USING HANDHELD COMPUTERS FOR CONSTANT DAILY REVIEW IN SIXTH GRADE MATHEMATICS

by

Faye Bland Obenschain

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A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy at George Mason University

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DEDICATION

This is dedicated to my daughters, Claudia and Julia. Always remember to finish what you start. It is also dedicated to my loving husband, Jeff, for all his support in this huge, long undertaking.

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ABSTRACT

USING HANDHELD COMPUTERS FOR CONSTANT DAILY REVIEW IN SIXTH GRADE MATHEMATICS

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This mixed methods study compared mathematics achievement after students reviewed using handheld computer games or using teacher-led reviews. A total of 54 sixth grade students were involved in the study. The study examined achievement by ability level and student gender.

The study occurred in one semester time frame during regular school hours in a public middle school. Students participated during their regularly scheduled mathematics classes. Each day in mathematics class, the students reviewed previous concepts taught to help keep the concepts easily accessible to the students' memory. This is usually accomplished by the teacher leading the review using a projector to ask questions. This was the teacher-led type of review. During the intervention, instead of completing the teacher-led daily review, the students used the same amount of time each day in class to review mathematical concepts using the handheld computers. The units were alternated with handheld computer units being first, third, and fifth; whereas, teacher-led reviews

were conducted during the second, fourth, and sixth units. The research questions were examined across multiple units and within each mathematical unit.

A within-group equivalent time series design was employed. The three different ability groups were compared across their own achievements over time. They were compared to themselves; not a different comparison group. Quantitatively, a pretest-posttest design with multiple measures was used to measure students' retention of mathematical concepts for low-ability, average-ability, and high-ability learners and for male and female learners. A delayed posttest was used to analyze retention later in the school year. Qualitatively, the teacher kept a journal that contained questions primarily about game design and observations of students' perceptions.

Overall, students who reviewed using the handheld computer mathematical games obtained a mean gain score on unit 1, unit 3, and unit 5 tests of 82.28 (SD = 30.00) and students who reviewed using the teacher-led reviews obtained a mean gain score on unit 2, unit 4, and unit 6 tests of 58.81 (SD = 45.64). Results from the paired samples t-test were statistically significant, $t(52) = 4.42$, $p<.001$. For student ability, this study showed that average-ability students using handheld computer mathematical review games do retain more mathematical content on unit tests. As for gender, average-ability female students using handheld computer mathematical review games retained more mathematical content on unit tests.

1. Introduction

Statement of the Problem

Student retention of mathematics concepts has long been a concern of teachers. Not only do teachers have to deal with students "losing" their knowledge over the summer break, teachers have to deal with students' lack of retention of concepts taught during the school year. Rohrer and Taylor (2006) found that long-term retention was boosted by distributed practice. In 1995, Wineland and Stephens concluded that spiral testing with continuous review did aid in the retention of mathematical concepts for below-average mathematics students. Research has shown that constant and cumulative review is best for students to retain the knowledge. Ideally, the review should be daily.

Retention of mathematical concepts is becoming even more important to public schools since the implementation of the federal No Child Left Behind Act of 2001. Now public schools are held accountable for student achievement based on standardized tests given in each state. These high-stakes tests have a lot of monetary consequences including the withdrawal of federal funds to school systems that are not complying with NCLB. Therefore, there is more pressure than ever for teachers to find new strategies to help facilitate long-term retention of mathematics concepts.

Technology use is becoming more prevalent among all populations, especially students. The National Council of Teachers of Mathematics (NCTM) stated in their

technology principle: “Technology is essential in teaching and learning mathematics; it influences the mathematics that is taught and enhances students’ learning” (p. 24, 2000). It further states the importance of teachers knowing how and when to use technology.

Technology use in the classroom is very motivating for most students. It meets different learning styles of the students. Even in 1985, Robert Gagne noted that different types of instruction are required for different learning outcomes. Some schools have computer labs that teachers sign up to use, and the students go to the computers. Some schools have mobile computer labs so the computers are brought to the students. The problem with many mobile computer labs is that they are very slow in operating and still take time to set up in the classroom. Handheld computers are much faster and easier to manage in the classroom. They are also only a fraction of the cost of laptop computers.

Computer-assisted instruction (CAI) is defined as any instruction where computers are used to teach or assist in the instruction. Computer-assisted instruction (CAI) has been studied since computers have been used in education. Two meta-analyses of CAI reported that more studies are needed on the effectiveness of CAI looking at student characteristics such as gender and ability (Akiba, 2002; Fletcher-Flinn & Gravatt, 1995). This study addressed whether using technology, specifically handheld computers, will influence longer-term retention of mathematical concepts among low ability, average ability, high ability, and male and female sixth grade learners.

Research Questions

The purpose of this study is to investigate the impact of playing games on the Palm® handheld computers in the sixth grade mathematics classroom on student

retention of mathematical concepts. In particular, the following research questions will guide this mixed methods study: (a) What is the relationship between student ability and performance on unit tests after using handheld review mathematical games? (b) How does students' ability influence students' retention of mathematical concepts? (c) What is the relationship between student gender and performance on unit tests after using handheld review mathematical games? (d) How does students' gender influence students' retention of mathematical concepts? These questions will be examined across multiple units and within each mathematical unit.

Delimitations

This mixed methods study included quantitative scores from pretests, posttests, and delayed posttests on unit tests. I also kept a journal about the students' use and perceptions of the games. The study did not include student interviews because the Human Subjects Review Board would not permit me to interview my own students.

The handheld computer review games used in this study were free software. The settings were left at the default for each game. Additional variables of game settings were not introduced into this study. This was found to be a limitation of this study.

2. Literature Review

Introduction

In this chapter, I reviewed the literature pertaining to the use of handheld computers for constant daily review in the sixth grade mathematics classroom. Since there is very little research on this specific topic, I broke the research into parts. The first section reports on technology use in the classroom. It begins with computers in the schools, and is followed by student motivation, student gender, student ability, computer-assisted instruction (CAI), handheld computers, and mathematical computer games. The second section discusses the literature on drill and practice. The third section discusses concept retention in mathematics. The final section addresses research implications.

Research on Technology

In this technological age, I have found that students prefer using computers to sitting in a classroom listening to the teacher or doing paper-based activities. The presence of computers in education has grown rapidly. In 2002, ninety-two percent of public school instructional rooms had Internet access (Kleiner & Lewis, 2004). Most public schools have access to the Internet, however, student access to computers remains limited (Peet, 2002). This is primarily due to the placement of computers in the school building (Livingston & Wirt, 2005; Schoepp, 2005). Some schools equally distribute computers so that each classroom has one or two computers; whereas, some schools place

computers in computer labs. Usually teachers have to sign up to use the computer labs, sometimes even up to a month prior to use. Due to this limited access to computers, the average public school student rarely uses a computer in their main academic subjects (Roschelle et al., 2000; Setati, 2003; Soloway et al., 2001).

Student Motivation

The research on technology use in the classroom shows that most students are more motivated when technology is used in the classroom (Abrams, 2008; Brookhart, 1997; Chouman, 1996; Kahn, 1985; Ke, 2006; Kebritchi, 2008; Kohn, 1999; Kulik, 1994). Most of the students are far more technologically savvy and comfortable using technology than their teachers (Ostler & Grandgenett, 2002), which presents a barrier for some teachers to incorporate technology in their classroom.

Technology can be a great motivator if used properly. Halverson (2005) describes computers as providing compelling activities for motivating otherwise indifferent learners but finding the appropriate math software and using it effectively is another challenge (Kaput, 1992; Murray et al., 1999; Squire, 2005). Evidence of technology's motivating influence can be seen in other ways. Hansen (2003) noted that in a school where a laptop program was implemented they found student attendance had increased and student disciplinary problems had decreased. Once the students are more likely to attend school, then educators can motivate students to be actively engaged in learning tasks by using technology (Akiba, 2002). One example of a handheld computer motivating students is when an elementary teacher had the students use handhelds to build an animation (using a program called Sketchy) showing how long division works.

The students finished the division unit ten days earlier than the other three classes in their grade. They also scored better on the division test (Ostler & Grandgenett, 2002). Student motivation is usually a key benefit of technology use in the classroom.

Student Gender

Some studies show girls have less positive attitudes towards technology, especially when it comes to video games (Inkpen et al., 1994). Observing children while they played electronic games at an interactive science museum, Inkpen et al. (1994) reported that girls did like the games when they were able to socially interact with others. Van Eck (2006) believes girls less positive attitudes towards technology are due to their difference in experience with technology. This was not the case in 1985 when Carrier, Post, and Heck found fourth grade girls had the same positive attitudes as boys and made greater gains in retention of division facts when they used computers. In a study of fourth grade learning disabled students with drill and practice on the computer, the three boys gained more on the daily timed multiplication facts worksheets than the three girls but attitude was not addressed (Chiang, 1986).

Some researchers argue that it has more to do with age than with gender, however results vary. With kindergarten to third grade students, Caftori (1994) found minor gender differences after analyzing questionnaires about software characteristics that were given to the 60 students. Fertsch (1985) looked at the attitudes towards computers of 115 seventh and eighth grade students. She found there were no significant effects of gender on attitudes.

In 1995, Claire Fletcher-Flinn and Breon Gravatt published the results of their meta-analysis of computer-assisted instruction (CAI). Working at the University of Auckland, they looked at quantitative results of experimental versus comparison groups using CAI. They included 120 studies from 1987-1992 that were free from obvious methodological flaws and easily retrievable. Their meta-analysis looked at nine variables including: grade level, course content, publication year, duration of treatment, teacher effects, CAI type, subject assignment, comparison group instruction, and retention. The effect size did not differ significantly with grade level, duration of treatment, teacher effects, retention of information over time, and type of CAI. The effect size was higher with mathematics than other subjects. They felt this may be due to more benefit with drill and practice programs in mathematics than reading and writing.

When Fletcher-Flinn and Gravatt (1995) completed their meta-analysis of CAI, they found girls benefited more from the use of computers and elementary students benefited more than older students. Their study included all ages of students. In Niemiec, Sikorski, and Walberg's (1996) meta-analysis of CAI, they looked at twenty-four studies and found younger, less able students achieved more but "most students are better off without CAI" (p. 172).

Similar findings to Fletcher-Flinn and Gravatt's findings about age were discussed in the much-cited Kulik, Kulik, and Bangert-Drowns (1985) meta-analysis of computer-assisted instruction. Looking at 28 computer-assisted instruction studies from the 1960's until 1984, they included 24 drill and practice and four tutorial studies. Four studies used grades 1-3, 11 studies used grades 1-6, and 13 studies used grades 4-6. There

were 15 low ability studies and 13 average ability studies included in their meta-analysis. The subject matter included 17 mathematics studies, seven language or reading studies, and four which included a combination of subjects. The years of publication included five before 1969, 12 from 1970-1974, six from 1975-1979, and five from 1980-1984. They found that CAI had the strongest effects in elementary school children. CAI was most beneficial for the achievement of the low ability students.

Most of the studies researching students' gender when using technology were written prior to 2006. In 2002, Akiba wrote in her chapter about the need for more studies on the effectiveness of computer-assisted instruction looking at student characteristics such as gender and ability. As you will read in the next section, there are few studies on computer use benefits for high-ability, average-ability, and low-ability students.

Student Ability

Educators are looking for the best strategies to help all students learn. At-risk students are frequently studied. In a college setting, Dedeo (2001) found that CAI was most beneficial to at-risk students. She looked at the success rate of college algebra classes that used interactive computer software (16 sections) to the traditionally taught classes (13 sections). The software group scored significantly higher, especially the at-risk college students. Bishop and Forgasz (2007) found that ability grouped students' technology use was related to the grouping level and the student's home access to technology. They noticed higher ability students and middle class students used technology more.

Looking at the effect of computer-assisted instruction on the achievement of at-risk students, Motoko Akiba (2002) conducted a meta- analysis of 17 studies from 1986 to 2002. She determined the average effect of a given intervention. She examined the three program characteristics of subject area, grade level, and nature of computer-assisted instruction. The subject area included mathematics and literacy. Grade level was broken into grades 1-2, 3-5, 6-8, and 9-12. The type of CAI included drill and practice, project and problem solving, or mixed. Most studies used pretest-posttest design between treatment and control groups. “The overall effect size was .37, which can be translated into a percentile difference of 14 points between the average achievement of the treatment group and the control group”, (p. 100-101). This means that CAI has a significantly positive effect on increasing the achievement of at-risk students.

Comparing the effects of CAI in mathematics to the effects of CAI in literacy, Akiba found the mean effect size for CAI in mathematics was .57, and a mean effect size of .16 in literacy. The difference in these compared mean effect sizes was statistically significant. Therefore, Akiba concluded that CAI in mathematics improves the achievement of at-risk students more than does CAI in literacy.

When comparing the effects of CAI in the various grade levels mentioned above, Akiba found the mean effect sizes were not statistically significant primarily due to the small sample size. The highest mean effect was on grades 9-12, followed closely by grades 1-2. Grades 3-5 and grades 6-8 had the lowest mean effect sizes. The mean effect sizes were calculated for the type of CAI implemented. The largest mean effect size was for the mixed program, followed by the project and problem solving mean effect size, and

finally drill and practice. The findings were not statistically significant. For all ages, Fletcher-Flinn and Gravatt (1995) found in their meta-analysis that high ability students using CAI improved more. However, in Akiba's (2002) meta-analysis, she found CAI to be more beneficial for at-risk students. Both of these meta-analyses included all ages of students.

Computer-assisted Instruction (CAI)

When searching for studies on technology, I found most handheld technology use in the mathematics classroom is with graphing calculators and computer algebra systems (CAS). I looked into CAI and found many older studies when computers began to be used in education in the 1970s.

Most of the following studies found CAI as an effective strategy but there are some other important findings. In his more recent meta-analysis on CAI studies, James Kulik (1994) concluded that it takes less time for students to learn certain concepts when they receive CAI and students score higher on achievement tests when they used CAI. In two different studies, regular education fourth and fifth grade students who used CAI improved more than the non-CAI students (Carrier, Post, & Heck, 1985; Steele, Battista, & Krockover, 1983). In a 1996 study of fourth grade children, Wittman looked at mathematics anxiety and the use of CAI. The high anxiety students showed the greatest improvement but more interesting to note is that the high anxiety girls reduced anxiety after using CAI. While I am not specifically looking at mathematics anxiety, this factor may impact gender studies of handheld computers.

Moore (1988) studied 117 remedial seventh and eighth grade math students. Rather than CAI, teacher personality was found to be a major influence on student achievement. Regardless of whether the student used CAI, if the teacher had a positive personality towards the student and mathematics, the student showed more improvement. I feel that was another variable that needed to be controlled. The teacher in my study needed to keep the same personality whether using CAI or not.

Looking at the importance of a one-to-one relationship of computers to students, Ferrell (1986) reported that sixth grade students who used CAI for an entire school year showed significant mathematics achievement. This is another reason to use handheld computers so the students will have that 1:1 ratio (Bayraktar, 2002). Educators also need to remember the importance of using CAI appropriately. Three more recent studies show the importance of using CAI as a supplement (Dedeo, 2001), not as a substitute for traditional instruction (Bayraktar, 2002; Christmann & Badgett, 2003).

Handheld Computers

One solution to help increase student access to computers is by using handheld computers (Bannasch, 2000). Handheld computers, also called PDAs (Personal Digital Assistants) or Palmtop calculators, put computing power in the individual student's hands. Primarily due to their lower cost, when compared to a regular computer, handhelds are finding their way into classrooms but there is little research on the effectiveness of handhelds in the classroom. Newly developed small laptop computers are becoming comparable in price to handheld computers. A 2001 study about Palm handheld computers was funded by the company (Hansen, 2003). Palm provided 86

classrooms with handhelds and since this study, school spending on handheld computers for classroom use has increased from about $40 million in 2003-2004 to nearly $300 million in 2005-2006. Still there are more school-issued laptop computers than school-issued handheld computers. Instructional technology and literacy consultant Kellie Doubek states some advantages of handheld computers by saying "along with their mobility and lower price, they promote interaction among students far more than laptop computers do" (Briggs, 2006, p. 2). Tony Vincent, a fifth-grade teacher who is a major proponent of using handhelds in the classroom, states the "market has exploded" since he began using them in 2001 (Briggs, 2006).

Stephen McNew published his doctoral dissertation in 2008 on the relationship of handheld computer use to student achievement in middle school mathematics. His quantitative study looked at 286 sixth grade mathematics students and their academic achievement on the national norm-referenced test, the TerraNova®. Two teachers used handheld computers to supplement their curriculum during the second semester of a school year. The 152 experimental students had full-time access to handheld computers during that semester. He found there was significant improvement in student achievement on the TerraNova®.

While there aren't any peer reviewed journal articles on using handhelds for review purposes in mathematics, there are some internet-based comments from teachers who have used the Palms. Harvard researcher Chris Dede (Feldman, 2004) states it is hard to find scientifically rigorous data on a lot of innovations in educational technology because the field is moving too fast. I found this to be especially true when researching

handheld use in the middle school mathematics classroom; therefore, I broadened my search.

There have been studies on the use of handheld computers in nursing, medical fields, law, and it is increasing in K-12 classrooms, however with most other disciplines (not mathematics) (Franklin et al., 2007). Some great uses of the handheld computer are for real-time data collection in scientific investigations, especially when using the probes (Gado et al., 2006; Tuttle, 2007). The major benefits of using handhelds are the mobility and lower cost than computers (Franklin et al., 2007; Gado et al., 2006; Mason & Dralle, 1999; Roschelle, 2003; Schrock, 2005). McMaster (2005) noted that poor technology (e.g., slow computers) can hinder student motivation and learning. Handheld computers are much faster than computers (Franklin et al., 2007). Lang (1999) notes that PDAs are ready when the students are ready to work, and due to their lower price more schools are able to achieve a 1:1 ratio. Depending on your opinion, one of the biggest benefits of technology use is that instruction may change from teacher-centered to more student-centered (Waxman & Huang, 1996). The biggest compliment for PDAs is when Ostler and Grandgenett (2002) called them the 21st century Swiss Army knife: one small device that can act as many different tools. Another benefit for learning with handheld computers is the social interaction it may create. Students are able to stand up and walk around with the handheld computers, which is difficult with laptop or classroom computers. Russian psychologist Lev Vygotsky explained in his zone of proximal development theory that children learn more effectively when they have others to support them and that social interaction is an integral part of learning (Powell & Kalina, 2009).

Due to the mobility of handheld computers, the students can be afforded social interaction.

Some of the problems with handheld computers are the screens being damaged, problems with synchronization, and inappropriate use by students (Batista, 2001; Franklin et al., 2007). Tony Vincent reports they generally have a four-year life span (Briggs, 2006). Franklin et al. (2007) discovered that 12% of the Palms did not work when they arrived. Educators need to be aware of these problems and try to minimize the consequences, however they are similar to the problems possible with almost any piece of technology.

Mathematical Computer Games

Since the games used in this study were drill and practice computer games, I looked at the literature on this topic. Neville Holmes (2005) commented that "basic skills such as reading, spelling, and arithmetic are ideally suited to being imparted by drill and practice using simple video gaming techniques" (p. 107). Originally computers were used frequently for drill and practice games. Wenglinsky (1998) looked at 6,227 fourth graders and 7,146 eighth graders' mathematics achievement on the National Assessment of Educational Progress. He found eighth graders gained more in math scores when using simulation and higher order thinking software than fourth graders using similar technology. However, both fourth- and eighth-grade students who used drill and practice software received lower math scores than students who did not use drill and practice games. Ke (2008) also found no significant effect on students' cognitive test performance when studying 15 fourth and fifth graders who used drill and practice

computer games in a summer school mathematics class. She found the students did develop more positive attitudes towards mathematics. Now role-playing games are opening up virtual worlds to students to help them learn and solve problems (Barab, Gresalfi, & Arici, 2009).

In addition to the technology research mentioned above, specific searches for computer gaming in mathematics revealed some dissertations but very few peer reviewed journal articles. In Jordan, Mouhamed Rayya (2001) looked at 101 sixth grade students that were learning addition, subtraction, multiplication, and division. One group was taught traditionally and the other group used computer-based educational games. The study measured immediate and postponed achievement. The group that used computer games saw statistically significant differences in both immediate and postponed achievement. However, looking at gender, there weren't any statistically significant differences.

Studying 33 below grade level elementary and middle school students who played educational computer games prior to receiving normal mathematical classroom instruction, Abrams (2008) found no statistically significant differences in this experimental group and her control group. Interest surveys found computer use improved students' self efficacy in learning mathematics and improved their interest and motivation in mathematics. Computer games should be used to supplement and enhance mathematics instruction. Kebritchi (2008) had different findings about student motivation when studying 193 high school students. She found significant improvement of mathematical

achievement after students in the experimental group used computer games but no significant improvement in student motivation.

Today's students are very comfortable using technology. Many of them play video or computer games daily. They communicate with computers and cell phones. Teachers need to find a way to harness this motivational tool of computer gaming without harming learning. Even with different results, most researchers commented on teachers needing to find the best way to use computers to supplement instruction for further comprehension.

Research on Drill and Practice

There have been some interesting studies on drill and practice in mathematics. Woodward (2006) found an integrated approach of using strategies for teaching facts and using timed practice drills helped 58 fourth graders perform better. In 1985, Fuson and Brinko tested 84 second, third, and fourth graders on their basic facts. They found that equivalent learning occurred when using computers and when using flash cards. Drill and practice games may lead to modest increases in computational speed and accuracy (Becker, 1990). On a small study of seven elementary students in Israel, Hativa (1988) looked at CAI for drill and practice in mathematics. She found that high-achieving students benefited more from CAI because they were more able to adjust; whereas, low-achieving students made less progress because of computer user errors. This is another variable that had to be addressed in my study because this may be true of the high-achieving and low-achieving students in my study. Finally, as stated earlier, in the meta-

analysis of CAI by Akiba (2002), drill and practice CAI was found to improve the achievement of at-risk students.

Research on Skill Retention

Retention of mathematics skills has long been a concern of teachers. Not only do teachers have to deal with students "losing" their knowledge over the summer break, teachers have to deal with students' lack of retention of procedures taught during the school year. Rohrer and Taylor (2006) found that long-term retention was boosted by distributed practice. In 1995, Wineland and Stephens concluded that spiral testing with continuous review did aid in the retention of mathematical concepts for below-average mathematics students. Research has shown that constant and cumulative review is best for students to retain the knowledge (Burns, 2005; Hazlett, 2001).Ideally, the review should be daily. This study looked at whether or not using handhelds in the classroom improved students' retention of mathematical skills.

The research on retaining information is not a topic of much recent interest. Teachers have wanted to know how to best help students with retention for many years, even as far back as 1929 when Morgan used specific training of sixth grade students in arithmetic that helped retention over the summer. Research shows that retention is boosted by distributed practice or daily reviews (Good, 1978; Hett, 1989). While some studies state that it is more effective with below-average mathematics students (Hartzler, 1984), Klausmeier and Feldhusen's (1959) study on students that were almost ten years old showed that retention of mathematical learning was the same among low, average, and high ability students when the task was graded to the learner's achievement level.

This study supported working with students on their ability level and challenging them appropriately; not giving all students the same instructional level materials.

Research Implications

Since handheld computer use is a recent advancement in technology, there is little research addressing the use of handheld mathematical games to influence students' retention of mathematical concepts. More specifically this study will see what, if any, influence the use of handheld computers have for low ability, average ability, and high ability learners of mathematics. This study will also see what impact, if any, handheld computers in the mathematics classroom have on male and female sixth grade learners.

Retention of mathematical concepts is becoming even more important to public schools since the implementation of the federal No Child Left Behind Act of 2001. Now public schools are held accountable for student achievement based on standardized tests given in each state. These high-stakes tests have a lot of monetary consequences including the withdrawal of federal funds to school systems that are not complying with NCLB (Wilson, 2007). Therefore, there is more pressure than ever, for teachers to find new strategies to help facilitate long-term retention of mathematics skills. Technology use is becoming more prevalent among all populations, especially students. This study addressed whether using technology, specifically handheld computers, influenced longer-term retention of mathematical concepts among low ability, average ability, high ability, and male and female sixth grade learners.

3. Methods

Research Questions

The purpose of this study was to investigate the impact playing games on the Palm® handheld computers in the sixth grade mathematics classroom on student retention of mathematical concepts. In particular, the following research questions guided this mixed methods study: (a) What is the relationship between student ability and performance on unit tests after using handheld review mathematical games? (b) How does students' ability influence students' retention of mathematical concepts? (c) What is the relationship between student gender and performance on unit tests after using handheld review mathematical games? (d) How does students' gender influence students' retention of mathematical concepts? The questions were examined across multiple units and within each mathematical unit.

Research Methodology

This mixed methods study occurred over one semester during regular school hours in a public middle school. Students participated during their regularly scheduled mathematics classes. A within-group equivalent time series design (Creswell, 2005) was used. The three different ability groups were compared across their own achievements over time. They were compared to themselves; not a different comparison group. Quantitatively, a pretest-posttest design with multiple measures was used to measure

students' retention of mathematical concepts for low ability, average ability, and high ability learners and for male and female learners. A delayed posttest was used to analyze retention later in the school year. Qualitatively, the teacher kept a journal that contained notes primarily about game design and observations of students' perceptions.

Participants and Setting

The setting was a public middle school in rural Virginia. Approximately 55 sixth grade students enrolled in the 2008-2009 school year were assigned to classes based on their mathematics ability through standardized testing methods. One below average (low) ability class (12 pupils), one average ability class (24 pupils), and one above average (high) ability class (18 pupils) participated in this study. The demographics varied for each group (See Table 1).

Table 1

Participant Demographics

Class	African American	Hispanic	Asian	White	Total	Female	Male
Low	4	5	0	3	12	4	8
Average	5	7	0	12	24	15	9
High	3	6	1	8	18	11	7
Total	12	18	1	23	54	30	24

The student demographics included 33% African American, 42% Hispanic, and 25% White in the low ability group. There were eight boys (67%) and four girls (33%) in the low ability group. The average ability class (24 pupils) included 20% African American, 30% Hispanic, and 50% White in the average ability group. There were nine boys (38%) and 15 girls (62%) in the average ability group. The above average ability class (18 pupils) included 17% African American, 33% Hispanic, 6% Asian, and 44% White. There were seven boys (39%) and 11 girls (61%) in this group.

During their regular mathematics class, the students usually completed teacher-made daily review questions. This was done using the overhead projector and the teacher asked the students to answer the review questions, one at a time, on individual dry erase boards. This teacher-led review usually took fifteen minutes each day. During the intervention, the students used mathematics games on the handheld computers to help facilitate retention of mathematical concepts instead of the teacher-made daily review questions. The students played assigned mathematical review games for approximately fifteen minutes each day during the intervention.

My students were the only participants in the study since I was the only teacher with access to the Palm® handhelds. I looked into loaning the handheld computers to another teacher but there wasn't another teacher who taught below ability, average ability, and high ability students, a major part of my study. While I know I have certain biases that had to be addressed, I felt this was the best way for me to research this topic. Since all students received the same intervention, I used a within-group equivalent time series design (Creswell, 2005). I looked at three different ability groups and compared

their achievements over time. Since there was only one teacher in the intervention, the groups of students who received the intervention were not compared to a control group. This helped to eliminate validity threats due to teacher differences if another teacher's classes were included. Also the use of one teacher helped improve procedural and treatment integrity.

Action Research

Doerr and Tinto (2000) explain action research as "a cyclic process of problem identification, action, and reflection aimed at changes in practice" (p. 403). I have seen the problem of students not retaining mathematical concepts without constant daily review. In 2008 I conducted a small pilot study on the use of handheld computers in the sixth grade mathematics classroom. My data was very limited due to a variety of factors but the initial findings were positive for student learning. The students enjoyed using the handheld computers and played some of the games used in this study. The students in the pilot study felt the games helped their mathematics concept retention but I did not have any statistical proof that was the case. For this study, I wanted meaningful data to see if I should encourage the use of handheld computers in more of our mathematics classrooms. Our school system was struggling to achieve adequate yearly progress and to comply with the federal No Child Left Behind Act of 2001.

Action research may address teacher learning (Heaton, 1994) or student learning (Lampert, 1986). My goal is student learning. Lampert (1998) looks at action research as blending construction of practice with analysis. Deborah Ball (2000) explains that design plays a critical role in first person research. The researcher-teacher has to create a way to

examine and develop that issue farther. There are some positive effects of being a teacher who is also the principal investigator. Having an ongoing relationship with students enables the investigator to know them more closely. Teachers understand the personalities of the various students in their class better than an outside observer may witness. Teachers may better know how to connect current research with successful student learning (Ball, 2000; Doerr & Tinto, 2000).

There are also some validity and reliability issues that arise when the teacher is the researcher in his/her own classroom. One must overcome the inherent bias of studying in your own classroom (Doerr & Tinto, 2000). The researcher must maintain objectivity and needs a critical edge for proper analysis. Another problem to be aware of during this study was to make sure that my attitude towards technology, reflected in my mannerisms and speech, did not affect the students and their performance, either positively or negatively (Ball, 2000).

Materials

The students used Palm® Tungsten E2 handheld computers during the intervention. Palm® handheld computers are devices that are personal digital assistants (PDA) that have color displays and are less than two hundred dollars each. Not only can they store calendars, contacts, documents, photos, and videos; Palm® handheld computers also have built-in Bluetooth wireless technology so the user can access the web using the classroom computer.

Each student was assigned a Palm® to use for the course of the study. At the end of each class session, the students returned the handheld computers for the next class to

use. The mathematical programs that are already installed were available to the students. The mathematical programs include Math Ace, Divisible, LcmGcf, PowerPlay, and Simplify. Additional programs already installed on the handheld computers were Coconut Fern and Clumps.

The aforementioned programs, installed on the handheld computers, are described in Table 2 and in the text for the additional programs. The students were given instructions as to which program or programs they were to use or they were given their own choice of program, depending on the lesson.

Table 2

Mathematical Handheld Computer Program Descriptions

Program	Topics	Question Format	Answer Format
Math Ace	Addition, subtraction, multiplication, and/or division, also negative numbers	Set up and beam preferences, can use timer, click out of program	First guess or correct quiz for scoring, records score in fraction form-may be exported
Divisible	Practice divisibility tests	One question with yes or no answer choices	Correct-next problem, incorrect-divisibility rule is given
LcmGcf	Find LCM or GCF of 2 or 3 given numbers	Problem given as quiz questions once preferences are set	Correct-next problem, incorrect-same question until correct, raw score
PowerPlay	Guess the missing bases or exponents in equations.	Easy or hard settings. Low score wins.	Final score given after 10 questions. Incorrect-tells if too high or too low but given new question.
Simplify	Reduce fractions to simplest form.	Given fraction, user must reduce.	Correct-“well done”, incorrect-tells the correct answer. Raw score.

Math Ace was played more times by all three ability level classes. The game required students to respond to basic arithmetic questions. The game gave a number pad for the students to tap their answer. Most students found it to be easy. The students who did not know their basic math facts found this game to be harder. Figure 1 shows the screen with a division problem. One flaw of the game was it sometimes counted two wrong when only one was missed. Average ability students commented on the miscounting more than high ability students. Miscounting was not a comment recorded for the low ability students.

Figure 1 Screen shot of the handheld computer game Math Ace.

Divisible is a game that enabled the students to practice their understanding of divisibility rules. The program gave a question that could be answered with a yes or no answer, which the game provided so the student only had to tap the correct answer. An example was “Is 645 divisible by 5?”. Most high and average ability students found it to be easy, especially after multiple days of playing. The low ability students did not like

Divisible. I think the main reason for that is because the students did not learn all the divisibility rules; therefore, making it more difficult for the lower ability students. Lower ability students also seem to have less mastery of multiplication and division facts, which is required for some of the rules.

Power Play required the students to have a good understanding of exponents. Most students found it hard and not fun. After multiple days, some high and average ability students discovered they could use the calculator on the Palm® to help them find the answer. The low ability students did not use the calculator and found this game to be very difficult. Even using the exponent-easy or base-easy settings on this game, some of the numbers were very large. An example is 7 to what power equals 16,807. This game also doesn't give the correct answer; it just says "incorrect-too high" or "incorrect-too low." It would have been helpful if it gave hints or even the correct answer so students could learn from their mistakes. Low score wins in Power Play and this confused some students because they are used to high score winning. As the figure below shows, this game also did not have a game pad so the students had to use Grafiti or use the number pad, both of which take more time.

Figure 2 Screen shot of the handheld computer game Power Play.

GCF presented two numbers and asked the student to find the greatest common factor of the two numbers. The game used a number pad for the students to tap their answer. There were mixed results for all three ability levels. Some students found the game easy and some found the game hard. A common comment made by all levels of students was that the game repeats problems. Some higher students commented on how boring this game felt to them. I found some high and average ability level students listing the factors to make it easier for them to find the answer.

LCM presented two numbers and asked the student to find the least common multiple of the two numbers. The game gave a number pad for the students to tap their answer. Figure 3 below shows the screen of the game with an LCM question. The high ability students found this game easier. They discovered they could multiply the two given numbers, especially if they were prime numbers, and find the LCM. There were times they also used the calculator to find the answer. The average ability students tended to hate it and felt it was too hard. They would just multiply the numbers and find a common multiple but not the LCM.

Figure 3 Screen shot of the handheld computer game LcmGcf.

Simplify was a game only used by the low ability students. They needed additional practice simplifying fractions. This was a hard game for some of them because it required the student to divide, which was difficult for some low ability students. I frequently saw them use their dry erase boards to figure out the answer. They could not complete it mentally. This game also did not give a game pad so the students had to use Grafiti or use the number pad, both of which take more time.

Occasionally the students were allowed to play two other games that were installed on the handheld computers. Coconut Fern is similar to Connect Four where the user is trying to get four red chips in a row before the computer gets four black chips in a row. Clumps is a game where different colored chips are randomly placed on the screen. The user taps on chips that have the same color beside them. The goal is to take as few moves as possible to clear the screen. The high scores are recorded. As a reward, the

students were allowed to play these games if they finished their work and did not want to replay their mathematical game.

Procedures

Each day in mathematics class, I reviewed previous concepts taught to help keep the concepts easily accessible to the students' memory. This is usually accomplished by my leading the review using a projector to ask questions. The students responded on individual dry erase boards. I quickly saw which students knew the concept being reviewed. Further instruction was sometimes necessary based on the students' responses. This was the teacher-led type of review.

During the intervention, instead of completing the teacher-led daily review, the students used the same amount of time each day in class to review mathematical concepts using the handheld computers. The first day the students received the handheld computers they investigated the different programs already installed on the handhelds. I gave basic instructions for how to operate the technology. The subsequent class sessions were more structured since I specified the game the students were required to use. The last day the students had the handheld computers I provided a little more latitude and allowed the students to select which mathematical program on the handheld computers they wanted to use.

Table 3

Chronological Schedule for the High- and Average-Ability Groups

Mathematical Unit	Type of review	Handheld Games	Days
Number Patterns and Algebra	Handheld computers	Math Ace	2
		Divisible	3
		Power Play	2
		Divisible	4
		Power Play	2
Statistics and Graphing	Teacher-led (Non-handheld)		12
Adding and Subtracting Decimals	Handheld computers	Math Ace	6
		Power Play	1
		Divisible	1
Multiplying and Dividing Decimals	Teacher-led (Non-handheld)		9
Fractions and Decimals (GCF/LCM)	Handheld computers	GCF	5
		LCM	3
Adding and Subtracting Fractions	Teacher-led (Non-handheld)		7

Table 4

Chronological Schedule for the Low-Ability Group

Mathematical Unit	Type of review	Handheld Games	Days
Number Patterns and Algebra	Handheld computers	Math Ace	4
		Divisible	1
		Power Play	3
		Divisible	1
		Math Ace	1
		Power Play	2
Statistics and Graphing	Teacher-led (Non-handheld)		15
Adding and Subtracting Decimals	Handheld computers	Math Ace	4
Multiplying and Dividing Decimals	Teacher-led (Non-handheld)		14
Fractions and Decimals (GCF/LCM)	Handheld computers	GCF	3
		LCM	3
		Simplify	2
Adding and Subtracting Fractions	Teacher-led (Non-handheld)		9

Data Sources

Several sources of data were collected during this study including pretests, during intervention tests, posttests, and delayed posttests of students' mathematical content knowledge. These sources were used to triangulate the data collected during the study.

Quantitative Measures

Pretest. The Entry Assessment Mathematics Evaluation (EAME) was administered in the fall (Form 2) and winter (Form 3). This test, consisting of twelve questions for each grade level, was created by Fairfax County Public Schools. There were twelve open-ended questions for each grade level, first through eighth; therefore, there were 96 total questions on each test form. Each question was worth one point. Each student's percentage of correctly answered questions was recorded.

Weekly tests. Students completed weekly open-ended or multiple-choice assessments that were created by the mathematics teachers, the approved textbook series, or a combination of both. Since the lengths of these assessments varied, the students' percentage of correctly answered questions was recorded. Each class completed one weekly assessment that was a pretest for each unit and one weekly assessment that was a posttest for each unit. Delayed posttests were given to each class usually three weeks after the posttests were given. Means on these tests and gain scores were calculated for each class and gender.

Posttest. The EAME-Form 3, also consisting of 96 open-ended questions, was given after the intervention. Each question was worth one point. The student's percentage

of correctly answered questions was recorded. Means on these tests and gain scores were calculated for each class and gender (See Table 5).

Table 5

Instruments Given for All Ability Groups

Phase	Instrument
Pretest-Fall	EAME-2
During Intervention	Unit pretests
Posttest	Unit posttests
Posttest	Delayed posttests
Posttest-Winter	EAME-3

Qualitative Measure

Teacher journal. I kept a notebook where I answered the following questions on the days when the students used the handheld computers.

1) Did this game enhance the curriculum? How?

2) What did I notice about students' perceptions with the game?

3) Game design comments: Likes? Dislikes?

4) Did certain groups or gender do better with this game?

The answers to these questions made this a richer study by addressing the teacher side of the game designs. This helped me to validate and to explain some of the quantitative results of the study. Again I was not allowed to directly ask the students their opinions;

therefore, I was only able to record my perceptions and comments I heard students make to one another.

Methods of Analysis

Each research question was answered using a variety of sources. The research questions were: (a) What is the relationship between student ability and performance on handheld review mathematical games? (b) How does students' ability influence students' retention of mathematical concepts? (c) What is the relationship between student gender and performance on handheld review mathematical games? (d) How does students' gender influence students' retention of mathematical concepts? These questions were examined across multiple units and within each mathematical unit.

Analyzing Quantitative Measures

Pretests, during intervention tests, and posttests. Since there were repeated instruments given in this within-group equivalent time series, a repeated measures analysis of variance (ANOVA) was used. The changes in the scores for the repeated instruments were studied. Post-hoc analyses determined if there were any differences in the groups. These tests were also conducted for gender. These tests determined if there was a gain among these groups. *T*-tests were also used to determine the test means. The means were examined to determine if there were patterns in the data over time and if there were patterns within each unit. Since there were a lot of analyses on the same data, I set the significance level at .01, rather than the standard level of .05.

Analyzing Qualitative Measure

Teacher journal. This mixed method study used the teacher journal to examine how the use of handheld mathematical games influenced students' retention of mathematical concepts. Understanding students' opinions about using the handheld computers was important to the researcher. The written comments were analyzed. This data was coded and analyzed to find emerging themes. This qualitative source allowed the researcher to triangulate the data.

Prior to completing the quantitative measures analyses, I coded my journal responses looking at each ability group separately and gender separately. First I coded responses about each particular game since each game varied with its responses from the students. Then I completed my quantitative analyses. I did this to help reduce my biases during the results phase of my study.

Conclusion

This study investigated the impact of using the game feature on the Palm® handheld computers in the sixth grade mathematics classroom on student retention of mathematical concepts. I wanted to investigate the relationship between student ability and performance on handheld computer mathematical review games and the relationship between student gender and performance on handheld computer mathematical review games. These were investigated across multiple units and within each mathematical unit. There were six units taught in this study. In three of the units, the students used the handheld computers to review mathematical concepts daily. In the alternating units, the teacher led the daily review. Multiple measures, including pretests, posttests, and delayed

posttests, were analyzed in the quantitative part of this study. Analysis of the teacher journal added to this mixed methods study.

4. Results

This study was a mixed methods study including both qualitative and quantitative results. The qualitative data included the results from the teacher journal that contained questions primarily about game design and observations of students' perceptions. This teacher journal was kept while the students were using the handheld computers for daily review. The quantitative data included the results of the statistical and descriptive analyses of the pretests and posttests, as well as the delayed posttests. Tables and figures are provided to help the reader better understand the quantitative data. This chapter begins with the qualitative results, followed by the quantitative analyses for each research question. Student ability and gender will be addressed separately. Each analysis was broken into each mathematical unit and across multiple units.

The three ability groups' achievement was analyzed over time. Since all students were in the same class, they were not compared to similar students from other classes. There were pretests prior to the intervention of handheld computers, multiple measures during the intervention phase, and posttests after the intervention, as well as delayed posttests. Quantitatively, a pretest-posttest design was used to measure students' retention of mathematical concepts for low-ability, average-ability, and high-ability learners and for male and female learners.

Research Questions A and B- Student Ability

The first two research questions were: (a) What is the relationship between student ability and performance on unit tests after using handheld review mathematical games? (b) How does students' ability influence students' retention of mathematical concepts?

Analysis of Qualitative Measure

Teacher journal. I kept a notebook where I answered the following questions on the days when the students used the handheld computers.

1) Did this game enhance the curriculum? How?

2) What did I notice about students' perceptions with the game?

3) Game design comments: Likes? Dislikes?

4) Did certain groups or gender do better with this game?

First, I looked at each ability level's journal entries. I divided the responses into each game since some games were played on multiple days. I color coded the comments that I had written by using pink for females and blue for males, green for positive comments and yellow for negative comments. The results of positive and negative comments made by the sixth graders and recorded by the teacher are presented in the following tables, broken down by student ability and each game played.

Table 6

Frequency of Positive and Negative Student Comments for High-Ability Students Recorded in the Teacher Journal

Handheld Game	Positive Comments	Negative Comments
Math Ace	12	9
Divisible	4	4
Power Play	1	3
GCF	3	5
LCM	3	0
Total	23	21

High-ability students who made comments while playing the games made more positive comments about Math Ace and LCM. Math Ace was “easy” for the high-ability students because it requires the student to respond to basic arithmetic questions. Many students thought it was “fun.” The negative comments from the high-ability students concerned the miscounting the program sometimes did. One student did mention he thought it was too easy. The high-ability students thought LCM was “easy.” This was after they had played GCF so it was a similar concept, just in reverse. The students felt it was easier to multiply then divide.

There were an equal number of positive and negative comments recorded for Divisible. Some high-ability students felt it was “hard and addicting” but some thought it

was “easy” and “fun.” More high-ability students made negative comments about Power Play and GCF than positive comments. They felt Power Play was” too hard and not fun.” GCF was also found to be “hard,” even a “brain fryer” by one student. After a few days of playing GCF one student who had said it was hard then said it was “easy.”

Table 7

Frequency of Positive and Negative Student Comments for Average-Ability Students Recorded in the Teacher Journal

Handheld Game	Positive Comments	Negative Comments
Math Ace	12	9
Divisible	8	2
Power Play	2	11
GCF	4	5
LCM	2	7
Total	28	34

The average-ability students made more positive comments about Math Ace and Divisible. The average-ability students liked Math Ace and thought it was easy. The negative comments about Math Ace primarily were about the miscounting, a programming error. Students who did not have a good grasp of basic arithmetic facts thought it was hard. With Divisible, I was surprised that so many average-ability students

thought the game was “cool” and “fun.” One student thought it was “kind of hard” and one student thought it was “dumb.”

There were more negative comments about Power Play, GCF, and LCM. Power Play was not liked by the average-ability students either. The students said it was “very hard” and “not fun.” Even two students said they “hated it.” Opposite of the high-ability students, the average-ability students in this study gave more negative comments about LCM. Students made comments like “too hard” or “challenging.” The students made similar comments about GCF. Some students found it to be “easy” and some students found it to be “hard.” One student said he “hated it because he can’t do it.”

Table 8

Frequency of Positive and Negative Student Comments for Low-Ability Students Recorded in the Teacher Journal

Handheld Game	Positive Comments	Negative Comments
Math Ace	4	1
Divisible	0	2
Power Play	1	2
GCF	0	1
LCM	0	0
Simplify	0	0
Total	5	6

The low-ability students made more positive comments about Math Ace. They thought it was “easy” or they “liked it.” One student thought it was “hard.” There were more negative comments about Divisible, Power Play, and GCF. The comments about Divisible were they “didn’t like it.” One student liked “playing a new game” when we began playing Power Play and the other comments were that it was “hard.” One student commented about GCF that the game miscounted. There were not any comments about LCM or Simplify.

Math Ace was played more times by all three classes. The game required students to respond to basic arithmetic questions. Most students found it to be easy. The students who did not know their basic math facts found this game to be harder. One flaw of the game is sometimes it counts two wrong when only one was missed. Average-ability students made that comment more than high-ability students. Miscounting was not a comment recorded for the low-ability students.

Divisible is a game that enabled the students to practice their understanding of divisibility rules. Most high- and average-ability students found it to be easy, especially after multiple days of playing. The low-ability students did not like Divisible. I think the main reason for that is because the students did not learn all the divisibility rules; therefore, making it more difficult for the lower-ability students. Lower-ability students also seem to have less mastery of multiplication and division facts, which is required for some of the rules.

Power Play required the students to have a good understanding of exponents. Most students found it hard and not fun. After multiple days, some high- and average-

ability students discovered they could use the calculator on the Palm® to help them find the answer. The low-ability students did not use the calculator and found this game to be very difficult. Even using the exponent-easy or base-easy settings on this game, some of the numbers were very large. An example is 7 to what power equals 16,807. This game also doesn't give the correct answer; it just says "incorrect-too high" or "incorrect-too low." It would have been helpful if it gave hints or even the correct answer so students could learn from their mistakes. Low score wins in Power Play and this confused some students because they were used to the high score winning. As Figure 2 shows, this game also did not give a game pad so the students had to use Grafiti or use the number pad, both of which take more time.

GCF presented two numbers and asked the student to find the greatest common factor of the two numbers. There were mixed results for all three ability levels. Some students found the game easy and some students found the game hard. A common comment made by all levels was that problems repeat. A new comment by some higher students was how boring this game felt to them. I found some high- and average-ability level students listing the factors by hand to make it easier for them to find the answer.

LCM presented two numbers and asked the student to find the least common multiple of the two numbers. The high-ability students found this game easier. They discovered they could multiply the two given numbers, especially if they were prime numbers, and find the LCM. There were times they also used the calculator to find the answer. The average-ability students tended to hate it and felt it was too hard. They would just multiply the numbers and find a common multiple but not the LCM.

Simplify was a game only used by the low ability students. They needed additional practice simplifying fractions. This was a hard game for some of them because it required the student to divide which was difficult for some low-ability students. I frequently saw them use their dry erase boards to figure out the answer. They could not complete it mentally.

In conclusion, the students enjoyed playing the games that were appropriate to their independent learning level. They would get bored or frustrated if the game was too easy or too hard. The games should have been individually programmed for each student's level. This would have introduced many more variables, such as appropriate setting of student's instructional level versus frustration level, into this study.

Analysis of Quantitative Measures

All of the data from the assessments was entered into SPSS. Since there were a lot of analyses on the same data, I set the significance level at .01, rather than the standard level of .05. Using SPSS, the mean scores were computed for all the tests given for each ability group. These included Pretest, Posttest, and Delayed Posttest for each unit, numbered 1-6, and the EAME-2 and EAME-3 tests. The mean scores for these tests are located in Tables 9-11, one for each ability level.

Table 9

Mean Scores from Tests for High-Ability Students (N = 18)

Mathematical Unit	Pretest	Posttest	Delayed Posttest
1 Number Patterns and Algebra (handheld review)	48.39	81.95	80.42
2 Statistics and Graphing	80.79	75.42	94.44
3 Adding and Subtracting Decimals (handheld review)	71.05	88.17	91.39
4 Multiplying and Dividing Decimals	52.78	69.39	71.32
5 Fractions and Decimals (GCF/LCM) (handheld review)	56.94	80.00	86.94
6 Adding and Subtracting Fractions	51.67	89.67	77.63
EAME 2	57.00		
EAME 3		69.56	

High-ability students showed pretest to posttest gains on each unit except for unit 2 (Statistics and Graphing). Using SPSS, paired samples *t*-tests were conducted. Results were statistically significant for unit 1 ($t(17) = 9.08$, $p<.001$), unit 3 ($t(17) = 4.54$, $p<.001$), unit 4 ($t(17) = 4.04$, $p = .001$), unit 5 ($t(17) = 5.68$, $p<.001$), and unit 6 ($t(17) =$

5.88, $p<.001$). However, they did not retain the information (posttest to delayed posttest) on units 1 (Number Patterns and Algebra) and 6 (Adding and Subtracting Fractions). On the paired samples *t*-tests from posttest to delayed posttest only unit 2 was statistically significant, $t(17) = -4.82$, $p<.001$. Their EAME test scores did increase from the fall to the winter with results being statistically significant, $t(17) = 10.13$, $p<.001$.

Table 10

Mean Scores from Tests for Average-Ability Students (N = 24)

Mathematical Unit	Pretest	Posttest	Delayed Posttest
1 (handheld review)	39.83	85.71	77.17
2	80.21	71.25	93.13
3 (handheld review)	74.58	91.25	92.08
4	52.08	68.25	67.29
5 (handheld review)	58.13	74.25	85.83
6	45.83	85.13	78.96
EAME 2	57.00		
EAME 3		66.83	

Average-ability students showed pretest to posttest gains on each unit except unit 2 (Statistics and Graphing). Results were statistically significant on unit 1 ($t(23) = 13.57$, $p<.001$), unit 3 ($t(23) = 5.46$, $p<.001$), unit 4 ($t(23) = 5.21$, $p<.001$), unit 5 ($t(23) = 4.18$, $p<.001$), and unit 6 ($t(23) = 8.46$, $p<.001$). However, they did not retain the information

(posttest to delayed posttest) on units 1 (Number Patterns and Algebra), 4 (Multiplying and Dividing Decimals), and 6 (Adding and Subtracting Fractions). On the paired samples *t*-tests from posttest to delayed posttest the following units were statistically significant: unit 1 ($t(23) = 2.87$, $p = .009$), unit 2 ($t(23) = -7.53$, $p<.001$), and unit 4 ($t(23) = .24$, $p<.001$).Their EAME test scores did increase from fall to winter, $t(23) = 6.86$, $p<.001$.

Table 11

Mean Scores from Tests for Low-Ability Students (N = 12)

Mathematical Unit	Pretest	Posttest	Delayed Posttest
1 (handheld review)	39.58	75.00	53.67
2	52.08	70.75	69.58
3 (handheld review)	46.67	76.58	67.08
4	34.17	65.83	38.75
5 (handheld review)	33.33	70.17	48.75
6	24.58	74.25	40.00
EAME 2	44.00		
EAME 3		49.92	

Low-ability students showed pretest to posttest gains on each unit. The results were statistically significant on unit 1 ($t(11) = 15.69$, $p<.001$), unit 2 ($t(11) = 6.04$, $p<.001$), unit 3 ($t(11) = 4.65$, $p = .001$), unit 4 ($t(11) = 3.78$, $p = .003$), unit 5 ($t(11) =$

6.71, $p<.001$), and unit 6 ($t(11) = 7.79$, $p<.001$). On the paired samples *t*-tests from posttest to delayed posttest the following units were statistically significant: unit 1 ($t(11) = 4.30$, $p = .001$), unit 4 ($t(11) = 4.82$, $p = .001$), unit 5 ($t(11) = 5.19$, $p<.001$) and unit 6 ($t(11) = 6.31$, $p<.001$). Their EAME test scores did increase from fall to winter but the results were not statistically significant.

Gain Scores and Delayed Scores

The next analysis used the paired samples *t*-test since each student received both handheld computer reviews and teacher led reviews so they could serve as his or her own comparison. Gain scores for each unit were calculated by subtracting the posttest score from the pretest score. Delayed gain scores were calculated by subtracting the delayed posttest score from the pretest score. Using SPSS, paired samples *t*-tests were conducted. Since there were a lot of analyses on the same data, I set the significance level at .01, rather than the standard level of .05. The results for each unit, separated by student ability class, are presented in Tables 12-14.

Table 12

Comparison of Gain Scores and Delayed Gain Scores for Each Unit for High-Ability Students (N = 18)

Unit Type	*M*	*SD*	*t*	*df*	*p*
Unit 1 Gain (handheld)	32.67	15.26			
Unit 1 Delayed Gain (handheld)	32.06	16.64	.26	17	.800
Unit 2 Gain	-5.39	16.82			
Unit 2 Delayed Gain	13.06	10.45	-4.82	17	<.001*
Unit 3 Gain (handheld)	16.50	15.42			
Unit 3 Delayed Gain (handheld)	19.72	15.67	-1.12	17	.278
Unit 4 Gain	16.61	17.43			
Unit 4 Delayed Gain	20.00	13.83	-.78	17	.449
Unit 5 Gain (handheld)	23.06	17.22			
Unit 5 Delayed Gain (handheld)	30.00	13.06	-2.54	17	.021
Unit 6 Gain	38.00	27.42			
Unit 6 Delayed Gain	28.61	24.00	2.77	17	.013
EAME 2	57.00	7.85			
EAME 3	69.56	8.90	10.13	17	<.001*

High-ability students had higher delayed gain scores on units 2, 3, 4, and 5. Results from the paired samples *t*-tests were statistically significant only on unit 2, $t(17) = -4.82$, $p<.001$. Unit 2 was a teacher-led review unit. High-ability students had higher gain scores on unit 1 (handheld computer review) and unit 6 (teacher-led review) but the results were not statistically significant. High-ability students performed better on the EAME 3 (posttest) than the EAME 2 (pretest), $t(17) = 10.13$, $p<.001$.

Table 13

Comparison of Gain Scores and Delayed Gain Scores for Each Unit for Average-Ability Students (N = 24)

Unit Type	*M*	*SD*	*t*	*df*	*p*
Unit 1 Gain (handheld)	45.88	16.57			
Unit 1 Delayed Gain (handheld)	37.33	13.12	2.87	23	.009*
Unit 2 Gain	-8.96	16.34			
Unit 2 Delayed Gain	12.92	9.55	-7.53	23	<.001*
Unit 3 Gain (handheld)	16.67	14.97			
Unit 3 Delayed Gain (handheld)	17.50	14.67	-.55	23	.590
Unit 4 Gain	16.17	15.19			
Unit 4 Delayed Gain	15.21	15.78	.24	23	.816
Unit 5 Gain (handheld)	16.13	18.92			
Unit 5 Delayed Gain (handheld)	27.71	12.94	-4.29	23	<.001*
Unit 6 Gain	39.29	22.76			
Unit 6 Delayed Gain	33.13	20.04	2.42	23	.024
EAME 2	57.00	5.67			
EAME 3	66.83	9.77	6.86	23	<.001*

Average-ability students had higher delayed gain scores on units 2, 3, and 5. Results from the paired samples *t*-tests were statistically significant only on unit 2 (*t*(23)

= -7.53, $p<.001$) and unit 5 ($t(23) = -4.29$, $p<.001$). Unit 2 was a teacher-led review unit and unit 5 was a handheld computer review unit. Average-ability students had higher gain scores on unit 1 (handheld computer review), unit 4 (teacher-led review) and unit 6 (teacher-led review). Results from the samples *t*-tests were statistically significant only on unit 1 ($t(23) = 2.87$, $p = .009$). Average-ability students performed better on the EAME 3 (posttest) than the EAME 2 (pretest), $t(23) = 6.86$, $p<.001$.

Table 14

Comparison of Gain Scores and Delayed Gain Scores for Each Unit for Low-Ability Students (N = 12)

Unit Type	*M*	*SD*	*t*	*df*	*p*
Unit 1 Gain (handheld)	35.42	7.82			
Unit 1 Delayed Gain (handheld)	14.08	16.07	4.30	11	.001*
Unit 2 Gain	18.67	10.71			
Unit 2 Delayed Gain	17.50	16.03	.23	11	.825
Unit 3 Gain (handheld)	29.92	22.27			
Unit 3 Delayed Gain (handheld)	20.42	25.63	2.00	11	.071
Unit 4 Gain	31.67	29.03			
Unit 4 Delayed Gain	4.58	15.29	4.82	11	.001*
Unit 5 Gain (handheld)	36.83	19.02			
Unit 5 Delayed Gain (handheld)	15.42	16.85	5.19	11	<.001*
Unit 6 Gain	49.67	22.09			
Unit 6 Delayed Gain	15.42	19.82	6.31	11	<.001*
EAME 2	44.00	7.52			
EAME 3	49.92	11.04	3.08	11	.011

Low-ability students did not have higher delayed gain scores on any unit. Low ability students had higher gain scores on all six units (1, 3, and 5 are handheld computer

review and 2,4, and 6 are teacher-led review). Results from the samples *t*-tests were statistically significant only on unit 1 ($t(11) = 4.30$, $p = .001$), unit 4 ($t(11) = 4.82$, $p = .001$), unit 5 ($t(11) = 5.19$, $p<.001$), and unit 6 ($t(11) = 6.31$, $p<.001$). Low-ability students performed better on the EAME 3 (posttest) than the EAME 2 (pretest) but the results were not statistically significant.

Figures 4 and 5 compare the mean gain scores for handheld units (1, 3, and 5) and the mean gain scores for teacher-led units (2,4, and 6) by each class; high, average, and low. Both the high and the average classes had negative gain scores on unit 2. The low classes had mean gain scores that were usually higher than the high and average classes probably due to the low pretest scores they started each unit with.

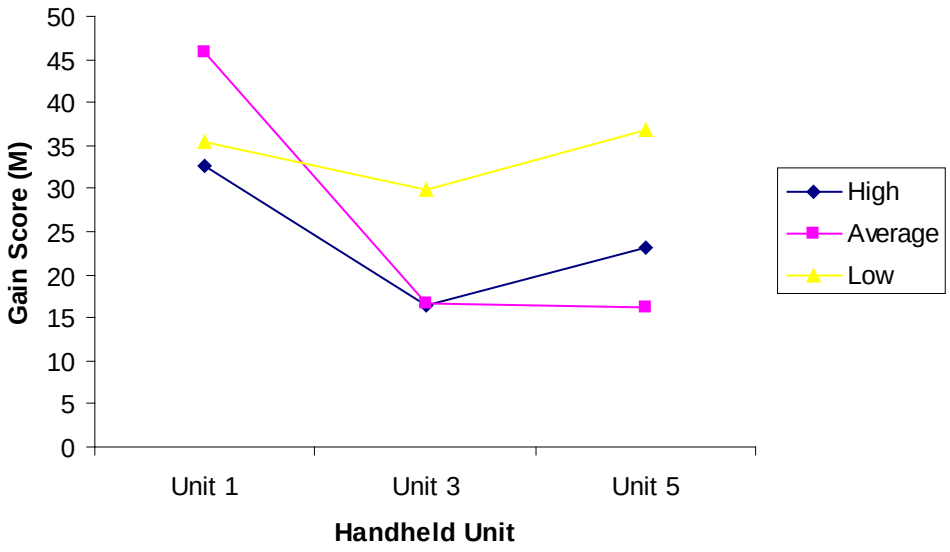


Figure 4 Mean gain scores for handheld units by class.

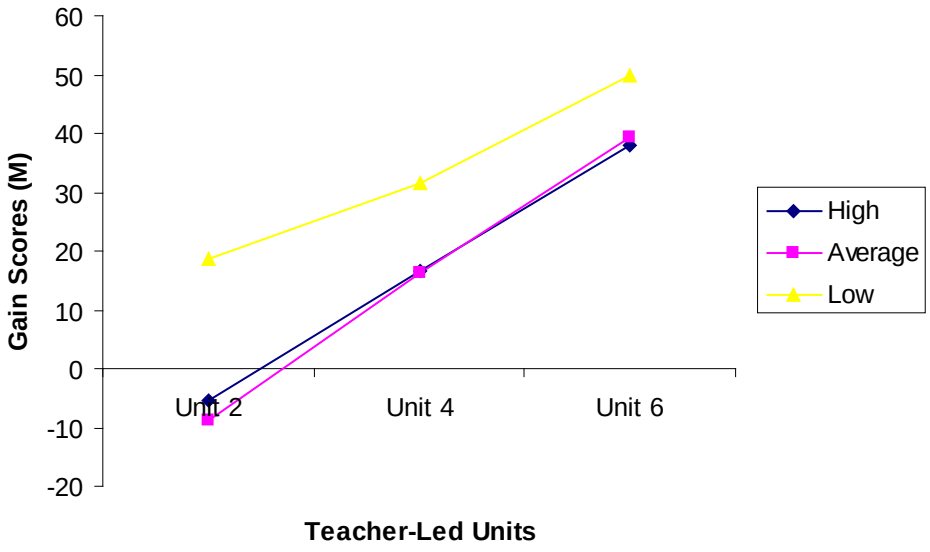


Figure 5 Mean gain scores for teacher-led units by class.

Across Multiple Units-Gain Scores

After looking at each unit separately, analyses across multiple units were conducted. This was to investigate possible overall differences between the units where the handheld computers were used for review and the units where the handheld computers were not used for review (teacher-led review). Using SPSS, analysis of variance with repeated measures were conducted. The results found there were statistically significant differences within Gain 1, Gain 3, and Gain 5 (handheld gains), $F(4, 100) = 4.09$, $p = .004$, but not within Gain 2, Gain 4, and Gain 6 (teacher-led gains), $F(4,102) = .94$, $p = .444$.

Combined gain scores for the handheld review units (1, 3, and 5) were calculated by adding the gain scores from each of those units. Similarly, combined gain scores for

the teacher-led review units (2, 4, and 6) were calculated by adding the gain scores from each of those units. The combined gain scores for each class's handheld computer review units, the combined gain scores for each class's teacher-led review units, and the results of the paired samples *t*-test are presented in Table 15.

Table 15

Combined Gain Scores for Each Class by Review Type

Review Unit Type	*M*	*SD*	*t*	*df*	*p*
High Handheld	73.35	25.43			
High Teacher-Led	47.12	46.41	2.60	16	.020
Average Handheld	78.67	26.30			
Average Teacher-Led	46.50	31.26	4.24	23	<.001*
Low Handheld	102.17	35.85			
Low Teacher-Led	100.00	47.74	.24	11	.816

The combined gain scores for the handheld review units and the teacher-led review units were calculated for each ability class. For the high-ability class, the handheld review units obtained a combined gain score of 73.35 (*SD* = 25.43) and the teacher-led review units obtained a combined gain score of 47.12 (*SD* = 46.41). Results from the paired samples *t*-test were not statistically significant. The average-ability class handheld review units obtained a combined gain score of 78.67 (*SD* = 26.30) and the

teacher-led review units obtained a combined gain score of 46.50 (*SD* = 31.26). The results were statistically significant, $t(23) = 4.24$, $p<.001$. The low-ability class produced non-significant results, $t(11) = .24$, $p = .816$. The handheld review units' combined gain score for the low ability class was 102.17 (*SD* = 35.85) and the teacher-led review units' combined gain score was 100.00 (*SD* = 47.74).

Overall, students who reviewed using the handheld computer mathematical games obtained a combined gain score on unit 1, unit 3, and unit 5 tests of 82.28 (*SD* = 30.00) and students who reviewed using the teacher-led reviews obtained a combined gain score on unit 2, unit 4, and unit 6 tests of 58.81 (*SD* = 45.64). Results from the paired samples *t*- test were statistically significant, $t(52) = 4.42$, $p<.001$. Since the probability was less than the .01 level, the researcher was able to reject the null hypothesis and conclude that there was a significant difference in the mean gain scores between the handheld computer mathematical games review units and the teacher-led review units.

Across Multiple Units- Delayed Gain Scores

Delayed gain scores were found by subtracting each unit pretest from each unit delayed-posttest. After looking at each unit separately, across multiple units analyses were conducted. This was to see if there were any differences in the delayed gain scores overall between the units where handheld computers were used (handheld delayed gains) and the units where the handheld computers were not used (teacher-led delayed gains). Using SPSS, analysis of variance with repeated measures were conducted. The results found there were not statistically significant differences within Delayed Gain 1, Delayed Gain 3, and Delayed Gain 5 (handheld delayed gains), $F(4,100) = 3.42$, $p = .011$, and

within Delayed Gain 2, Delayed Gain 4, and Delayed Gain 6 (teacher-led delayed gains), $F(4,102) = 2.87$, $p = .027$.

Combined delayed gain scores for the handheld review units (1, 3, and 5) were calculated by adding the delayed gain scores from each of those units. Similarly, combined delayed gain scores for the teacher-led review units (2, 4, and 6) were calculated by adding the delayed gain scores from each of those units. The combined delayed gain scores for each class's handheld computer review units, the combined delayed gain scores for each class's teacher-led review units, and the results of the paired samples *t*-test are presented in Table 16.

Table 16

Combined Delayed Gain Scores for Each Class by Review Type

Review Unit Type	*M*	*SD*	*t*	*df*	*p*
High Handheld	84.18	28.10			
High Teacher-Led	60.88	34.34	2.58	16	.020
Average Handheld	82.54	21.52			
Average Teacher-Led	61.25	30.19	3.06	23	.006*
Low Handheld	49.92	44.01			
Low Teacher-Led	37.50	35.26	.98	11	.352

The combined delayed gain scores for the handheld review units and the teacher-led review units were calculated for each ability class. For the high-ability class, the

handheld review units had a combined delayed gain score of 84.18 (*SD* = 28.10) and the teacher-led review units had a combined delayed gain score of 60.88 (*SD* = 34.34). Results from the paired samples *t*-test were not statistically significant. For the average-ability class, handheld review units had a combined delayed gain score of 82.54 (*SD* = 21.52) and the teacher-led review units had a combined delayed gain score of 61.25 (*SD* = 30.19). The results were statistically significant, $t(23) = 3.06$, $p = .006$. The low-ability class produced non-significant results. The handheld review units' combined delayed gain score for the low ability class was 49.92 (*SD* = 44.01) and the teacher-led review units' combined delayed gain score was 37.50 (*SD* = 35.26).

Overall, students who reviewed using the handheld computer mathematical games obtained a mean combined delayed gain score on unit 1, unit 3, and unit 5 tests of 75.68 (*SD* = 32.50) and students who reviewed using the teacher-led reviews obtained a mean combined delayed gain score on unit 2, unit 4, and unit 6 tests of 55.75 (*SD* = 33.59). Results from the paired samples *t*-test were statistically significant, $t(52) = 3.92$, $p<.001$. Since the probability was less than the .01 level, the researcher was able to reject the null hypothesis and conclude that there was a significant difference in the mean delayed gain scores between the handheld computer mathematical games review units and the teacher-led review units.

Research Questions C and D- Student Gender

The second two research questions were: (c) What is the relationship between student gender and performance on unit tests after using handheld review mathematical

games? (d) How does students' gender influence students' retention of mathematical concepts?

Analysis of Qualitative Measure

Teacher journal. I kept a notebook where I answered the following questions on the days when the students used the handheld computers.

1) Did this game enhance the curriculum? How?

2) What did I notice about students' perceptions with the game?

3) Game design comments: Likes? Dislikes?

4) Did certain groups or gender do better with this game?

After looking at each ability level's journal entries, I divided the responses by game since some games were played on multiple days. I color coded the comments that I had written by using pink for females and blue for males, green for positive comments and yellow for negative comments. The answers to these questions made this a richer study by addressing the teacher side of the game designs. This helped me to validate some of the quantitative results of the study.

The results of positive and negative comments made by the sixth graders and recorded by the teacher are presented in the following tables, broken down by student gender and each game played.

Table 17

Frequency of Positive and Negative Student Comments by Student Gender for High-Ability Students Recorded in the Teacher Journal

Handheld Game	Male Positive	Male Negative	Female Positive	Female Negative
Math Ace	4	2	8	7
Divisible	1	0	3	4
Power Play	1	2	0	1
GCF	3	1	0	4
LCM	3	0	0	0
Total	12	5	11	16

During Math Ace and Divisible, more female students made comments. During Power Play and LCM more male students made comments. With Math Ace, most of the positive comments were “fun” or “easy;” whereas, most of the negative comments made by the females were about the miscounting of the game if the student missed a question. The males felt it was hard or it was not hard enough. With Divisible, the male and female positive comments were “fun” or “easy.” With the females, this was after a couple days of playing this game. The first days the females commented it was “hard.” One female called it “addicting!” Only one male student felt Power Play was “fun”. The three negative comments included “not fun” or “hard.” Initially, the students found GCF to be “hard” or “boring”; but after subsequent days of play, some of the male comments were

"easy." I noted that after the third day of playing GCF that males wanted to stick with it; whereas, the females wanted to socialize. The male positive comments about LCM were that it was "easy."

Table 18

Frequency of Positive and Negative Student Comments by Student Gender for Average-Ability Students Recorded in the Teacher Journal

Handheld Game	Male Positive	Male Negative	Female Positive	Female Negative
Math Ace	1	2	11	7
Divisible	1	1	7	1
Power Play	2	2	0	9
GCF	2	3	2	2
LCM	0	4	2	3
Total	6	12	22	22

During Math Ace, Divisible, Power Play, and LCM, more average-ability female students made comments about the games. Only GCF had more male comments. With Math Ace, one male thought it was "fun" but two males thought it was "boring" and "hard." The females liked it and thought it was "fun" or "easy." The negative comments made by females were the miscounted problem with the game. Only one female "hated" Math Ace, according to my journal responses.

The average-ability students liked Divisible. One male thought it was “dumb” and one female thought it was “kinda hard.” Overwhelmingly, the females did not like Power Play because they thought it was “hard,” “boring,” and even one female comment was “not fun.” The males felt it was “awesome” or “hard.” GCF also received mixed reactions when males thought it was “easy” or “too hard” and the female comments included “awesome” and “hard.” With LCM, the males commented that they thought it was “challenging” or they “hated it.” The females had mixed reactions. Some thought it was “okay”; whereas, some thought it was “too hard” or they “hated it.”

Table 19

Frequency of Positive and Negative Student Comments by Student Gender for Low-Ability Students Recorded in the Teacher Journal

Handheld Game	Male Positive	Male Negative	Female Positive	Female Negative
Math Ace	3	1	1	0
Divisible	0	1	0	1
Power Play	0	1	1	1
GCF	0	1	0	0
LCM	0	0	0	0
Simplify	0	0	0	0
Total	3	4	2	2

There were fewer comments about the games played by the low ability students. The first reason is because they started with a smaller class (n = 12) whereas the average-ability and high-ability classes were larger. Secondly, these students are of lower ability and have to concentrate more to play these handheld computer games. I also had to help more students when they were having difficulty with the games so I recorded fewer comments from the students.

With Math Ace, the males and female thought it was “easy” or they “liked it.” One male thought it was “hard.” The male and female comment about Divisible was they “didn’t like it.” One female liked “playing a new game” when we began playing Power Play and the other comments were that it was “hard.” Power Play was very difficult for them because the game presents some larger numbers and the low-ability students did not have a good grasp of exponents. One male commented about GCF that the game miscounted. The low-ability students worked very hard playing the games but I found them having difficulty so they listed factors for GCF or multiples for LCM on their dry erase boards. They also did a lot of work on their dry erase boards for Simplify.

Analysis of Quantitative Measures

Using SPSS, I found the mean scores for all the tests given for each gender. These included Pretest, Posttest, and Delayed Posttest for each unit, numbered 1-6, and the EAME-2 and EAME-3 tests. The mean scores for these tests are located in Tables 20-23, one for total gender and each ability level.

Table 20

Mean Scores for Tests from All Level Students by Gender (N = 53)

Mathematical Unit	Pretest Male	Posttest Male	Delayed Posttest Male	Pretest Female	Posttest Female	Delayed Posttest Female
1 (handheld review)	39.20	76.24	69.60	45.59	86.93	76.13
2	70.60	69.52	86.25	77.33	75.13	90.00
3 (handheld review)	62.00	85.00	85.42	71.67	88.53	87.00
4	43.13	64.58	53.60	52.50	70.90	69.83
5 (handheld review)	48.75	70.96	76.88	55.00	78.70	78.83
6	37.5	84.13	66.20	47.50	84.30	73.17
EAME 2	51.84			56.07		
EAME 3		59.56			67.53	

Overall, females scored higher on pretests than male students. Females also scored higher on posttests and delayed posttests than male students. They also scored higher on both EAME tests. Comparing gender on the EAME 2 and EAME 3 tests produced non-significant results.

Table 21

Mean Scores for Tests from High-Ability Level Students by Gender (N = 18)

Mathematical Unit	Pretest Male	Posttest Male	Delayed Posttest Male	Pretest Female	Posttest Female	Delayed Posttest Female
1 (handheld review)	41.00	74.75	74.00	54.30	87.18	85.09
2	83.13	70.88	92.14	79.09	78.73	95.91
3 (handheld review)	68.75	84.14	90.00	72.73	90.73	92.27
4	47.14	59.57	65.00	56.36	75.64	75.91
5 (handheld review)	59.29	72.71	91.43	55.45	84.64	84.09
6	52.14	86.86	76.88	51.36	91.45	78.18
EAME 2	54.88			58.70		
EAME 3		64.63			72.27	

High-ability males outperformed high-ability females on pretests for units 2, 5, and 6. The males did not score higher on any of the posttests. Males only outperformed high-ability females on the unit 5 delayed posttest. Females scored higher on both EAME tests.

Table 22

Mean Scores for Tests from Average-Ability Level Students by Gender (N = 24)

Mathematical Unit	Pretest Male	Posttest Male	Delayed Posttest Male	Pretest Female	Posttest Female	Delayed Posttest Female
1 (handheld review)	36.89	78.11	73.78	41.60	90.27	79.20
2	75.56	64.44	92.22	83.00	75.33	93.67
3 (handheld review)	68.89	86.78	91.67	78.00	93.93	92.33
4	45.00	62.56	53.33	56.33	71.67	75.67
5 (handheld review)	55.56	66.56	83.89	59.67	78.87	87.00
6	37.22	82.22	73.33	51.00	86.87	82.33
EAME 2	55.22			58.07		
EAME 3		61.89			69.80	

Average-ability females scored higher than males on all the unit pretests, posttests, and delayed posttests. They also scored higher on both EAME tests.

Table 23

Mean Scores for Tests from Low-Ability Level Students by Gender (N = 12)

Mathematical Unit	Pretest Male	Posttest Male	Delayed Posttest Male	Pretest Female	Posttest Female	Delayed Posttest Female
1 (handheld review)	40.00	75.63	60.50	38.75	73.75	40.00
2	52.50	73.88	74.38	51.25	64.50	60.00
3 (handheld review)	47.50	83.75	74.38	45.00	62.25	52.50
4	37.50	71.25	42.50	27.50	55.00	31.25
5 (handheld review)	31.88	74.38	56.25	36.25	61.75	33.75
6	25.00	83.88	47.50	23.75	55.00	25.00
EAME 2	45.00			42.00		
EAME 3		51.88			46.00	

Low-ability males outperformed females on pretests for units 1, 2, 3, 4, and 6. Males outperformed females on all posttests and delayed posttests. Males also outscored females on both EAME tests.

Gain scores for each unit were calculated by subtracting the posttest score from the pretest score. Mean gain scores for the handheld review units (1, 3, and 5) were calculated by adding the gain scores from each of those units and dividing by three. Similarly, mean gain scores for the teacher-led review units (2, 4, and 6) were calculated

by adding the gain scores from each of those units and dividing by three. The handheld computer review units mean gain score for all males was 27.58 (*SD* = 11.69) and the teacher-led review units mean gain score for all males was 22.39 (*SD* = 16.32). Results of the paired samples *t*-test for all males were not statistically significant. The female handheld computer review units mean gain score was 27.30 (*SD* = 8.57) and the female teacher-led review units mean gain score was 17.30 (*SD* = 14.11). Results of the paired samples *t*-test for all females were statistically significant, $t(28) = 3.92$, $p = .001$. Using SPSS, analysis of variance was conducted for the gain scores. Comparing gender, none of the comparisons had statistically significant differences.

Gain scores for each unit were calculated by subtracting the posttest score from the pretest score. Delayed gain scores were calculated by subtracting the delayed posttest score from the pretest score. Using SPSS, paired samples *t*-tests were conducted using the gain scores and the delayed gain scores. The results for each unit, separated by student ability class and gender, are presented in Tables 24-29.

Table 24

Comparison of Gain Scores and Delayed Gain Scores for Each Unit for High-Ability Male Students (N = 8)

Unit Type	*M*	*SD*	*t*	*df*	*p*
Unit 1 Gain	33.75	13.12			
Unit 1 Delayed Gain	33.00	18.24	.16	7	.877
Unit 2 Gain	-13.29	14.75			
Unit 2 Delayed Gain	7.14	10.75	-2.54	7	.044
Unit 3 Gain	14.14	18.56			
Unit 3 Delayed Gain	20.00	20.41	-1.05	7	.336
Unit 4 Gain	12.43	22.47			
Unit 4 Delayed Gain	20.71	16.69	-.90	7	.405
Unit 5 Gain	13.43	17.60			
Unit 5 Delayed Gain	32.14	17.29	-6.97	7	<.001*
Unit 6 Gain	34.71	10.92			
Unit 6 Delayed Gain	31.43	16.76	.71	7	.503
EAME 2	54.88	6.52			
EAME 3	64.63	8.21	-6.27	7	<.001*

High-ability male students had higher delayed gain scores on units 2, 3, 4, and 5. Results from the paired samples *t*-tests were statistically significant only on unit 5, $t(7) =$

-6.97, $p<.001$. Unit 5 was a handheld computer review unit. High-ability male students had higher gain scores on unit 1 (handheld computer review) and unit 6 (teacher-led review). Results from the paired samples *t*-tests were not statistically significant. High-ability male students had higher EAME 3 (posttest) scores than EAME 2 (pretest) scores, $t(7) = -6.27$, $p<.001$.

Table 25

Comparison of Gain Scores and Delayed Gain Scores for Each Unit for High-Ability Female Students (N = 11)

Unit Type	*M*	*SD*	*t*	*df*	*p*
Unit 1 Gain	31.80	17.43			
Unit 1 Delayed Gain	31.30	16.21	.21	9	.836
Unit 2 Gain	-.36	16.69			
Unit 2 Delayed Gain	16.82	8.74	-4.34	10	.002*
Unit 3 Gain	18.00	13.82			
Unit 3 Delayed Gain	19.55	12.93	-.48	10	.640
Unit 4 Gain	19.27	13.91			
Unit 4 Delayed Gain	19.55	12.54	-.07	10	.950
Unit 5 Gain	29.18	14.57			
Unit 5 Delayed Gain	28.64	10.27	.29	10	.781
Unit 6 Gain	40.09	34.55			
Unit 6 Delayed Gain	26.82	28.31	2.96	10	.014
EAME 2	58.70	8.72			
EAME 3	73.50	2.42	9.43	9	<.001*

High-ability female students had higher delayed gain scores on units 2, 3, and 4. Results from the paired samples *t*-tests were statistically significant only on unit 2, *t*(10)

= -4.34, p = .002. Unit 2 was a teacher-led review unit. High-ability female students had higher gain scores on unit 1 (handheld computer review), unit 5 (handheld computer review), and unit 6 (teacher-led review). Results from the paired samples *t*-tests were statistically significant only on the EAME 2 (pretest) to EAME 3 (posttest), $t(9) = 9.43$, $p<.001$.

Table 26

Comparison of Gain Scores and Delayed Gain Scores for Each Unit for Average-Ability Male Students (N = 9)

Unit Type	*M*	*SD*	*t*	*df*	*p*
Unit 1 Gain	41.22	19.89			
Unit 1 Delayed Gain	36.89	11.10	.77	8	.465
Unit 2 Gain	-11.11	19.93			
Unit 2 Delayed Gain	16.67	7.91	-5.24	8	.001*
Unit 3 Gain	17.89	9.06			
Unit 3 Delayed Gain	22.78	9.39	-3.84	8	.005*
Unit 4 Gain	17.56	20.29			
Unit 4 Delayed Gain	8.33	17.32	1.06	8	.321
Unit 5 Gain	11.00	21.41			
Unit 5 Delayed Gain	28.33	16.39	-3.06	8	.016
Unit 6 Gain	45.00	22.97			
Unit 6 Delayed Gain	36.11	16.92	2.13	8	.066
EAME 2	55.22	3.93			
EAME 3	61.89	10.46	-2.27	8	.053

Average-ability male students had higher delayed gain scores on units 2, 3, and 5. Results from the paired samples *t*-tests were statistically significant on unit 2 ($t(8) = -$

5.24, $p = .001$) and unit 3 ($t(8) = -3.84$, $p = .005$). Unit 2 was a teacher-led review unit and unit 3 was a handheld computer review unit. Male average-ability students had higher gain scores on unit 1 (handheld computer review), unit 4 (teacher-led review), and unit 6 (teacher-led review). Results from the paired samples *t*-tests were not statistically significant. The EAME pretest to posttest comparison also produced non-significant results.

Table 27

Comparison of Gain Scores and Delayed Gain Scores for Each Unit for Average-Ability Female Students (N = 15)

Unit Type	*M*	*SD*	*t*	*df*	*p*
Unit 1 Gain	48.67	14.24			
Unit 1 Delayed Gain	37.60	14.56	3.32	14	.005*
Unit 2 Gain	-7.67	14.38			
Unit 2 Delayed Gain	10.67	9.98	-5.76	14	<.001*
Unit 3 Gain	15.93	17.87			
Unit 3 Delayed Gain	14.33	16.57	.76	14	.459
Unit 4 Gain	15.33	11.92			
Unit 4 Delayed Gain	19.33	13.74	-1.12	14	.282
Unit 5 Gain	19.20	17.28			
Unit 5 Delayed Gain	27.33	11.00	-3.35	14	.005*
Unit 6 Gain	35.87	22.72			
Unit 6 Delayed Gain	31.33	22.08	1.39	14	.185
EAME 2	58.07	6.39			
EAME 3	69.80	8.32	8.85	14	<.001*

Average-ability female students had higher delayed gain scores on units 2, 4, and 5. Results from the paired samples *t*-tests were statistically significant on unit 2 ($t(14) = -$

5.76, $p<.001$) and unit 5 ($t(14) = -3.35$, $p = .005$). Unit 2 was a teacher-led review unit and unit 5 was a handheld computer review unit. Female average-ability students had higher gain scores on units 1 and 3 (handheld computer review) and unit 6 (teacher-led review). Results from the paired samples *t*-tests were statistically significant only on unit 1, $t(14) = 3.32$, $p = .005$ and the EAME 2 (pretest) to EAME 3 (posttest) comparison, $t(14) = 8.85$, $p<.001$.

Table 28

Comparison of Gain Scores and Delayed Gain Scores for Each Unit for Low-Ability Male Students (N = 8)

Unit Type	*M*	*SD*	*t*	*df*	*p*
Unit 1 Gain	35.63	5.63			
Unit 1 Delayed Gain	20.50	14.92	3.20	7	.015
Unit 2 Gain	21.38	11.58			
Unit 2 Delayed Gain	21.88	12.80	-.10	7	.923
Unit 3 Gain	36.25	22.41			
Unit 3 Delayed Gain	26.88	29.52	1.72	7	.131
Unit 4 Gain	33.75	27.09			
Unit 4 Delayed Gain	5.00	17.73	5.02	7	.002*
Unit 5 Gain	42.50	20.51			
Unit 5 Delayed Gain	24.38	12.94	3.46	7	.011
Unit 6 Gain	58.88	17.78			
Unit 6 Delayed Gain	22.50	20.36	6.12	7	<.001*
EAME 2	45.00	6.33			
EAME 3	51.88	11.85	-2.68	7	.032

Low-ability male students had higher delayed gain scores only on unit 2, a teacher-led review unit. Results from the paired samples *t*-test were not statistically

significant. Low-ability male students had higher gain scores on the other five units (1, 3, and 5 are handheld computer review and 4 and 6 are teacher-led review). Results from the samples *t*-tests were statistically significant on unit 4 ($t(7) = 5.02$, $p = .002$), and unit 6 ($t(7) = 6.12$, $p<.001$). The EAME 2 (pretest) to EAME 3 (posttest) comparison produced non-significant results for low-ability male students.

Table 29

Comparison of Gain Scores and Delayed Gain Scores for Each Unit for Low-Ability Female Students (N = 4)

Unit Type	*M*	*SD*	*t*	*df*	*p*
Unit 1 Gain	35.00	12.25			
Unit 1 Delayed Gain	1.25	9.92	3.57	3	.038
Unit 2 Gain	13.25	7.00			
Unit 2 Delayed Gain	8.75	20.16	.35	3	.752
Unit 3 Gain	17.25	18.05			
Unit 3 Delayed Gain	7.50	6.46	.94	3	.417
Unit 4 Gain	27.50	36.63			
Unit 4 Delayed Gain	3.75	11.09	1.73	3	.183
Unit 5 Gain	25.50	9.40			
Unit 5 Delayed Gain	-2.50	2.89	4.58	3	.020
Unit 6 Gain	31.25	19.31			
Unit 6 Delayed Gain	1.25	8.54	2.45	3	.092
EAME 2	42.00	10.30			
EAME 3	46.00	9.42	-1.40	3	.256

Low-ability female students did not have any higher delayed gain scores than gain scores. Low-ability female students had higher gain scores on the six units (1, 3, and 5

are handheld computer review and 2, 4, and 6 are teacher-led review). Results from the samples *t*-tests were not statistically significant. The EAME 2 (pretest) to EAME 3 (posttest) comparison produced non-significant results for low-ability female students.

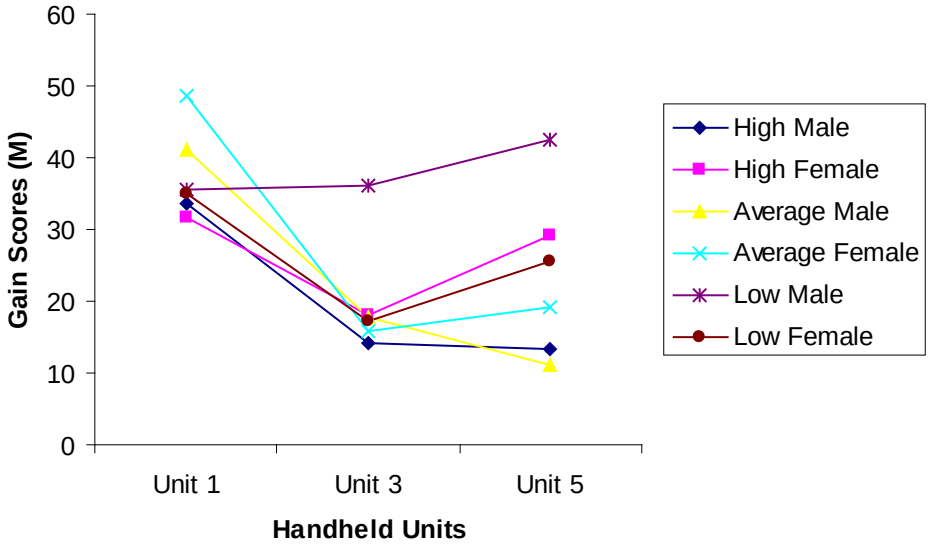


Figure 6 Handheld gain scores by ability level and gender.

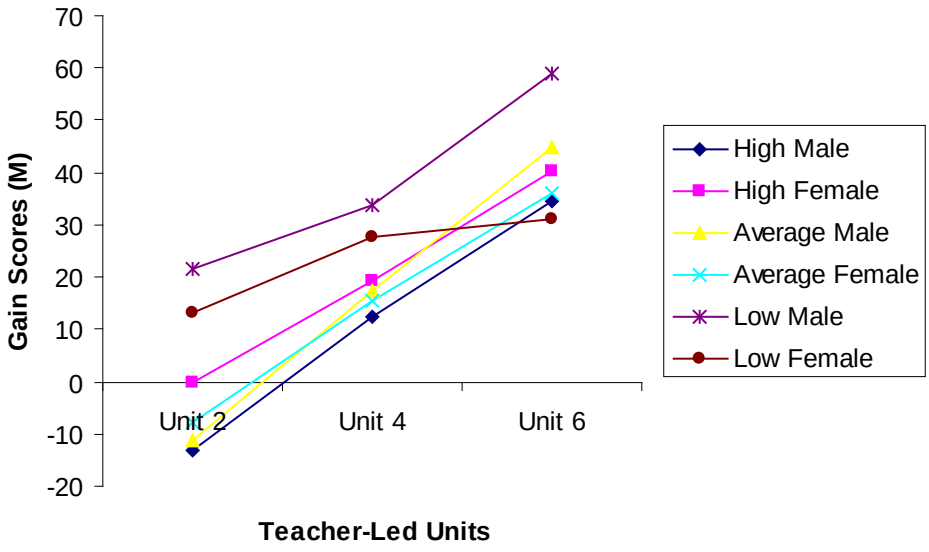


Figure 7 Teacher-led gain scores by ability level and gender.

Figures 6 and 7 show the mean gain scores for the handheld units and the teacher-led units. Unit 3 gain scores were very similar except for the low-ability males who had a higher gain score on that unit. High- and average-ability males and females had negative gain scores on unit 2.

Across Multiple Units- Gain Scores

After looking at each unit separately, across multiple units analyses were conducted. This was to see if there were any differences overall between the units where the handheld computers were used for review and the units where the handheld computers were not used for review (teacher-led review). Using SPSS, analysis of variance with repeated measures were conducted. The results found there were not any statistically significant differences for gender. Within Gain 1, Gain 3, and Gain 5

(handheld), F (2, 102) = 1.00, p = .370, nor within Gain 2, Gain 4, and Gain 6 (teacher-led), F(2,104) = .81, p = .449. There were no statistically significant differences between the genders on Gain 1, Gain 3, Gain 5; F(1,51) = .01, p = .919 and Gain 2, Gain 4, Gain 6, F(1,52) = 1.31, p = .258.

Across Multiple Units- Delayed Gain Scores

Delayed gain scores were found by subtracting each unit pretest from each unit delayed-posttest. After looking at each unit separately, across multiple units analyses were conducted. This was to see if there were any differences in the delayed gain scores overall between the units where handheld computers were used (handheld delayed gains) and the units where the handheld computers were not used (teacher-led delayed gains). Using SPSS, analysis of variance with repeated measures were conducted. The results found there were no statistically significant differences within Delayed Gain 1, Delayed Gain 3, and Delayed Gain 5 (handheld), F(2,102) = .64, p = .532, and within Delayed Gain 2, Delayed Gain 4, and Delayed Gain 6 (teacher-led), F(2,104) = 1.94, p = .149. There were no statistically significant differences between the genders on Delayed Gain 1, Delayed Gain 3, and Delayed Gain 5, F(1,51) = 2.48, p = .122 and between the genders on Delayed Gain 2, Delayed Gain 4, and Delayed Gain 6 (teacher-led), F(1,52) = .01, p = .914.

Limitations of the Study

There are several limitations to this study. This study included only one teacher. Being the teacher and researcher, there were inherent biases that I tried to reduce. I tried to maintain objectivity and keep a critical edge for proper analysis of the data. I tried to

make sure that my attitude towards the technology, which reflected in my mannerisms and speech, did not affect the students and their performance, either positively or negatively (Ball, 2000).

Since there was only one teacher in the intervention, all the students received the same intervention and were not compared to a control group. The students' performance was analyzed by comparing gain scores from pretests to posttests and pretests to delayed posttests. Including only one teacher also meant the sample size was small, particularly within the sub-groups of the whole sample.

The reliability and validity of the tests used in this study were also a limitation to this study. The pretests and posttests, with the exception of the EAME tests, were textbook and/or teacher created. However, the assessments were consistent with other assessments in the class and hence familiar in format and structure to the students.

A major problem with the teacher journal is I only responded with my perceptions. I only recorded what I heard. I did not ask each student for their opinions. Therefore, only vocal student's comments were recorded. Many students did not make comments so the silent majority was not represented in the teacher's journal. This may have skewed my qualitative results.

There are many handheld computer mathematical games available but I chose to use only free games. Also, in order to reduce the variables in this study, I didn't differentiate instruction with the students in using the games. All of the students used the same game settings for review. I should have individualized instruction more by setting

the appropriate games to the individual students' needs. I felt this was a huge variable that I did not want to introduce into this study, but it is an area for further investigation.

5. Discussion

This study investigated the use of handheld computer mathematical games for constant daily review to help students improve the retention of mathematical concepts. The purpose of this chapter is to discuss the results of this study and implications for use of handheld computer mathematical games in the classroom. This mixed methods study was guided by the following research questions: (a) What is the relationship between student ability and performance on unit tests after using handheld review mathematical games? (b) How does students' ability influence students' retention of mathematical concepts? (c) What is the relationship between student gender and performance on unit tests after using handheld review mathematical games? (d) How does students' gender influence students' retention of mathematical concepts? These questions were examined across multiple units and within each mathematical unit. Based on the research questions of the study and after analysis of the quantitative and qualitative data collected, the following major conclusions were drawn. These conclusions are presented below and explained in further detail in this chapter.

Conclusion One: High-ability students using handheld computer mathematical games do not retain more mathematical content on unit tests.

Conclusion Two: Average-ability students using handheld computer mathematical games do retain more mathematical content on unit tests.

Conclusion Three: Low-ability students using handheld computer mathematical games do not retain more mathematical content on unit tests.

Conclusion Four: High-ability male and female students using handheld computer mathematical games do not retain more mathematical content on unit tests.

Conclusion Five: Average-ability female students using handheld computer mathematical games retain more mathematical content on unit tests; whereas, average-ability male students do not retain more mathematical content on unit tests.

Conclusion Six: Low-ability male and female students using handheld computer mathematical games do not retain more mathematical content on unit tests.

First, results from the statistical analyses showed that there was a statistically significant difference between handheld computer review units and teacher led review units. Overall, the units where students reviewed using handheld computers did significantly better than units where the students completed teacher-led reviews. This was true of both gain scores and delayed gain scores. My goal was retention of mathematical concepts so I looked more carefully at the delayed gain scores but I also related any findings with the gain scores. In general the delayed posttest scores, while lower than the posttest scores, were higher than the pretest scores. I looked across multiple units and within each unit to see the results. Yet, deeper analyses showed differences with students' ability and gender. These differences will be discussed in this chapter.

Student Ability

Looking at overall results, students who reviewed using the handheld computer mathematical games obtained statistically significant higher mean gain scores and higher mean delayed gain scores. When the data is disaggregated, only average-ability students have statistically significant higher mean gain scores and higher mean delayed gain scores. When looking across multiple units and broken into ability groups high-ability students had much higher mean gain scores and mean delayed gain scores on the handheld computer review units than the teacher-led review units. The low-ability students' results were very different. The combination of the 18 high-ability and the 24 average-ability students' scores helped cause the statistically significant results for the overall comparison. There were only 12 low-ability students in this study. Discussion of the disaggregated data is presented below.

Discussion About High-Ability Students

For all ages, Fletcher-Flinn and Gravatt (1995) found in their meta-analysis that high-ability students using CAI improved more. I did not find this to be the case with this study. For the 18 high-ability students included in this study, their delayed gain mean scores outperformed their unit gain mean scores on units 2 (teacher-led review), 3 (handheld review), 4 (teacher-led review), and 5 (handheld review). So, two handheld computer review units and two teacher-led review units produced higher delayed gain mean scores in high ability students. Unit 2 delayed gain mean scores were statistically significant.

After analyzing the unit scores, mean gain scores, and delayed gain scores, unit 2 scores, especially for the high-ability and average-ability classes, looked different. The students' scores decreased from pretest to posttest, then made major delayed gains from pretest to delayed posttest. Upon looking at the units, unit 2 included statistics and graphing with topics of bar, line, and circle graphs, stem and leaf plots, and calculating mean, median, mode, and range. The delayed posttest for unit 2 was given during unit 3 which included comparing and ordering decimals, rounding decimals, and adding and subtracting decimals. There wasn't anything that was taught during unit 3 that would have helped the students on the unit 2 delayed posttest. Upon looking at the students' tests, the unit 2 posttest questions seemed harder for the students than either the unit 2 pretest or the unit 2 delayed posttest. This is the only explanation I could find for the much higher delayed gain scores on unit 2 than gain scores on unit 2.

The high-ability students gave more positive comments about the mathematical games Math Ace and LCM. Math Ace was easy for the high-ability students because it requires the student to respond to basic arithmetic questions. Math Ace was the first mathematical game the students played on the handheld computers; therefore, the novelty may have excited some students. Many students thought it was "fun." The negative comments from the high ability students concerned the miscounting the program sometimes did. One student did mention he thought it was too easy.

The high-ability students thought LCM was easy. This was after they had played GCF so it was a similar concept, just in reverse. The students felt it was easier to multiply then divide. This game presented two numbers and asked the student to find the least

common multiple of the two numbers. The high ability students found this game easier. They discovered they could multiply the two given numbers, especially if they were prime numbers, and find the LCM. There were times they also used the calculator on the handheld computer to find the answer. The students played LCM after five days of playing GCF. The students were more familiar with the mathematical concepts of GCF and LCM when they began playing LCM. I think this is another reason for the more positive comments for LCM from the high-ability students.

High-ability students did not like Power Play. This game required the students to have a good understanding of exponents. Most students found it hard and not fun. After multiple days, some high ability students discovered they could use the calculator on the handheld computer to help them find the answer, like they did with LCM. When using the exponent-easy or base-easy settings on this game, some of the numbers were very large. An example is 7 to what power equals 16,807. This game also doesn't give the correct answer; it just says "incorrect-too high" or "incorrect-too low." It would have been helpful if it gave hints or even the correct answer so students could learn from their mistakes. Low score wins in Power Play and this confused some students because they are used to high score winning. This is a different mindset for these competitive high-ability students. This game also did not give a game pad so the students had to use Grafiti or use the number pad, both of which take more time. These various factors led to the high-ability students not liking Power Play even after multiple days.

The results for the high-ability students show there is not any evidence for using handheld computer review games with this group of students. There were not enough

statistically significant differences on the gain mean scores or the delayed gain mean scores. The students may have enjoyed using the handheld computers but their mathematics achievement on the unit tests did not significantly improve with their use. One variable that I did not want to introduce was to change the settings on the computer programs to more accurately fit the student's needs. This may have helped challenge these high-ability students more and improved their retention of mathematical concepts.

Bishop and Forgasz (2007) found that ability grouped students' technology use was related to the grouping level and the student's home access to technology. They noticed higher ability students and middle class students used technology more. The high-ability students in this study were also familiar with technology. The novelty of the Palm® handheld computers wore off after about one day with each new review game. This is another reason why the settings should be set for the student's needs. Most of the high-ability students needed more of a challenge. For all ages, Fletcher-Flinn and Gravatt (1995) found in their meta-analysis that high ability students using CAI improved more. While the high-ability students test scores did show improvement, there were not statistically significant improvements evidenced by the gain or delayed gain scores. Since there were a lot of analyses on the same data, I set the significance level at .01, rather than the standard level of .05. When looking across multiple units both gain scores and delayed gain scores for high ability students had *p* values of .020. High-ability students did have higher mean gain scores and higher mean delayed gain scores on the handheld computer review units just not statistically significantly higher.

Discussion About Average-Ability Students

Results from this study found that 24 average-ability students performed better on units 2 (teacher-led review), 3 (handheld review), and 5 (handheld review) delayed gain scores. Therefore, average-ability students retained information on two handheld review units and one teacher-led unit. Unit 2 delayed gain mean scores and unit 5 delayed gain mean scores were statistically significant. Looking across multiple units, average-ability students performed statistically significantly better on both gain scores and delayed gains scores on the handheld computer review units than the teacher-led review units. Handheld computer mathematical games helped the average students more than the teacher-led reviews.

The average-ability students made more positive comments about Math Ace and Divisible. As with the high ability students, Math Ace was the first handheld mathematical game the students played so the novelty added to their excitement. The average-ability students liked Math Ace and thought it was easy. The negative comments about Math Ace primarily were about the miscounting, a programming error. Students who did not have a good grasp of basic arithmetic facts thought it was hard. With Divisible, I was surprised that so many average-ability students thought the game was "cool" and "fun." Maybe one reason they liked Divisible is because after repeated use of the divisibility rules they were catching on to the mathematical concept, thus making it cool. One student thought it was "kind of hard" and one student thought it was dumb. Divisible is a game that enabled the students to practice their understanding of divisibility

rules. Most average-ability students found it to be easy, especially after multiple days of playing.

Power Play was not liked by the average-ability students. The students said it was "very hard" and "not fun." Two students said they "hated it." Again, I feel this is primarily due to the fact that the game presented some hard questions even when it was set for easy. Some of the students used the calculator on the Palm to help figure out the answer, but that takes more time which the students did not like. Also, the students did not like that low score wins. They are used to high scores winning.

Opposite of the high-ability students, the average-ability students in this study gave more negative comments about LCM. Students made comments like "too hard" or "challenging." I am not sure why they felt this game was harder than GCF because LCM uses more multiplication where GCF uses more division. It is also confusing because the students played GCF before playing LCM. Maybe they were used to finding the GCF of the numbers so it was more challenging to reverse and find the LCM of two numbers.

The results for the average-ability students show there is some evidence for using handheld computer review games with this group of students. There were statistically significant differences on gain scores for three handheld computer review units and two teacher-led review units. There were also statistically significant differences on delayed gain scores on one handheld computer review unit and one teacher-led review unit. Statistically significant differences were found in overall mean gain scores and mean delayed gain scores on the handheld computer units. For these average-ability students, it is beneficial to use the handheld computers to help the students review the concepts so

they perform better on unit tests. The students also enjoyed using the handheld computers. The games used in this study were probably programmed for the average student in mind; therefore, these students found more success when they used handheld computer review games.

Most of the research found that high-ability and at-risk students showed more improvement when using CAI. My study found that using handheld computer mathematical review games was more beneficial for the average-ability students. As previously noted, the games were programmed with the average student in mind. They were not too challenging and not too easy for most of the average-ability students. The average-ability students also did not have as much prior technology use as the high-ability students in this study. Also there were 24 average-ability students, more than the 18 high-ability students or the 12 low-ability students. When the data is not disaggregated, the 24 average-ability students' scores helped the mean increase.

Discussion About Low-Ability Students

In Akiba's (2002) meta-analysis, she found CAI to be more beneficial for at-risk students and in the much-cited Kulik, Kulik, and Bangert-Drowns (1985) meta-analysis of computer-assisted instruction they found CAI was most beneficial for the achievement of the low-ability students. This was not the result in my study. The 12 low-ability students did not receive higher mean delayed gain scores on any of the units. There were statistically significant differences in unit 1 (handheld review), unit 4 (teacher-led review), unit 5 (handheld review), and unit 6 (teacher-led review) gain scores. So the low-ability students did better on two handheld computer review units and two teacher-

led review units but they were unable to retain the information taught over longer time since there were not any statistically significant delayed gain scores.

One of the factors for the results of this study may have been the lower number of students in the low-ability class. This makes all comments more powerful. There were fewer comments recorded in the teacher's journal because the students seemed to be concentrating more and I also had to help students more. This is in part due to the fact that the students were not strong with their math facts and in part due to the technology. Bishop and Forgasz (2007) found that higher-ability students used technology more. I felt that the lower-ability students needed more help with the technology as compared to the higher-ability and average-ability students. The lower-ability students also needed more help with the mathematical aspect of the games.

The lower-ability students liked Math Ace. Again, this is primarily due to the ease of the basic arithmetic facts. These students were slower and seemed to have to concentrate harder. On a small study of seven elementary students in Israel, Hativa (1988) looked at CAI for drill and practice in mathematics. She found that high-achieving students benefited more from CAI because they were more able to adjust; whereas, low-achieving students made less progress because of computer user errors. This may also contribute to why the lower-ability students did not progress as much with the handheld computer review units.

The students did not like Divisible and Power Play. The problem with Divisible is that the low-ability students did not learn all of the divisibility rules prior to playing the game so that was more difficult. The students said they "didn't like it," especially when

compared to Math Ace. Power Play was difficult for all students so it is understandable that the lower-ability students would think it is hard. They were not as technologically savvy so they did not use the calculator on the Palm® and repeated multiplication was more difficult for the lower-ability students.

The low-ability students' performance did not improve with these particular games; however there could be ways to adjust the settings so that games were less frustrating and more suited to the students' level that could make them more conducive to learning. There were not enough statistically significant differences on the gain mean scores or the delayed gain mean scores. The students may have enjoyed using the handheld computers for some review games but their mathematics achievement on the unit tests, especially delayed posttests, did not significantly improve with their use. Handheld computer review games with the settings used in this study did not help these low-ability students to retain the information they were taught. The handheld mathematical review games need to be set lower to better meet the low-ability students' needs. As previously noted, this is a variable I did not want to introduce into this study.

Student Gender

When looking at all the males versus all the females in this study, some generalizations can be made. The females scored higher on most of the tests than the males. When comparing the mean gain scores on the handheld review units and the mean gain scores on the teacher-led review units, both the males and the females had statistically significant differences on certain units. The males had an overall mean gain score on the handheld computer review units of 27.58 (SD = 11.69) and an overall mean

gain score on the teacher-led review units of 22.39 (*SD* = 16.32), which are not statistically significant results. The females' overall mean gain score on the handheld computer review units was 27.30 (*SD* = 8.58) and the overall mean gain score on the teacher-led review units was 17.30 (*SD* = 14.11), $t(28) = 3.92$, $p = .001$. Female students using handheld computer mathematical games did retain more mathematical content on unit tests. I thought this was interesting because most studies found minor gender differences. Looking across multiple units at delayed gain scores, no statistically significant differences were discovered in this study. When separated by ability, some of the analyses produced significant results, as described below.

Discussion About Male and Female High-Ability Students

High-ability males were not significantly different from high-ability females. The results from this study found that the seven male high-ability students and the eleven female high-ability students were very similar. High-ability males had higher delayed gain scores on two handheld computer review units (3 and 5) and two teacher-led review units (2 and 4). For the males, unit 5 was statistically significant. High-ability females had higher delayed gain scores on one handheld computer review unit (3) and two teacher-led review units (2 and 4) but the females only found unit 2 to be statistically significant.

More positive comments were recorded for high-ability male students with Math Ace, Divisible, GCF, and LCM. With Math Ace, which was the first game played on the Palms, most males thought it was "fun" or even "super fun" but one male was recorded as asking "can we make this harder?." The males thought Divisible was fun and

GCF/LCM were easy. These game settings were too easy for the high-ability male students. More positive comments were recorded from the high-ability female students for Math Ace. Most of the females said they liked it or thought it was fun. The negative comments about Math Ace concerned the miscounting, a computer design mistake, with the exception of one female who said she "hated it" but on a different day she said she thought it was "easy."

The high-ability male and female students did not like Power Play. They thought it was "not fun" or "hard." The females made more negative comments about Divisible and GCF. Most females said Divisible was "hard" or "difficult" but on later days it was recorded that they felt Divisible was "fun." It just seemed to take them a longer time to find it fun. The females felt GCF was a "brain fryer." I noted that after the third day of playing GCF that males wanted to stick with it; whereas, the females wanted to socialize. Some of those females seemed to find it too difficult and some of those females were bored because they felt it was too repetitive and easy.

This study has similar findings to Inkpen et al. (1994) who found studies show girls have less positive attitudes towards technology, especially when it comes to video games. Van Eck (2006) believes this is due to their difference in experience with technology. My journal comments noted that the high-ability female students were less enthusiastic than the high ability male students especially on subsequent days for games. The novelty seemed to wear off faster with the high-ability females than the males. This study, with all the game settings set at the default, did not meet all the students' needs.

The results for the high-ability males and females did not indicated handheld computer review games should be used with these students. There were not enough statistically significant differences on the gain mean scores or the delayed gain mean scores. The students may have enjoyed using the handheld computers but their mathematics achievement on the unit tests did not significantly improve with their use. I feel one major problem with the handheld computer review games used in this study was leaving them set where the programs defaulted. This is especially true with the high-ability students and was also seen in the results for the low-ability students. Most of the games, with the exception of Power Play, may have been too easy and not enough of a challenge. There is a fine line between having a game be an appropriate challenge versus being frustrating. Setting the games to match the students' needs is a factor that should be researched further.

Discussion About Male and Female Average-Ability Students

Overall, average-ability males' performance was not significantly different than average-ability females' performance. Upon comparison of gain scores and delayed gain scores, the nine male average-ability students had statistically significant differences on one handheld computer review units (3) and one teacher-led review unit (2). The fifteen female average-ability students had statistically significant differences on two handheld computer review units (1 and 5) and one teacher-led review unit (2). Average-ability females may do better using handheld computer review games for concept retention. This was also shown by the results of the mean gain scores by all females on the handheld

computer review units and the teacher-led review units; the handheld computer review units' mean gain score was statistically significant.

More negative comments made by male average-ability students were recorded in the teacher's journal. This is especially true of Math Ace, GCF, and LCM. The males felt Math Ace was boring or hard. Again, this must have been due to individual strengths and weaknesses on basic mathematical concepts. One male said about GCF that he "hates it" and "can't do it" but by the third day he commented "he liked it," so therefore he must have finally grasped the mathematical concept of greatest common factor. LCM was challenging, too hard, and they hated it. This surprised me because the students had been playing GCF for five days prior to playing LCM for three days. The average ability students were not able to easily flow from finding GCF to LCM, which involves multiplying.

Divisible and Power Play received an equal number of positive comments and negative comments. Divisible was "dumb" and "cool," according to some average-ability males. This may be in part due to the game setting or in part due to the student grasping the mathematical concept of divisibility rules. Power Play is "awesome," "boring," and "hard," according to the teacher's journal for the male average ability students. Many males found this challenging, whether they commented verbally on it or not. I witnessed the males more attentive to the games than the females, especially GCF/LCM. Most of the males wanted to beat their previous day's score, if they were playing the same day. While we were putting away the handheld computers each day, more males boasted about how many problems they had completed.

More positive comments made by female average-ability students were recorded in the teacher's journal than male positive comments. The females liked Math Ace and Divisible and disliked Power Play and LCM. Most of the average-ability females thought Math Ace was fun or liked it which may be attributable to the novelty of the handheld computers or the accurate program setting for their skill level. Divisible was liked by more of the female students because they made comments like "cool" or "fun." They may have begun to understand the divisibility rules and apply them to the game. Power Play was noted as being "hard" or "I hate this game." As mentioned previously, most students found this game to be difficult, even with the easiest setting. Females thought LCM was "too hard" or they "hated it"; whereas, mixed comments were noted for GCF, such as, "awesome" and "not fun." I also find that interesting because they had played GCF for five days prior to playing LCM.

Results from the average-ability students were different between the males and the females. The females had better mean gain scores on the handheld review units than the males. The males had more negative comments about using the handheld computers, which is different than what the research stated. This may be due to the fact that this group of males was more vocal about the negative aspects of using handheld computers than females. I did not notice this group of females getting bored with the games as I had noticed with the high ability females. This study showed that average-ability female students using handheld computer mathematical games retain more mathematical content on unit tests; whereas, average-ability male students do not retain more mathematical content on unit tests.

Discussion About Male and Female Low-Ability Students

The results from this study found that eight male low-ability students were able to retain information only on unit 2 (teacher-led review) because the only delayed gain score that was higher than the gain scores were on unit 2. The males did have statistically significant gain scores on units 4 and 6 (two teacher-led review units). The male low ability students outperformed the female low-ability students on unit 1 pretest, unit 2 pretest, unit 3 pretest, unit 4 pretest, unit 6 pretest, all the posttests, and all the delayed posttests. Neither the males nor the females had statistically significant gain scores on the EAME tests. The four female low-ability students were unable to retain information because all of the delayed gain scores were lower than the gain scores. There were not any statistically significant differences for the female students on their gain scores. When comparing low-ability males and females, there were non-significant results.

There were fewer notes written about comments from the low-ability students for a variety of reasons. The students were concentrating more and they needed more of the teacher's help to complete the review games. Male low-ability students liked Math Ace and disliked Divisible, Power Play, and GCF. Math Ace was "easy"; whereas, the other games were "hard." This is primarily due to the students' mathematical ability on computation skills or the settings of the games. Also Divisible was harder for the low-ability students because they did not learn all the divisibility rules, making it harder to answer the questions on that game. Female low ability students liked Math Ace but disliked Divisible. One female thought Math Ace "makes you smart." She was a student who liked to be challenged and thought that made you smarter.

For both male and female low-ability students, this study found that handheld computer reviews do not produce higher unit test scores on delayed posttests. Akiba (2002) found that CAI has a significantly positive effect on increasing the achievement of at-risk students. Akiba did a meta-analysis of many studies; my study only included twelve low ability students. My study did not find that handheld computer review games helped them retain mathematical concepts. The games may have been too difficult but they did not retain their mathematical concepts on any unit so that leads one to believe that it is not the use of computer games that is a factor but the low-ability students themselves. More studies need to address low ability learners and the use of technology.

Another factor which needs to be addressed is the number of low-ability students in this study. There were 12 low-ability students including eight males and four females. Together two handheld computer review units gain scores and two teacher-led review gain scores were statistically significantly higher. Separately the low-ability male students had statistically significant gain scores on two teacher-led review units and the low-ability female students produced non-significant results. The four lower-ability females pulled down the scores for the low ability group.

Implications and Recommendations to Instructional Designers

Students seemed to want to race through the handheld computer mathematical games. In order to accomplish this, they appeared to like games which had a numerical keyboard embedded in the game. The students did not want to have to write the answer, using Grafiti, or go to the numerical keypad on the Palm. These took too much time. Therefore, instructional designers need to keep that in mind when creating games.

A major concern of some students was the miscounting of the mistakes in Math Ace. Game designers need to make sure there is not a problem with the game program. This really frustrated some sixth graders who are very competitive and felt misjudged. A frustration for both the student and the teacher was that the Power Play game does not give the correct answer to a question. It just tells the player they were incorrect and their guess was too high or too low. This did not help to teach the students about their mistakes. They were just randomly guessing.

Implications for Classroom Instruction and Recommendations

What I learned while watching the students play these mathematical games: The games are fun and engaging (most of the games). The games only ask basic problems---drill and practice. They are not good review for more complex problems. Some of the games were too difficult for the low ability students. It just seemed to frustrate them. Some of the games were too easy or boring for the high and average students. Teachers need to individualize the games more by changing the settings for particular students. The balance between being too easy for some students and too hard for some students is tricky when planning for all students. Ke (2008) also noted this problem. The handheld computer mathematical review games used in this study did have some settings that could have addressed that balance on an individual basis but, as mentioned earlier, I did not want to introduce that additional variable into this study.

When tailored to meet students' needs, handheld computer review games should be used in education. This is especially true of average-ability students. Handheld

computers offer mobility that neither laptop nor other computers can provide. Students enjoy being interactive so this is a tool that teachers can use when it is appropriate.

Technology can be a great motivator if used properly. Halverson (2005) describes computers as providing compelling activities for motivating otherwise indifferent learners but finding the appropriate math software and using it effectively is another challenge (Kaput, 1992; Murray et al., 1999; Squire, 2005). Student motivation can also be tricky. Some students want more of a challenge; whereas, some students do not want to challenge themselves. The teacher needs to work on finding that balance with these games' settings for each individual student.

Educators also need to remember the importance of using CAI appropriately. Three more recent studies show the importance of using CAI as a supplement (Dedeo, 2001), not as a substitute for traditional instruction (Bayraktar, 2002; Christmann & Badgett, 2003). This study used the handheld computer mathematical games for constant daily review. They were not used in place of the normal classroom instruction.

Teachers also need to look at which games are best suited for mathematical concepts. For the purpose of this study I alternated handheld computer review units and teacher-led review units. The games used were best suited for those particular units. These particular games, when set at appropriate challenging levels for the students, were useful tools in the classroom, particularly for average ability students.

Implications for Research and Further Study

This small study ($N = 54$) investigated the use of handheld computer mathematical review games in a regular education sixth grade mathematics classroom for

approximately four months. More specifically it addressed student ability and gender. It found that average-ability students and average-ability female students using handheld computer mathematical review games did retain more mathematical content on unit tests. More research needs to be conducted on this topic, looking specifically at student ability and gender.

Researchers need to look at more students and more teachers. This study only had the resources for one set of handheld computers. If there were more handheld computers, more teachers and students could be included in the study. Additional studies could include control groups. A researcher needs to address the different settings on the handheld computer mathematical review games. The teacher should be able to meet the needs of the individual students by differentiating within the computer games.

From the beginning of this study, the researcher's purpose was to investigate whether using handheld computer review games would help students retain mathematical concepts and how students' gender and ability level influence students' retention of mathematical concepts. My goal was long-term retention of the concepts.

Constant daily review has been proven to help with retention of mathematical concepts (Burns, 2005; Hazlett, 2001). The best way to provide this review is what needs to be researched. Technology is a great motivator but researchers need to address the effectiveness of handheld computer mathematical review games. This study looked at some specific drill and practice games but there are many games available for use. Teachers would like to know which games are most effective with student ability and student gender. More research is needed but this small study showed that that average

ability students and average ability female students using handheld computer mathematical review games do retain more mathematical content on unit tests.

APPENDICES

Chapter 1 pretest

CHAPTER 1

NAME _____ DATE _____ PERIOD ____

Chapter 1 Test, Form 1

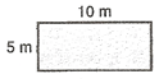
SCORE ____

Write the letter for the correct answer in the blank at the right of each question.

1. **ALLOWANCE** Juyong saves $10 of her allowance each week. Use the four-step plan to determine how many weeks she must save to buy a $40 radio.
   A. 45 weeks **B.** 4 weeks **C.** 40 weeks **D.** 10 weeks 1. ____

2. **LAWN CARE** Luis mows lawns. The first week of spring he mowed 2 lawns. The second week he mowed 4 lawns. The third week he mowed 6 lawns. If this pattern continues, how many lawns did Luis mow the fourth week?
   F. 8 **G.** 12 **H.** 5 **I.** 10 2. ____

3. Find the area of the rectangle.
   A. 15 m^2 **B.** 2 m^2
   C. 30 m^2 **D.** 50 m^2



3. ____

4. Find the next three numbers in the pattern 2, 4, 6, 8, ___, ___, ___.
   F. 16, 32, 64 **G.** 10, 12, 14 **H.** 8, 10, 12 **I.** 9, 10, 11 4. ____

For Questions 5–7, tell whether each number is divisible by 2, 3, 4, 5, 6, 9, or 10.

5. 15
   A. 3 **B.** 2, 3, 5 **C.** 3, 5 **D.** 5 5. ____

6. 55
   F. 5, 11 **G.** 5, 10 **H.** 2, 5, 10 **I.** 5 6. ____

7. 800
   A. 2, 4, 5, 10 **B.** 2, 400 **C.** 2, 4, 5 **D.** 2, 4, 10 7. ____

8. Write $3 \cdot 3$ using an exponent.
   F. $2 \cdot 3$ **G.** 3^2 **H.** $3 \cdot 2$ **I.** 9 8. ____

9. Evaluate 2^3.
   A. 8 **B.** 6 **C.** 9 **D.** 5 9. ____

10. Write 5^4 as a product.
    F. $5 \cdot 4$ **G.** $4 \cdot 4 \cdot 4 \cdot 4 \cdot 4$ **H.** $5 \cdot 5 \cdot 5 \cdot 5$ **I.** 625 10. ____

11. Evaluate $2 \cdot 4^2 - 3$.
    A. 26 **B.** 29 **C.** 61 **D.** 13 11. ____

12. Find the value of $5 + 7 \times 4$.
    F. 48 **G.** 33 **H.** 574 **I.** 39 12. ____

Assessment

CHAPTER 1

NAME _____ DATE _____ PERIOD ____

Chapter 1 Test, Form 1 *(continued)*

13. Find the value of $21 + 4 - 5 \times 2$.
A. 81 **B.** 40 **C.** 74 **D.** 15 **13.** ____

14. Find the value of $58 - 2 \times 3 + 1$.
F. 50 **G.** 53 **H.** 169 **I.** 224 **14.** ____

15. Find the value of $4 \times 3 + 9 \times 8$.
A. 84 **B.** 168 **C.** 384 **D.** 59 **15.** ____

16. Evaluate cd if $c = 9$ and $d = 8$.
F. 98 **G.** 17 **H.** 72 **I.** 89 **16.** ____

17. Evaluate $2 + 3n$ if $n = 5$.
A. 37 **B.** 10 **C.** 25 **D.** 17 **17.** ____

18. Evaluate $s + t - u$ if $s = 12$, $t = 8$, and $u = 20$.
F. 10 **G.** 0 **H.** 15 **I.** 18 **18.** ____

For Questions 19–21, find the prime factorization of each number.

19. 14
A. 2×7 **B.** 1×14 **C.** $2 \times 2 \times 3$ **D.** $2 \times 2 \times 7$ **19.** ____

20. 26
F. 1×13 **G.** 1×26 **H.** 2×13 **I.** $2 \times 2 \times 7$ **20.** ____

21. 200
A. $2 \times 2 \times 5 \times 5$ **B.** $2 \times 2 \times 2 \times 5 \times 5$
C. 2×100 **D.** 4×25 **21.** ____

22. Which number is the solution of $x - 4 = 3$?
F. 12 **G.** 1 **H.** 7 **I.** 6 **22.** ____

23. Which number is the solution of $14 = y + 4$?
A. 12 **B.** 20 **C.** 18 **D.** 10 **23.** ____

24. Solve $n + 27 = 29$ mentally.
F. 2 **G.** 56 **H.** 3 **I.** 55 **24.** ____

25. Solve $30 = f - 5$ mentally.
A. 25 **B.** 35 **C.** 45 **D.** 150 **25.** ____

Bonus Find the greatest prime number that is less than 29. **B:** _____

Chapter 1 posttest

CHAPTER 1

NAME _____ DATE _____ PERIOD ____

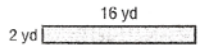
Chapter 1 Test, Form 2C

SCORE ____

1. **SWIMMING** On Saturday, 221 adults were at the swim club. On Sunday, there were 198 adults. How many more adults were at the swim club on Saturday than on Sunday? 1. _____

2. Complete the pattern: 7, 10, 13, 16, ___, ___, ___. 2. _____

3. Find the area of the rectangle. 3. _____



Tell whether each number is divisible by 2, 3, 4, 5, 6, 9, or 10. Then classify each number as *even* or *odd*.

4. 20 4. _____

5. 81 5. _____

6. 1,300 6. _____

7. 4,896 7. _____

Write each product using an exponent. Then find the value of the power.

8. $11 \cdot 11$ 8. _____

9. $5 \cdot 5 \cdot 5$ 9. _____

10. $10 \cdot 10 \cdot 10 \cdot 10$ 10. _____

11. $8 \cdot 8 \cdot 8$ 11. _____

Write each power as a product. Then find the value of the product.

12. 3^2 12. _____

13. 4^3 13. _____

14. 10^5 14. _____

15. five squared 15. _____

Chapter 1 posttest (cont.)

CHAPTER 1

NAME _____ DATE _____ PERIOD ____

Chapter 1 Test, Form 2C *(continued)*

Find the prime factorization of each number.

16. 21 **16.** _____

17. 31 **17.** _____

18. 88 **18.** _____

19. 100 **19.** _____

Find the value of each expression.

20. $5 + 20 - 7$ **20.** _____

21. $8 + (29 - 11)$ **21.** _____

22. $3 \times 4 - 2 \times 2$ **22.** _____

23. $55 \div 5 \times 2^3$ **23.** _____

Evaluate each expression if $a = 3$, $b = 10$, *and* $c = 6$.

24. $12 - b$ **24.** _____

25. $2a + 5$ **25.** _____

26. $2c + 3a$ **26.** _____

27. $c^2 + 3a \times b$ **27.** _____

Identify the solution of each equation from the list given.

28. $14 + d = 20$; 6, 7, 8 **28.** _____

29. $p - 11 = 17$; 26, 27, 28 **29.** _____

Solve each equation mentally.

30. $j + 3 = 13$ **30.** _____

31. $m - 5 = 10$ **31.** _____

32. $14 - h = 12$ **32.** _____

33. $20 + k = 25$ **33.** _____

Bonus Find the value of the expression $36 \div 3^2 + (15 \div 3) - 8 + 1$. **B:** _____

Chapter 1 delayed posttest

CHAPTER 1

NAME _____ DATE _____ PERIOD ____

Chapter 1 Test, Form 2B

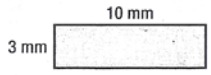
SCORE ____

Write the letter for the correct answer in the blank at the right of each question.

1. **SHOPPING** A television sells for $495 plus tax. The tax is $24. Use the four-step plan to find the total cost of the television.
   A. $471 **B.** $419 **C.** $529 **D.** $519 **1.** ____

2. **JOGGING** Wendie decided to start training for track. The first day, she jogged 6 laps. The second day, she jogged 12 laps. The third day, she jogged 18 laps. If this pattern continues, how many laps did she jog on the fourth day?
   F. 22 **G.** 24 **H.** 36 **I.** 30 **2.** ____

3. Find the area of the rectangle.
   A. 26 mm^2 **B.** 13 mm^2
   C. 30 mm^2 **D.** 109 mm^2



3. ____

4. Find the next three numbers in the pattern 1, 5, 9, 13, ___?___, ___?___, ___?___.
   F. 3, 7, 9 **G.** 15, 17, 19 **H.** 17, 21, 25 **I.** 19, 25, 31 **4.** ____

For Questions 5–7, tell whether each number is divisible by 2, 3, 4, 5, 6, 9, or 10.

5. 16
   A. 2, 4 **B.** 2, 4, 6 **C.** 2, 8 **D.** 4 **5.** ____

6. 170
   F. 2 **G.** 5 **H.** 2, 5 **I.** 2, 5, 10 **6.** ____

7. 780
   A. 2, 3, 5, 6 **B.** 2, 3, 4, 5 **C.** 2, 3, 4, 5, 6, 10 **D.** 2, 3, 4, 6 **7.** ____

8. Write $5 \cdot 5 \cdot 5 \cdot 5$ using an exponent.
   F. 4^5 **G.** 5^4 **H.** $5 \cdot 4$ **I.** $4 \cdot 5$ **8.** ____

9. Evaluate 10^5.
   A. 10,000 **B.** 50 **C.** 1,000,000 **D.** 100,000 **9.** ____

10. Write 4^3 as a product.
    F. $4 \cdot 3$ **G.** $3 \cdot 3 \cdot 3 \cdot 3$ **H.** $4 \cdot 4 \cdot 4$ **I.** $4 \cdot 4 \cdot 4 \cdot 4$ **10.** ____

11. Evaluate $5^2 \cdot 3 - 2$.
    A. 73 **B.** 28 **C.** 25 **D.** 60 **11.** ____

12. Find the value of $20 - 8 \div 4$.
    F. 48 **G.** 3 **H.** 22 **I.** 18 **12.** ____

Assessment

CHAPTER 1

NAME _____ DATE _____ PERIOD ____

Chapter 1 Test, Form 2B *(continued)*

13. Find the value of $28 + 6 \times 4 - 2$.
A. 134 **B.** 50 **C.** 68 **D.** 40 **13.** ____

14. Find the value of $51 - 2 \times 13 + 14$.
F. 1,323 **G.** 3 **H.** 39 **I.** 651 **14.** ____

15. Find the value of $42 \times 3 - 10 \div 5$.
A. 23 **B.** 7 **C.** 124 **D.** 84 **15.** ____

16. Evaluate mn if $m = 23$ and $n = 5$.
F. 115 **G.** 235 **H.** 28 **I.** 523 **16.** ____

17. Evaluate $3 + 2m$ if $m = 6$.
A. 30 **B.** 15 **C.** 29 **D.** 11 **17.** ____

18. Evaluate $a + b - c$ if $a = 20$, $b = 10$, and $c = 5$.
F. 5 **G.** 35 **H.** 25 **I.** 22 **18.** ____

For Questions 19–21, find the prime factorization of each number.

19. 30
A. $2 \times 3 \times 5$ **B.** 5×6 **C.** 3×10 **D.** 2×15 **19.** ____

20. 47
F. $2 \times 2 \times 2 \times 2 \times 3$ **G.** 2×23
H. 4×12 **I.** 47 **20.** ____

21. 68
A. 4×17 **B.** $2 \times 2 \times 17$ **C.** $1 \times 2 \times 17$ **D.** 2×34 **21.** ____

22. Which number is the solution of $x - 7 = 42$?
F. 29 **G.** 35 **H.** 49 **I.** 52 **22.** ____

23. Which number is the solution of $24 = 14 + m$?
A. 10 **B.** 38 **C.** 28 **D.** 18 **23.** ____

24. Solve $5 + n = 14$ mentally.
F. 10 **G.** 19 **H.** 8 **I.** 9 **24.** ____

25. Solve $36 - r = 9$ mentally.
A. 4 **B.** 27 **C.** 5 **D.** 45 **25.** ____

Bonus Find the value of the expression $4 + 2^3 \times (8 - 5) \div 2 + 7$. **B:** _____

Chapter 2 pretest

CHAPTER 2

NAME _____ DATE _____ PERIOD ____

Chapter 2 Test, Form 1

SCORE ____

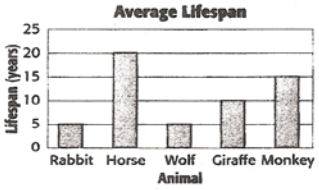
TELEVISION Refer to the frequency table.

Cartoon Watchers	
Age	**Frequency**
1–5	10
6–10	8
11–15	4
16–20	7

1. What is the most common age of cartoon watchers?
   A. 1–5 B. 6–10
   C. 11–15 D. 16–20 — 1. ____

2. How many people 11 years or older watched cartoons?
   F. 18 G. 19 H. 11 I. 29 — 2. ____

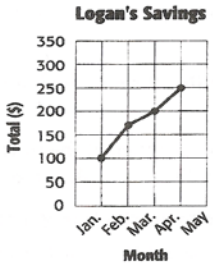
ANIMALS Refer to the bar graph.



3. Which animal has the same average lifespan as a wolf?
   A. rabbit B. horse
   C. giraffe D. monkey — 3. ____

4. Which animal lives twice as long as a giraffe?
   F. rabbit G. horse
   H. wolf I. monkey — 4. ____

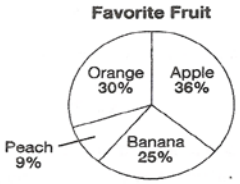
MONEY Refer to the line graph.



5. What was Logan's balance in March?
   A. $100 B. $150
   C. $200 D. $250 — 5. ____

6. What is the best prediction for Logan's May balance?
   F. $200 G. $250
   H. $300 I. $350 — 6. ____

FOOD Refer to the circle graph.



7. Which fruit is most popular?
   A. apple B. peach
   C. banana D. orange — 7. ____

8. Which fruit is least popular?
   F. apple G. peach
   H. banana I. orange — 8. ____

Refer to the stem-and-leaf plot.

Stem	Leaf
1	0 4 4
2	6 7
3	5

9. What is the greatest number shown in the plot?
   A. 67 B. 53
   C. 35 D. 1,044 — 9. ____

2|6 = 26

Assessment

CHAPTER 2

NAME _____ DATE _____ PERIOD ____

Chapter 2 Test, Form 1 *(continued)*

10. How many numbers shown are less than 20?
F. 0 **G.** 5 **H.** 2 **I.** 3 **10.** ____

11. How many times is the number 14 shown in the plot?
A. 0 **B.** 1 **C.** 2 **D.** 3 **11.** ____

BUTTERFLIES Refer to the table that shows Miko's butterfly counts.

Day	Count
Mon.	10
Tues.	13
Wed.	15
Thurs.	52
Fri.	10

12. What is the mean of the butterfly counts?
F. 10 **G.** 12
H. 13 **I.** 20 **12.** ____

13. Which value is the outlier?
A. 10 **B.** 13 **C.** 15 **D.** 52 **13.** ____

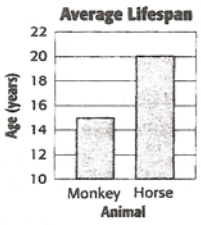
14. What is the mean without the outlier?
F. 10 **G.** 12 **H.** 13 **I.** 20 **14.** ____

15. What is the median of the butterfly counts?
A. 10 **B.** 12 **C.** 13 **D.** 20 **15.** ____

16. What is the mode of the butterfly counts?
F. 10 **G.** 12 **H.** 13 **I.** 20 **16.** ____

17. What is the range of the butterfly counts?
A. 10 to 60 **B.** 10 to 52 **C.** 42 **D.** 52 **17.** ____

ANIMALS Refer to the bar graph.



18. How many years is a horse expected to live?
F. 10 **G.** 15
H. 20 **I.** 30 **18.** ____

19. How many years is a monkey expected to live?
A. 10 **B.** 15
C. 18 **D.** 20 **19.** ____

20. Why is the graph misleading?
F. The interval starts at 10, not 0. **G.** Not enough animals are shown. **20.** ____
H. The scale starts at 10, not 0. **I.** The interval is not consistent.

Bonus MONEY Sophie's savings usually increases each month. The only time it decreased was in March, when she withdrew some money for a new bike. On a separate sheet of paper, draw a line graph that could show her savings from January through May. **B:** _____

Chapter 2 posttest

CHAPTER 2

NAME _____ DATE _____ PERIOD ____

SCORE ____

Chapter 2 Test, Form 2C

VOTING Refer to the table that shows the number of votes cast for Mia (M), Ali (A), Ted (T), and Hattie (H) for best costume.

1. Make a frequency table for the data. 1.

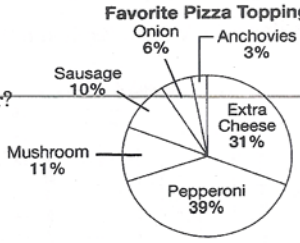
Votes			
M	T	A	H
T	T	H	A
A	A	H	M
A	M	H	H
A	T	A	M

2. Who won first place? 2. _____

3. Make a vertical bar graph of the data. 3.

4. How does the number of votes for Hattie compare to votes for Mia? 4. _____

POLLS Refer to the circle graph that shows the result of an online poll.



5. Which topping is most popular? 5. _____

6. Which two toppings are about equally favored? 6. _____

7. How does onion compare with mushroom as a favorite pizza topping? 7. _____

SHOPPING Refer to the table of book costs.

Book Costs ($)		
5	5	9
49	11	5

8. Identify the outlier. 8. _____

9. Find the mean cost of a book at the store. How does the outlier affect the mean? 9. _____

10. The store claims the average item costs $5. Which measure of central tendency are they using to describe the data? Is their claim misleading? Explain. 10. _____

Assessment

Chapter 2 posttest (cont.)

CHAPTER 2

NAME _____ DATE _____ PERIOD ____

Chapter 2 Test, Form 2C *(continued)*

SCHOOL Refer to the table of test scores.

11. Make a stem-and-leaf plot of the data.

Test Scores			
68	73	72	79
81	79	91	87
85	92	95	87
66	87	96	90

11.

12. How many students scored 80 or more on the test? 12. _____

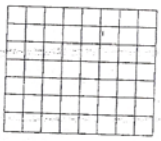
13. What is the range of the scores? 13. _____

14. What are the median and mode of the scores? 14. _____

MONEY Ella's savings account balance for January through July was $250, $80, $100, $120, $225, $250, and $275, respectively.

15. Draw a line graph of Ella's savings for the 7 months. 15.

Ella's Savings

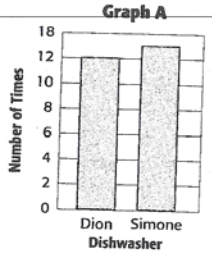


16. Ella bought a stereo, and her savings decreased that month. In which month did she buy the stereo? 16. _____

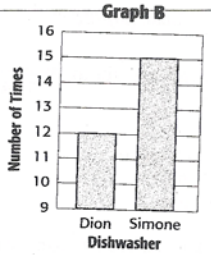
17. Predict Ella's balance in August. Explain how you made your prediction. 17. _____

CHORES Last month, Simone did the dishes 16 times, and Dion did them 12 times. Refer to the graphs that they made for their mom.

Graph A



Graph B



18. Simone claims she does the dishes twice as often as her brother. Which graph is Simone's? 18. _____

19. Dion claims he does the dishes nearly as often as his sister. Which graph is Dion's? 19. _____

20. Explain how they made the graphs misleading. 20. _____

Bonus Write a set of nine numbers that has a mean and median of 5. B: _____

Chapter 2 delayed posttest

CHAPTER 2

NAME _____ DATE _____ PERIOD ____

Chapter 2 Test, Form 2B

SCORE ____

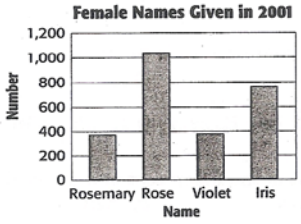
MUSIC Refer to the frequency table.

Music Store Customers	
Age	Frequency
5–8	2
9–12	8
13–16	28
17–20	21

1. What is the most common age of music store customers?
   A. 5–8 **B.** 9–12 **C.** 13–16 **D.** 17–20 1. ____

2. How many people 12 years or younger shopped at the music store?
   F. 2 **G.** 10 **H.** 8 **I.** 49 2. ____

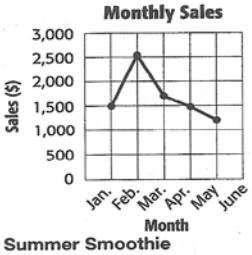
NAMES Refer to the bar graph.



3. What two names shown had about the same popularity?
   A. Rose and Iris
   B. Rosemary and Iris
   C. Violet and Rosemary
   D. Rose and Rosemary 3. ____

4. How did the popularity of the name Iris compare with that of Violet?
   F. Violet was given about the same number of times as Iris.
   G. Violet was given about twice as often as Iris.
   H. Iris was given about twice as often as Violet.
   I. Iris was given about three times more often than Violet. 4. ____

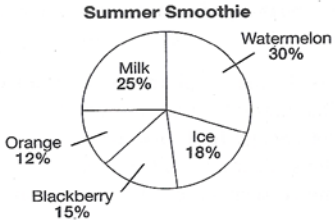
MONEY Refer to the line graph.



5. In what month did the greatest decrease in sales occur?
   A. January **B.** March **C.** February **D.** April 5. ____

6. What is the best prediction for June sales?
   F. $500 **G.** $1,000 **H.** $1,250 **I.** $1,500 6. ____

FOOD Refer to the circle graph.



7. What is the main ingredient?
   A. ice **B.** watermelon **C.** milk **D.** blackberry 7. ____

8. Which two ingredients make up more than half of a Summer Smoothie?
   F. watermelon and ice
   G. milk and watermelon
   H. milk, ice, and blackberry
   I. blackberry and milk 8. ____

Assessment

CHAPTER 2

NAME _____ DATE _____ PERIOD ____

Chapter 2 Test, Form 2B *(continued)*

Use the stem-and-leaf plot.

Stem	Leaf
2	0 9
3	2 3 6 6 7
4	1 7

3 | 2 = 32

9. What is the greatest number shown in the plot?
A. 47 **B.** 48 **C.** 67 **D.** 323,668 **9.** ____

10. What is the least number shown in the plot?
F. 0 **G.** 2 **H.** 20 **I.** 209 **10.** ____

11. How many numbers shown are less than 40?
A. 7 **B.** 5 **C.** 2 **D.** 0 **11.** ____

12. How many times is the number 36 shown in the plot?
F. 0 **G.** 1 **H.** 2 **I.** 3 **12.** ____

SHOPPING For Exercises 13–19, refer to the table.

Dress Costs ($)			
38	50	32	42
50	32	10	50

13. What is the mean cost of a dress at the store?
A. $38 **B.** $40 **C.** $42 **D.** $50 **13.** ____

14. What is the mean cost without the outlier?
F. $38 **G.** $40 **H.** $42 **I.** $50 **14.** ____

15. Which value is the outlier?
A. $38 **B.** $10 **C.** $42 **D.** $50 **15.** ____

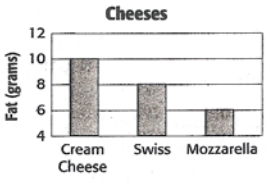
16. What is the median of the data?
F. $38 **G.** $40 **H.** $42 **I.** $50 **16.** ____

17. What is the mode of the data?
A. $32 **B.** $40 **C.** $32 and $50 **D.** $50 **17.** ____

18. What is the range of the data?
F. $8 **G.** $40 **H.** $10 to $50 **I.** $52 **18.** ____

19. Which measure of central tendency is the most misleading?
A. none **B.** median **C.** mode **D.** mean **19.** ____

20. Why is the bar graph at the right misleading?
F. The interval starts at 4, not 0.
G. Not enough foods are shown.
H. The scale starts at 4, not 0.
I. The vertical scale is not consistent. **20.** ____



Bonus If three numbers have a mode of 3 and a mean of 5, what are the three numbers? **B:** _____

Chapter 3 pretest

CHAPTER 3

NAME _____ DATE _____ PERIOD ____

Chapter 3 Test, Form 1

SCORE ____

Write the letter for the correct answer in the blank at the right of each question.

1. Write 0.4 in word form.

A. four **B.** four tenths
C. four hundredths **D.** four thousandths **1.** ____

2. Write 2.15 in word form.

F. two fifteen **G.** two and fifteen hundredths
H. two and fifteen thousandths **I.** two and fifteen two-thousandths **2.** ____

3. Write *four and twelve hundredths* in standard form.

A. 4.12 **B.** 4.012 **C.** 0.0412 **D.** 0.412 **3.** ____

4. Write *six and thirty-two hundredths* in expanded form.

F. (632×0.001) **G.** $(6 \times 0.1) + (3 \times 0.1) + (2 \times 0.1)$
H. $(6 \times 1) + (32 \times 0.001)$ **I.** $(6 \times 1) + (3 \times 0.1) + (2 \times 0.01)$ **4.** ____

5. Which number is less than 2.5?

A. 5.2 **B.** 2.50 **C.** 2.05 **D.** 2.6 **5.** ____

6. Which number is equal to 5.8?

F. 58 **G.** 5.80 **H.** 5.81 **I.** 5.08 **6.** ____

7. Order 5, 4.2, 5.02, and 4.3 from least to greatest.

A. 5.02, 5, 4.3, 4.2 **B.** 4.3, 4.2, 5, 5.02
C. 4.2, 4.3, 5, 5.02 **D.** 5.02, 4.2, 4.3, 5 **7.** ____

8. Round 3.25 to the nearest tenth.

F. 3.0 **G.** 3.2 **H.** 3.3 **I.** 4.0 **8.** ____

9. Round 9.27 to the nearest one.

A. 9 **B.** 9.2 **C.** 9.3 **D.** 10 **9.** ____

10. Round 202.339 to the nearest hundredth.

F. 200 **G.** 202 **H.** 202.34 **I.** 202.3 **10.** ____

For Questions 11–13, estimate using rounding.

11. $10.75 − $5.21

A. $5.00 **B.** $5.50 **C.** $5.52 **D.** $6.00 **11.** ____

Assessment

CHAPTER 3

NAME _____ DATE _____ PERIOD ____

Chapter 3 Test, Form 1 *(continued)*

12. 2.15 + 5.75

F. 7 **G.** 7.65 **H.** 8 **I.** 9 **12.** ____

13. **RESTAURANTS** Eddie orders one $4.25 ham sandwich and one $1.95 large orange juice. About how much is his meal?

A. $4.00 **B.** $5.00 **C.** $6.00 **D.** $7.00 **13.** ____

For Questions 14 and 15, estimate using front-end estimation.

14.
$$\begin{array}{r} 74.53 \\ +\ 5.25 \\ \hline \end{array}$$

F. 79.00 **G.** 89.00 **H.** 79.70 **I.** 80.00 **14.** ____

15. About how much more is $22.15 than $12.49?

A. $20.00 **B.** $10.00 **C.** $8.00 **D.** $34.00 **15.** ____

16. Estimate 5.18 + 5.61 + 4.95 + 5 using clustering.

F. 15 **G.** 16 **H.** 20 **I.** 19 **16.** ____

17. **TRAVEL** Maria's family went on a biking trip for four days. The table shows how many miles they traveled each day. Use clustering to estimate the total number of miles they rode on their trip.

A. 75 miles **B.** 80 miles

C. 100 miles **D.** 125 miles **17.** ____

Day	Miles
Sunday	26.5
Monday	25.1
Tuesday	25.6
Wednesday	24.8

For Questions 18 and 19, add or subtract.

18.
$$\begin{array}{r} 2.5 \\ +\ 1.3 \\ \hline \end{array}$$

F. 1.2 **G.** 3.0 **H.** 4.0 **I.** 3.8 **18.** ____

19.
$$\begin{array}{r} 6.5 \\ -\ 2.4 \\ \hline \end{array}$$

A. 4 **B.** 4.1 **C.** 5 **D.** 8.9 **19.** ____

20. **ALGEBRA** Evaluate $a + b$ if $a = 16.5$ and $b = 3.1$.

F. 13.4 **G.** 19.0 **H.** 19.6 **I.** 20.0 **20.** ____

Bonus Insert the missing number to make the following equation true. 5.1 + ● = 10.5 **B:** _____

CHAPTER 3

NAME _____ DATE _____ PERIOD ____

Chapter 3 Test, Form 2C

SCORE ____

Assessment

For Questions 1–3, write each decimal in word form.

1. 0.9 — 1. _____
2. 7.26 — 2. _____
3. 15.731 — 3. _____
4. Write *forty-seven and fifteen hundredths* in standard form. — 4. _____
5. Write *forty-seven and fifteen hundredths* in expanded form. — 5. _____

For Questions 6 and 7 use >, <, or = to compare each pair of decimals.

6. 2.001 ● 2.01 — 6. _____
7. 87.02 ● 86.025 — 7. _____
8. Order 16.851, 15.852, 16.1, 15.802 from least to greatest. — 8. _____

For Questions 9–12, round each decimal to the indicated place-value position.

9. 5.345; tenths — 9. _____
10. 12.536; ones — 10. _____
11. 47.899; hundredths — 11. _____
12. 2.0121; thousandths — 12. _____
13. **ENERGY** An electric company charges $0.138295 per kilowatt hour of electricity used. Round $0.138295 to the nearest cent. — 13. _____

For Questions 14–17, estimate using rounding.

14. 63.87 + 26.25 — 14. _____
15. $31.45 − $3.52 — 15. _____
16. 5.3 + 6.08 + 8.7 — 16. _____
17. **FOOD** Anita orders one $4.89 dish of chicken chow mein, one $2.69 bowl of miso soup, and one $1.49 side order of steamed rice. Estimate the price of her meal. — 17. _____

For Questions 18–20, estimate using front-end estimation. — 18. _____

18. $\begin{array}{r} 78.35 \\ -\ 13.51 \\ \hline \end{array}$

19. $\begin{array}{r} 16.55 \\ +\ 12.92 \\ \hline \end{array}$ — 19. _____

CHAPTER 3

NAME _____ DATE _____ PERIOD ____

Chapter 3 Test, Form 2C *(continued)*

20. About how much more is \$56.10 than \$13.78? **20.** _____

21. Estimate 6.7 + 7.51 + 6.8 + 7.1 using clustering. **21.** _____

Add or subtract. **22.** _____

22. $\begin{array}{r} 8.3 \\ +\ 2.6 \\ \hline \end{array}$ **23.** $\begin{array}{r} 18.75 \\ -\ 3.92 \\ \hline \end{array}$ **23.** _____

24. 6.7 − 3.359 **24.** _____

25. 4 + 3.61 **25.** _____

26. 0.078 + 42.35 + 0.2 **26.** _____

27. WOODWORKING Tanya is making a doll house for her sister. One piece of wood is 11.5 inches long. If she uses 6.75 inches for the window sill, how much does she have left for the welcome sign? **27.** _____

ALGEBRA Evaluate each expression if $a = 4.95$ and $b = 16.775$.

28. $b - a$ **28.** _____

29. $9 + a + b$ **29.** _____

WEATHER For Questions 30–33, refer to the table at the right that shows the average monthly rainfall for New Orleans, Louisiana.

Month	Inches
Jan.	5.12
Feb.	6.00
Mar.	5.00
Apr.	4.51

30. Use clustering to estimate the total rainfall for the four months shown. **30.** _____

31. Use rounding to estimate the total rainfall for the four months shown. **31.** _____

32. Find the actual total rainfall for the four months shown. **32.** _____

33. Miami, Florida, gets an average of 2.9 inches of rainfall in April. How much less rainfall does Miami get than New Orleans in April? **33.** _____

Bonus SHOPPING Tai buys three gifts for his family that cost \$12.99, \$7.10, and \$8.05, including tax. Tai gives the sales clerk \$30. How much change should he get back? **B:** _____

Chapter 3 delayed posttest

NAME _____ DATE _____ PERIOD ____

Chapter 3 Test, Form 2B

SCORE ____

Write the letter for the correct answer in the blank at the right of each question.

1. Write 10.052 in word form.
   A. ten fifty-two **B.** ten and fifty-two thousandths
   C. ten and fifty-two hundredths **D.** ten and fifty-two ten-thousandths 1. _____

2. Write *thirty and seventeen hundredths* in standard form.
   F. 30.017 **G.** 30.17 **H.** 0.317 **I.** 0.3017 2. _____

3. Write *three and fourteen hundredths* in expanded form.
   A. $(3 \times 0.1) + (1 \times 0.1) + (4 \times 0.1)$ **B.** $(3 \times 1) + (14 \times 0.001)$
   C. $(3 \times 1) + (1 \times 0.1) + (4 \times 0.01)$ **D.** (314×0.001) 3. _____

4. Which number is less than 3.07?
   F. 7.03 **G.** 3.7 **H.** 3.070 **I.** 3.007 4. _____

5. Which number is equal to 17.75?
   A. 1775 **B.** 17.075 **C.** 17.750 **D.** 17.751 5. _____

6. Order 17, 16.2, 17.02, and 16.471 from greatest to least.
   F. 17.02, 17, 16.471, 16.2 **G.** 16.471, 16.2, 17, 17.02
   H. 17.02, 17, 16.2, 16.471 **I.** 17, 16.2, 17.02, 16.471 6. _____

For Questions 7–9, round each decimal to the indicated place-value position.

7. 8.357; tenths
   A. 8 **B.** 8.36 **C.** 8.3 **D.** 8.4 7. _____

8. 19.465; ones
   F. 9 **G.** 19 **H.** 19.5 **I.** 20 8. _____

9. 116.563; hundredths
   A. 116 **B.** 116.56 **C.** 116.57 **D.** 116.6 9. _____

For Questions 10–12, estimate using rounding.

10. $71.75 − $5.21
    F. $67 **G.** $66 **H.** $66.54 **I.** $77 10. _____

11. 4.7 + 5.07 + 5.8
    A. 15.5 **B.** 16 **C.** 15 **D.** 14 11. _____

Chapter 3 delayed posttest (cont.)

CHAPTER 3

NAME _____ DATE _____ PERIOD ____

Chapter 3 Test, Form 2B *(continued)*

12. RESTAURANTS Vashti orders a $3.59 tuna sandwich, a $1.89 side of potato salad, and $1.29 large orange juice. About how much is her meal?
F. $6.50 G. $9.00 H. $8.00 I. $7.00 12. ____

For Questions 13 and 14, estimate using front-end estimation.

13. 34.05
+ 12.65
A. 46.00 B. 47.00 C. 46.70 D. 22.00 13. ____

14. About how much more is $65.19 than $34.69?
F. $28.00 G. $30.52 H. $31.00 I. $30.00 14. ____

15. Estimate 8.48 + 7.439 + 8.2938 + 8 using clustering.
A. 24 B. 28 C. 31 D. 32 15. ____

For Questions 16 and 17, add or subtract.

16. 16.3
+ 3.2
F. 13.1 G. 19.5 H. 20 I. 19.0 16. ____

17. 18.25
− 2.43
A. 15.82 B. 20.68 C. 16.00 D. 1.582 17. ____

WEATHER For Questions 18 and 19, refer to the table at the right that shows the annual rainfall for Vero Beach, Florida.

Month	Inches
June	6.46
July	6.09
Aug.	6.1
Sept.	7.15

18. Use clustering to find an estimate for the total rainfall for the four months shown.
F. 18 inches G. 20 inches
H. 24 inches I. 25 inches 18. ____

19. Find the actual total rainfall for the four months shown.
A. 19.70 inches B. 20.31 inches C. 25.70 inches D. 25.80 inches 19. ____

20. ALGEBRA Evaluate $b - a$ if $a = 2.35$ and $b = 36.258$.
F. 38.608 G. 15.242 H. 34.000 I. 33.908 20. ____

Bonus Insert the missing number to make the equation true. B: _____
5.3 + 3.1 + ● = 10.3

Chapter 4 pretest

CHAPTER 4

NAME _____ DATE _____ PERIOD ____

SCORE ____

Chapter 4 Test, Form 1

Write the letter for the correct answer in the blank at the right of each question.

1. Find the perimeter of a square whose sides measure 1.5 inches.
   A. 6 in. **B.** 3 in. **C.** 27 in. **D.** 2.25 in. **1.** ____

2. Evaluate $a \div b$ if $a = 4.4$ and $b = 2$.
   F. 8.8 **G.** 2.4 **H.** 2.2 **I.** 22 **2.** ____

3. Find 0.9×0.3.
   A. 2.7 **B.** 0.27 **C.** 0.6 **D.** 0.3 **3.** ____

4. Express 4.1×10^2 in standard form.
   F. 41 **G.** 4,100 **H.** 410 **I.** 41,000 **4.** ____

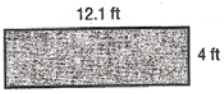
5. Multiply 1.2 and t if $t = 3.4$.
   A. 0.408 **B.** 408 **C.** 40.8 **D.** 4.08 **5.** ____

6. Multiply 8 and 0.9.
   F. 72 **G.** 7.2 **H.** 0.72 **I.** 0.072 **6.** ____

7. Find $\$1.98 \times 78$.
   A. \$15.60 **B.** \$15.44 **C.** \$145.44 **D.** \$154.44 **7.** ____

8. Find 7.6×1.4.
   F. 10.64 **G.** 106.4 **H.** 1,064 **I.** 1.64 **8.** ____

9. Find the area of the rectangle.
   A. 322 ft^2 **B.** 4.84 ft^2
   C. 48.4 ft^2 **D.** 32.2 ft^2



9. ____

10. Find the area of a rectangle with a length of 5.3 centimeters and a width of 3.6 centimeters.
    F. 190.8 cm^2 **G.** 19.08 cm^2 **H.** 17.8 cm^2 **I.** 33.39 cm^2 **10.** ____

11. Find $7\overline{)19.6}$.
    A. 28 **B.** 280 **C.** 2.8 **D.** 0.28 **11.** ____

Assessment

CHAPTER 4

NAME _____ DATE _____ PERIOD ____

Chapter 4 Test, Form 1 *(continued)*

12. Divide 5.28 by 0.8.
F. 6.6 **G.** 66 **H.** 0.66 **I.** 0.066 **12.** ____

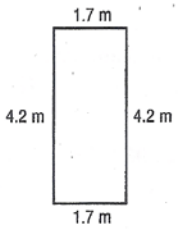
13. Find $0.9\overline{)2.736}$.
A. 34 **B.** 3.4 **C.** 30.4 **D.** 3.04 **13.** ____

14. Divide. Round to the nearest hundredth: $36\overline{)154.5}$.
F. 4.2 **G.** 4.29 **H.** 4.3 **I.** 0.43 **14.** ____

15. Divide. Round to the nearest tenth: $10.5\overline{)5.45}$.
A. 0.5 **B.** 0.52 **C.** 5.2 **D.** 0.519 **15.** ____

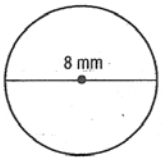
16. Evaluate $40.6 \div y$ if $y = 20$.
F. 20.3 **G.** 2.03 **H.** 203 **I.** 0.203 **16.** ____

17. Find the perimeter of the figure.
A. 5.9 m **B.** 7.14 m
C. 11.8 m **D.** 14.28 m **17.** ____



18. A rectangle measures 4 feet by 3 feet. What is the perimeter?
F. 28 ft **G.** 12 ft
H. 7 ft **I.** 14 ft **18.** ____

19. Find the circumference of the circle. Round the answer to the nearest tenth.
A. 50.3 mm **B.** 12.6 mm
C. 25.1 mm **D.** 78.9 mm **19.** ____



20. Find the circumference of a circle with a radius of 10 inches. Round the answer to the nearest tenth.
F. 62.8 in. **G.** 314.2 in. **H.** 31.4 in. **I.** 15.7 in. **20.** ____

Bonus **PAYMENTS** Rina is making payments of $39.50 per month for 18 months for her new stereo. How much will she pay in all? **B:** _____

Chapter 4 posttest

CHAPTER 4

NAME _____ DATE _____ PERIOD ____

Chapter 4 Test, Form 2C

SCORE ____

1. Find the perimeter of a square with sides of 6.5 inches. 1. _____

2. Evaluate $c \div d$ if $c = 526.64$ and $d = 58$. 2. _____

Multiply.

3. 38.4×5.7 3. _____

4. 5.4×10^6 4. _____

5. 0.89×48 5. _____

6. 3.61×3.61 6. _____

7. 0.7×3.8 7. _____

8. 428×1.32 8. _____

Find the area of each rectangle.

9. 2.5 yd, 5 yd 9. _____

10. 14.3 in., 9.7 in. 10. _____

Divide.

11. $75.6 \div 42$ 11. _____

12. $47\overline{)145.7}$ 12. _____

13. $3.822 \div 0.49$ 13. _____

14. $3.6\overline{)273.6}$ 14. _____

15. $344.28 \div 57$ 15. _____

16. $296.805 \div 42.1$ 16. _____

Assessment

CHAPTER 4

NAME _____ DATE _____ PERIOD ____

Chapter 4 Test, Form 2C *(continued)*

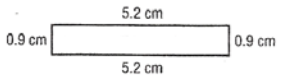
Divide. Round to the nearest hundredth.

17. $456.7 \div 6$ **17.** _____

18. $2.3\overline{)13.4}$ **18.** _____

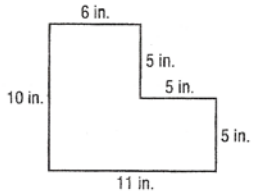
Find the perimeter of each figure.

19.



19. _____

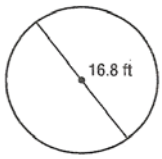
20.



20. _____

For Questions 21–24, find the circumference of each circle shown or described. Round to the nearest tenth.

21.



21. _____

22.

22. _____

23. $r = 3.7$ in. **23.** _____

24. $d = 15$ mi **24.** _____

25. SHARING If 4 people are going to share 14.8 ounces of cheese, how much will each person get? **25.** _____

Bonus WALLPAPER A rectangular room is 12 feet long by 9.5 feet wide. How many feet of wallpaper border are needed to border the ceiling? **B:** _____

Chapter 4 delayed posttest

CHAPTER 4

NAME _____ DATE _____ PERIOD ____

Chapter 4 Test, Form 2B

SCORE ____

Write the letter for the correct answer in the blank at the right of each question.

1. Find the perimeter of a square whose sides measure 8.5 inches.
   A. 72.25 in. **B.** 17 in. **C.** 32 in. **D.** 34 in. **1.** ____

2. Evaluate $s \div t$ if $s = 237.98$ and $t = 73$.
   F. 3.26 **G.** 0.326 **H.** 32.6 **I.** 326 **2.** ____

3. Find 31.6×4.2.
   A. 13.272 **B.** 132.72 **C.** 1.3272 **D.** 1327.2 **3.** ____

4. Write 2.7×10^4 in standard form.
   F. 2,700 **G.** 270,000 **H.** 27,000 **I.** 0.00027 **4.** ____

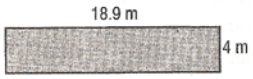
5. Multiply 3.45 and w if $w = 7.28$.
   A. 25.116 **B.** 2,511.6 **C.** 251,160 **D.** 2.5116 **5.** ____

6. Find 19×0.7.
   F. 13.3 **G.** 133 **H.** 1.33 **I.** 0.133 **6.** ____

7. Find 3.06×48.
   A. \$14.69 **B.** \$1,468.80 **C.** \$146.88 **D.** \$14,688 **7.** ____

8. Find 0.7×0.003.
   F. 2.1 **G.** 0.21 **H.** 0.021 **I.** 0.0021 **8.** ____

9. Find the area of the rectangle.



   A. 45.8 sq m **B.** 75.6 sq m
   C. 22.9 sq m **D.** 7.56 sq m **9.** ____

10. Find the area of a rectangle with a length of 3.5 yards and a width of 1.8 yards.
    F. 5.3 sq yd **G.** 63 sq yd **H.** 6.3 sq yd **I.** 10.6 sq yd **10.** ____

Assessment

Chapter 4 delayed posttest (cont.)

CHAPTER 4

NAME _____ DATE _____ PERIOD ____

Chapter 4 Test, Form 2B *(continued)*

11. Find $34\overline{)47.6}$.
A. 14 **B.** 140 **C.** 0.14 **D.** 1.4 **11.** ____

12. Find $4.44 \div 0.37$.
F. 1.2 **G.** 12 **H.** 120 **I.** 0.12 **12.** ____

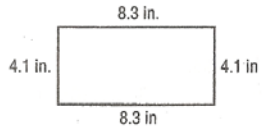
13. Find $1.6\overline{)4.944}$.
A. 3.09 **B.** 3.9 **C.** 30.9 **D.** 39 **13.** ____

14. Divide. Round to the nearest hundredth: $21\overline{)131.38}$.
F. 62.56 **G.** 62.57 **H.** 6.26 **I.** 6.25 **14.** ____

15. Divide. Round to the nearest tenth: $6.7\overline{)4.32}$.
A. 0.6 **B.** 0.64 **C.** 0.645 **D.** 6.4 **15.** ____

16. Evaluate $204.96 \div s$ if $s = 12$.
F. 170.8 **G.** 17.08 **H.** 1,708 **I.** 1.708 **16.** ____

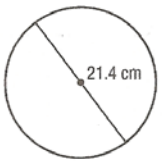
17. Find the perimeter of the figure.
A. 12.4 in. **B.** 34.03 in.
C. 68.06 in. **D.** 24.8 in.



17. ____

18. A rectangle measures 20 meters by 10 meters. What is the perimeter?
F. 30 m **G.** 200 m **H.** 60 m **I.** 900 m **18.** ____

19. Find the circumference of the circle. Round the answer to the nearest tenth.
A. 134.5 cm **B.** 67.2 cm
C. 33.6 cm **D.** 67.23 cm



19. ____

20. Find the circumference of a circle with a radius of 0.83 inch. Round the answer to the nearest tenth.
F. 2.6 in. **G.** 1.3 in. **H.** 5.2 in. **I.** 2.2 in. **20.** ____

Bonus MONEY Irma bought 6 rolls of film for $19.44. How much did each roll of film cost? **B:** _____

Chapter 5 pretest

CHAPTER 5

NAME _____ DATE _____ PERIOD ____

Chapter 5 Test, Form 1

SCORE ____

Write the letter for the correct answer in the blank at the right of each question.

1. What is the GCF of 6 and 8?
   A. 1 **B.** 2 **C.** 6 **D.** 12 **1.** ____

2. **GARDENING** Liam is planting 30 bean plants and 45 pea plants in his garden. If he puts the same number of plants in each row and if each row has only one type of plant, what is the greatest number of plants he can put in one row?
   F. 10 **G.** 15 **H.** 5 **I.** 3 **2.** ____

3. Replace the ● with a number so that $\frac{1}{3} = \frac{●}{12}$.
   A. 2 **B.** 1 **C.** 4 **D.** 3 **3.** ____

4. What is the fraction $\frac{8}{12}$ in simplest form?
   F. $\frac{8}{12}$ **G.** $\frac{4}{6}$ **H.** $\frac{2}{3}$ **I.** $\frac{3}{4}$ **4.** ____

5. **PETS** Four out of sixteen students in a classroom have cats as pets. Write $\frac{4}{16}$ in simplest form.
   A. $\frac{2}{8}$ **B.** $\frac{1}{8}$ **C.** $\frac{1}{4}$ **D.** $\frac{8}{32}$ **5.** ____

6. Write $3\frac{1}{2}$ as an improper fraction.
   F. $\frac{7}{2}$ **G.** $\frac{6}{2}$ **H.** $\frac{6}{3}$ **I.** $\frac{7}{3}$ **6.** ____

7. **COOKING** A recipe calls for $1\frac{1}{4}$ cups of flour. Write $1\frac{1}{4}$ as an improper fraction.
   A. $\frac{5}{4}$ **B.** $\frac{5}{6}$ **C.** $\frac{6}{4}$ **D.** $\frac{3}{2}$ **7.** ____

8. Write $\frac{21}{5}$ as a mixed number.
   F. $4\frac{1}{21}$ **G.** $\frac{1}{5}$ **H.** $4\frac{4}{5}$ **I.** $4\frac{1}{5}$ **8.** ____

9. What is the LCM of 3 and 12?
   A. 3 **B.** 6 **C.** 12 **D.** 36 **9.** ____

10. **HOUSEWORK** Every 2 days Jen takes out the trash. Every 3 days she sweeps the kitchen. How often does she have to do both chores on the same day?
    F. every 3 days **G.** every 2 days **H.** every 6 days **I.** every 12 days **10.** ____

Assessment

CHAPTER 5

NAME _____ DATE _____ PERIOD ____

Chapter 5 Test, Form 1 *(continued)*

11. Which fraction is less than $\frac{1}{2}$?

A. $\frac{3}{8}$ **B.** $\frac{5}{8}$ **C.** $\frac{5}{7}$ **D.** $\frac{9}{16}$ **11.** ____

12. Which fraction is greater than $\frac{1}{3}$?

F. $\frac{1}{6}$ **G.** $\frac{2}{6}$ **H.** $\frac{4}{6}$ **I.** $\frac{4}{12}$ **12.** ____

13. Which fraction is equal to $\frac{3}{4}$?

A. $\frac{4}{3}$ **B.** $\frac{6}{8}$ **C.** $\frac{4}{6}$ **D.** $\frac{3}{8}$ **13.** ____

14. Order the fractions $\frac{3}{4}$, $\frac{1}{2}$, $\frac{3}{8}$, and $\frac{5}{8}$ from least to greatest.

F. $\frac{1}{2}, \frac{3}{4}, \frac{3}{8}, \frac{5}{8}$ **G.** $\frac{1}{2}, \frac{3}{8}, \frac{3}{4}, \frac{5}{8}$

H. $\frac{3}{8}, \frac{1}{2}, \frac{3}{4}, \frac{5}{8}$ **I.** $\frac{3}{8}, \frac{1}{2}, \frac{5}{8}, \frac{3}{4}$ **14.** ____

15. Write 0.9 as a fraction in simplest form.

A. $\frac{90}{100}$ **B.** $\frac{9}{10}$ **C.** $\frac{1}{9}$ **D.** $\frac{9}{100}$ **15.** ____

16. Write 2.3 as a mixed number.

F. $2\frac{3}{10}$ **G.** $\frac{23}{10}$ **H.** $2\frac{3}{100}$ **I.** $2\frac{1}{3}$ **16.** ____

17. Write $\frac{1}{5}$ as a decimal.

A. 0.5 **B.** 0.2 **C.** 2.0 **D.** 0.02 **17.** ____

18. Write $\frac{2}{3}$ as a decimal.

F. $0.\overline{6}$ **G.** 2.3 **H.** $0.\overline{3}$ **I.** 0.6 **18.** ____

19. Write $6\frac{1}{4}$ as a decimal.

A. 6.5 **B.** 6.2 **C.** 6.25 **D.** 6.025 **19.** ____

20. MEASURING The post office requires all letters be at least $3\frac{1}{2}$ inches high. Write $3\frac{1}{2}$ as a decimal.

F. 3.25 **G.** 0.35 **H.** 3.5 **I.** 3.2 **20.** ____

Bonus Write a fraction that is between 0.25 and 0.35. **B:** _____

Chapter 5 posttest

CHAPTER 5

NAME _____ DATE _____ PERIOD ____

SCORE ____

Chapter 5 Test, Form 2C

For Questions 1 and 2, find the GCF of each set of numbers.

1. 15 and 21 — 1. _____

2. 9 and 14 — 2. _____

3. **TREES** Ms. Cole is planting 42 peach trees, 54 pear trees, and 48 plum trees in her orchard. If she puts the same number of trees in a row and if each row has only one type of tree, what is the greatest number of trees Ms. Cole can put in one row? — 3. _____

Replace the ● with a number so the fractions are equivalent.

4. $\frac{6}{7} = \frac{\bullet}{42}$ — 4. _____

5. $\frac{12}{28} = \frac{3}{\bullet}$ — 5. _____

For Questions 6 and 7, write each fraction in simplest form. If the fraction is already in simplest form, write *simplest form*.

6. $\frac{40}{35}$ — 6. _____

7. $\frac{18}{48}$ — 7. _____

8. **ANIMALS** A giant panda eats up to 18 hours a day. Write a fraction in simplest form that compares the time spent eating to the total hours in a day. — 8. _____

Write each mixed number as an improper fraction.

9. $6\frac{1}{5}$ — 9. _____

10. $4\frac{2}{3}$ — 10. _____

For Questions 11 and 12, write each improper fraction as a mixed number.

11. $\frac{48}{7}$ — 11. _____

12. $\frac{29}{9}$ — 12. _____

13. **COOKING** Ray and his grandmother are making fresh lemonade for a large picnic. In adjusting the recipe for the large amount, they calculate they need $\frac{19}{3}$ cups of sugar. Write this amount as a mixed number. — 13. _____

Assessment

CHAPTER 5

NAME _____ DATE _____ PERIOD ____

Chapter 5 Test, Form 2C *(continued)*

For Questions 14 and 15, find the LCM of each set of numbers.

14. 12 and 16 **14.** _____

15. 5 and 7 **15.** _____

16. **MUSIC** Callie is recording a rap song called "The Jungle Jubilee." The rhythm section consists largely of animal noises. At the song's start, all the creatures make noise. After that, the cricket chirps every 2 seconds, the monkey screeches every 8 seconds, and the bullfrog croaks every 12 seconds. How often can you hear these three creatures at the same time? **16.** _____

For Questions 17–19, replace each ● with <, >, or = to make a true sentence.

17. $\frac{2}{3}$ ● $\frac{11}{18}$ **17.** _____

18. $\frac{14}{18}$ ● $\frac{7}{9}$ **18.** _____

19. $\frac{11}{15}$ ● $\frac{4}{5}$ **19.** _____

20. Order the fractions $\frac{3}{4}$, $\frac{2}{3}$, $\frac{5}{6}$, and $\frac{5}{7}$ from least to greatest. **20.** _____

Write each decimal as a fraction or mixed number in simplest form.

21. 0.024 **21.** _____

22. 16.35 **22.** _____

Write each fraction or mixed number as a decimal.

23. $\frac{3}{16}$ **23.** _____

24. $\frac{4}{9}$ **24.** _____

25. $2\frac{4}{25}$ **25.** _____

Bonus **WEATHER** It usually rains $\frac{4}{50}$ of an inch more in El Paso than in Phoenix during the month of May. If the average May rainfall for Phoenix is 0.12 inch, how much does it rain in El Paso? Write this amount as a fraction in simplest form. (*Hint*: First write the fraction as a decimal.) **B:** _____

Chapter 5 delayed posttest

CHAPTER 5

NAME _____ DATE _____ PERIOD ____

Chapter 5 Test, Form 2B

SCORE ____

Write the letter for the correct answer in the blank at the right of each question.

1. What is the GCF of 12 and 30?
   A. 60 B. 6 C. 3 D. 2 1. ____

2. What is the GCF of 12, 16, and 30?
   F. 60 G. 4 H. 3 I. 2 2. ____

3. **RETAIL** Sally is putting out 36 toy cars, 24 puppets, and 18 stuffed animals in a store display. If she puts the same number of toys in each row and if each row has only one type of toy, what is the greatest number of toys Sally can put in a row?
   A. 3 B. 6 C. 12 D. 18 3. ____

4. Replace the ● with a number so $\frac{5}{9} = \frac{●}{63}$.
   F. 30 G. 35 H. 40 I. 45 4. ____

5. Which of the fractions is *not* in simplest form?
   A. $\frac{9}{25}$ B. $\frac{14}{27}$ C. $\frac{7}{8}$ D. $\frac{16}{34}$ 5. ____

6. **MUSIC** Leona has a music collection of 80 records. Of those records, 24 are country. Write a fraction in simplest form that compares the number of country records to the total number of records.
   F. $\frac{6}{20}$ G. $\frac{24}{80}$ H. $\frac{4}{5}$ I. $\frac{3}{10}$ 6. ____

7. Write $6\frac{3}{5}$ as an improper fraction.
   A. $\frac{33}{3}$ B. $\frac{90}{5}$ C. $\frac{33}{5}$ D. $\frac{18}{5}$ 7. ____

8. Write $\frac{45}{7}$ as a mixed number.
   F. $7\frac{4}{7}$ G. $6\frac{3}{7}$ H. $6\frac{4}{7}$ I. $6\frac{3}{45}$ 8. ____

9. **COOKING** Belle's brother is baking bread. The recipe calls for $4\frac{2}{3}$ cups of flour. Write $4\frac{2}{3}$ as an improper fraction.
   A. $\frac{8}{3}$ B. $\frac{14}{12}$ C. $\frac{7}{6}$ D. $\frac{14}{3}$ 9. ____

10. What is the LCM of 6 and 15?
    F. 3 G. 30 H. 90 I. 150 10. ____

Assessment

Chapter 5 delayed posttest (cont.)

CHAPTER 5

NAME _____ DATE _____ PERIOD ____

Chapter 5 Test, Form 2B *(continued)*

11. **GARDENING** Mrs. Rodriguez waters her vegetables every 3 days, her flowers every 6 days, and her fruit trees every 9 days. If she waters them all on the first day of spring, how many days pass before she has to water all three kinds again on the same day?

A. 3 days **B.** 9 days **C.** 18 days **D.** 36 days **11.** ____

12. Which fraction is greater than $\frac{1}{4}$ and less than $\frac{1}{2}$?

F. $\frac{2}{3}$ **G.** $\frac{5}{8}$ **H.** $\frac{1}{5}$ **I.** $\frac{5}{12}$ **12.** ____

13. Which fraction is equal to $\frac{7}{8}$?

A. $\frac{8}{9}$ **B.** $\frac{21}{40}$ **C.** $\frac{35}{40}$ **D.** $\frac{42}{54}$ **13.** ____

14. Order the fractions $\frac{3}{4}, \frac{1}{3}, \frac{3}{8}$ and $\frac{5}{8}$ from least to greatest.

F. $\frac{1}{3}, \frac{3}{4}, \frac{3}{8}, \frac{5}{8}$ **G.** $\frac{3}{8}, \frac{1}{3}, \frac{3}{4}, \frac{5}{8}$ **14.** ____

H. $\frac{3}{8}, \frac{1}{3}, \frac{5}{8}, \frac{3}{4}$ **I.** $\frac{1}{3}, \frac{3}{8}, \frac{5}{8}, \frac{3}{4}$

15. Write 0.95 as a fraction in simplest form.

A. $\frac{19}{50}$ **B.** $\frac{95}{100}$ **C.** $\frac{19}{20}$ **D.** $\frac{1}{95}$ **15.** ____

16. Write 14.06 as a mixed number.

F. $14\frac{6}{10}$ **G.** $14\frac{3}{5}$ **H.** $14\frac{3}{25}$ **I.** $14\frac{3}{50}$ **16.** ____

17. **WEATHER** Overnight it was so foggy that the measurable precipitation was 0.016 inch. Write 0.016 as a fraction in simplest form.

A. $\frac{4}{25}$ **B.** $\frac{2}{125}$ **C.** $\frac{4}{250}$ **D.** $\frac{8}{500}$ **17.** ____

18. Write $\frac{5}{8}$ as a decimal.

F. 0.65 **G.** 0.625 **H.** 0.675 **I.** 0.525 **18.** ____

19. Write $\frac{3}{11}$ as a decimal.

A. 0.2 **B.** $0.\overline{27}$ **C.** $0.\overline{2}$ **D.** 0.27 **19.** ____

20. Write $4\frac{7}{20}$ as a decimal.

F. 4.28 **G.** 4.35 **H.** 4.7 **I.** $4.\overline{35}$ **20.** ____

Bonus Write two numbers with a GCF of 3 and a LCM of 12. **B:** _____

Chapter 6 pretest

CHAPTER 6

NAME _____ DATE _____ PERIOD ____

SCORE ____

Chapter 6 Test, Form 1

Write the letter for the correct answer in the blank at the right of each question.

1. Round $\frac{1}{8}$ to the nearest half.
   A. 0 B. $\frac{1}{2}$ C. 1 D. $\frac{1}{4}$ 1. ____

2. Round $4\frac{5}{6}$ to the nearest half.
   F. 4 G. $4\frac{1}{2}$ H. 5 I. $4\frac{3}{4}$ 2. ____

3. Estimate $3\frac{1}{5} + 4\frac{6}{7}$.
   A. 7 B. 8 C. 9 D. 10 3. ____

4. Estimate $\frac{8}{9} - \frac{1}{8}$.
   F. 0 G. $\frac{1}{2}$ H. 1 I. $\frac{1}{4}$ 4. ____

5. Estimate $2\frac{2}{3} - \frac{1}{5}$.
   A. 1 B. $1\frac{1}{2}$ C. 2 D. $2\frac{1}{2}$ 5. ____

6. **WOODWORKING** Janelle is buying a board to make a shelf that is $28\frac{3}{4}$ inches long. Which length of board would be the best choice to buy?
   F. 28 in. G. $28\frac{1}{2}$ in. H. 29 in. I. 25 in. 6. ____

7. Find $\frac{4}{5} + \frac{3}{5}$.
   A. $\frac{9}{10}$ B. $\frac{1}{5}$ C. $\frac{7}{10}$ D. $1\frac{2}{5}$ 7. ____

8. Find $\frac{5}{9} - \frac{2}{9}$.
   F. 0 G. $\frac{1}{3}$ H. $\frac{7}{9}$ I. 1 8. ____

9. **CHOCOLATE MILK** A recipe calls for $\frac{7}{8}$ cup of milk and $\frac{1}{8}$ cup of syrup. What is the total amount of milk and syrup in the recipe?
   A. $1\frac{1}{8}$ cups B. $\frac{1}{2}$ cup C. $\frac{3}{4}$ cup D. 1 cup 9. ____

10. Find $\frac{6}{7} - \frac{6}{7}$.
    F. 0 G. $\frac{6}{7}$ H. $\frac{3}{7}$ I. $1\frac{5}{7}$ 10. ____

CHAPTER 6

NAME _____ DATE _____ PERIOD ____

Chapter 6 Test, Form 1 *(continued)*

11. Find $\frac{3}{10} + \frac{2}{5}$.

A. $\frac{5}{15}$ B. $\frac{1}{2}$ C. $\frac{7}{10}$ D. $\frac{1}{3}$ **11.** ____

12. Find $\frac{3}{4} - \frac{1}{2}$.

F. $\frac{3}{8}$ G. 1 H. $\frac{1}{2}$ I. $\frac{1}{4}$ **12.** ____

13. What is the sum of $\frac{3}{4}$ and $\frac{1}{6}$?

A. $\frac{11}{12}$ B. $\frac{2}{5}$ C. $\frac{2}{3}$ D. 1 **13.** ____

14. Find $7\frac{9}{10} - 3\frac{1}{10}$.

F. $4\frac{1}{2}$ G. $4\frac{4}{5}$ H. 4 I. $4\frac{3}{10}$ **14.** ____

15. Find $6\frac{1}{2} + 3\frac{1}{4}$.

A. $3\frac{1}{4}$ B. $9\frac{1}{2}$ C. $9\frac{3}{4}$ D. none of these **15.** ____

16. Find $8\frac{5}{12} - 3\frac{1}{12}$.

F. $5\frac{1}{2}$ G. $11\frac{1}{2}$ H. $11\frac{1}{3}$ I. $5\frac{1}{3}$ **16.** ____

17. Evaluate $a + b$ if $a = 3\frac{2}{3}$ and $b = 6\frac{3}{4}$.

A. $9\frac{5}{7}$ B. $10\frac{5}{12}$ C. $9\frac{5}{12}$ D. $10\frac{5}{7}$ **17.** ____

18. Find $7\frac{3}{10} - 2\frac{4}{5}$.

F. $5\frac{1}{5}$ G. $4\frac{1}{2}$ H. $5\frac{1}{2}$ I. $4\frac{1}{4}$ **18.** ____

19. Find $10 - 5\frac{1}{2}$.

A. $4\frac{1}{2}$ B. $5\frac{1}{2}$ C. 5 D. none of these **19.** ____

20. BOTANY In a science experiment, a plant was $4\frac{7}{8}$ inches tall at the beginning of the week. By the end of the week, the plant was $6\frac{1}{4}$ inches tall. How much did the plant grow during the week?

F. $11\frac{8}{12}$ in. G. $1\frac{3}{8}$ in. H. $2\frac{3}{8}$ in. I. $11\frac{1}{8}$ in. **20.** ____

Bonus GASOLINE Jerry filled the gas tank on his car that holds 14 gallons by pumping $8\frac{7}{10}$ gallons of gasoline into the tank. How much gas was already in the tank? **B:** _____

Chapter 6 posttest

CHAPTER 6

NAME _____ DATE _____ PERIOD ____

Chapter 6 Test, Form 2C

SCORE ____

Round each number to the nearest half.

1. $5\frac{10}{11}$ 1. _____

2. $\frac{5}{8}$ 2. _____

3. $1\frac{1}{10}$ 3. _____

Estimate.

4. $6\frac{5}{6} - 1\frac{1}{8}$ 4. _____

5. $\frac{4}{5} + \frac{7}{8}$ 5. _____

CURTAINS Carlos is going to hang curtains in two different windows. One is $38\frac{1}{8}$ inches wide, and the other is $37\frac{7}{16}$ inches wide.

6. When Carlos buys fabric for the curtains, should he round the widths of the windows up or down? 6. _____

7. Estimate the total width of the two windows. 7. _____

For Questions 8–15, add or subtract. Write in simplest form.

8. $\frac{4}{5} + \frac{3}{5}$ 8. _____

9. $\frac{3}{8} - \frac{1}{8}$ 9. _____

10. $\frac{5}{8} - \frac{1}{2}$ 10. _____

Chapter 6 posttest (cont.)

CHAPTER 6

NAME _____ DATE _____ PERIOD ____

Chapter 6 Test, Form 2C *(continued)*

11. $\frac{5}{6} + \frac{1}{3}$ — 11. _____

12. $4\frac{3}{4} - 2\frac{1}{4}$ — 12. _____

13. $\frac{1}{8} + \frac{3}{4}$ — 13. _____

14. $6 - 3\frac{1}{3}$ — 14. _____

15. $4\frac{1}{6} - 2\frac{1}{2}$ — 15. _____

16. How much more is $\frac{11}{12}$ gallon than $\frac{3}{4}$ gallon? — 16. _____

17. **CARPENTRY** A sheet of plywood is $\frac{3}{4}$ inch thick. It is nailed to a board $1\frac{5}{8}$ inches thick. What is the total thickness of the plywood and the board? — 17. _____

18. Find the sum of $\frac{1}{7}$, $\frac{5}{7}$, and $\frac{4}{7}$. — 18. _____

19. **CRAFTS** Megan has a ribbon $3\frac{7}{12}$ feet long. How much will she cut off to make a ribbon $2\frac{2}{3}$ feet long? — 19. _____

20. What is $\frac{4}{5}$ minus $\frac{3}{10}$? — 20. _____

Bonus What fraction makes this equation true? $4\frac{3}{4} + \bullet = 4\frac{15}{16}$ — B: _____

Chapter 6 delayed posttest

CHAPTER 6

NAME _____ DATE _____ PERIOD ____

Chapter 6 Test, Form 2B

SCORE ____

Write the letter for the correct answer in the blank at the right of each question.

1. Round $\frac{11}{13}$ to the nearest half.

A. 0 B. $\frac{1}{2}$ C. 1 D. $\frac{3}{4}$ 1. ____

2. Round $2\frac{1}{8}$ to the nearest half.

F. 2 G. $2\frac{1}{2}$ H. 3 I. $2\frac{1}{4}$ 2. ____

3. Estimate $4\frac{7}{8} + 6\frac{5}{6}$.

A. 22 B. 11 C. 12 D. 13 3. ____

4. Estimate $\frac{2}{9} - \frac{2}{11}$.

F. 0 G. $\frac{1}{2}$ H. 1 I. $\frac{1}{4}$ 4. ____

5. Estimate $5\frac{5}{8} - 5\frac{1}{6}$.

A. 0 B. $1\frac{1}{2}$ C. $\frac{1}{2}$ D. 1 5. ____

6. **WINDOW BLINDS** Roberto is buying blinds for a window that is $28\frac{3}{4}$ inches wide. Which is the best choice if the blinds come in these widths?

F. 28 in. G. $28\frac{1}{2}$ in. H. 29 in. I. 30 in. 6. ____

7. Find $\frac{4}{5} + \frac{3}{5}$.

A. $\frac{7}{10}$ B. $1\frac{2}{5}$ C. 1 D. $\frac{2}{5}$ 7. ____

8. Find $\frac{5}{7} - \frac{2}{7}$.

F. 0 G. $\frac{3}{14}$ H. $\frac{3}{7}$ I. 1 8. ____

9. Find the sum of $\frac{1}{12}$, $\frac{5}{12}$, and $\frac{7}{12}$.

A. 1 B. $1\frac{1}{12}$ C. $\frac{1}{3}$ D. $\frac{13}{36}$ 9. ____

10. Find $\frac{2}{5} + \frac{3}{10}$.

F. $\frac{1}{2}$ G. $\frac{1}{5}$ H. $\frac{1}{3}$ I. $\frac{7}{10}$ 10. ____

11. Find $\frac{8}{9} - \frac{2}{3}$.

A. $\frac{2}{9}$ B. 0 C. 1 D. $\frac{2}{3}$ 11. ____

Assessment

Chapter 6 delayed posttest (cont.)

CHAPTER 6

NAME _____ DATE _____ PERIOD ____

Chapter 6 Test, Form 2B *(continued)*

12. Find $\frac{1}{3} + \frac{1}{5}$.

F. $\frac{2}{3}$ G. 1 H. $\frac{1}{4}$ I. $\frac{8}{15}$ **12.** ____

13. What is the sum of $\frac{3}{4}$ and $\frac{1}{12}$?

A. $\frac{1}{2}$ B. 1 C. $\frac{1}{4}$ D. $\frac{5}{6}$ **13.** ____

14. Find $5\frac{2}{5} - 2\frac{1}{10}$.

F. $3\frac{3}{10}$ G. $2\frac{1}{10}$ H. $35\frac{1}{5}$ I. $2\frac{9}{10}$ **14.** ____

15. Find $9\frac{3}{8} + 2\frac{5}{6}$.

A. $11\frac{5}{24}$ B. $12\frac{5}{24}$ C. $11\frac{29}{48}$ D. $11\frac{4}{7}$ **15.** ____

16. Find $9\frac{4}{7} - 5\frac{1}{2}$.

F. $4\frac{3}{5}$ G. $3\frac{5}{7}$ H. $4\frac{1}{14}$ I. 4 **16.** ____

17. How much longer than $\frac{1}{2}$ mile is $\frac{9}{10}$ mile?

A. 0 mi B. $\frac{2}{5}$ mi C. $\frac{3}{5}$ mi D. 1 mi **17.** ____

18. Find $18 - 5\frac{4}{5}$.

F. $13\frac{4}{5}$ G. $12\frac{4}{5}$ H. $13\frac{1}{5}$ I. $12\frac{1}{5}$ **18.** ____

19. Find $15\frac{1}{4} - 7\frac{7}{8}$.

A. $7\frac{1}{2}$ B. $7\frac{5}{8}$ C. $7\frac{3}{8}$ D. $8\frac{5}{8}$ **19.** ____

20. **BOOKSHELF** A shelf is $30\frac{1}{4}$ inches long. The space for the shelf is $29\frac{1}{3}$ inches long. How much longer is the shelf than the space?

F. 1 in. G. $\frac{1}{2}$ in. H. $\frac{11}{12}$ in. I. $1\frac{1}{12}$ in. **20.** ____

Bonus **ICE** Josiah had a 40-quart cooler that was partially filled with ice. He added $21\frac{3}{4}$ quarts of ice to fill it up. How much ice was in the cooler before Josiah added any ice?

B: _____

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CURRICULUM VITAE

Faye Bland Obenschain was born in Greenville, N.C. on September 13, 1967. In 1973 her family moved and she was raised in Harrisonburg, Virginia. She received a Bachelor of Science in Elementary Education (4-8) from James Madison University in May 1989. After one year of substitute teaching, including two long-term substitutions, she began full time teaching for Harrisonburg City Public Schools in August 1990. She taught sixth grade mathematics, science, and social studies until single subject teaching assignments were given in 2006. During that time she received her Master of Education in Middle School from James Madison University in July 1998 and successfully completed the National Board for Professional Teaching Standards Early Adolescence/Generalist certificate in November 2002. In 2004, she enrolled in the Ph.D. in Education program at George Mason University. She has taught sixth grade mathematics from 2006 until present. When the new city middle school, Skyline Middle School, opened in August 2008, she was transferred to teach sixth grade mathematics there. She also became the instructional team leader for the sixth grade.