disabilities, the importance of incorporating effective instructional practices for secondary students with learning disabilities is stressed given the current emphasis on high-stakes testing, standards and accountability. Their research points to studies of efficacy that reported students with learning disabilities perceived mathematics problems to be more difficult, required more time to complete, and used fewer strategies than their peers. The authors indicated the most effective instruction for students with learning disabilities included modeling, guided practice, independent practice, monitoring student performance, and corrective feedback.

Students in secondary school, who have experienced failure, are more likely to avoid engaging in classroom activities. Students' past performance is the single greatest contributor to their confidence and ability to achieve in school (Siegle & McCoach, 2007). Smith, Kass, Schneider, and Schneider, (2006) demonstrated that the occurrence of failure feedback decreased students' taskspecific self-efficacy. The perceived ability to accomplish a skill or task can lead to avoidance if a student has low self-efficacy. This low self-efficacy affects the effort expended and the persistence on the task (Schunk, 1989). Students who believe they are capable are more likely to eagerly participate in a task. Students who engage in avoidance goals try to minimize the negative impact of failure and the perception of others as being incompetent (Chouinard et al., 2007).

Schunk and Gunn (1986) hypothesized that self-efficacy influences a student's choice of activities, effort expended, persistence, and task accomplishment. Success is viewed by the student as a result of ability, effort, task difficulty, and luck. Effective emphasis and use of task strategy has been shown to improve student motivation, self-efficacy, and mathematical skill development (Schunk & Gunn). The use of task strategies should increase ability attributions since success in problem solving tasks leads to an increased view of ability. Pajares and Graham (1999) cited research that indicated regardless of ability level, students with higher self-efficacy are more accurate in their mathematical computations and show greater persistence on task difficulty than students with low self-efficacy. In sum, self-efficacy beliefs are good predictors of students' mathematical performance.

Schunk (1989) recommended the use of cues to signal student success so they can assess efficacy for continued learning. A higher efficacy for learning will enhance motivation and skill acquisition. These cues included performance outcomes, attributions, social comparisons, persuader credibility, and bodily symptoms. Schunk also listed impacts on student task engagement including purpose of instruction, content difficulty, instructional context, instructional events, strategy instruction, performance feedback, goal setting, attributive feedback, and rewards.

It is important to understand that many factors shape a person's self-efficacy. Bandura (1997) recognized four main influences on self-efficacy; mastery experience, vicarious experience, social persuasions and physiological experience. Mastery experience is the most powerful influence and is an individual's interpretation based on his or her previous attainments (Usher & Pajares, 2008). Self-efficacy is most affected by successful performance. Vicarious experience is an individual's interpretation of beliefs developed from observing others. In other words, an individual gauges his or her capabilities by the performance of others. Feedback in the form of encouragement from parents, teachers, and peers, contribute to self-efficacy through social persuasions. Emotional states such as

anxiety, physical, and emotional well-being comprise the fourth influence on self-efficacy known as physiological experience (Usher & Pajares). Self-efficacy presents a challenging area in research since many of these concepts are difficult to measure in observable terms.

Formative Assessment Using New Technology

Black and Wiliam (1998) argue that formative assessment is at the heart of effective teaching. Assessment in general refers to information used as feedback for teaching and learning activities, which becomes a formative assessment when it is used to adapt the teaching to meet the needs of the students. Roschell, Penuel, and Abrahamson (2004) indicate that the use of a networked classroom aids in the collection, management, and analysis of data vital to effective formative assessment. The authors analyzed research that reported student gains in achievement when math and science teachers implemented technology in the classroom. A networked classroom is not just networked with computers, but interactive learning with technology through activities such as collecting student responses and displaying responses back to the classroom for discussion.

Classroom Response Systems

Fies and Marshall (2006) define classroom response systems as "transmitters that students use to send responses, receivers that collect these inputs, and a computer that runs software designed to interpret and aggregate these responses in real time" (p. 101). However, response collection was available before the advent of technology. Gardner, Heward, and Grossi (1994) discussed the advantages of using a response card approach versus traditional classroom interaction through handraising. The use of response cards substantially increased student academic responses in class, provided direct and ongoing assessment to modify instructions as needed and increased students' ability to retain greater amounts of academic information. The authors reported an added benefit of response cards was that students were less disruptive and stayed more on task in class.

Salend (2009) outlined newer technological classroom response systems that can be used in presentations to motivate learning and provide effective use of real-time assessments of student

learning. These systems provide engaging, interactive classrooms that rely on whole-class participation. Students are less likely to passively react to presentations if they can interactively respond and be recognized in classroom activities.

The use of formative assessments provides important feedback for students, but also has demonstrated benefits for teacher self-efficacy. Colvin, Flannery, Sugai, and Morgan (2009) observed a teacher and provided performance feedback on classroom activities. The teacher was able to make changes in instruction based on feedback that resulted in substantial gains in class engagement and a reduction in problem behavior. A recommendation to increase questioning to check for student understanding and encourage whole class responses resulted in positive gains in improving class engagement. Teachers have a direct impact on students' self perception and performance in mathematics since they constantly reflect judgments of students' skills (Chouinard et al., 2007). It is just as important for teachers to have a positive self-efficacy towards mathematics as it is for students due to the reciprocal nature of teaching. Teachers with high self-efficacy can provide a positive model of task success and mastery for their students.

Advances in technology provide some solutions to effective instruction in the classroom. Salend (2009) describes the ability to perform a range of both formative and summative assessment using technology-based resources. In particular, technology can enhance formative assessment by monitoring students' learning progress, and allowing the teacher to make informed decisions for improving instructional practice. Students and teachers receive unobtrusive, immediate feedback that aids in targeting needed areas for additional instruction.

Black and Wiliam (1998) argue for the need for more formative assessment in education, and cite studies that demonstrate the impact of formative assessments in the classroom, producing significant and often substantial learning gains. The authors emphasize that formative assessment goes beyond summative assessments because the evidence is actually used to adapt teaching to meet student needs. Additionally, formative assessments have been particularly successful in raising the

achievement of low achieving students more than other students (Black & Wiliam). Chappuis and Stiggins (2002) emphasize the need for day-to-day classroom assessment to extend beyond the goals of performance measurement. Students can become engaged and motivated when immediate, descriptive feedback can be used for self-assessment. Therefore, the focus of education becomes progress and achievement, instead of failure and competition. Technology can help manage multiple variables like performance feedback, goal setting, and attributive feedback, especially in secondary schools where teachers have many students through short periods of the day.

Modern technology in the classroom has the potential to greatly enhance the amount of formative assessment that occurs in the classroom. In turn, this formative assessment can provide the needed feedback and positive supports necessary to improve self-efficacy in students. A crucial component of using a response system for feedback is the constant interaction and task engagement by the entire class. However, there are still some concerns in using a response system. Students may still choose not to actively participate in activities even though they know their participation is being monitored. Previous personal experience has also shown that fascination with new technology can result in a temporary increase in participation, only to wear off over time. The goal for using an interactive response system to collect formative assessment is to actively engage students in classroom tasks and show them that they have the ability to perform mathematics successfully.

Gradual successes over time should be accompanied by an increase in self-efficacy. An increase in self-efficacy should then be followed by increased performance in, and understanding of mathematics. The amount of time required for improvements in self-efficacy is questionable, especially in secondary students who have experienced continuous school failure in mathematics. Siegle and McCoach's (2007) findings indicate that significant increases in self-efficacy can occur over a short period of time; however their study was completed with fifth graders.

The current technology provides ample opportunity to research the effectiveness of formative assessments and their effects on student self-efficacy. Continued research is also indicated to

investigate the current trends for increased inclusion and differentiated instruction to include students with learning disabilities in a whole-class general education environment. Further, this research is necessitated by the new emphasis on successful math and science instruction made necessary by global, political, and economic demands on society.

Method

The purpose of this research was to examine the relationship between changes in self-efficacy towards mathematics with an increased use of formative assessment in the classroom. Significant improvements in student achievement for mathematics using networked classrooms have already been verified by recent research (Roschelle et al., 2004). The formative assessment provided by such networked classrooms is believed to be one on the contributors to improved achievement. The research conducted in this study attempts to link achievement with changes in student self-efficacy. This research was designed to answer the following research question: Will the continuous feedback and discussion of student performance provided by the Smart Senteo Interactive Response System during classroom lessons improve students' perceived ability in mathematics?

Research Site

The participants in this study included one Integrated Math II class held for one 50-minute period daily in a high school. The class was designed to teach the 10th grade math standards required by the Ohio Department of Education. A pacing chart for the grade-level indicators covered during the school year was established by a county cohort of math teachers and the Literacy Curriculum and Alignment Program (LCAP). Integrated Math II is designed for students planning on attending vocational school their junior and senior year, and is not considered a college preparatory class. Along with typical 10th grade standards, the class focused on preparation for the Ohio Graduation Test (OGT).

The high school used for this study is located in a rural area of south central Ohio. According to the 2008-2009 Ohio District Report Card for the high school, there is an average daily enrollment

of 392 students, with 30.1% considered economically disadvantaged and 26.0% of the students having disabilities. The classroom is housed in a modern facility constructed in 2003, in a K-12 building that contains the entire school district. The classroom is complete with up-to-date technology including internet access, phone systems, and a Smart Interactive White Board. Students are also provided with calculators in math class. This study occurred during the fourth nine weeks of the high school year in the months of April and May.

Participants

The study involved 14 students enrolled in the class. Although designed for 10th grade students, there was one 12th grade student enrolled in the class. Nine of the 14 students enrolled in the class had an Individualized Education Plan (IEP). There were nine male and five female students in the class.

Procedures

Control phase lessons. This study was designed with four lessons developed using an ABAB phase pattern. *Phase A* lessons were typically taught lessons consistent with methods used throughout the school year in this classroom. A typical lesson began with a homework review, where the teacher systematically went around the room and had students individually contribute solutions to the homework from the previous day's lesson. Time was spent reviewing questions that the teacher observed the students' struggled to understand. At times, students were asked to write their responses on the board and show work. This typically took 10-15 minutes.

Next, students were provided with guided notes nearly identical to those used and displayed on the Smart Interactive White Board by the teacher for whole-group presentations. Definitions and concepts were presented in fill-in-the blank format, requiring students to discuss and write responses in their notes while the teacher completed her version of notes at the board. The teacher used a guided practice approach where new problems were completed with group discussion on appropriate steps and strategies to solve a math problem. Examples in the guided notes were chosen to model the problems in their homework for independent practice. The teacher tried to accommodate the lesson to provide 10 minutes of class time to begin homework, but was not always successful in providing this time.

Formative assessment during *Phase A* lessons consisted of verbal feedback to individuals answering questions during discussion, teacher observation of student work, and one-on-one assistance during individual practice. Although the teacher tried to walk around the room to observe student work, she was often restricted to the board to write responses and model problem-solving strategies.

Homework for these lessons was spot checked for completeness the day after the lesson. However, it was not collected until the day of the assessment when students were graded for a notebook check, and at that point, the grade was based on effort. It was the students' responsibility to review and correct their own homework in class. This is a typical homework system in a high school, where a teacher cannot realistically correct daily assignments with a class load of 100-150 students.

Intervention phase lessons. *Phase B* lessons implemented the availability of new technology. Two main pieces of technology were added to the lesson format. First, the teacher used a wireless slate that allowed her to write responses on the board without having to stand next to the board. This allowed her to continuously walk among and interact with the students. Second, a Smart Senteo Interactive Response System was added to the Smart Board. This system consisted of handheld wireless response clickers that could be individually assigned to each student. Students could enter responses in several formats including true/false, yes/no, multiple choice, and numeric input answers. Student responses were immediately displayed in chart format on the Smart Board. Anonymity of student responses was maintained in the displays. Students' wireless handhelds also displayed whether a response was correct or not on their individual display screens. In addition, the system stored the data for individual student and whole class performance. The typical lesson format did not change during *Phase B*. The lessons began with homework review, then whole-class instruction, followed by individual practice. However, responses to homework and guided practice were collected using the wireless handheld system and displayed on the Smart Board to be discussed with the whole class. Individual practice responses were not collected with the system until the homework review the following day.

For both homework and guided practice, problems were pre-programmed using Senteo Smart Response software to record students' correct/incorrect responses. In addition to the formative assessment available in *Phase A*, the interactive response system provided additional formative assessment by recording and displaying individual student responses in an anonymous format. The teacher's ability to observe and interact with students was increased with improved mobility through the use of the wireless slate during the lesson. Both the individually required responses with the wireless handheld and teacher proximity were predicted to increase student task engagement.

During both *Phase A* and *B*, the phase spanned a total of five days and was divided into three lessons, followed by a review day and a quiz. At times, these five days were not consecutive due to an ongoing quarter-long project and student interviews being conducted by the vocational school. On the review days, students were divided into groups of 3 or 4, and given handheld marker boards to compete in groups answering questions from a PowerPoint review game. Copies of the PowerPoint were provided to the students for review outside of class.

During *Phase B*, the students still played the review game as before, but they used the response wireless handhelds to record their responses. The quizzes for both *Phases A* and *B* covered material presented from the previous three lessons and were scored out of a total of 30 points. All quizzes were given in paper and pencil format, so that full student work could be evaluated. As part of the study, the students were given an 8-item Likert survey, immediately prior to each quiz, to assess their attitudes towards learning. Responses to the survey questions were collected using the response wireless handhelds.

The lessons were divided into four phases covering material typically taught in the fourth nine weeks of Integrated Math II. The first A-B phase covered properties of circles. *Phase A* included parts of a circle, central angles, arcs, and chords. *Phase B* included the properties of inscribed angles and the coordinate equation of a circle. The second A-B phase covered probability. *Phase A* included probability of an event, compound probability, and geometric probability. *Phase B* included factorials, permutations, and combinations. As much as possible, an attempt was made to keep the subject material similar within each A-B phase. However, varying from circles to probability during the study allowed for a range of students' strengths and weaknesses to be accommodated.

Data Collection Instrument

The survey used for data collection in this study was developed by modeling questions from Chouinard et al. (2007), Marsh (1992), and Usher and Pajares (2009). The purpose of the survey was to monitor changes in students' self-reported attitudes towards mathematics instruction and self-efficacy during the lessons. The survey consisted of eight questions using a 7-point Likert scale ranging from 1 – strongly disagree, 4 – neutral, to 7 – strongly agree.

Although researchers have not reached consensus on how to effectively measure self-efficacy, Usher and Pajares (2009) reported that self-reporting methods where students rate their own opinion of their success are much better measures of self-efficacy than performance indicators such as grades.

Chouinard et al. (2007) and Usher and Pajares (2009) maintained in their research that students' self-concept of mastery was the most reliable predictor of self-efficacy when using selfreporting techniques. Other sources of self-efficacy such as vicarious experience, social persuasions and physiological experience have proven difficult to measure reliably. The eight questions were designed to focus on the students' self concept of their ability, level of understanding, the utility value, level of interest, and personal performance goals for the math lessons being taught.

Results

The findings reported in this section are the results from student quizzes from both *Phase A* and *Phase B* as well as student ratings of self-efficacy.

Quiz Results

Quiz results are displayed in Figures 1 and 2. Figure 1 displays individual student performance on all four quizzes. *Phase A* consisted of Quiz 13.1 to 13.3 and Quiz 14.1 to 14.3. *Phase B* consisted of Quiz 13.4 to 13.6 and Quiz 14.4 to 14.6.

Figure 1





Figure 2 displays class averages on all four quizzes and class averages when *Phase A* and *Phase B* averages are combined. Scores were taken from a total of 30 points on all four quizzes. Quiz 13.1 to 13.3 had a class average of 21.308 points or 71.03% with a range from 12-29 and a standard deviation of 5.040. Quiz 13.4 to 13.6 had a class average of 19.615 points or 65.38% with a range from 12-28 and a standard deviation of 4.700. Quiz 14.1 to 14.3 had a class average of 23.000 points

or 76.67% with a range from 14-28 and a standard deviation of 4.223. Quiz 14.4 to 14.6 had a class average of 25.231 points or 84.10% with a range from 18-30 and a standard deviation of 3.789. However, it should be noted that student 4 was either absent or suspended during several lessons and his scores have been removed from the class averages, since his results were not dependent on how the lessons were conducted.

Figure 2



Class Averages on Quizzes

When the quiz results are grouped by *Phase A* and *B*, *Phase A* quizzes had a class average of 22.153 points or 73.85% with a range from 15-27.5 and a standard deviation of 4.140. *Phase B* quizzes had a class average of 22.423 points or 74.74% with a range from 16-28 and a standard deviation of 3.101. *Phase B* quizzes increased an average of 0.269 points or 0.90% over *Phase A* quizzes. Individual student change in scores ranged anywhere from a five-point drop to a six-point gain from *Phase A* to *Phase B* quiz performances. Overall six of the fourteen students increased their quiz averages while eight of the fourteen students decreased their quiz averages (including student 4).

Survey Results

Survey questions as presented to the students are listed in Figure 3.

Figure 3

Self-Efficacy Survey Questions

8. I am content with my current performance in math class

Survey results based on class averages grouped by phase are displayed in Figure 4. The eight questions were scored using a 7-point Likert scale. Question 2 and question 5 were reverse scored. Class averages were again calculated without data from student 4. Based on class averages, questions 2 and 4 increased 0.364 and 0.406 respectively, while questions 5 and 6 decreased 0.154 and 0.224 respectively. Responses to question 2 ranged from 1 to 7 with a standard deviation of 1.474. Question 4 responses ranged from 1 to 7 with a standard deviation of 1.969. Question 5 responses ranged from 1 to 7 with a standard deviation of 1.955. Question 6 responses ranged from 1 to 7 with a standard deviation of 2.010. Questions 1, 3, 7, and 8 had a change $< \pm 0.1$ of a point, and therefore displayed no significant change.

Figure 4

Survey Results for Phase A and Phase B, by Question



Figure 5 shows class average scores for all eight questions during each of the four survey

sessions.

Figure 5

Class Average of Survey Results by Session



Formative Assessment Reports

Data was also collected from the Senteo Interactive Response System software during *Phase B* lessons using technology for formative assessment. Figure 6 shows class averages of correct responses collected from the wireless handhelds during each lesson.

Figure 6



Formative Assessment Reports from Senteo Interactive Response System

For classroom lessons, students input responses ranged from four to five questions collected during the lesson to reinforce concepts being demonstrated, with the exception of Lesson 13-6 where only one of the five planned question responses was collected. Review of homework for 13-5 extended into time for the 13-6 lesson, and response collection was eliminated due to time constraints. Review for 13-4/6 collection was limited to 4 of the 11 questions in the PowerPoint, because time for lesson 13-6 was extended into the next day. Homework response collection ranged from 9 to 18 inputs depending on the assignment. Review for 14-4/6 response collection covered 10 of the 11 questions in the PowerPoint.

For the formative assessment data collected, individual lesson scores ranged from 0% to 100% with a standard deviation of 30.25%. Individual homework scores ranged from 0% to 100% with a standard deviation of 30.45%.

Discussion, Recommendations, and Conclusions

Evaluation of Results

Quizzes. There was an improvement of 0.9% from the quizzes given during *Phase A* to *Phase B*. This is consistent with findings of previous research that demonstrated improved student achievement with the use of networked classrooms (Roschelle et al., 2004). However, the improvement from *Phase A* quizzes to *Phase B* quizzes was not substantial. There are several factors that may have contributed to this. The scores for quizzes in lesson 13 from *Phase A* to *Phase B* decreased 5.65%, while the scores for quizzes in lesson 14 from *Phase A* to *Phase B* increased 7.43%. It was the marked gain from lesson 14 that led to an overall gain for the entire study.

Several factors were felt to have contributed to poorer performance on Quiz 13.4 to 13.6. In particular, the methods applied to lesson 13.4 and 13.5 were not used in lesson 13.6 due to time constraints. Responses from students were not collected with the wireless handhelds to provide feedback during lesson 13.6. This was mainly due to loss of time from an extended review of homework 13.5 from the previous day. The students were not grasping the homework and needed corrective feedback. This, after all, is one of the underlying principles of formative assessment. However, instead of extending the overall timeline for the next lesson, the teacher tried to keep to her original schedule as planned in her lesson plans. This led to inadequate coverage and less formative assessment provided on lesson 13.6 and the quiz review.

Lesson 13.6 also covered material, inscribed angles and the coordinate equation of a circle, which the students have never been exposed to before. The other lessons involved material that had been scaffolded through the learning spiral of grade-indicator development. From previous teaching experience, these concepts have proven difficult to master. Given the level of material taught and the loss of proper formative assessment as designed in the study, the scores from Quiz 13.4 to 13.6 were not felt to truly reflect the techniques planned for in the study. The study may have been better served

by using a second control group where the scores were more of a reflection of the teaching techniques, and not the material being taught.

Surveys. Questions 1, 3, 7, and 8 displayed no significant change when comparing student averages from *Phase A* to *Phase B*. However, it is interesting to note that all four of these questions mirrored the quiz performance patterns. The students' Likert scores decreased for lessons 13.4 to 13.6. Questions 3, 7, and 8 were all reflections of the students' view of their performance, while question 1 was a reflection on their level of understanding. This data supports the hypothesis that a lower self-efficacy is linked to lower achievement, and vice-versa.

Both questions 2 and 4 showed increases from *Phase A* to *Phase B*. Question 2 was reversescored and dealt with feelings of learned helpless and avoidance. Question 2 had the smallest standard deviation of 1.474 suggesting students were more closely united in their views. In fact, only four of the 50 responses collected received a score of three or less (reverse-scored). The feedback provided by the formative assessment in *Phase B* did appear to improve student attitudes about their capabilities to learn mathematics. This supports previous research that students base their perceived ability in math on how well they complete and master the tasks given to them in class (Chouinard et al., 2007; Siegle & McCoach, 2007; Usher & Pajares, 2009). Providing students in class with opportunities to demonstrate mastery during a lesson by collecting student responses and increasing engagement reinforces their perceptions of their own ability. It is interesting to note that during lessons 13.4 to 13.6 the Likert scores only decreased an average of 0.3076 points on this question compared to the much larger drops in questions 1, 3, 7, and 8.

Question 4 displayed the most significant improvement, increasing 0.406 Likert points from *Phase A* to *Phase B*. This question dealt with lesson enjoyment, and clearly indicates that students liked the interactive engagement provided by the wireless handhelds. From observation, the students were more comfortable with multiple choice options, than open-ended, numerical responses. It was also more likely that students understood a question, but missed the open-ended collection input due

to mistypes or errors such as decimal placement. However, these mistakes could be pointed out when responses were displayed on the board. The multiple choice option was more likely to ensure a correct response from the student. Question 4 also displayed a decrease in Likert scores on lessons 13.4 to 13.6, so even the enjoyment value of using the wireless handhelds did not override the feelings of not learning during this lesson.

Questions 5 (reverse-scored) and 6 displayed decreases in Likert scores from *Phase A* to *Phase B*. Although both scores decreased, they exhibited the least amount of variation of all the question responses. The class averages for question 5 differed by only 0.538 points, and dealt with the students' attitudes towards challenging problems. The class averages for question 6 differed by only 0.461 points, and dealt with the students' view of utility for math. However, question 6 had the greatest standard deviation of 2.010 among answers, indicating that although individual responses did not vary much between survey sessions, the students were more divergent on their views of utility. This suggests that regardless of students' views of their ability, these two factors are weakly influenced by the material being taught, or how well the students believe they understand the material. Chouinard et al.'s (2007) research supports the notion that outside influences, such as parental views and support, are more strongly associated with the students' value of mathematics, while the teacher has a greater influence on the students' beliefs of competence.

Formative Assessment Reports. The data provided by the Senteo Interactive System software also supports the trends seen in the quizzes and self-efficacy surveys. In lessons 13.4 to 13.6, classroom averages were consistently in the 50% range. The homework for these lessons ranged from 16.23% to 35.70% accuracy. For lessons 14.4 to 14.6, formative assessment during the lesson improved and ranged from 45.83 % up to 80.00%. The homework scores for these lessons were significantly better ranging from 57.70% to 86.80%. It could be interpreted that the positive feedback provided from accurately responding to questions during lesson 14 led to an improved desire to achieve on this homework. However, even with corrective feedback, if there is not enough positive

reinforcement during a lesson, the students are more likely to not take interest in the homework, or even dismiss it entirely. Another important consideration when looking at the data is the fact that the students were initially exposed to the wireless handhelds during lesson 13, and spent time learning their use. By lesson 14, students were much more comfortable with the operations of the wireless handhelds, and could concentrate more on the content of the lesson.

Negative Consequences of Classroom Response Systems

Some negative consequences were observed during *Phase B* using the Senteo Interactive Response System. Foremost, there was a marked drop in note-taking and showing work for calculations. As part of the traditional routine in the classroom, notebooks were collected at the end of every lesson and scored for a participation grade based on note-taking, homework completion, organization, and keeping all class paperwork. There was a noticeable drop in the amount written on both the note packets and the homework worksheets. Some students seemed to feel that since their responses were getting collected electronically, there was no longer a need to record them in writing. This poses a problem in mathematics class, where one of the greatest challenges as a teacher is to teach students to communicate their problem-solving process. The OGT emphasizes the need for this skill by using short answer and extended response questions on state assessments. For this reason, this study chose to use paper and pencil quizzes for the final assessment, but if the students are not practicing written responses during the lesson, will the quality of responses diminish?

Another short coming of the electronic responses was the increased likelihood for the students to make random guesses. For instance, even though it was observed in the notebook checks that some of the students did not complete a homework worksheet during *Phase B*, these same students input answers for all the questions when this homework was collected using the Senteo. Concern should also be raised whether the response entered is truly the student's work or not. Even when formative response collection occurred during lessons, there was the possibility that a student asked his or her neighbor what to input. However, these concerns are present even with traditional lecture techniques.

It can be pointed out that even if a student is getting the answer from another source, they are still actively engaged and aware of the correct answer. This cannot be said about traditional lectures where a student may choose not to participate at all.

Effective Formative Assessment

Fies and Marshall (2006) listed several benefits of classroom response systems following their review of the literature. These included greater student engagement, increased student understanding of complex subject matter, increased student interest and enjoyment, heightened discussion and interactivity, increased student awareness of individual levels of comprehension, and increased teacher insight into student difficulties. However, just using a classroom response system does not guarantee that the benefits of formative assessment are occurring in the classroom. Owens, Pape, Irving, Sanalan, Boscardin, and Abrahamson (2008), in their comprehensive research involving 118 teachers using interactive technology, found that teachers did not make full use of the available formative assessment. Not all teachers changed their instructional procedures based on the data they had collected about students' knowledge. The goal of a networked classroom is to make education more learner-centered. Instructors and students should use the technology to increase awareness of students' understanding, leading to more responsive instruction (Fies & Marshall, 2006).

Guskey (2003) argued for three important changes in the use of assessments to improve instruction in education; make use of information gathered by assessments, follow assessments with corrective instruction, and give students second chances to demonstrate success. One of the concerns raised about the use of corrective instruction is the time intensiveness "re-teaching" that may affect the quality of other curriculum. However, Guskey contends that as corrective instruction is instituted, students become more prepared for future learning tasks, and less and less time will be allocated to corrective work. In this way, formative assessment can be viewed as the preventative medicine of education. Although time and effort must be applied initially, the long term result will be a healthier, smoother running educational system. As demonstrated in this study, teachers and administrators must acknowledge the need to be flexible in lesson planning, and permit adjustments to scheduled timelines.

One of the most notable advantages discussed in the research involving interactive technology, is the increased interaction and discussion occurring in the classroom. Hegedus and Kaput (2004) state "the paradigm is shifting towards one where the technology serves not primarily as a cognitive interaction medium for individuals, but rather as much more pervasive medium in which teaching and learning are instantiated in the social space of the classroom" (p. 130). The authors suggest interactive technology gives students both individual responsibility and group accountability to contribute to the construction of concepts through vicarious participation. It is important to remember that the classroom responses systems themselves are just a tool. It is up to teachers and students to effectively use this tool to create better classrooms.

Implications for Practice

Technology Used for Formative Assessment

Evidence exists to support good use of formative assessment in the classroom benefits student learning. However, like most educational methods, there is not a simple solution such as introducing a new form of technology into the classroom. Penuel, Boscardin, Masyn, and Crawford (2007) surveyed 498 educators using classroom response systems in their instruction and found the educators who reported the most success with the technology were also the instructors who were more likely to have had professional development with the technology for using a broad array of strategies in the classroom. As with most educational philosophies, the underlying principle of success is proper implementation and professional development.

Fies and Marshall (2006) identify several aspects of classroom response systems that currently need to be researched. These are tighter controls eliminating variables other than the response system as the source of improved learning; more diverse use of different pedagogies when using response systems; more comparisons varying diverse populations and diverse content; and how response systems affect efficacy in individual versus group modes of learning. The research done for this paper confirms the need for tighter controls. Also, little research has focused on the needs of students with learning disabilities. Many students with learning disabilities are now included in general education classrooms where such technologies are being used. The freedom to respond with anonymity using the wireless handhelds allows for private accountability without any public humiliation (Fies & Marshall). More research should focus on whether this improves self-efficacy in students with disabilities, and whether behaviors such as learned helplessness and work avoidance are decreased.

Research measuring levels of self-efficacy relies on self-reported data, and makes it difficult to objectively measure concepts such as the effort applied by the student (Chouinard et al., 2007). Caution must also be taken in generalizing the results of self-efficacy research to a broad population. For instance, research has demonstrated that girls are more likely to engage in mathematics because of success expectations, while boys are more influenced by value and goals (Chouinard et al.). Differences in gender, age, and ethnicity result in different influences on individual self-efficacy. Therefore, uses of technology such as classroom response systems should be examined for a variety of influences that contribute to task engagement and self-efficacy.

Finally, caution should be taken when introducing new teaching techniques. Learning gains in one area may be accompanied by losses somewhere else, as demonstrated by the reduction in note-taking and showing work for calculations in this study. With emphasis on the development of higher order thinking skills, the reduction of detailed work requiring students to communicate their problem-solving process is a valid concern. But one should also question whether the skills such as traditional note-taking are truly influential in the learning process, or is it just too hard to give up some traditional aspects of teaching? The use of electronic response collection may be sufficient for students being taught with modern 21st century learning skills. Some researchers are finding the rich communication being developed from classroom discussions using displays from electronic response

collection are improving constructive cognitive development and higher-order thinking skills (Fies & Marshall, 2006; Hegedus & Kaput, 2004; Owens et al., 2008).

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Appendix

Individual Student Scores

