AN INSTRUCTIONAL LEADER'S EVALUATION OF MIXED PRACTICE AND BLOCKED PRACTICE IN HIGH SCHOOL MATHEMATICS

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The undersigned, appointed by the dean of the Graduate School, have examined the dissertation entitled

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Presented by Tamara J. DuBois

A candidate for the degree of Doctor of Education

And hereby certify that in their opinion it is worthy of acceptance.

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DEDICATION

To Geoff, my husband and best friend, for all of the love, support, and laughter.

To Hayden, Jathan, Zeb, and Jessa, my wonderful children, who gave of their time with me.

To Donna, my mom, for inspiring in me a love of learning.

To Junior, my dad, for teaching me the importance of hard work.

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AN INSTRUCTIONAL LEADER'S EVALUATION OF MIXED PRACTICE AND BLOCKED PRACTICE IN HIGH SCHOOL MATHEMATICS

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ABSTRACT

The researcher conducted a quantitative study to compare mixed practice to blocked practice in mathematics. Patton's (2008) utilized focused evaluation along with Rossi, Lipsey, and Freeman's (2004) program evaluation were used as a framework to determine if mixed practice produced any positive results in college readiness as evidenced by ACT mathematics scores as suggested by Rohrer (2009a).

The ACT mathematics scores of a class of 2010 high school graduates who learned mathematics with blocked practice were compare to 2011 high school graduates who learned mathematics using mixed practice. All students attended the same high school. However, these students converged to high school from one of six K-8 districts.

The findings of this study have implications for mathematics department heads, administrators, and curriculum directors. One finding is that students who transfer into high school from other school districts perform better on the ACT mathematics test than those who transfer to high school from other districts and learn with mixed practice. No significant differences were found which indicate that mixed practice is ever the best practice for high school mathematics.

CHAPTER ONE

Introduction of the Study

Background

College readiness of high school students is an area of concern for educational leaders at both the high school level and college level. The transition is particularly difficult in mathematics. Corbishley and Truxaw (2010) found studies world-wide suggesting twelfth grade students from the United States are not proficient in mathematics. According to Sladsky (2010), almost one-third of college freshmen are placed in remedial courses each year. The rate of remedial placement increases to over 40% at the two-year college level. The majority of these students graduated from high school with three or four years of mathematics. The remedial courses students are placed into once in college address the same curriculum learned in high school (Corbishley & Truxaw, 2010; Sladky, 2010). In addition, remedial mathematics courses do not usually count toward a degree program. Thus, the remedial courses waste students' time and money. In some universities, course placement is determined in whole or in part by ACT mathematics performance (Corbishley & Truxaw, 2010; Hichens, 2009; Madison, 2010; MSU, 2010; Sladky, 2010).

Educational leaders concerned with this phenomenon seek knowledge about how to better prepare the nation's high school students for the challenges of college, particularly in the discipline of mathematics. One area leaders can explore to address the issue lies in the presentation of the mathematics lessons. Two of these methods are mixed practice and blocked practice (Rohrer, 2009a). Mixed practice distributes practice of one concept over several episodes of study and presents a variety of concepts in each practice session. This is in contrast to blocked practice teaching methods, which has traditionally been the dominant practice in mathematics education. Blocked practice masses all practice over one concept together to be practiced in one learning session. Massing practice together refers to grouping problems of one type in a single lesson. According to Rohrer (2009a), many studies have shown that utilizing mixed practice teaching methods improves learning retention. However, few of these studies have addressed the possibility of mixed practice improving knowledge retention in the discipline of mathematics.

Prior to the 2007-2008 school year, a public high school, which will be referred to by the pseudonym Midwestville High School (MHS), addressed the concern of students' retention of mathematical knowledge. Members of the MHS mathematics department, along with school administrators, decided to change lesson practice from blocked practice to mixed practice. This decision was supported by adopting the Saxon (2003) mathematics series. This textbook series employees mixed practice as the means by which to present mathematics practice to students. The Saxon (2003) textbook presents concepts on a lesson-by-lesson basis, rather than in a traditional unit or chapter. Each lesson contains a practice set of 30 problems. The practice set combines a few (typically three to seven) problems addressing the newly covered material. The remaining problems are a mixture of problems previously introduced to students. The implementation of the program was put into action with the aim of increasing students' long-term retention of mathematics concepts.

The seniors of 2010-2011 were the first group of students who were taught all four years of high school with the Saxon (2003) program. In 2007-2008, Saxon (2003) texts were adopted for Pre-Algebra and Algebra I. In each of the next three school years, Algebra II, Algebra III, and Calculus were also transitioned to the Saxon (2003) series, respectively. The Saxon (2003) series integrates concepts from geometry into the algebra series rather than offering the subject in a separate textbook. For this study, data gathered from the 2010-2011 seniors were compared with students from the previous year's senior class. Seniors from 2009-2010 were taught using only blocked practice. Findings from this study will inform the MHS mathematics department of the impact of the program as well as contribute data to the larger mathematics education community.

Statement of the Problem

Secondary education and higher education practitioners express concern about the mathematical readiness of students transitioning from high school to college (Corbishley & Truxaw, 2010; Hichens, 2009). This issue leads to questions concerning mathematics curriculum. Some authors have suggested the problem is not that students are not learning mathematics, but they are not retaining the knowledge. The majority of mathematics classrooms use blocked practice as the method by which to teach mathematics. Blocked practice masses practice over a single concept together in one lesson and groups related concepts together in units or chapters. Thus, blocked practice may allow students to learn concepts on a short term basis but not reinforce learning for long-term retention which is necessary for college readiness (Rohrer, 2009a).

Rohrer (2009a) listed many studies in which knowledge retention through blocked practice has been compared with mixed practice. Mixed practice differs from blocked practice by distributing practice of concepts over many learning sessions rather than massing practice into only one learning session. Also, mixed practice, as its name implies, mixes practice from a variety of concepts together in each learning session. As a result, students are required to recall and apply a variety of concepts over multiple learning sessions. The mixing of problems requires students to be able to discriminate between various types of problems and appropriate solutions. Studies comparing blocked practice and mixed practice span many disciplines; however, few of these studies have compared the two practices in the subject area of mathematics (Rohrer, 2009a). The problem investigated in this study was whether mixed practice lessons are better for increasing retention of mathematical knowledge than blocked practice lessons.

Purpose of the Study

Preparing students for the rigors of college-level mathematics is an area of importance for leaders in mathematics education. Students are taught many math concepts during their years in high school. The concepts are taught in preparation for students to transition to college-level mathematics. As a result, maximum long-term retention of the concepts learned by students is crucial to readiness for college (Hichens, 2009; Rohrer, 2009a). College readiness is often determined by the administration of the ACT (Hichens, 2009).

According to Mertens (2005), causal-comparative studies are used to compare people possessing different characteristics in order to reveal cause-and-effect relationships. The purpose of this causal-comparative study was to determine if using mixed practice lessons had an effect on mathematics ACT scores for the 2011 seniors as compared to the 2010 seniors who were taught using blocked practice lessons at MHS.

The purpose includes determining if differences in baseline mathematics skills of freshmen entering MHS in 2006 and 2007 existed. Most freshmen at MHS enter the high school from one of six districts including the Midwestville School District (MSD). Students from each district are subject to a different curriculum and thus enter the high school with assorted skill sets. As a result, the researcher found it important to determine if differences existed in the mathematics skills of incoming freshmen.

In addition to determining if differences exist in mathematics ACT scores for seniors based on mixed practice lessons versus blocked practice lessons, the researcher segregated the findings into groups. Midwestville Middle School (MMS) students also learn mathematics by means of mixed practice lessons. Transfer students previously learned mathematics by means of blocked practice lessons. Separating the data into these two groups helped inform the MSD of the outcomes of the utilization of mixed practice lessons in mathematics as compared to students who learn with blocked practice lessons.

Finally, the researcher grouped the data by the mathematics courses students chose to take in high school. Students at MHS have two choices when fulfilling mathematics requirements. Students may choose to take honors mathematics courses or non-honors mathematics courses. Honors mathematics courses are more rigorous and faster paced than non-honors courses. By separating the data into these two groups, the researcher was able to determine if differences existed in ACT scores of students based on mixed practice lessons or blocked practice lessons and the type of mathematics courses taken by the student. This finding informed the MHS mathematics department, as well as the larger mathematics community, of best practices in teaching students in different course paths.

Research Questions

The research questions for this study are as follows:

1. Are there differences in baseline mathematics skills for freshmen entering MHS from District A, District B, District C, District D, District E, and Midwestville Middle School (MMS)?
2. Are there differences in mathematics ACT scores for:
    a. High school seniors based on mixed practice lessons versus blocked practice lessons methods?
    b. High school seniors who continued schooling from MMS to MHS based on mixed practice lessons versus blocked practice lessons?
    c. High school seniors who transferred to MHS from other districts based on mixed practice lessons versus blocked practice lessons?
3. Are there differences in mathematics content knowledge of students taking honors mathematics courses versus students taking non-honors mathematics courses, as evidenced by the ACT, based on mixed practice lessons versus blocked practice lessons?

Conceptual Framework

Evaluations of any program should have an “intended use by intended users” (Patton, 2008, p. 37). Such evaluations are called utilized-focused evaluations. The theory of utilized-focused evaluations emphasizes the importance of evaluative studies having applications in real world situations (Patton, 2008). Utilized-focused evaluations are particularly useful for leaders who place great importance on learning to improve understanding within organizations. Effective leaders revere learning within their organizations and encourage learning to take place as a building block to reach goals. Preskill and Brookfield (2009) discussed the importance of learning to those in leadership positions. Leaders need to embrace learning to improve understanding within their organization. Successful leaders strive to find new information and knowledge which will benefit their organizations and increase understanding. When leaders are actively involved in learning and supportive of learning, the organization can identify the best practices to implement. These learning leaders recognize the importance of individual learning as well as organizational learning (Gill, 2010; Preskill & Brookfield, 2009).

Evaluations of programs can produce a source of information through which leaders may learn. Information gained through program evaluations can provide an impetus for decision making and problem solving for organizations (Gill, 2010; Patton, 2008; Rossi, Lipsey, & Freeman, 2004). Gill (2010) wrote organizations as a whole operate more successfully when they seek to answer tough questions. These questions can be answered by what Gill (2010) called “evaluative inquiry” (p. 110). Rossi et al. (2004) referred to answering these questions as program evaluation.

Program evaluation can take many forms ranging from needs assessments to efficiency assessments. This study is an impact assessment. Impact assessments measure the degree to which a program generates the outcomes for which it is intended to produce (Rossi et al., 2004). The study will help determine if the implementation of a mixed practice curriculum in mathematics at MHS improved college mathematics readiness of seniors as evidenced by mathematics ACT scores. The utilized-focused evaluation will be used to determine if the mixed practice program is working as intended or if further changes should be implemented.

The benefits of mixed practice, which is the program under question in this study, are attributed to spacing effects. Spacing effect refers to an increase in learning when related items are spaced over a period of time as opposed to massed together. Many theorists have explained the spacing effect by means of encoding variability theory (Benjamin & Tullis, 2010; Cepeda, Pashler, Vul, Wixted, & Rohrer, 2006; Leicht & Overton, 1987).

Encoding variability theorists suggest mixed practice is beneficial because the spacing of items leads to a wider variety of encoded contextual elements. Furthermore, events that are separated by a longer time interval are likely to differ more than events that are closer together. Thus, there are more contexts by which to cue memories than when items are massed together. Encoding variability results in higher levels of successful retrieval of learned items. This is because it becomes more likely that the retrieval context will be similar to at least one of the study contexts (Benjamin & Tullis, 2010; Cepeda et al., 2006; Leicht & Overton, 1987).

Blocked practice refers to study time in which a given item is not subject to any interruptions of intervening items or periods of time. Practice items which are blocked together are associated only to the two items which directly proceed and follow. When these two items are of the same type, there is no variety in the contextual associations with the item. Those who support encoding variability theory suggest learning is increased by a variety of associations; thus blocked practice is a less preferred instructional method than mixed practice (Cepeda et al., 2006). In addition, inattention theory advocates advise that when items are blocked together rather than spaced out as in mixed practice, the learner pays less attention to each subsequent item due to familiarity. Thus, learners may solve problems mindlessly which does not contribute to learning (Langer & Imber, 1979). This idea lends further support to mixed practice lessons over blocked practice lessons (Cepeda et al., 2006).

Limitations, Assumptions, and Design Controls

This study was conducted using a causal-comparative design to determine if a mixed practice lessons provided any benefit in retention of knowledge over blocked practice lessons in mathematics (Cresswell, 2009). Retaining mathematical knowledge is essential in mathematics to prepare students for college-level coursework. Quantitative data were gathered from ACT scores and eighth grade Missouri Assessment Program (MAP) scores from 2009-2010 and 2010-2011 MHS seniors. The methods employed by this study include both limitations and assumptions.

Limitations

This study includes several limitations. First, at the time of this study, only one class of seniors at MHS had been instructed using mixed practice instruction. This was a limitation since including several years of data might provide stronger results. A second limitation arose from the study being conducted at only one school. Data gathered from other geographic locations may have provided different results. A third limitation was that the researcher did not have access to eighth grade MAP data of all of the MHS seniors who took the ACT. This limited the data because eighth grade MAP scores were utilized as a baseline score by which to compare to ACT scores. A fourth limitation of the study was that students whose test scores were used for data were not all instructed by the same teacher. Different teaching methods could have had an impact on test scores.

Assumptions

This study was causal-comparative, and as such, comparison groups were utilized. Data were obtained from existing test scores. Thus, the first assumption in this study was that the seniors from 2009-2010 were similar to seniors from 2010-2011. They came from similar backgrounds, had similar experiences, and were of similar ability (Cresswell, 2009).

Cresswell (2009) explained the importance of the reliability and validity of a measuring instrument. Thus, a second assumption was that the ACT is a reliable and valid instrument. The ACT is an instrument used widely in the United States to determine college readiness of students (Mitchell, 2011). An additional assumption was that the eighth grade MAP test is a reliable and valid instrument. The eighth grade MAP test was utilized for an analysis of covariance to determine the students' knowledge before being introduced to blocked practice instruction or mixed practice instruction (Field, 2009).

Design Controls

Since there was only one year of ACT data available for students taught with mixed practice lessons, that group of data were compared with only one year of ACT data from students taught using blocked practice lessons. The data for the group taught using blocked practice lessons were gathered from senior ACT scores from 2009-2010. The data for the group taught using mixed practice lessons were senior ACT scores from 2010-2011. Since these two groups were from the same school, the sample size of both variables was comparable (Cresswell, 2009).

This study was conducted in only one Midwest, small-town high school. As a result, generalizations may be made to other populations of students transitioning from high school to college in similar schools (Gay & Airasian, 2000). To generalize the results to other populations will require further study.

Eighth-grade MAP data were used for an analysis of covariance (Field, 2009). However, due to the lapse in time from eighth grade to twelfth grade, the eighth grade MAP data were not available for all seniors who took the ACT. The students for whom the eighth grade MAP scores are lacking are those who transferred into MHS from other school districts. This allowed the researcher to determine if mixed practice lessons provided different effects for students transferring into the school district as compared to those who had been in the district since eighth grade.

Although students were not all instructed by the same teacher, all instructors used the same mixed practice lessons and resources for the seniors of 2010-2011. In addition, teachers of the same course closely collaborated for consistency between classrooms. This reduced the threat to external validity (Cresswell, 2009).

Definition of Key Terms

In this study, which compared mixed practice instruction to blocked practice instruction, there were several terms that were used. These key terms are defined in this section.

ACT. The ACT, formerly known as the American College Test, is an instrument which measures skills students obtain during high school. The measurements are used to predict the success of students during the first year of college (ACT, 2011).

Blocked practice. For this study, blocked practice referred to the use of textbooks or other learning materials in which the practice sets consist of exercises related to only one concept. These resources provide a mass of practice problems over one concept in each daily lesson. Learning materials which use blocked practice rely heavily on repetition (Rohrer, 2009a).

Episodes of study. One episode of study referred to one period of time in which a concept is presented. For example, at MHS an episode of study for one mathematics class contains 50 minutes (Cepeda et al., 2006).

Honors mathematics courses. For this research, honors mathematics courses consisted of the following courses: (a) Algebra I, (b) Algebra II, (c) Algebra III, (d) College Algebra, (e) Pre-Calculus, and (f) AP Calculus (MHS, 2012).

Interleaving. The term interleaving used in this study referred to the way in which practice problems are arranged in mixed practice instruction. Interleaving combines exercises from many concepts without grouping them according to any pattern. The exercises cover a variety of concepts, both new and old. They are woven together to form one practice set. For example, the assignment given to students for the fiftieth lesson of a school year would contain problems selected from the first forty-nine lessons as well as the problems from the new lesson (Rohrer, 2009a).

MAP. The Missouri Assessment Program (MAP) is a grade-span test intended to measure content standards and grade-level expectations. Exams are given in (a) communication arts, (b) mathematics, and (c) science (Egan & Schneider, 2008).

Mixed practice. In this study, a mixed practice consisted of two characteristics. First, mixed practice distributes the rehearsal of the same concept over several episodes of study. The second characteristic is mixed practice interleaves problems in each learning session. Thus, students are practicing multiple concepts during each learning episode (Rohrer, 2009a).

Non-honors mathematics courses. Non-honors mathematics courses for this study referred to the following courses: (a) Algebra A, (b) Algebra B, and (c) Algebra C (MHS, 2012).

Practice set. The term practice set in this study was used to describe a group of problems that are assigned to mathematics students in which the students practice concepts related to the curriculum of the course in which they are enrolled (Rohrer & Taylor, 2007; Saxon, 2003).

Retention. Retention addresses the ability of one to retain knowledge in his memory over the long-term. Retaining information allows one to recall and use information stored in memory (Bahrick & Hall, 1991).

Significance

This study added research about the comparison of mixed practice to blocked practice specifically in the discipline of mathematics. Comparison of the two practices already existed in plenitude among other disciplines, but little research existed in mathematics (Rohrer, 2009a). In addition, many of the studies which compare mixed practice to blocked practice took place on a micro scale or in a simple lab setting. These studies have been generalized to a macro scale or a more practical environment ranging over a longer period of time (Goettl, Yadrick, Connolly-Gomez, Regian, & Shebilske, 1996). This study contributed to the body of knowledge on a macro scale rather than being generalized from a micro scale.

Research Question One provided baseline information about the mathematical abilities of freshmen entering MHS which allowed the researcher to account for previous student knowledge on ACT scores. This was important to find so that differences in mathematics ACT scores could be adjusted to reflect differences in teaching practices rather than reflecting knowledge or skills acquired by the students before learning mathematics via mixed practice lessons.

Research Question Two was used to find differences in mathematics ACT scores between students who transferred into the MSD from other districts as freshmen and students who continued to MHS as freshmen from MMS based on mixed practice lessons versus blocked practice lessons. Since MMS also uses mixed practice lessons to teach mathematics and the surrounding school districts do not, the findings from this question inform the MSD about the effect of blocked practice lessons and mixed practice lessons on the two different populations which exist at MHS. This information can be utilized to inform the MHS mathematics department of the best practices to incorporate for most students. Equally important, the findings may be used as a discussion point between the MSD and the surrounding school districts to discuss the need for coherent curriculum. In addition the findings should direct this discussion to which practice, mixed or blocked, is more fruitful to the learning of mathematics.

The third research question analyzes any effect of mixed practice and blocked practice on honor students as well as determining any effect of mixed practice and blocked practice on non-honors mathematics students. This is important to mathematics educators who strive to differentiate learning for students of different levels. Honors mathematics students are typically more motivated and possess more skills than those students who chose to take non-honors mathematics courses. It is essential for mathematics educators to find the means by which to best educate students in each group.

This research provided information to leaders in mathematics education as well as curriculum developers and instructors about the best practices in mathematics learning. The study was used to determine whether one lesson structure was superior to the other for teaching mathematics. This could have great implications for how students are prepared for college level mathematics.

Finally, this utilized-focused evaluation provided the MHS mathematics department with an evaluation of the newly implemented mixed practice lessons. The findings of the evaluation were used to aid members of the department in making decisions about changes that should be made to the mathematics program. The actions taken by the department based on the findings of this study were implemented with the desire to produce students who are well-prepared for the rigors of college mathematics.

Summary

Preparing high school students for college mathematics is an important task for high school mathematics educators and leaders. Large numbers of college freshmen enrolling in remedial mathematics courses in college indicate high schools are struggling to meet this goal (Corbishley & Truxaw, 2010; Hichens, 2009). One area which may help educators with meeting this challenge is in the means by which practice of the curriculum is administered. Some researchers believe the traditional blocked practice may not be the best strategy of teaching mathematics students for long-term retention. Although it has advantages in the short term, such as remembering for a test over a chapter of material, blocked practice are not as valuable for long-term knowledge retention which is necessary for college readiness (Cepeda et al., 2006; Rohrer, 2009a). This study compared the use of the traditional blocked practice with mixed practice by utilizing ACT scores of seniors graduating from MHS in 2009-2010 and 2010-2011.

In Chapter Two, the researcher provides a review of literature addressing the problem of students transitioning from high school mathematics to college mathematics. The effect of homework on learning is reviewed along with the methods of blocked practice and mixed practice. In Chapter Three, the population and sample of the research is presented as well as data collection and analysis procedures. In Chapter Four the results and findings of the research are presented, and Chapter Five contains conclusions, discussion, limitations, and implications of the research.

CHAPTER TWO

Review of Related Literature

Introduction

The literature review in this study includes several topics. First, the role and importance of mathematics education in the United States is outlined. This is followed by a presentation of research regarding difficulties with American students transitioning from high school mathematics to college mathematics. The history of homework as a tool for learning retention is presented. In addition, research regarding the role homework plays in learning is analyzed. The role homework has in and retention of mathematics is also explored. This leads into specific discussion about two different types of homework practice problems, mixed practice and blocked practice. Blocked practice and how it could contribute to difficulty in long-term knowledge retention is visited. This is followed by an examination of mixed practice. Research supporting mixed practice is reviewed. Then, theories which explain why mixed practice works are discussed. As a final point, the review uncovers why blocked practice has been traditionally used over mixed practice.

Mathematics Education in the United States

The importance of mathematics education was underscored by the establishment of the National Mathematics Advisory Panel (NMAP) in 2006 by order of the President of the United States. NMAP was established to “foster greater knowledge of an improved performance in mathematics among American students” (Kelly, 2008, p. 561). The vision for the panel was to supply mathematics education with research that would inform best practices in this field with the end goal of educating American students and thus supporting the American economy (Kelly, 2008).

With many of the people employed in science and mathematically based jobs in the United States retiring and other countries attracting those with talents in science and mathematics, our country must develop students with great mathematical skills. It has been estimated that jobs which are mathematically intensive as compared to other jobs will increase by a ratio of three to one in the future (NMAP, 2008). This is not only important for those who will become scientists and engineers but also other citizens. A strong background in mathematics provides individuals with more options for college and careers. This in turn affects the earning potential of individual citizens (Corbishley & Truxaw, 2010; NMAP, 2008; Scott, 2009).

Successfully completing a college degree has become increasingly more important in the United States. As society becomes more globalized, goods and services fluidly move from one country to another based on productivity. For American workers to be able to compete with other peoples, it is imperative they gain more skills and knowledge by means of a college education. As a result of global competition, college enrollment has increased over the past 30 years (Lee & Lee, 2009). As knowledge and skill becomes more indispensable, mathematics becomes more relative as it is one of the important subjects needed to complete a higher degree (Corbishley & Truxaw, 2010; Lee & Lee, 2009).

In addition, citizens who complete college degrees have a positive impact on our American way of life. College graduates vote and become civic leaders at a higher rate than those who do not graduate from college. Also, college graduates are less likely to engage in criminal activity than those without college degrees (NMAP, 2008). Thus, ensuring Americans have both the opportunity to attend a post-secondary institution as well as graduate impacts the American way of life.

Furthermore, college success affects the pocketbooks of taxpayers. College drop-outs are costly to the United States since it depends on educated college graduates to stimulate economic growth by increasing a skills-based economy. According to Bettinger, Evans, and Pope (2011), 35% of students who enrolled in an institute of higher education in the fall of 2003 had dropped out after six years. According to Magee (2010), research has shown students who are initially enrolled in remedial college courses are less likely to complete a degree. Sladky (2010) found students placed in remedial courses are more likely to drop out of college than those entering at the college level. This is particularly devastating when one sees the number of students in remedial courses. About one-third of first-year students take at least one remedial course in four-year institutions. The percentage increases to 42 at the community college level (Sladky, 2010).

In addition, remediation is demanding of university and national resources. Sladky (2010) found data from The Alliance for Excellent Education which stated remedial education for students who have recently completed high school cost the nation $1.4 billion. Magee (2010) wrote that about 10% of the teaching load at community colleges in 2006-2007 was appropriated to remediation. Also, costs are incurred by the student who drops out and the student who could have been admitted to the institution in his or her place. Colleges incur expenses in recruiting and orienting future drop outs (Bettinger et al., 2011). Based on this data, it would be best for college freshmen to be prepared for college level mathematics.

Most agree mathematics is an important skill for students to succeed in college (Lee & Lee, 2009). Kelly (2008) wrote “even the simplest economic activity is dependent on mathematical skills” (p. 561). Ganter and Barker (2004) wrote “few educators would dispute that students who can think mathematically and reason through problems are better able to face the challenges of careers on other disciplines—including those in non-scientific areas” (p. 1). As such, analyzing the relationship between mathematical knowledge and success in college is important.

Because of the positive implications of furthering one’s education, some post-secondary institutions have an open admissions policy which provides the opportunity to all to further their education. Although this has opened doors once closed to many, it has also brought with it challenges in mathematics education (Magee, 2010). One of the initial challenges for students is the transition from high school mathematics to college mathematics.

Transition from High School to College

As post-secondary institutions have worked to make higher education available to more people, accommodating the diversity of the academic needs of the students has become a challenge (McNabb, 1990; NMAP, 2008). Most community colleges have an open admissions policy which means anyone can be admitted without consideration of academic proficiency. Many students admitted to community colleges are not prepared to take college-level courses and are placed into remedial courses to prepare them for college-level work. Mathematics is the most common remedial course taken by incoming freshmen (Corbishley & Truxaw, 2010; Magee, 2010; NMAP, 2008).

Data gathered from ACT suggest more than half of high school graduates who take the test are not academically prepared for college (Nonis, Hudson, Philhours, & Teng, 2005). Herbert (2010) wrote the number of unprepared first-year college students is now as high as 77 % based on benchmarks determined by ACT. Thus, the transition from high school to college is difficult for many students. To help cushion the change from high school to college, many college freshmen are placed in remedial college courses (Corbishley & Truxaw, 2010; Hichens, 2009).

According to Corbishley and Truxaw (2010) as well Frost, Coomes, and Lindeblad (2009) and Madison (2010), one of the most challenging transitions from high school to college is in the discipline of mathematics. Corbishley and Truxaw (2010) defined mathematical readiness as “the degree to which a student is predicted to succeed in the college environment in mathematics” (p. 72). Studies which support the concern about college readiness of incoming freshmen have also found that college faculty do not view the average freshmen as mathematically prepared for the rigor of college mathematics. The skills the faculty identified as the lowest in freshmen were algebraic skills, reasoning, and generalization. Specific skills identified by college faculty include topics covered in high school mathematics curricula (Corbishley & Truxaw, 2010). Many students who leave high school with three or four years of math are placed in remedial college math courses that cover the same content as the courses taken in high school. Student placement in these courses is based on mathematics ACT scores or college placement tests which examine the skills students should have learned and retained during the three-to-four years of high school mathematics.

Placement into the correct college mathematics course is important for students in the short term and long-term. If students are placed in a course which is too low for their abilities, they may become bored. If students are placed in courses that are too difficult, there is little chance of success in passing the course or being able to apply the material from the course. When students are placed in courses which reflect their mathematical abilities, their self-esteem increases, and they are likely to succeed in college (Ingalls, 2008).

College readiness in mathematics is defined as a score of 22 or greater according to ACT. Colleges which use the ACT for mathematics placement often require a math score of 22 for students to be placed into college algebra. Typically, college algebra is the basic mathematics requirement for degrees (Hichens, 2009; MSU, 2010).

ACT

The ACT is administered to more than one million students each year in the United States (Koenig, Frey, & Detterman, 2007). The ACT test is “a curriculum-based educational and career planning tool that assesses the mastery of state and college readiness standards” (ACT, 2011, p. 30). The test is designed to measure skills acquired by students during high school and predict the success of students during the first year of college (Allen & Sconing, 2005; Ingalls, 2008).

The ACT composite score is determined by student scores in four areas: (a) English, (b) Reading, (c) Science, and (d) Mathematics. Sub test scores range from one to 36 and are averaged to determine a student's composite score (ACT, 2011; Allen & Sconing, 2005; Bettinger et al., 2011; Ingalls, 2008; Koenig et al., 2007). The ACT Mathematics (ACT-M) sub test covers basic math content that is typically covered by the eleventh grade. The test consists of 60 questions to be completed in 60 minutes (Bettinger et al., 2011).

The ACT has historically been shown to be a very reliable predictor of student success as it has a reliability coefficient of 0.9. The ACT-M has been used to predict student success in college algebra (Ingalls, 2008). In particular, high ACT-M scores have a high correlation to success in college mathematics (Bettinger et al., 2011). In addition, the ACT test has shown to be consistent in Missouri. The average ACT score for the state has been 21.7 for the past seven years (Mitchell, 2011).

As a reliable predictor of college readiness, the ACT is a major tool used to place students into appropriate courses. Some placement mechanisms include placement tests, teacher judgment, and high school grade point average. However, the ACT is often a major contributor to the decision. It is often the most economically feasible means by which to determine an incoming college student's basic skills (Ingalls, 2008). In addition, it is one of the most consistent means by which to measure college preparedness. This is because the standardized measures provided by the ACT "sustain meaning across schools and years" (Allen & Sconing, 2005, p. 1). Other measures, such as high school grade point averages, can vary from school to school; thus, standardized test scores, such as the

ACT, remain the best single forecaster of college success (Nonis et al., 2005). A mathematics department chair at a four-year university commented in a study on mathematics placement that she believed using only the ACT for course placement would be the means her department will utilize as the university grows because it is “adequate and it’s fast” (Ingalls, 2008, p. 50).

Ingalls (2008) reported the ACT Corporation conducted a study of 80 universities in 1994. The selected universities utilized only the ACT-M for mathematics placement. It found that 33% of students were prepared for college algebra and were placed into the course with a 71% accuracy rate. The ACT-M also found 33% of students ready for intermediate algebra with 69% accuracy. The students who were placed into elementary algebra were correctly placed 73% of the time.

By gathering data and conducting research, people at ACT have determined that students with an ACT-M score of 22 have a 75% chance of completing typical college algebra courses with a grade of a C or better (Allen & Sconing, 2005). This provides post-secondary institutions with a benchmark by which to place incoming students into the course for which they are best prepared.

College Mathematics Requirements and Remediation

Most colleges require one or two mathematics courses at a certain level of knowledge for all undergraduate programs (Ingalls, 2008). It is imperative to place students who are not mathematically prepared for the required level of understanding to be placed in a remedial course which will prepare them for the requirements. One of the main reasons students drop out of college is academic difficulty. Thus, a student’s academic success often depends on proper assessment and placement into courses (Allen & Sconing, 2005; Ingalls, 2008; McNabb, 1990).

Missouri State University (MSU) requires students to take a mathematics course numbered 130 or higher. This includes a choice between Contemporary Mathematics, which is a problem-solving and applications course, College Algebra, or Pre-Calculus. MSU offers three remedial courses for students who are not academically ready to address these courses. They are Intermediate Algebra I, Intermediate Algebra II, and Intermediate Algebra. Students may be placed into the appropriate course by their ACT-M scores. For students to be placed in any course numbered 130 or above, they must score at least a 22 on the ACT-M test (MSU, 2011). Similarly, the University of Missouri-Columbia (MU) and Southwest Baptist University (SBU) require mathematics courses at the college algebra level or above for graduation. In addition, these institutions offer at least one remedial mathematics course for those students who are not at the college algebra level (MU, 2011a; SBU, 2011).

As aforementioned, ACT-M data may be used to place college freshmen into the mathematics course which is appropriate for their ability level. Most universities have two levels of mathematics courses in which freshmen may be placed. The first is college algebra, which is the standard level in which most freshmen enroll. The second level consists of one or more remediation courses in which students may be placed to help them gain the skills necessary to complete the university's standard mathematics requirement (Sawyer, 1989). The remediation courses include material that should have been learned in high school (Corbishley & Truxaw, 2010). Students do not receive credit toward their degree program for remedial courses. However, the courses are required for students not academically prepared for freshmen-level mathematics (Frost, Coomes, & Lindeblad, 2009). Rohrer and Taylor (2006) wrote “benefits of learning are mostly lost if the material is forgotten” (p. 1209). Since the remediated material is covered in high school, researchers are interested in how learning can be saved in memory. One method used to enhance learning is homework assignments (Cooper, Robinson, & Patall, 2006).

Homework Assignments

Homework assignments are lessons assigned by teachers that are to be completed by students to aid in the learning process (Cooper et al., 2006; Dettmers, Trautwein, Ludtke, Kunter, & Baumert, 2010; Gorgievski, 2011; Kaur, 2011; Rayburn & Rayburn, 1999; Trautwein & Koller, 2003). Homework assignments are formatted in one of two ways: (a) mixed practice or (b) blocked practice (Rohrer, 2009a). Homework practice enhances learning by activating prior knowledge and by applying previously acquired knowledge to new problems. Homework involves teachers, students, and parents as actors. Homework also serves a variety of purposes (Dettmers et al., 2010). At the high school level, homework reinforces the purpose of skills introduced in class; it aids in the mastery of course objectives, and it is used to introduce new material (Murphy & Decker, 1989). The discussion, checking, and grading of homework has an impact on the organization of daily lessons. Thus, homework is a complex issue which has been the focus of much research (Dettmers et al., 2010; Trautewein & Koller, 2003).

Homework assignments have both pros and cons that have been debated for over 100 years (Gill & Schlossman, 2004; Murphy & Decker, 1989; Trautwein & Koller, 2003). The effect of homework assignments on a student's knowledge retention depends upon how it is received by the student. When taken seriously, homework has a positive effect on the retention of new material. In addition, homework can help improve a student's attitude toward learning and help develop study skills and responsibility. Homework assignments have a negative effect when students choose to cheat or avoid doing the assignments (Cooper, Robinson, & Patall 2006; Cooper & Valentine, 2001; Corno, 1996). As a result of the various perceptions of homework, there have been many changes in its implementation in the history of schooling in the United States.

History of Homework

Historically, perceptions and ideas about homework have changed cyclically (Cooper & Valentine, 2001; Gill & Schlossman, 2004). In the early 1900s, homework was viewed as a mechanism to discipline the minds of children. The 1940s brought a greater emphasis on problem-solving skills rather than learning through drills. Homework was criticized by educational researchers as taking away from "non-school learning activities" (Gill & Schlossman, 2004, p. 176). This emphasis, along with homework being viewed as intrusive in the private lives of students, led to a decline in homework during that time. Some areas completely removed homework (Cooper & Valentine, 2001; Gill & Schlossman, 2004).

This thought process was reversed during the Cold War when the Soviet Union launched the satellite Sputnik before the United States; this was in the late 1950s. At this time, educators became concerned that the lack of rigor would leave American students less technologically prepared to compete with other nations. As a result, homework became viewed more favorably as a means to increase the rate of the knowledge attainment (Cooper & Valentine, 2001; Gill & Schlossman, 2004).

The 1960s contemporary learning theories supported the belief that too much homework was creating too much pressure on students and was becoming mentally unhealthy. As a result, this era saw a decrease in the use of homework by educators and was replaced by more social and creative activities (Cooper & Valentine, 2001).

A third awakening of homework then occurred in the 1980s as a result of a decline in achievement-test scores. Researchers became concerned that Americans may not be able to compete well in a global society. Thus, homework was used as a means to once again increase knowledge of American students (Cooper & Valentine, 2001; Gill & Schlossman, 2004). In light of the cyclical history of homework, Cooper and Valentine (2001) concluded that homework has not been used because of its effectiveness. Rather, homework has been used based on economic trends.

Efforts have been made in many ways to improve student performance in mathematics. Most of these endeavors focus on curriculum, technology, or pedagogical practices (Gorgievski, 2011). The effect of homework on achievement has also been studied in depth (Cooper, 1989; Cooper, Lindsay, Nye, & Greathouse, 1998; Cooper et al., 2006; Truatwein, 2007). In fact, homework has been actively investigated by researchers in the United States since the 1920s; however, the research has not been used widely to inform policies or practice regarding homework (Cooper & Valentine, 2001; Corno, 1996; Rohrer & Taylor, 2007).

Effect of Homework Assignments on Achievement

Most teachers assign homework with the expectation of it improving students' learning and understanding of concepts learned in class (Cooper et al., 1998; Cooper et al., 2006). Homework adds a great deal of time on task. In core areas it provides an extra occasion to learn. Hence, one of the main reasons homework is assigned is to provide an increase in study time (Dettmers et al., 2010). Whether or not homework positively influences academic achievement has been the subject of debate in the educational community for many years (Cooper et al., 1998; Cooper et al., 2006; Cooper & Valentine, 2001; Trautwein & Koller, 2003).

Cooper et al. (1998) synthesized research from 1987 to 2003 about the effect of homework on academic achievement. The rigor of the research techniques of this study surpassed those of previous studies. Earlier meta-analyses could be utilized to argue either for or against homework due to the lack of organizing the content. In Cooper et al.'s (1998) synthesis both published and unpublished studies were located by using exhaustive searching strategies. Procedures which parallel those of content analysis were implemented to obtain data from the various studies. The data were synthesized quantitatively to summarize all of the literature. In general, the quantitative synthesis found that students in the United States who do homework outperform those who do not (Cooper & Valentine, 2001).

In 32 documents, 69 correlations were found between homework and academic achievement. Of these, 50 were positive correlations and 19 were negative. In an earlier study, Cooper (1989) analyzed almost 120 empirical studies about the effects of homework. One type of study compared students who received homework to students who received no homework. In 20 studies, 14 showed positive effects of homework while only six found it favorable to do no homework. The effect size was d=.21. The effect was more positive for high school students than for younger students (Cooper et al., 1998; Cooper & Valentine, 2001).

Another part of the study correlated the amount of time spent on homework to achievement-test scores (Cooper et al., 1998; Cooper & Valentine, 2001). Of 50 studies that addressed this correlation, 43 showed students who do more homework have better academic achievement. Seven of the 50 studies indicated a negative effect. Once again an effect was observed by grade level. There was a higher correlation between homework and achievement-test scores of high school students (r=.25) than middle school students (r=.14) and elementary students (r=.04). Interestingly, the researchers found no evidence that the academic subject of the homework influenced academic achievement (Cooper et al., 1998; Cooper & Valentine, 2001).

Although homework has been shown to increase student learning, it has not been shown to increase learning for all (Cooper et al., 2006; Ronning, 2011; Trautwein & Koller, 2003). Ronning (2011) found a larger difference in test scores in classes where all students received homework than in courses in which no one received homework. It is believed students whose families have a higher socioeconomic status learn more when homework is assigned. Students from well-to-do homes can have greater support for studying, and parents may be more willing and able to assist students. Students from less advantaged families are not affected positively by homework because they do not have the same support (Cooper et al., 2006: Ronning, 2011). In his study, Ronning (2011) observed homework has a much greater positive effect for students whose mothers had education beyond high school than for children whose mothers only had a traditional high school education.

Some studies have compared the effect of homework over material covered in class by blocked practice homework, or same-day homework, versus mixed practice homework, or homework which includes practice and/or preparation problems. Homework that provides rehearsal of problems focused on that day are monotonous and are not as cognitively demanding as those which include review problems or preparation problems (Cooper et al., 1998; Trautwein, Koller, Schmitz, & Baumert, 2002). An average effect size of d=.14 favored the more demanding homework assignments which included review and/or preparation (Trautwein et al., 2002).

In the meta-analysis by Cooper et al. (2006), there was an overall positive effect found in research between homework time and achievement; however, several shortcomings in the methodological approaches of the studies were observed (Cooper et al., 2006; Dettmers et al., 2010). These deficiencies included (a) a lack of control for other predictors of achievement, (b) inadequate modeling of the various structures in homework studies, (c) vagueness about reliability of homework measures utilized in the studies, and (d) the lack of use of a theoretical model supporting homework assignments and behaviors (Dettmers et al., 2010; Trautwein & Koller, 2003).

Trautwein, Ludtke, Kastens, and Koller (2006) addressed these issues by proposing a theoretical model for homework. Their model accounts for the various actors in the homework process: (a) students, (b) teachers, and (c) parents. The model incorporates the major variables involved which include (a) achievement, (b) homework behavior, (c) homework motivation, (d) student characteristics, (e) parental behavior, and (f) the learning environment. The model predicts student effort on homework is positively related to achievement (Detters et al., 2010). The model includes a prediction for family characteristics. Specifically, the model implies the quality of parent assistance on homework is associated with student homework effort. In addition, student characteristics such as prior knowledge, intellectual ability, and conscientiousness are predicted to have an impact on homework motivation and effort. Finally, the model incorporates the characteristics of homework. The characteristics include (a) homework frequency, (b) homework length, (c) homework control, and (d) homework quality (Detters et al., 2010; Trautwein et al., 2006).

Homework, which is a set of practice problems, is of importance in this study. Since this study compares two types of mathematics practice, homework quality is of concern. Detters et al. (2010) wrote that much preparation and thought are vital during the selection of homework. Problems selected should be cognitively stimulating but not too difficult. Cognitively challenging assignments require students to synthesize knowledge or combine problem-solving strategies where lower cognitive activities do not.

Detters et al. (2010) also claimed there are few studies discussing homework quality. Most studies have addressed quantity of homework. Their work discussed the few studies that have addressed quality of homework. Each of these studies indicated homework quality is important to achievement. The quality of homework depends in part on the level of cognitive challenge presented to the student (Detters et al., 2010; Trautwein et al., 2006; Zhu & Leung, 2011). Also of note is one study which surveyed teachers about homework attitudes and behaviors. This study found that a smaller emphasis on drill and practice tasks along with an increase in emphasis on motivation accompanied positive development in effort and achievement on homework (Trautwein, Niggli, Schnyder, & Ludtke, 2009).

Mathematics Homework

Studies exist specific to mathematics homework. Some studies arose in light of the Trends in International Mathematics and Science Study (TIMSS) of 2007 (Mullis, Martin, & Foy, 2008). Efforts to study the practices of educators in the highest achieving countries on the TIMSS study have ensued. Kaur (2011) qualitatively studied the homework practices of three eighth grade mathematics classrooms in Singapore. This study found mathematics teachers in Singapore assign students homework to consolidate material learned in class, and to prepare for tests and examinations. The teachers' rationale for giving homework to their students was centered on their belief that practice makes perfect. The teachers expressed belief that students need to sharpen their skills and comprehension of mathematical concepts. Singapore mathematics teachers often assign mixed practice homework assignments, including problems from present and past lessons for student practice (Kaur, 2011). Also worth noting is that 75% of Singapore eighth grade mathematics students report always or almost always completing their homework (Kaur, 2011; Mullis et al., 2008).

In a similar study by Zhu and Leung (2011), the researchers studied the effect of homework on mathematics achievement of eighth grade students in Hong Kong based on evidence from the TIMSS 2003. This study was quantitative, utilizing data from the test. The focus of this study was to assess the quality of homework in Hong Kong as well as the effect of homework on mathematics achievement. Zhu and Leung (2011) found both quality and quantity of homework is important in mathematics achievement. The longer time students worked on their homework, the better scores they achieved on mathematics assessment. In addition, problem/question type homework assignments showed a positive impact on achievement. Results were inconclusive about application type assessments and performance on the TIMSS 2003, thus the authors suggested further research (Zhu & Leung, 2011).

Detters et al. (2010) conducted further research on the quality of mathematics homework and achievement. The type of homework assigned was found to be positively associated with motivation on homework and effort and time spent on homework. Also found was a positive relationship between homework quality and achievement. High homework quality is characterized by cognitive challenging tasks which go beyond basic recall of information and requires the learner to synthesize concepts. This could include a combination of practice of previously learned and newly learned topics (Cooper et al., 2006; Dettmers et al., 2010)

For this study, homework can be presented to students in two basic forms. One form is called blocked practice in which homework is focused on one topic. The other form is called mixed practice which combines practice over newly learned material with previously learned concepts (Rohrer, 2009a). The next sections compare and contrast these two configurations.

Blocked Practice Lessons

If students taking three to four years of mathematics are still placing into remedial mathematics courses, what has been going wrong in the courses they are taking in high school? Rohrer (2009a) suggested low test scores are many times blamed on lack of acquiring required skills, while the possibility of forgetting the material is ignored. Acquiring skills without retaining them will result in failure on cumulative tests such as the ACT. Is it possible that the type of practice, or homework, students are performing is not contributing to learning retention?

Rohrer (2009a), Rohrer and Pashler (2010), as well as Rohrer and Taylor (2007) proposed that a quick look at student mathematics textbooks show that most students are taught mathematics by means of blocked or massed practice. Cepeda et al. (2006) defined massing as the presentation of practice problems in which each item is separated by zero items and a time lag of less than one second. Also known as blocked practice, massing is a method of study in which all problems of a particular type are completed before practice is begun on another type of problem (Rohrer, 2009a; Rohrer & Pashler, 2010; Simon & Bjork, 2001). For example, one lesson in a text may teach how to solve a quadratic equation by factoring. The practice set would then consist only of problems on which students solve a quadratic equation by factoring. Solving quadratic equations by the quadratic formula would be taught and practiced in a separate lesson. Although most mathematics textbooks include blocked practice and mixed review, the majority of these resources are characterized by heavy repetition or blocked practice (Rohrer, 2009a; Rohrer & Pashler, 2010). This section explores blocked practice and the theory of overlearning.

Overlearning

Blocking repetitive problems together is a strategy utilized for over-learning. Driskell, Willis, and Copper (1992) defined overlearning as "the deliberate overtraining of a task past a set criterion" (p. 615). This means that a student meets a criteria set for mastery of a skill. Upon mastery, rather than learning a new skill, the student continues practicing the same skill on a predetermined amount of rehearsal. In other words, students continue practicing after they have already learned the skill, hence, overlearning (Rohrer, 2009b; Rohrer & Taylor, 2006; Rohrer & Taylor, 2007; Rohrer et al., 2005).

Dougherty and Johnston (1996) said overlearning "refers to training that leads to improved retention" (p. 289). Overlearning is the predominant learning strategy employed in mathematics and is widely advocated. Textbook assignments typically present students with many problems of the same type in one set (Gorgievski, 2011; Rohrer & Taylor, 2006; Rohrer et al., 2005).

Some studies have indicated overlearning sustains knowledge recall when compared to learning only to a certain criterion (Rohrer & Taylor, 2006). In an early study by Krueger (1929), participants were given a list of one syllable nouns to memorize. Two groups of participants received several learning sessions with the same words, but the overlearning group received twice as many sessions as the control group. In tests given in intervals of 1 to 28 days later, the overlearning group recalled the words statistically better than the control group. Since this study, many other researchers have conducted this experiment and have discovered the same phenomena for the short time interval of 1 to 28 days (Bromage & Mayer, 1986; Carroll & Nelson, 1993; Gilbert, 1957; Nelson, 1982; Rohrer & Taylor, 2006; Rohrer et al., 2005; Rose, 1992).

Studies have shown test scores improve when learners practice the same tasks repeatedly even after achieving success. Driskell et al. (1992) performed a meta-analysis of 15 studies on overlearning. Eleven of the 15 studies were with cognitive tasks. The studies had a total of 88 hypotheses for which Driskell et al. (1992) presented comparisons of significance levels and effect sizes. The outcome of the meta-analysis showed the effects were of moderate magnitude (z=.307, r=.298, and d=.625) and significance (z=21.782, and p<.0001). Thus, there was moderate improvement in knowledge retention produced by overlearning (Driskell et al., 1992). The effect was even stronger when analysis was completed solely on cognitive tests where the effect on retention was stronger (z=.368, r=.352, d=.753, and p<.0001). This further supports the premise that overlearning aids in retention and thus supports test performance.

However, there are limitations to the findings. One limitation is addressed by the deficient-processing theory which explains that during massed repetition less effort is required by subjects for the second and subsequent presentations than if the presentations were spaced. The spaces can be filled with other types of practice, a period of time, or both. It is believed the quality of the processing at the time of learning has a large effect on the degree of learning. Thus, when learners are not required to pay as much attention to items which are massed together, recall is less successful. As a result, learning is not enhanced and time is wasted (Delaney, Verkoeijen, & Sprigel, 2010). Further, Cooper et al. (2006) and Dettmers et al. (2010) added that blocked practice assignments are less cognitively demanding, and thus, less effort is given by students working these problems.

Langer and Imber (1979) suggested that since each repetition of a task requires less thought, a level of mindlessness is reached in which the participant no longer thinks about the task he or she is performing. While this may be helpful to save time for other thought processes for some tasks (i.e. a small child learning to walk without thinking about it), it may be a waste of time for other tasks. Even with this limitation, overlearning may be beneficial in some instances. For example, if one is seeking short term retention such as studying for an exam the same day it is given overlearning may be helpful (Roher et al., 2005).

A second limitation is that little is known about the retention interval of overlearning (Rohrer et al., 2005). In other words, little research exists that reveal if there is a positive effect of overlearning on recall over long periods of time. Rohrer and Taylor (2006) addressed this limitation in a study with mathematics students.

The study conducted by Rohrer and Taylor (2006) is the only known study about the effect of overlearning on mathematics retention. In their experiment (n=100), they tested the effect of overlearning on retention by changing the number of mathematics practice problems presented in a learning episode. Students were separated into two groups. One group was labeled the Hi Massers and the other group was labeled the Lo Massers. Participants in each group solved problems involving calculating permutations of letter sequences with at least one repeated letter (Rohrer & Taylor, 2006).

Group members were tested either one week or four weeks later. This is a longer retention interval than the many of the retention intervals used in previous studies. The results did not indicate any statistical differences between the Hi Massers and the Lo Massers on either test interval. However, the overlearning benefit acquired by the Hi Massers declined more drastically over time than did that of the Lo Massers. Rohrer and Taylor (2006) disclosed that the null effect they observed does not mean that overlearning is not helpful to mathematics students. However, they cautioned against too much overlearning. The caution is from the belief that each extra problem performed creates a smaller increase in test score until eventually there is no impact in the heavy repetition (Rohrer, 2009a; Rohrer, 2009b). They suggested presenting students with three or four practice problems about new concepts in the most recent lesson is sufficient for overlearning. They believed students should spend extra time on practice from earlier concepts to realize the benefits of mixed practice instead of blocking practice (Rohrer & Taylor, 2006).

Although the data uncovered in their study contradicted existing pedagogical and empirical literature, there are implications that overlearning may not be the best strategy for achieving long-term retention (Rohrer, 2009b; Rohrer & Taylor, 2006; Rohrer et al., 2005). The reason for the discrepancy in previous studies and Rohrer and Taylor's (2006) study could lie in procedure. The studies analyzed by Driskell et al. (1992) relied on retention intervals of one week or less. Thus, it is reasonable that the results would show strong support for overlearning. In addition, many of the studies included only one retention interval which does not allow analysis of declining benefits of overlearning (Rohrer & Taylor, 2006).

Rohrer and Taylor (2007) discussed the troubling implications of their experiment on overlearning. Their study showed no long-term benefit to overlearning in mathematics. This is worrisome because the majority of mathematics texts use overlearning strategies with practice sets often containing a dozen or more problems of the same type. If overlearning is not effective, this implies students are wasting their time by overlearning (Rohrer & Taylor, 2007).

Furthermore, Rohrer and Taylor (2007) suggested texts which depend upon the theory of overlearning, and thus employ blocked practice, do not give students practice in discriminating different procedures to use on different types of problems. For example, one lesson may teach solving quadratic equations by factoring. However, not all quadratic equations can be solved by this method. Although other methods are taught, such as the quadratic formula, they are taught in separate lessons and thus various methods are not practiced together. It is important for students to be able to discriminate between problem types and the procedure needed to solve the problem. This is particularly challenging in mathematics because problems which require different problem-solving techniques may appear to be similar. Blocked practice does not lend itself well to allowing students to pair problem types and procedures (Rohrer & Taylor, 2007). Because of these things, some argue mixed practice is a better way to use practice to solidify learning.

Mixed Practice Lessons

Mixed practice is a method of teaching with two significant characteristics. First, mixed practice distributes practice of the same concept over several episodes of study. In addition, mixed practice interleaves, or combines, different topics in each learning session (Rohrer, 2009a). This means new concept practice is woven, or interleaved, into practice problems which review previously learned content. According to Cooper et al. (2006) and Dettmers et al. (2010), the rigor of this type of practice is more mentally stimulating for students. Mixed practice is in contrast to massed or blocked practice in which study devoted to a topic is uninterrupted by subsequent topics or time (Cepeda, Pashler, Vul, Wixted, & Rohrer, 2006; Rohrer, 2009a; Rohrer & Taylor, 2007; Simon & Bjork, 2001).

Practice Distribution

Distributing, or spacing, practice problems over many practice sessions is one part of mixed practice (Cepeda et al., 2006; Rohrer, 2009a; Rohrer & Taylor, 2006; Rohrer & Taylor, 2007). Blocked practice may provide ten problems over the same topic in one lesson. Mixed practice, on the other hand, distributes the same ten problems over several learning sessions which are implemented over an extended period of time. Experiments comparing massed and distributed practice began in the 19th century with a study published by Ebbinghaus (1913) about human memory. Ebbinghaus (1913), using himself as the subject, tried to learn a series of meaningless 12-syllable letters by repetition. He found better results when he spread the practice over a span of three days rather than massing his practice into one learning episode. From this experiment, the idea of the spacing effect became known. The spacing effect indicates that concepts studied once and then studied again after a delay are remembered better over the long-term than items studied repeatedly with no delay (Bahrick, Bahrick, Bahrick, & Bahrick, 1993; Benjamin & Tullis, 2010; Cepeda et al., 2006; Dempster, 1988; Ebbinghaus, 1913; Kornell & Bjork, 2008; Rohrer & Taylor, 2006; Rohrer & Taylor, 2007).

The 20th century brought many more studies on the spacing effect. Studies from the 1960s and 1970s concluded that the spacing effect was one of the strongest findings in learning research (Rohrer, 2009a). Dempster (1989) believed the spacing effect is the most dependable finding in literature and it is easily reproduced. Various experiments have been conducted which have shown that spacing increases test performance compared to blocked practice (Bahrick et al., 1993; Bjork, 1979, 1994; Carpenter & DeLosh, 2005; Goettl et al., 1996; Karpicke & Roediger, 2007; Rohrer & Taylor, 2006; Rohrer & Taylor, 2007; Seabrook, Brown, & Solity, 2005). Many researchers have suggested distributed practice should be used in all disciplines for learning to utilize the spacing effect (Bahrick et al., 1993; Bjork, 1979, 1994; Carpenter & DeLosh, 2005; Cepeda et al., 2006; Dempster, 1988, 1989; Rohrer & Taylor, 2007; Willingham, 2002).

Studies showing the positive effects of distribution have taken place in both a lab setting and in classrooms. Both environments have yielded findings which support spacing of practice problems (Rohrer, 2009a; Seabrook et al., 2005). However, for brief retention intervals, there is generally no difference in distributed practice or blocked practice. Thus, cramming for a test may be acceptable if one does not need to retain the information. However, to remember concepts which need to be learned for the future, such as prerequisite knowledge for college-level work, distributed or mixed practice is important (Rohrer & Taylor, 2006). In a nine-year longitudinal study, Bahrick et al. (1993) found distributing practice benefitted long-term memory of foreign language terms compared to massed practice. In a classroom setting, Grote (1992) found physics topics were learned more efficiently through distributed practice than through blocked practice.

Cepeda et al. (2006) completed a meta-analysis of the distributed practice, or spacing effect. The review spanned 839 assessments of distributed practice which were undertaken in 317 experiments. The experiments exhibited several characteristics. Experiments analyzed several episodes of study covering the same material. Episodes were separated by a variable time gap, then a final memory test was administered after a retention interval. The retention interval was the time span between the last practice episode and the test (Cepeda, Vul, Rohrer, Wixted, & Pashler, 2008).

The meta-analysis focused on retention of verbal information. Total study time in each of the examined cases was equivalent. After compiling the studies, Cepeda et al. (2006) found there is always a greater benefit to using distributed practice as opposed to massed practice whether the retention interval is very short (less than one minute) or very long (more than 30 days).

Cepeda et al. (2008) acknowledged an enormous amount of research exists on spacing effects. However, the retention intervals of many studies were very short. To find answers about promoting retention over longer time intervals, such as the amount of time a student is in high school, more longitudinal studies are imperative. Seeing this need, Cepeda et al. (2008) conducted a new study involving 1,354 new subjects. Material included obscure but true trivia facts. The study included a variety of gaps between first and second learning sessions and a variety of retention intervals. The results of the study agreed with that of the study by Bahrick et al. (1993). Researchers found compressing learning into short periods is likely misleading in that test results will show high levels of immediate mastery. However, the mastery will not carry over during large periods of times. Rather, to retain information over several years, which is required of students taking standardized tests such as the ACT, one should distribute review over several months. Distributed practice could possibly double the amount of information remembered compared to a massed study schedule (Cepeda et al., 2008; Dempster, 1988).

Although there is a plenitude of research comparing mixed practice with blocked practice, few of these studies have been applied to practice in mathematics. Most of the studies showing significance are in the areas of foreign language, spelling, and science (Cepeda et al., 2006; Rohrer, 2009a). Bahrick and Hall (1991) explored the retention of content learned in high school mathematics over a life span. The study included 1,726 participants. The goal of the study was to determine the methods of acquisition of knowledge and the types of courses that contribute to knowledge maintenance.

Bahrick and Hall (1991) found algebra content which is relearned and used in subsequent math courses is retained for over 50 years. This was true even for subjects who reported no further rehearsal after high school graduation. Subjects exposed to content during only one year retained little content. These findings were uncovered accompanied by no statistically significant relationship between standardized test scores and grades. Thus, the decline in knowledge retention was not related to aptitude and achievement in this study (Bahrick & Hall, 1991). Rohrer (2009a), as well as Bahrick and Hall (1991), found mixed practice instruction increases retention in mathematical tasks over blocked practice instruction. Ironically, despite the evidence found in research, mixed practice is greatly underutilized in educational settings (Bahrick & Hall,1991; Dempster, 1988; Rohrer & Pashler, 2010; Seabrook et al., 2005). This is particularly true in mathematics where blocked practice is the primary means of learning (Rohrer, 2009a; Rohrer & Pashler, 2010; Rohrer & Taylor, 2006; Rohrer & Taylor, 2007).

Interleaving

Because of the spacing effect, which is the improvement in learning retention due to distributing learning practice to more than one practice session (Dempster, 1988; Ebbinghaus, 1913), interleaving may be used to practice concepts in an educational setting. Interleaving is the process of introducing new problems in a practice set along with problems reviewed from previous learning sessions. When more than one skill is taught, alternating the practice of the different skills can serve as spacers. In fact, the spacing effect may be maximized by filling the spaces with other cognitive activities rather than allotting an unstructured space of time between learning. The combination of distributing practice and interleaving concepts is mixed practice (Goettl et al., 1996; Rohrer & Pashler, 2010; Rohrer & Taylor, 2007; Seabrook et al., 2005).

Rohrer (2009a) explained how the method of interleaving problems can be expressed algorithmically. Review problems are not selected at random but are chosen in a particular sequence so all topics get equal review. For example, if each topic is practiced ten times, the first three practices may be placed in the first learning session with the last seven practices extended out intermittently over the next several learning sessions. Each additional practice problem over the same topic may become more complex in subsequent learning sessions.

Interleaving also allows learners to practice distinguishing between various problem-solving methods that may be applied to a concept. For example, students will use factoring and the quadratic formula to solve quadratic equations in the same practice session. This allows students to make connections between content and problem-solving techniques (Rohrer & Taylor, 2007).

Kornell and Bjork (2008) conducted a study in which subjects viewed several paintings by 12 artists with similar styles. Participants were divided into two groups. One group was shown the paintings blocked by artist and the other group viewed the paintings interleaved together. Kornell and Bjork (2008) found the interleaving group performed better on a subsequent test in which they had to use induction to determine the artist who created a painting based on what they had learned. The interleaving method increased the ability of participants to discriminate between the style of each artist and apply the style to other works.

Rohrer and Taylor (2007) found the same effect in a mathematical context. In their study, college students learned methods to find volumes of arbitrary solids by practicing either problems which were interleaved or problems which were blocked. It was found that interleaving increased test scores by a factor of 3 (Rohrer & Pashler, 2010; Rohrer & Taylor, 2007).

Rohrer and Pashler (2010) pointed out interleaving is not just another form of the spacing effect. Rather, interleaving ensures a larger degree of spacing than blocked practice. In fact, interleaving spaces problems algorithmically which fixes the degree of spacing (Rohrer, 2009a).

As mentioned before, despite the vast amount of research that supports both the spacing effect and interleaving, the majority of mathematics textbooks present practice problems in a blocked format. This means each lesson is followed by practice problems which address only the material covered in that section (Rohrer, 2009a; Rohrer & Pashler, 2010); therefore, students solve several problems of the same type consecutively. This process has been shown by many studies to be inferior to mixed practice (Bahrick & Hall, 1991; Cepeda et al., 2006; Dempster, 1988; Rohrer & Pashler, 2010; Rohrer & Taylor, 2006; Rohrer & Taylor, 2007; Seabrook et al., 2005).

Mixed Practice Theories

Some attribute the benefits of mixed practice to spacing effects. The spacing effect refers to an increase in learning when related items are spaced over a period of time as opposed to being massed together. Many theorists have explained the spacing effect by means of encoding variability theory (Bahrick et al., 1993; Benjamin & Tullis, 2010; Cepeda et al., 2006; Dempster, 1988; Ebbinghaus, 1913; Goettl et al., 1996; Kornell & Bjork, 2008; Leicht & Overton, 1987; Rohrer & Taylor, 2006; Rohrer & Taylor, 2007).

Developers of encoding variability theory suggest mixed practice is beneficial because the spacing of items leads to a wider variety of encoded contextual elements. This indicates items learned are encoded in memory in a variety of contexts which allows a larger number of cues to trigger the memory. The theorists claim events that are separated by a longer time interval are likely to differ more than events that are closer together. Thus, there are more contexts by which to cue memories that are spaced out than when memories are massed together. Encoding variability results in higher levels of successful retrieval of learned items. This is because the retrieval context will more likely be similar to at least one of the study contexts (Benjamin & Tullis, 2010; Cepeda et al., 2006; Leicht & Overton, 1987).

Blocked practice refers to study time in which a given item is not subject to any interruptions of intervening items or periods of time. Practice items which are blocked together are associated only to the two items which directly proceed and follow. When these two items are of the same type, there is no variety in the contextual associations with the items. Also, encoding variability theorists suggest items are either encoded or un-encoded in memory. Therefore, if an item is encoded during a learning event, performance will not change if it is encoded again in a subsequent event (Benjamin & Tullis, 2010). According to encoding variability theory, learning is increased by a variety of associations; thus, blocked practice is a less preferred instructional method than mixed practice (Benjamin & Tullis, 2010; Cepeda et al., 2006; Leicht & Overton, 1987).

In addition, proponents of inattention theory advise that when items are blocked together rather than spaced out as in mixed practice, the learner pays less attention to each subsequent item due to familiarity. Furthermore, if the amount of time is small between subsequent items, the learner pays less attention to the item than if it were spaced over a longer interval. This idea lends further support to mixed practice lessons contribution to long-term memory over blocked practice lessons (Cepeda et al., 2006; Dempster, 1988).

Why Blocked Practice has been Utilized over Mixed Practice

If mixed practice produces long-term retention superior to blocked practice, why are students taught using the inferior strategy? This is possibly because people, including educators and learners, are fooled by the learning they think they are achieving during massed practice sessions. When performing problems in a blocked practice format, students know the correct technique or concept to apply before reading the problem. Some word problems which are in a blocked practice format may even be solved without reading the problem. The student may simply pick out the numerical information and apply the newly learned procedure without much thought (Rohrer & Pashler, 2010). Rohrer and Pashler (2010) concluded “blocked practice provides students with a crutch that is unavailable during cumulative final exams and standardized tests” (p. 409).

One reason learners may favor blocked practice over mixed practice is that mixed practice may produce more errors during the learning of the material, even though it boosts future test performance (Rohrer & Pashler, 2010). While the learners may feel more confident in what they have learned in a massed session, they do not realized they will retain less of what they have learned in the future than they would had the practice been mixed over time (Rohrer & Pashler, 2010; Simon & Bjork, 2001). For example, in

Rohrer and Taylor's (2007) study comparing blocked practice with mixed practice, they found that during the practice sessions blocked practice proved superior to mixed practice; however, the opposite was true for test scores. This same result was found by Simon and Bjork (2001) with subjects being taught keyboarding. Blocked practice increased performance while learning but hampered later test recall. However, the participants in the blocked practice group were fooled into thinking they had learned the keystrokes. When Kornell and Bjork (2008) asked participants which method they would predict to be superior for learning the style of artist, 78% predicted blocked practice would be superior even though the interleaving group performed better than the blocked group.

Metacognition is a term that refers to "what we know about what we know" (Simon & Bjork, 2001, p. 907). Various research has been conducted on the ability of people to predict their own future recall of material learned. The research has shown people's predictions of their knowledge are often inaccurate and often overconfident (Simon & Bjork, 2001). The overconfidence may result from the ease of performance while learning under massed conditions.

The judgment of learning (JOL) is a metacognitive index used to measure how learners assess their own learning (Simon & Bjork, 2001). In an experiment by Dunlosky and Nelson (1994), cued recall was found to be better on massed items than distributed items. It also found blocked study fostered overconfidence in JOLs. Thus, JOL predictions do not often relate to future test performance. This term has been coined as "illusions of competence" (Simon & Bjork, 2001, p. 908).

One reason mixed practice works is because it introduces desirable difficulties while learning, which improves retention (Bjork, 1999; Kornell & Bjork; 2007). Desirable difficulties require more effort by the learner. The delay in mixed practice between subsequent exposures to a problem makes retrieval difficult for subjects. Thus, the delay requires more thought than if the problems are consecutive as in massed practice. This may slow learning in the beginning compared to blocked practice, but it is attributed to retention over the long-term. The metacognition of desirable difficulties causes learners to believe that blocked practice is more effective than mixed practice because they feel a false sense of confidence in the short term. The security is derived from the fluency assumed by the learner during blocked practice. As a result, educators tend to value learning strategies based on performance during training, and thus, sometimes they choose tools that do not yield the best long-term results (Bjork, 1999; Karpicke & Roediger, 2007; Kornell & Bjork, 2008; Rohrer & Pashler, 2010).

Similarly, blocked practice is widely supported. The espousal of blocked practice is the result of many studies which show overlearning boosts subsequent test performance. However, the tests administered are usually over a short retention interval and thus do not show the long-term effect of overlearning (Dempster, 1988; Rohrer & Taylor, 2007). Furthermore, only one overlearning experiment has been applied to mathematics, and it found no effect of overlearning on test performance (Rohrer &Taylor, 2006; Rohrer & Taylor, 2007).

Dempster (1988), as well as Seabrook et al. (2005), believed one reason mixed practice has not been more implemented is that it is not well known by educators. In addition, although mixed practice and the spacing effect have been studied extensively by psychologists, little is known about its application in classrooms. Dempster (1988) wrote more understanding of mixed practice would help with its application in the educational system and could help with appropriate implementation.

Summary

This literature review has covered much research concerning long-term learning retention of mathematical concepts. The chapter began with the importance of mathematics education in the United States. It was found that jobs which are mathematically intensive will increase in our country by a ratio of three to one in the near future (NMAP, 2008). Furthermore, college success in the United States often depends upon success in college mathematics (Lee & Lee, 2009). Hence, long-term retention of mathematical knowledge is essential to the economy of our nation.

Unfortunately, many entering college students find they are not prepared for college-level mathematics even though the prerequisites for this level are covered in the high school mathematics curriculum (Corbishley & Truxaw, 2010). In Chapter Two, this led into discussion about homework and its importance in mathematics.

Many researchers have found evidence that homework positively affects achievement in most disciplines, including mathematics (Cooper et al., 2006). Further, the quality of mathematics homework was found to have an impact on performance on mathematics assessments (Dettmers et al., 2010). Finally, homework assignments were broken down into two types: (a) blocked practice and (b) mixed practice.

Blocked practice is the traditional format of homework problems in American mathematics textbooks (Rohrer & Pashler, 2010). It is characterized by massing problems of one type into one practice set (Rohrer, 2009a; Simon & Bjork, 2001). Blocked practice is steeped in the theory of overlearning; a means of learning by practice in which learners reach a set mastery criterion and continue practicing beyond that benchmark (Rohrer, 2009a). However, some would suggest this type of learning is not cognitively demanding and thus negatively impacts achievement (Cooper et al., 2006; Dettmers, 2010).

Although many studies show overlearning improves knowledge recall (Driskell et al., 1992), opponents claim the studies are administered over short time intervals and thus do not reflect the effect of overlearning on long-term knowledge retention (Simon & Bjork, 2001). Rohrer & Taylor (2006) found after extended periods of time the effect of overlearning drastically declines.

Mixed practice is in contrast to blocked practice. This type of homework combines practice from newly learned topics with practice from topics previously learned. Thus, practice over each concept is spaced over time and interleaved with other topics. Some research suggests this may benefit long-term retention of knowledge over blocked practice (Rohrer, 2009a).

Although blocked practice has traditionally been the accepted form of training, some believe that it is explained by the metacognition of educators and learners. Since blocked practice makes each repetition of the concept seem easier, learners are fooled into thinking it is a superior form of learning (Simon & Bjork, 2001). Because of this phenomena the lack of knowledge of mixed practice, along with the many short term experiments claiming the positive effects of overlearning, blocked practice has been employed much more than mixed practice (Dempster, 1988; Rohrer & Taylor, 2007). As a result, more research is needed to determine if mixed practice should be implemented in mathematics classrooms.

In Chapter Three, the research design and methodology are presented. This includes discussion of the population and sample, data collection and implementation, data sources, and data analysis. Chapter Four includes the results and findings of the research questions. This is followed by Chapter Five in which conclusions, discussion, limitations, and implications of the research are addressed.

CHAPTER THREE

Research Design and Methodology

Introduction

One mission of PK-12 educational leaders is to prepare students to transition to college after high school graduation. Corbishley and Truxaw (2010) found through national and international studies that twelfth grade students in the United States are not prepared to make the transition from high school to college mathematics. With approximately one-third of college freshmen being placed in remedial mathematics courses each year, it is apparent changes should be made in mathematics to better prepare students for the transition (Sladky, 2010). The result of inadequate preparation for college mathematics forces unprepared students to enroll in remedial mathematics courses.

Students unprepared to take college-level mathematics are required to take remedial courses designed to help them reach college-level. The intent of the remediation is to help students; however, the remedial courses do not generally count toward a degree program. As a result, the courses cost students extra time and money. In addition, the content of remedial mathematics courses is the same as the content of high school mathematics courses (Sladky, 2010). Thus, students should already possess the knowledge taught in the remedial courses. College placement tests or ACT mathematics performance provides data to indicate mathematics placement of incoming students for colleges. These instruments reveal some students are not retaining the information learned in high school mathematics well enough to be placed into college mathematics

(Corbishley & Truxaw, 2010; Hichens, 2009; Madison, 2010; MSU, 2010; Sladky, 2010). Thus, educational leaders and mathematics educators need to examine why students who are passing high school courses preparing them for college mathematics are not performing well enough on college placement tests or the ACT mathematics test to indicate college preparedness.

Since students are learning the mathematics concepts required for transition to college mathematics while in high school, but not possessing the same knowledge when being placed into college, some believe the problem is with knowledge retention (Rohrer, 2009a; Rohrer et al., 2005; Rohrer & Taylor, 2007). Students learn the concepts in the short term and pass the math class. However, the students do not possess the required knowledge over the long-term. It is thought by some experts in mathematics education that the issue of mathematics knowledge retention can be explored by investigating the presentation of mathematics curriculum (Rohrer, 2009a).

This study addressed two methods of practice of mathematics problems at the high school level. The first method was the blocked practice lessons. Blocked practice lessons are currently and historically the dominant tool used to teach mathematics in the United States. Blocked practice lessons masses practice over a single concept together in one learning episode and groups related concepts together in units or chapters. The blocked practice lessons are utilized for overlearning. Overlearning is beneficial for short term knowledge retention but not for retaining knowledge over extended periods of time (Rohrer, 2009a; Rohrer & Taylor, 2006). Since college mathematics readiness requires long-term retention, blocked practice lessons may not be the best means by which to teach mathematics in high school.

The second practice strategy this study addressed was mixed practice lessons. Mixed practice lessons distribute exercises of concepts over many episodes of study rather than presenting the exercises to the student in one session. In addition, the practice problems over the new concept in each learning session are interleaved, or woven, with practice problems from previous learning sessions. This method requires students to recall and apply concepts at many different time periods throughout the school year (Rohrer, 2009a; Rohrer & Taylor, 2006).

The research design and methodology of this study contains seven sections. The paper includes an introduction, research questions, design for the study, population and sample, data collection and instrumentation, data analysis, and a summary. The introduction establishes the background of the research as well as the problem which was studied. The research questions are also presented to show how this study was guided. The third section is the design for the study. Here, the approach and design for the quantitative study are presented. The population and sample size section describes the subjects of the study from the origin to the size. This is followed by a section describing data collection and implementation. In this section, the reader will find how the data for the study were acquired. The data analysis section describes how the data were utilized in the study. Finally, the summary briefly reviews the design and methodology of the study.

This study was intended to compare two types of lesson practice, mixed practice and blocked practice, for mathematics knowledge retention. ACT scores were used to determine if a difference exists between the two methods. Retaining mathematics knowledge is imperative in the preparation of high school students for college-level mathematics. Hence, knowledge of best practices to support is essential to educational leaders.

Research Questions

The research questions for this study are as follows:

1. Are there differences in baseline mathematics skills for freshmen entering MHS from District A, District B, District C, District D, District E, and MMS?
2. Are there differences in mathematics ACT scores for:
    a. High school seniors based on mixed practice lessons versus blocked practice lessons?
    b. High school seniors who continued schooling from MMS to MHS based on mixed practice lessons versus blocked practice lessons?
    c. High school seniors who transferred to MHS from other districts based on mixed practice lessons versus blocked practice lessons?
3. Are there differences in mathematics content knowledge of students taking honors mathematics courses versus students taking non-honors mathematics courses, as evidenced by the ACT, based on mixed practice lessons versus blocked practice lessons?

Design for the Study

Educators in PK-12, as well as higher education, agree that preparing high school students for college mathematics is a challenge (Corbishley & Truxaw, 2010; Hichens, 2009; Madison, 2010; Sladky, 2010). An area in which all educators do not agree is the best means by which to meet the challenge. This study compared presenting mathematics using blocked practice lessons to mixed practice lessons. The approach used to compare the practices was an impact assessment. According to Rossi et al. (2004), an impact assessment is a program evaluation utilized to determine effects of a program on intended outcomes. In addition, impact assessments assist evaluators in identifying unintended effects of programs.

The MHS mathematics department changed teaching methods from blocked practice to mixed practice beginning in the 2007-2008 school year. The evaluation of the mathematics program at MHS allowed the researcher to compare the two types of lessons. Evaluating the mixed practice instructional program implemented by the MHS mathematics department helped determine whether mixed practice improved mathematics knowledge retention over blocked practice.

This study was quantitative in nature. A quantitative design was chosen since numerical data from the ACT could be used to compare blocked practice instruction with mixed practice instruction. A causal-comparative method was used in this study. The groups used in this study were divided prior to the study based on an independent variable (Gay & Airasian, 2000; Rossi, Lipsey, & Freeman, 2004). For this study, the groups were divided by the type of mathematics instruction received throughout high school. Graduating seniors of 2010 learned mathematics using blocked practice while graduating seniors of 2011 learned mathematics using mixed practice. Causal-comparative studies use a comparison of means to analyze data. This study used independent means *t*-test since each group contained different participants (Field, 2009). In this study, mathematics ACT scores were compared to determine if mixed practice lessons caused any change in ACT scores.

Population and Sample

This research had a causal-comparative design with the purpose of comparing mixed practice to blocked practice in mathematics. As such, two comparison samples were chosen for study (Gay & Airasian, 2000). The first sample consisted of students taught mathematics using only blocked practice. The second sample consisted of students taught mathematics using only mixed practice.

The population utilized for Research Question One was high school students who have studied mathematics using either blocked practice or mixed practice. High school freshmen converge to MHS from one of five school districts: District A, District B, District C, District D, District E, or from MMS. The sample utilized consisted of 294 MHS freshmen who took the ACT as seniors. This sample included 24 District A students, 26 District B students, 23 District C students, 18 District D students, 35 District E students, and 128 MMS students who were freshmen in 2006-2007 and 2007-2008.

The population from which the two samples for Research Question 2a originated was high school students who have studied mathematics using either blocked practice or mixed practice. MHS 2010 seniors learned mathematics using only blocked practice. The MHS 2011 seniors learned mathematics using only mixed practice. The sample size was 294. This includes 153 MHS 2010 seniors and 141 MHS 2011 seniors.

Similarly, the population utilized for Research Question 2b was high school students who have studied mathematics using either blocked practice or mixed practice. The sample size was 128 MHS high school seniors who continued schooling at MHS from MMS. Included in the sample were 69 MHS 2010 seniors and 59 MHS 2011 seniors. Students in each of these groups took the ACT.

The population for Research Question 2c was high school students who have studied mathematics using either blocked practice or mixed practice. A large number of MHS students transfer to the district from other K-8 school districts upon entering ninth grade. The sample includes 166 MHS high school seniors who transferred to MHS from other school districts. Participants in the sample took the ACT during or before their senior year. Eighty-four of these transfer students from the 2010 MHS seniors took the ACT and 82 of these transfer students from the MHS 2011 seniors took the ACT.

Research Question Three addressed the academic path of the 2010 and 2011 seniors. The population for Research Question Three consisted of high school students who studied mathematics using either blocked practice or mixed practice. The sample size was 294. This included two sets: 153 MHS 2010 seniors and 141 MHS 2011 seniors. The students took the ACT during high school. From each of the 2010 and 2011 seniors, two sub-sets were utilized for the study. From the 2010 MHS seniors, the first sub-set consisted of 110 seniors who completed honors mathematics courses during high school. The second sub-set contained 43 students who completed non-honors mathematics courses while in high school. From the 2011 MHS seniors, the first sub-set consisted of

77 seniors who completed honors mathematics courses during high school. The second sub-set contained 63 seniors who completed non-honors courses while in high school.

Seniors of 2011 were the first group of students taught mathematics using only mixed practice. Thus, the researcher only had access to one group of students receiving this treatment. As a result, this class was compared to the senior class of 2010. Since the classes graduated in consecutive years, the groups were similar in nature. The groups had more characteristics in common than two groups separated by a large amount of time. According to Gay and Airasian (2000), selecting similar samples is important when designing causal-comparative research.

Data Collection and Instrumentation

Data collected in this research were used with a causal-comparative design to determine if there are differences in mathematical knowledge retention resulting from the type of instruction used in the classroom. Specifically, this study compared blocked practice to mixed practice. The procedures used by the researcher to collect the data are outlined in this section. In addition, the instruments used in the study are identified followed by steps taken to protect the human subjects involved in the study.

Data Collection Procedures

In this research, archival data were utilized. Mathematics ACT scores from MHS seniors from the years 2010 and 2011 were gathered. Permission to use the ACT scores was obtained from the MHS building principal and the district superintendent. The technology office provided access to the data via Lumen. Lumen is the web-based program utilized by the school district to organize and store student data.

In addition to ACT scores, the eighth grade Missouri Assessment Program (MAP) test data were gathered from the seniors of 2010 and 2011. The data were used to provide a baseline from which to compare the growth in mathematical knowledge between students who were taught using blocked practice to students who were taught using mixed practice. Permission to use the MAP data was obtained through the district's central office. The high school counseling office provided the researcher access to the eighth grade MAP data.

ACT

This study examined mathematical knowledge retention necessary for students to be prepared for college mathematics. The ACT test is an instrument utilized to determine college readiness. Staff members at ACT (2005) wrote, "The ACT is an effective and reliable measure of student readiness for college" (p. 1). The ACT is used to predict the success of first year college students (Ingalls, 2008; Allen & Sconing, 2005). Reliability of testing instruments indicates the degree of dependability the document provides. Reliability addresses the consistency of measures gathered by instruments (Gay & Airasian, 2000). The reliability coefficient is a numerical value between zero and one that indicates the reliability of an instrument. Instruments with coefficients close to one are the most reliable. Coefficients close to zero are unreliable (Gay & Airasian, 2000). According to Mertens (2005), one method of determining reliability is by a parallel-forms approach. With the parallel-forms approach, reliability is determined by administering a test and retest with the retest being an equivalent form of the original test. This eliminates any practice effect gained by subjects if they are given the same version of a test for a test-retest approach to measuring reliability. Using the parallel-forms approach, ACT (2007) reported that the reliability of ACT composite scores was 0.96. The parallel reliability of the mathematics section was 0.91. These measures were based on 2005-2006 data.

In addition, Sawyer (2010) described ACT test scores as utilized by some higher education institutions for college placement as well as initial admission to the institutions. Sawyer (2010) also stated the ACT has predictive validity. According to Gay and Airasian (2000), predictive validity is “the degree to which a test can predict how well individuals will do in a future situation” (p. 165). The predictive validity of the mathematics ACT is thus a good indicator of student mathematics ability. Thus, it is useful to institutions for placing students into the mathematics courses.

The ACT is nationally renowned for its reliability and validity. Because of this, the ACT was chosen for this study. The mathematics ACT test scores from MHS seniors of 2010 were compared to the mathematics ACT scores of the 2011 MHS seniors.

MAP

The eighth grade mathematics MAP scores from the MHS 2010 and 2011 seniors were also utilized in this study. The role this instrument played was used for an analysis of covariance. According to Gay and Airasian (2000), analysis of covariance is important to incorporate into causal-comparative research to account for differences which may exist between two groups being studied.

Staff members at the Missouri Department of Elementary and Secondary Education (DESE, 2006) claimed the MAP test is an overall reliable assessment. The reliability of the MAP was calculated in several ways: (a) reliability of raw scores, (b) overall standard error measurement, (c) IRT-based conditional standard error of measure, and (d) decision consistency of achievement level classifications. All portions of the MAP test had reliability coefficients above 0.90 in 2006. A reliability coefficient of 0.923 was established for the eighth grade mathematics portion of the MAP test in 2006.

Staff at DESE (n.d.) proclaimed the validity of the MAP test by discussing the means by which it was constructed. The MAP test possesses construct validity because it was developed by "using methodical and rigorous test-development procedures" (p. 3). In addition, members of DESE (n. d.) described the insurance of validity by comparing performance on one assessment item to performance on another similar assessment item. In addition, performance on one assessment item was compared to the performance on the entire test. These comparisons were analyzed by researchers and used to show that the MAP test does indeed assess the information it claims to test. Staff at DESE (2006) also addressed content validity in the design of the instrument. The MAP test items were developed by Missouri educators. Pilot tests were performed and scored by Missouri educators. Through this process, the item quality and scoring process were improved. Following the pilot, a content and bias review was conducted by DESE with Missouri educators. During this time, the content was checked for accuracy and grade-level appropriateness.

As a result of its reliability and validity, the mathematics MAP test was determined to be an acceptable instrument to use for an analysis of covariance. The analysis was utilized to determine if differences in mathematic abilities of freshmen entering MHS from six school districts existed. Differences in students' mathematical abilities determined from the mathematics MAP assessment were accounted for when comparing the same students' mathematics ACT scores.

Human Subjects Protection

The mathematics ACT scores and mathematics MAP test scores utilized for this study are data that is owned by the Midwestville High School District. As such, a letter requesting permission to use the data for research was sent to the superintendent of the district as well as the high school principal. The letter described the study and informed the leaders of the measures taken to ensure confidentiality. Since the data are archival, informed consent was not required of participants.

To provide confidentiality of data, a key was made assigning a number to each student name. The key was used to match each student's demographic data, ACT mathematic score, and mathematic MAP test score together. The key was placed in a filing cabinet that remained locked except at times when data were being gathered. Once all data were gathered, the key was destroyed to maintain the anonymity of the students.

The Institutional Review Board (IRB) at the University of Missouri-Columbia is concerned with and upholds the privacy, welfare, civil liberties, and rights of research subjects (MU, 2011b). This research project was reviewed and approved by the IRB. Upon IRB approval, demographic, honors or non-honors status, ACT mathematics score, and mathematics MAP score data were collected by the researcher

Data Analysis

The design of this study was causal-comparative. In this type of research, groups are divided prior to the study based on an independent variable (Gay & Airasian, 2000). For this study, the groups are divided by the type of mathematic instruction received throughout high school. Graduating seniors of 2010 learned mathematics using blocked practice while graduating seniors of 2011 learned mathematics using mixed practice. Causal-comparative studies use a comparison of means to analyze data. ACT scores were used to form comparisons. Eighth grade MAP test scores were utilized as a covariate which aided the researcher in finding initial mathematical ability differences in the subjects of the study. Treatment of each research question is discussed in the remainder of this section.

Research Question One

The first research question sought to determine if differences in mathematics ability existed between freshmen entering MHS from five separate school districts in addition to MMS. Statistical Package for the Social Sciences (SPSS) software was used to generate a one-way ANOVA. The independent variables were students' transfer status. The dependent variable was the mathematics MAP test score. Data that were significantly different indicated the need for a covariate when determining the differences in mathematics ACT achievement of the students. In addition, an independent *t*-test was used to compare MMS and transfer district 8^{th} grade mathematics MAP scores.

Research Question 2a

The first part of Research Question Two sought to determine if a difference existed between the mathematics ACT scores for high school seniors based on mixed practice versus blocked practice. The independent variable was the type of instructional method. The dependent variable was the mathematics ACT score. The ACT scores represent students who attended MMS in eighth grade as well as students who attended eighth grade at another institution. SPSS was used to test the significance of the data using an independent means *t*-test since the data used were interval. The significance level was determined by $p<.05$ (Field, 2009).

Research Question 2b

The second part of Research Question Two was utilized to determine if differences existed in mathematics ACT scores for high school seniors who continued schooling from MMS to MHS based on mixed practice lessons versus blocked practice lessons. The independent variable was the type of instructional method. The dependent variable was the mathematics ACT scores of students who attended MMS as eighth graders. SPSS was used to test the significance of the data using an independent means *t*-test since the data used were interval. The significance level was determined by $p<.05$ (Field, 2009).

Research Question 2c

The third part of Research Question Two asked if differences existed in the mathematics ACT scores for high school seniors who transferred to MHS from other districts after eighth grade based on mixed practice lessons versus blocked practice lessons. The independent variable for this question was the type of instructional method.

The dependent variable was the mathematics ACT scores of students who transferred to MHS after eighth grade. SPSS was used to test the significance of the data using an independent means *t*-test since the data used were interval. The significance level was determined by $p<.05$ (Field, 2009).

Research Question Three

Research Question Three was used to determine if differences existed in retention of mathematics content of students taking honors mathematics courses versus students taking non-honors mathematics courses, as evidenced by the ACT, based on mixed practice lessons versus blocked practice lessons. This question was analyzed by an independent means *t*-test. The significance level was determined by $p<.05$ (Field, 2009).

Reliability

Reliability in causal-comparative studies is weakened by lack of randomization, manipulation, and control. Since groups already exist in causal-comparative research and have already received the independent variable, random assignment is not possible. As a result, it is possible groups may differ by some variable other than the established independent variable. For example, groups could differ by gender, age, or experience (Gay & Airasian, 2000).

To address reliability in this study, the researcher carefully chose the sample utilized. Samples were chosen from the same school district which controlled for socio-economic status from 2010 to 2011. Choosing from the same school district also ensures that members of the samples received the same or very similar educational experiences. Also, the samples were chosen from consecutive school years which ensured there were no effects from historical changes such as technological innovations. The technology each group had available for learning was the same. In addition, samples chosen were from those seniors who took the ACT, thus the members of the samples were approximately the same age and had the goal of continuing their education. Therefore, the groups were as similar as possible.

Validity and Generalizability

Gay and Airasian (2000) wrote, "any uncontrolled extraneous variables affecting the performance on the dependent variable are threats to validity" (p. 371). Validity occurs when the outcomes of research are only attributed to the independent variable. Internal validity addresses factors other than the independent variable that affect the dependent variable. External validity is concerned with generalizability or the ability to apply outcomes to groups other than those in the study.

Threats to internal validity include history, maturation, and instrumentation. History refers to major events which occur during a study that affect the dependent variable such as a major catastrophe (Gay & Airasian, 2000). Since the groups used for the dependent variables in this study were seniors from consecutive school years and from the same district, students in each graduating class were exposed to the same history. Although they graduated in two separate years, there were no significant historical events during that time. As a result, there was no historical threat to internal validity.

"Maturation refers to natural physical, intellectual, and emotional changes that occur in participants over a period of time" (Gay & Airasian, 2000, p. 373). Maturation can affect the dependent variable in studies that occur over a long period of time. This study addresses the treatment of the dependent variable over a four year period, from each participant's freshmen year of high school to his or her senior year of high school. Thus maturation could be an issue. However, since the members of each group are in the same age group and same geographic area, maturation was similar for each member.

Internal validity can also be affected by instrumentation or the unreliability of a measuring instrument. Lack of consistency in a measuring instrument can invalidate tests of performance (Gay & Airasian, 2000). The researcher in this study took great care in choosing instruments used to measure the independent variable. Since the ACT and the MAP tests have been shown to be reliable, instrumentation did not affect the internal validity of this study.

Anything that threatens external validity limits the generalizability of a study. One of those threats is called multiple-treatment interference. Multiple-treatment interference happens when participants are subjected to more than one treatment in succession. The threat is the effects from an earlier treatment may carry over and cause difficulty in assessing the current treatment (Gay & Airasian, 2000). In this study, multiple-treatment interference would only have occurred before participants came to ninth grade. For example, the participants who received mixed practice instruction in grades nine through twelve may have received blocked practice instruction in elementary or middle school. Since this study utilized the ACT, multiple-treatment interference did not occur. The ACT measures objectives learned in high school. Since participants were only exposed to one treatment in mathematics classes in high school, multiple-treatment interference is not a threat to generalizability in this study.

A second threat to generalizability is selection-treatment interaction which occurs when random selection is not used for choosing participants. Selection-treatment interaction causes the results of the study to apply only to groups involved. Thus, the results cannot represent an extended population (Gay & Airasian, 2000). Selection-treatment interaction issue is addressed in this study. Only seniors who took the ACT were included in the samples for this study. This would indicate the results could only be generalized to college-bound students and not to students who plan to go from high school into the work force. However, the researcher did segregate the seniors who took the ACT into two groups which can extend the results to two other populations of students: (a) those who took honors mathematics courses in high school and (b) those who took non-honors courses in high school. This allows the research to be generalized to other students who take an honors path of instruction or a non-honors path of instruction in high school mathematics.

Specificity is a third threat to generalizability of the results of research. Specificity of variables indicates that any study (a) uses a specific type of participant, (b) is based on a specific definition of the independent variable, (c) utilizes given dependent variables, (d) is conducted at a particular time, and (e) is conducted under a certain set of conditions. To address the threat of specificity, researchers define variables such that they have meaning outside of the research and take care when stating conclusions and generalizations (Gay & Airasian, 2000). This researcher strove to clearly define the variables of the study and describe the conditions under which the research was conducted. In addition, the researcher used great care when forming conclusions and generalizations from the data.

Experimenter bias can also threaten the generalizability of research. Experimenter bias occurs when the researcher has an effect on the outcome of the study. This can be by influencing participant behavior by communicating emotions or expectations to particiants (Gay & Airasian, 2000). This researcher did not know the majority of the participants and did not discuss the study with any of the participants. In addition, the researcher was conscientious of her opinions and was careful to distance herself from those during the study.

Finally, reactive arrangements which address the attitudes of research participants can affect the generalizability of the study. Reactive arrangements are also called participant effects. Threats from participant effects stem from study participants behaving differently than they normally behave because of their knowledge of being a member of a study (Gay & Airasian, 2000). This study utilized archival data owned by a school district, thus the participants were not aware before the study that their data would be utilized for research. Hence, participant effects are not a threat in this study.

Validity and generalizability are important to establish in research. The attention this researcher provided to validity and generalizability in this study strengthened the findings. Hence, the results are generalizable to other high school students living in rural areas of the United States of America.

Summary

This Chapter presented an overview of the research design and methodology of this study. Retaining mathematical knowledge is imperative for students to be adequately prepared for college mathematics. Knowledge retention may be different based upon the instructional method used in the learning process (Rohrer, 2009a). This research compared two types of practice: blocked practice and mixed practice.

This program evaluation used quantitative data and a causal-comparative design to answer the research questions. The research questions addressed differences of bloced practice and mixed practice. Data were gathered from mathematics ACT scores and eighth grade mathematics MAP test scores of 2010 and 2011 MHS graduating seniors. Reliability and validity of the instruments were established. Finally, the data were analyzed using SPSS to determine the answers to the questions.

In Chapter Four, the results and findings of the research are presented. Chapter Five includes conclusions, discussion, limitations, and implications which can be extracted from the research.

CHAPTER FOUR

Results and Findings

Introduction

Higher education institutions are observing an increase in the amount of students unprepared for college mathematics (Corbishley & Truxaw, 2010; Sladky, 2010). This phenomenon is forcing college students to enroll in remedial mathematics courses which do not count toward their degree; only prepare them to take college-level mathematics. Remedial courses cover the same material students are provided the opportunity to learn when in high school (Corbishley & Truxaw, 2010; Madison, 2010; Sladky, 2010). Remediation is less favorable than prior preparation for several reasons. One reason is that students who take remedial courses are more likely to drop out of college than those entering at the college level (Sladky, 2010). Also, remediation is demanding of university and national resources. Researchers from The Alliance for Excellent Education found data indicating remedial education for students who have completed high school cost the nation $1.4 billion (Sladky, 2010). Thus, the challenge presented to educational leaders is to better prepare high school students for college-level work.

In the United States, college readiness is often measured by the ACT (Koenig, Frey, & Detterman, 2007). The ACT is an assessment designed to measure skills acquired by students in high school and predict the success of students during the first year of college (Allen & Sconing, 2005; Ingalls, 2008). In addition, many institutions use the ACT to place students in mathematics courses (Hichens, 2009; MSU, 2010). Researchers at ACT have determined that students with an ACT-M score of 22 have a 75% chance of completing a typical college algebra course with a C or better (Allen & Sconing, 2005). Unfortunately, researchers have gathered data from ACT which have also shown more than half of high school graduates who take the test are not academically prepared for college (Nonis et al., 2005).

High school students are taught mathematics in preparation for college-level mathematics. As a result, maximum long-term retention of the concepts learned by students is crucial to readiness for college (Hichens, 2009; Rohrer, 2009a). One area leaders may study to address the issue of college readiness in mathematics is by observing methods used to provide students with mathematics practice. The two main methods of mathematics practice are mixed practice and blocked practice (Rohrer, 2009a). This study sought to determine if one method increases long-term retention of mathematics concepts over the other method. If this is the case, then college readiness could be affected by the type of mathematics practice used for student learning.

The purpose of this causal-comparative study was to determine if using mixed practice lessons had an effect on ACT-M scores for the 2011 seniors as compared to the 2010 seniors who were taught using blocked practice. For this study, the population was high school students who have studied mathematics using either blocked practice or mixed practice. Eighth-grade MAP data were gathered to determine if the skill level of incoming high school freshmen was equal. The ACT-M scores were analyzed using independent *t*-tests to determine if differences exist in mathematics abilities of students who studied with mixed practice versus blocked practice.

In this chapter, the results of the statistical analysis performed on the data collected for the study are presented. First, demographics of the participants are revealed. Next, the research questions of this study are presented. Finally, the statistical analysis performed to address each question is reviewed followed by the findings of the analysis.

Demographics

To conduct this study, archival data were obtained from 2010 and 2011 seniors at MHS who took the ACT. From the 2010 graduating class, data from 153 students were gathered. Of these students, 64 were males and 89 were females. In addition, the data from 141 students graduating MHS in 2011 were collected. This group consisted of 71 males and 70 females. Students from each of the graduating classes at MHS were organized by their K-8 school and by the mathematics courses taken in high school; honors or non-honors.

Students at MHS are comprised of a combination of students from five surrounding K-8 school districts as well as MMS. Data were divided according to 2010 and 2011 MHS graduates' 8th grade school district (see Table 1). In 2010, the number of participants attending MHS from other school districts ranged from 11 to 20. A total of 84 participants were sent to MHS from outside the district, while 69 participants who graduated MHS in 2010 attended 8th grade at MMS. In 2011, the number of participants attending MHS from other school districts ranged from 7 to 15. Outside school districts sent 82 of the 2011 participants to MHS, whole 59 of the 2011 graduates attended 8th grade at MMS.

Table 1

K-8 School District

District	2010 Seniors		2011 Seniors		Total	
	N	%	*N*	%	*N*	%
MMS	69	45.1	59	41.8	128	43.5
District A	13	8.5	11	7.8	24	8.2
District B	11	7.2	15	10.6	26	8.8
District C	12	7.8	11	7.8	23	7.8
District D	11	7.2	7	5.0	18	6.1
District E	20	13.1	15	10.6	35	11.9
Other	17	11.1	23	16.3	40	13.6
Total	153	100.0	141	100.0	294	100.0

Note. 2010 Seniors learned with blocked practice and 2011 Seniors learned with mixed practice.

From the data collected, 71.9% of 2010 MHS seniors who took the ACT were enrolled in honors mathematics courses during high school while 28.1% took non-honors mathematics courses during high school. From the 2011 MHS graduating class, 54.6% of students who took the ACT were enrolled in honors mathematics courses during high school and 45.4% took non-honors mathematics courses during high school (see Table 2).

Table 2

Honors and Non-Honors Data

Graduation Year	Honors		Non-Honors		Total	
	N	%	*N*	%	*N*	%
2010	110	58.8	43	40.6	153	52.0
2011	78	41.2	63	59.4	141	48.0
Total	187	100.0	106	100.0	294	100.0

Research Questions Findings

Archival data were utilized in this study. Demographic data, ACT-M, and 8th grade mathematics MAP scores were collected and entered into SPSS 16.0 edition. Demographic data included the students' year of graduation, K-8 district, and whether the student took honors or non-honors mathematics courses in high school. Students who took at least three courses at the Algebra I level or above were considered to have taken an honors path in mathematics. Otherwise, students were considered to have taken a non-honors path.

The data used to answer the research questions were obtained from the 8th grade mathematics MAP test and the ACT-M. The mathematics MAP scores from the students as 8th graders had a lowest obtainable scale score of 525 and a highest obtainable scale score of 885 (DESE, 2006). For the ACT-M, the lowest obtainable score is 1 and the highest obtainable score is 36 (ACT, 2007).

The research questions for this study are as follows:

1. Are there differences in baseline mathematics skills for freshmen entering MHS from District A, District B, District C, District D, District E, and MMS?
2. Are there differences in mathematics ACT scores for:
    a. High school seniors based on mixed practice lessons versus blocked practice lessons?
    b. High school seniors who continued schooling from MMS to MHS based on mixed practice lessons versus blocked practice lessons?
    c. High school seniors who transferred to MHS from other districts based on mixed practice lessons versus blocked practice lessons?
3. Are there differences in mathematics content knowledge of students taking honors mathematics courses versus students taking non-honors mathematics courses, as evidenced by the ACT, based on mixed practice lessons versus blocked practice lessons?

Differences in Baseline Mathematics Skills

To address Research Question One, 8th grade mathematics MAP scores of students were compared to determine if baseline mathematics skills differed in the students entering MHS as 9th graders. MAP data for all 2010 and 2011 students who took the ACT were not available. More than half of the *N*=294 possible scores had an accessible 8th grade mathematics MAP score, while more than a third had no 8th grade mathematics MAP score or one which was inaccessible to the researcher (See Table 3).

Table 3

8th Grade Mathematics MAP Data Available

District	Useable Data		Non-Useable Data	
	N	%	*N*	%
MMS	124	64.9	4	3.9
District A	21	11.0	3	2.9
District B	6	3.1	20	19.4
District C	12	6.3	11	10.7
District D	7	3.7	11	10.7
District E	21	11.0	14	13.6
Other	0	0.0	40	38.8
Total	191	100.0	103	100.0

A one-way ANOVA was calculated on SPSS. There was no significant difference found in the 8th grade mathematics MAP scores based on K-8 school district, $F(5,185)=1.15$, $p>.05$ (see Table 4). Since District B, District C, and District D data were small, the ANOVA may be problematic. Gay and Airasian (2000) recommended at least 30 participants be used for a causal-comparative study. Thus, the number of participants from districts other than MMS is not large enough to generalize the data to the entire population from each district. As a result, the researcher also used SPSS to calculate the mean 8th grade mathematics MAP score for each district. The average 8th grade mathematics MAP scores for the districts ranged from a high of 746.29 (District D) to a low of 710.50 (District C; see Table 4).

Table 4

8th Grade Mathematics MAP Scores

	df	*F*	*p*
Between Groups	5	1.15	.34
Within Groups	185		
Total	190		

	M	*N*	*SD*
District A	721.52	21	30.32
District B	720.00	6	19.67
District C	710.50	12	32.43
District D	746.29	7	27.34
District E	720.00	21	28.43
MMS	719.60	124	38.62
Total	720.27	191	32.33

Since the one-way ANOVA provided no significant differences at the .05 level between the 8th grade mathematics MAP scores of each school district in the study, the researcher investigated further. To determine whether there were differences in mathematics ability of the participants as they entered MHS, the researcher compared the means of the 8th grade MAP scores of students who attended MMS to the 8th grade MAP scores of all transfer students that was available. These sample sizes were large enough to make a direct comparison based on Gay and Airasian's (2000) recommendations; $N=124$ for MMS and 67 for transfer students. No significant difference was found in an independent t-test between the mean 8th grade mathematics score for MMS students (M=719.6, SD=32.42) and transfer students (M=721.5, SD=32.34; $t(189)=-.39$, $p>.05$).

Differences in ACT-M Scores

Research Question Two was used to determine if differences existed in ACT-M scores for students who learned mathematics in high school through mixed practice as compared to the ACT-M scores of students who learned mathematics in high school by means of blocked practice. This question was divided into three components. The first part of the question determined if an overall difference existed in ACT-M scores of 2010 MHS students compared to 2011 MHS students. Then the data were disaggregated into students who attended 8th grade at MMS and the means of the ACT-M scores of 2010 MHS seniors were compared to those of 2011 seniors. Finally, the researcher explored ACT-M scores of 2010 and 2011 MHS seniors who transferred to MMS from other K-8 school districts.

All Seniors of 2010 and 2011. To determine if differences existed between ACT-M scores of high school seniors based on mixed practice or blocked practice, an independent means *t*-test was employed. The average ACT-M of MHS seniors from 2011 who learned mathematics with blocked practice was 21.63. The average ACT-M of MHS seniors from 2010 who learned mathematics using mixed practice was 20.35. This difference was not significant ($t(292)=2.22$, $p>.05$; see Table 5).

MMS to MHS students. The data were also analyzed to determine if differences existed in ACT-M scores of MMS students who graduated from MHS based on whether they learned mathematics with mixed practice or with blocked practice. To accomplish this, SPSS was used to generate an independent means *t*-test. MHS students who attended MMS and who learned mathematics using blocked practice had an average ACT-M score of 21.49. MHS students who attended MMS and who learned mathematics using mixed practice had an average ACT-M score of 20.61. This difference was not significant ($t(127)=1.01$, $p>.05$; see Table 5).

MHS students from other districts. Finally, the data were analyzed to determine if differences existed in ACT-M scores of 2010 and 2011 seniors from outside K-8 school districts based on whether mathematics was learned via mixed practice or blocked practice. SPSS was used to generate an independent means *t*-test. MHS seniors of 2011 who attended K-8 schools outside of the school district and who learned using mixed practice had a mean ACT-M of 20.17. MHS seniors of 2011 who attended K-8 school outside of the school district and who learned mathematics using blocked practice had an average ACT-M score of 21.75. This difference was significant with students who attended K-8 outside the school district and learned mathematics using blocked practice scoring higher on the ACT-M ($t(163)=2.04$, $p<.05$; see Table 5).

Table 5

Independent Means t-test for ACT-M

Source	*t*	*df*	*p*	
MHS graduates with ACT	2.22	292	.91	
MMS to MHS	1.01	127	.32	
Transfer student to MHS	2.04	163	.04*	
	N	*M*	*SE*	*SD*
MHS graduates with ACT				
Senior 2010 (Blocked)	153	21.63	.40	4.90
Senior 2011 (Mixed)	141	20.35	.42	4.94
MMS to MHS students				
Senior 2010 (Blocked)	70	21.49	.55	4.60
Senior 2011 (Mixed)	59	20.61	.68	5.25
Transfer students to MHS				
Senior 2010 (Blocked)	83	21.75	.57	5.17
Senior 2011 (Mixed)	82	20.17	.52	4.74

Note. *$p<.05$.

Honors versus Non-Honors

Research Question Three compared ACT-M scores of students who took honors mathematics courses to those who took non-honors mathematics courses. The data in SPSS were split into two categories: (a) honors, and (b) non-honors. Then SPSS was used to compare the means of the ACT-M scores for 2010 and 2011 MHS seniors in each category. The average ACT-M score of seniors from 2011 who took honors mathematics

Table 6

Independent means t-test: Honors versus Non-Honors

	t	*df*	*p*	
Honors Students	-.07	186	.98	
Non-Honors Students	1.45	104	.06	
Source	*N*	*M*	*SE*	*SD*
Honors				
Senior 2010 (Blocked)	110	23.28	.42	4.45
Senior 2011 (Mixed)	78	23.33	.52	4.60
Non-Honors				
Senior 2010(Blocked)	43	17.40	.49	3.20
Senior 2011 (Mixed)	63	16.67	.25	1.98

Note. $*p<.05$.

courses and learned by mixed practice was 23.33. The average ACT-M score of 2010 seniors who took honors mathematics and learned using blocked practice was 23.28. This difference was not significant ($t(186)=-1.16$, $p>.05$; see Table 6).

The independent means *t*-test for non-honors students showed the mean ACT-M score for 2010 seniors who learned mathematics by blocked practice was 17.40. The 2011 seniors who learned mathematics by mixed practice had an average ACT-M score of 16.67. This difference was not significant ($t(104)=1.45$, $p>.05$; see Table 6).

Summary

The purpose of this study was to determine if using mixed practice in mathematics had an effect on ACT-M scores for 2011 MHS seniors as compared to 2010 MHS seniors who learned mathematics using blocked practice. Three research questions were developed to help guide the study. Demographic data, ACT-M data, and 8th grade MAP data were collected and entered in SPSS. Data were analyzed using a one-way ANOVA, comparison of means, and independent means *t*-tests.

Research Question One, “Are there differences in baseline mathematics skills for freshmen entering MHS from District A, District B, District C, District D, District E, and MMS?”, were studied with a one-way ANOVA to compare the 8th grade mathematics MAP scores for 2010 and 2011 MHS seniors. The researcher found no significant difference in the data. The mean 8th grade mathematics MAP scores from each district were calculated by SPSS and presented in the research. In addition, the mean 8th grade mathematics MAP scores were compared for MMS and transfer students. No significant differences were found on the .05 level.

Research Question 2a, “Are there differences in ACT-M scores for high school seniors based on mixed practice lessons versus blocked practice lessons?”, was addressed using an independent means *t*-test. The study revealed no significant difference at the significance level .05. Research Question 2b, “Are there differences in mathematics ACT scores for high school seniors who continued schooling from MMS to MHS based on mixed practice lessons versus blocked practice lessons?”, was also addressed by an independent means *t*-test. The difference found between the means was not significant for this question of $p<.05$. Research Question 2c, “Are there differences in ACT-M scores for high school seniors who transferred to MHS from other districts based on mixed practice lessons versus blocked practice lessons?” was examined with an independent means *t*-test. The results of this test were found to be significant at the .05 level.

Finally, Research Question Three, “Are there differences in mathematics content knowledge of students taking honors mathematics courses versus students taking non-honors mathematics course, as evidenced by the ACT, based on mixed practice lessons versus blocked practice lessons?”, was explored with an independent means *t*-test. Differences were observed between the means. At the .05 significance level, however, no significant difference was found.

Chapter Four described the results of the data analysis used to address this study. Chapter Five provides a discussion of the major finding of the study, implications for practice, and recommendations for future research. Following Chapter Five, readers will find an Appendix section of supplementary materials which supported this study.

CHAPTER FIVE

Summary and Conclusions

Introduction

The transition from high school mathematics to college mathematics is difficult for a large number of college freshmen (Corbishley & Truxaw, 2010; Sladsky, 2010). The rate of placement of students into remedial mathematics courses in college suggests twelfth grade students from the United States are not proficient in mathematics (Corbisley & Truxaw, 2010). Sladsky (2010) stated one-third of college freshmen are required to enroll in remedial courses each year. The remedial college courses address the same curriculum taught in high school (Corbishley & Truxaw, 2010; Sladky, 2010).

Addressing the lack of preparation of high school students entering college is of great concern to educational leaders. Students who must be remediated in college are more likely to drop out of college than those students who enter at the college prepared for college-level math classes (Sladky, 2010). In addition, remediation is expensive and demanding of resources. Thus, educational leaders are searching for better practices in preparing high school students for college-level work.

The intent of this study was to compare two types of mathematics practice: (a) mixed practice and (b) blocked practice. To accomplish this, ACT-M scores of students who were taught mathematics using only mixed practice were compared with ACT-M scores of students who were taught mathematics using only blocked practice. Three research questions were established to guide the study. Data were gathered from the population of students who were taught mathematics using either mixed or blocked practice while in high school. The sample consisted of those students who took the ACT. In addition, 8^{th} grade mathematics MAP data were collected to determine if any pre-existing biases existed for any group of students. Demographics were also collected to determine from which K-8 district each student came and whether they took honors mathematics or non-honors mathematics while in high school.

In Chapter Four, results of the data analysis were presented. In this chapter, conclusions of the study are offered based on the results of the data analysis. A discussion section is presented to provide further understanding of the study's findings. Next, the limitations of the study are explained to provide information about the challenges of the study. Then, implications for current practice are provided based on the results and the discussion. Finally, recommendations for future research are presented.

Conclusions

This study was designed to provide insight into the differences between mixed practice and blocked practice in the mathematics classroom. Research questions were developed to determine if ACT-M scores were different for students who had learned mathematics using only mixed practice than for students who learned mathematics using only blocked practice. Data were collected and analyzed to address each research question.

Through an analysis of demographic data, the researcher found the majority of 2010 and 2011 MHS seniors who took the ACT were enrolled in honors mathematics courses over non-honors mathematics courses. And, although the largest single contributing K-8 school to MHS seniors who took the ACT test in 2010 and 2011 was MMS, over half of each class was comprised of students from surrounding K-8 school districts, home schools, private schools, or districts outside of the MHS area.

A one-way ANOVA run in SPSS found no significant difference in the 8th grade mathematics MAP scores based on the students' K-8 school district. Most of the school districts had small *N* values. Gay and Airasian (2000) wrote about the importance of appropriately sized samples. When sample sizes are too small, data analysis should not be generalized to the entire population. To gain more insight into the data, the mean 8th grade mathematics MAP scores were found for each school district. The mean 8th grade mathematics MAP score for MMS was lower than the 8th grade mathematics MAP scores of all other K-8 districts except District C. District D had the highest 8th grade mathematics MAP score mean, but it also had the smallest sample size.

Since the sample sizes were small for individual school districts outside of MMS, the researcher compared the mean 8th grade mathematics scores of MMS students and transfer students. The sample sizes of each group met the recommendations of Gay and Airasian (2000). There was no significant difference between the mean 8th grade mathematics scores of MMS students and transfer students.

An analysis of the data was conducted to compare ACT-M scores of students who learned mathematics with mixed practice to students who learned mathematics with blocked practice. First, no significant difference was found at the .05 level between ACT-M scores of students who learned mathematics with blocked practice when compared to those who learned with mixed practice. Second, the data were analyzed for only MHS students who attended 8^{th} grade at MMS. The results showed no significant difference between the average ACT-M scores for students who learned high school mathematics using blocked practice and those who learned mathematics using mixed practice. Third, the data from the surrounding K-8 districts were analyzed. The researcher found students from the K-8 districts who learned mathematics using only mixed practice in high school scored significantly lower on the ACT-M test as compared to those who learned mathematics using blocked practice.

The final analysis of this study was used to determine if mixed practice or blocked practice benefits students of mathematics based on the types of course they enroll in during high school. The mean ACT-M scores were compared and no significant difference was found.

Discussion

No significant difference was found in the 8^{th} grade mathematics MAP test based on the 8^{th} grade the 2010 and 2011 MHS students attended. A one-way ANOVA found no significant difference of the 8^{th} grade mathematics MAP scores of between each district that sends students to MHS. In addition, there was no significant difference found by an independent means *t* test between MMS and all transfer students. The findings of this researcher indicate that all freshmen who entered MHS 2006 and 2007, and who took the ACT as seniors possessed approximately the same level of mathematics skills. However, all seniors who took the ACT were not represented by an 8^{th} grade mathematics MAP score.

Although there was no significant difference in the very close means of the ACT-M scores of 2010 and 2011 MHS seniors, examination of two subgroups of students was analyzed to determine if differences existed. No significant difference was found between the ACT-M scores of MMS to MHS students who learned mathematics with blocked practice than the ACT-M scores of those who learned using mixed practice. This could indicate that blocked practice and mixed practice worked equally in preparing students for college. However, the differences found in the ACT-M means of MHS students from other K-8 districts were significantly higher when the students learned mathematics with blocked practice.

The significant difference found when comparing ACT-M scores of students who attended K-8 schools outside of the MHS district showed students who learned mathematics using blocked practice scored higher on the ACT-M than those who learned mathematics using mixed practice. Although this contradicts many studies such as those by Roher (2009a), Benjamin and Tullis (2010), and Cepeda et al. (2006), this same significance was not found with MMS to MHS students. Interestingly, MMS students also learn mathematics using mixed practice methods whereas students in the surrounding school districts learn primarily with blocked practice. The findings from this analysis show that learning mathematics in high school by blocked practice produces higher ACT-M scores than mixed practice for students who transfer into the district from surrounding K-8 districts.

The results of the independent means *t*-test of the ACT-M scores of honors students who learned with mixed practice versus blocked practice indicated no significant difference. In addition, there was no significant difference found at the .05 level of ACT-M scores of non-honors students who learned with mixed practice versus blocked practice. These results indicate the type of learning practice does not have an effect on student mathematics achievement. Further investigation is needed to determine if one type of mathematics practice is superior to the other in the high school classroom setting.

Researchers have shown mixed practice to be favorable for knowledge retention over blocked practice in many disciplines (Bahrick et al., 1993; Bjork, 1979, 1994; Carpenter & DeLosh, 2005; Ebbinghaus, 1913; Karpicke & Roediger, 2007). Cepeda et al. (2008) acknowledged much of the research was conducted with short retention intervals. These authors suggested studying the effects of mixed practice versus blocked practice over longer retention intervals. In a longitudinal study by Bahrick and Hall (1991), the researchers found algebra content which is relearned and used in subsequent high school mathematics courses is retained for many years after graduation. Rohrer (2009a) also found mixed practice instruction increases retention in mathematical tasks over blocked practice instruction. Although this study is small, the results supply insight into the effects of mixed practice and blocked practice in various subsets of students. Despite the limits of the study, the findings do add to the existing body of research on mixed practice and blocked practice. The most interesting findings are perhaps the questions uncovered which can lead to further study.

Limitations

In this research, as in any, it is important to address the limitations present in the study. A number of limitations existed in this study. One limitation is that this research studied only one high school located in the Midwest. The high school studied has a population of approximately 1200 students (DESE, 2012). Data gathered from other locations or schools with different demographics may show different results.

A second limitation is that the data collected compared only two years of senior ACT-M data. The 2010 data were from students who learned mathematics using only blocked practice. Data from 2011 were gathered from students who learned mathematics using only mixed practice. At the time of this study, this was the only data available for representing students who practiced mathematics using mixed practice. More accurate results may be found by comparing larger groups of student data from both blocked practice and mixed practice.

A third limitation was the lack of a complete set of data. The researcher was able to access the ACT-M scores of all 2010 and 2011 seniors from MHS who took the ACT. However, the set 8^{th} grade mathematics MAP scores were not complete for this study. Students who graduated from MHS in 2010 or 2011 who attended 8^{th} grade at a location not required to take the MAP test had no baseline mathematics score to report. In addition, some of the students from the K-8 schools surrounding MHS did not have a MAP score on their permanent record for reasons unknown to the researcher. Complete knowledge of any differences in mathematics ability of students entering MHS as 9^{th} graders would aid the researcher in determining if differences in ACT-M scores could have been attributed to previous knowledge rather than differences in mathematics practice.

A fourth limitation in this study is that students who graduated in 2010 and 2011 at MHS were not all instructed by the same teacher. The MHS mathematics department consists of nine teachers. The teachers do collaborate closely in their instruction. For example, those who teach Algebra II communicate closely to ensure students are learning the same concepts and practicing the same problems. In addition, the students took common quarter assessments. However, the fact remains that not all students were taught by the same teacher. Since different teaching methods could have impacted ACT-M scores, this is a limitation of the research.

Implications for Practice

As noted in Chapter Two, there are proponents for learning with both blocked practice and mixed practice. Blocking practice together is utilized for overlearning which "refers to training that leads to improved retention" (Dougherty & Johnston, 1996, p. 289). Several studies support this premise for a time interval of 1 to 28 days (Bromage & Mayer, 1986; Carroll & Nelson, 1993; Gilbert, 1957; Krueger, 1929; Nelson, 1982; Rohrer & Taylor, 2006; Rohrer et al., 2005; Rose, 1992). Researchers who support mixed practice argue that the improved retention over short-time intervals does not translate to improved retention over longer time intervals (Cepeda et al., 2006; Rohrer, 2009a; Rohrer, 2009b; Rohrer & Taylor, 2006; Rohrer & Taylor, 2007; Rohrer et al., 2005). Mixed practice supporters have found that distributing practice benefits knowledge retention over several years which is necessary for students who are college bound. These researchers believe mixed practice should be utilized in more disciplines (Bahrick & Hall, 1991; Cepeda et al., 2008; Dempster, 1988; Rohrer & Pashler, 2010; Seabrook et al., 2005). The results of this study provided some viewpoints about blocked and mixed practice in high school mathematics.

A significant difference was found between ACT-M scores of 2010 MHS graduates and 2011 MHS graduates who transferred to MHS from other K-8 school districts. This significant difference showed that when high school students are taught mathematics using mixed practice after transferring to the MHS district from other districts ACT-M scores are lower. The implication to the researcher is that blocked practice is better for students who transfer into MHS from the surrounding rural districts. In addition, although there was no significance, the mean ACT-M scores of 2010 MHS graduates who learned math in high school via blocked practice and who went to MMS were greater than the mean ACT-M scores of the 2011 MHS graduates who learned math in high school via mixed practice and who went to MMS.

Together the two previous results could indicate that blocked practice is more beneficial to college preparation of high school students regardless of district or learning method used for mathematics in K-8 (See Figure 1). However, blocked practice may be more beneficial when used not only in high school but also in K-8. This could support the belief that blocked practice contributes to overlearning (Dougherty & Johnston, 1996; Driskell et al., 1992) which in turn increases students' college mathematics readiness as indicated by the ACT.

On a local level, these findings suggest a need for more collaboration. Since MHS is a combination of several school districts, each district has its own course offerings, curriculum, and teaching practices. The results of this study may suggest that students

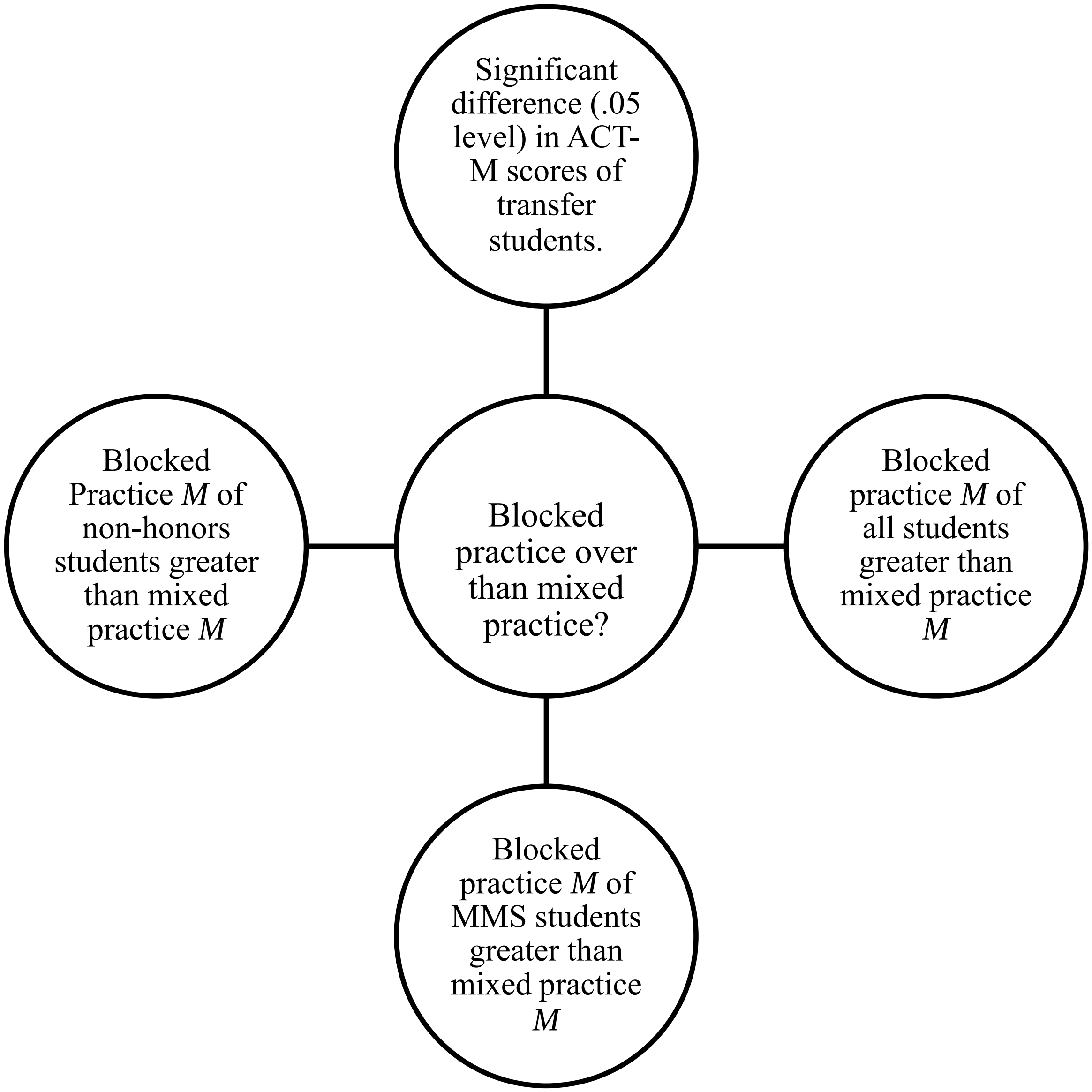

Figure 1. Possible Implication for Blocked Practice as Best Practice in Mathematics

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who attend K-8 schools and learn mathematics with blocked practice, then go on to high school and learn mathematics using blocked practice are more successful on the ACT-M test than students who use mixed practice. Thus all districts contributing to MHS could collaborate to ensure all students are receiving the best and same benefits. Open communication between district leaders is necessary to address best education practices for all students. Perhaps leaders should examine research and begin working in unison to better prepare students for the challenges of college.

No conclusion can be drawn about the effect of the type of math practice in ACT-M scores of honors and non-honors students. The data did not show significant difference between honors and non-honors students who learned mathematics with mixed practice versus blocked practice. Neither did the data show a significant difference between non-honors students who learned mathematics with mixed practice versus blocked practice. As a result, no implication can be derived which places either mixed practice or blocked practice over the other.

Recommendations for Future Research

This study revealed interesting findings; however, further study is needed to better compare mixed practice to blocked practice in the classroom setting. In this study, the focus was on a comparison of mixed practice to blocked practice in mathematics as it relates to college readiness of high school students. Although some perspective was provided by this study, additional research could show more. First, a study with a larger sample size could strengthen the results of the study. This could be accomplished by comparing several classes of students who learned with mixed practice to several classes of students who learned with blocked practice. This could also be accomplished by expanding the study to include other school districts. Larger samples could reveal more comparisons that meet the .05 significance level. In addition, a study with greater control which begins with a pre-test for all participants, as well as close monitoring of data throughout its collection, could provide more accurate data.

In addition, further research could be gathered to better distinguish between students who choose an honors mathematics path in high school as compared to those who choose a non-honors mathematics path in high school. Better understanding these groups of students could help explain any significant differences found in future data. Examining the differences in culture as well as aptitude of each group more closely could aide instructional leaders in choosing learning practices that are best suited to their students.

Furthermore, the role anxiety toward mathematics plays may reveal reasons students choose honors mathematics courses over non-honors mathematics courses. Students with higher levels of anxiety toward mathematics may opt out of taking college preparatory courses. If these students decided to go to college, they may not be prepared to enter at the college level and thus require remediation. Studying the course choices of students with high mathematics anxiety, as well as factors contributing to the anxiety could direct leaders to the best methods for preparing high school students for college mathematics.

A second suggestion would be to examine students who enter MHS according to the school district from which they originate. This study was conducted using only 8^{th} grade mathematics MAP data and ACT-M data. A qualitative study which analyzes more closely the classroom and school environments from which the MHS students originated prior to high school could provide a more comprehensive view of any differences in students' mathematics backgrounds as they enter MHS. Such a study could answer why there was a significant difference indicating ACT-M scores of students who learned mathematics blocked practice were higher than those who learned with mixed practice and who transferred into MHS from rural K-8 districts.

Mixed practice has been shown by researchers to increase knowledge retention in many disciplines including mathematics (Cepeda et al., 2006; Cepeda et al., 2008; Rohrer, 2009a, Rohrer & Taylor, 2006). This study attempted to compare mixed practice to blocked practice as related to college readiness of high school seniors in a real-world setting. The insight provided by this study can assist MHS and other high schools in determining the practices best for their students in preparing them for the rigors of college mathematics. As the job market for careers in science, mathematics, engineering, and technology become more important to our country, the best means to prepare our students to become productive citizens in such an environment is imperative to all educational leaders.

REFERENCES

ACT. (2005). Incorporating ACT scores into your statewide assessment. Retrieved on July 8, 2011, from http://www.act.org/research/policymakers/pdf/incorporating_act_scores.pdf.

ACT. (2007). Technical manual. Retrieved on July 8, 2011, from http://www.act.org/aap/pdf/ACT_Technical_Manual.pdf.

ACT. (2010). History of ACT. Retrieved April 22, 2010, from http://www.act.org/aboutact/history.html.

ACT. (2011). *College and career readiness workshops: Resource manual 2011.* Iowa City, IA: ACT, Inc.

Allen, J. & Sconing, J. (2005). *Using ACT assessment scores to set benchmarks for college readiness.* (ACT Research Rep. No. 2005-3). Iowa City, IA: ACT, Inc.

Bahrick, H. P., Bahrick, L. E., Bahrick, A. S., & Bahrick, P. E. (1993). Maintenance of foreign language vocabulary and the spacing effect. *Psychological Science, 4*(5). 316-321.

Bahrick, H. P., & Hall, L. K. (1991). Lifetime maintenance of high school mathematics content. *Journal of Experimental Psychology: General, 120*(1), 20-33.

Benjamin, A. S., & Tullis, J. (2010). What makes distributed practice effective? *Cognitive Psychology, 61,* 228-247.

Bettinger, E. P., Evans, B. J., & Pope, D. G. (2011). Improving college performance and retention the easy way: Unpacking the ACT exam. National Bureau of Economic Research (Working Paper 17119), Cambridge, MA.

Bjork, R. A. (1979). Information-processing analysis of college teaching. *Educational Psychologist, 14*(1), 3-15.

Bjork, R. A. (1994). Memory and metamemory considerations in the training of human beings. In J. Metcalfe & A. P. Shimamura (Eds.), *Metacognition: Knowing about knowing*. (pp. 185-205). Cambridge, MA: The MIT Press.

Bjork, R. A. (1999). Assessing our own competence: Heuristics and illusions. In D. Gopher & A. Koriat (Eds.), *Attention and performance XVII. Cognitive Regulation of performance: Interaction of theory and application* (pp. 435-459). Cambridge, MA: MIT Press.

Bromage, B. K., & Mayer, R. E. (1986). Quantitative and qualitative effects of repetition on learning from technical text. *Journal of Educational Psychology, 78*(4), 271-278.

Carpenter, S. K., & DeLosh, E. L. (2005). Application of the testing and spacing effects to name learning. *Applied Cognitive Psychology, 19*(5), 619-636.

Carroll M., & Nelson, T. O. (1993). Effect of overlearning on the feeling of knowing is more detectable in within-subject than in between-subject designs. *American Journal of Psychology, 106*(2), 227-235.

Cepeda, N. J., Pashler, H., Vul, E, Wixted, J. T., & Rohrer, D. (2006). Distributed practice in verbal recall tasks: A review of quantitative synthesis. *Psychological Bulletin, 132* (3), 354-380.

Cepeda, N. J., Vul, E., Rohrer, D., Wixted, J. T., & Pashler, H. (2008). Spacing effects in learning: A temporal ridgeline of optimal retention. *Psychological Science, 19*(11), 1095-1102.

Cooper, H. (1989). *Homework.* White Plains, NY: Longman.

Cooper, H., Lindsay, J. J., Nye, B., & Greathouse, S. (1998). Relationships among attitudes about homework, amount of homework assigned and completed, and student achievement. *Journal of Educational Psychology, 90*(1), 70.

Cooper, H., Robinson, J. C., & Patall, E. A. (2006). Does homework improve academic achievement? A synthesis of research, 1987-2003. *Review of Educational Research, 76*(1), 1-62.

Cooper, H., & Valentine, J. C. (2001). Using research to answer practical questions about homework. *Educational Psychologist, 36*(3), 143-153.

Corbishley, J. B., & Truxaw, M. P. (2010). Mathematical readiness of entering college freshmen: An exploration of perceptions of mathematics faculty. *School Science and Mathematics, 110*(2), 71-85.

Corno, L. (1996). Homework is a complicated thing. *Educational Researcher, 25*(8), 27-30.

Cresswell, J. W. (2009). *Research design: Qualitative, quantitative, and mixed methods approaches* (3rd ed.). Los Angeles: Sage.

Delaney, P. F., Verkoeijen, P. J. L., & Spirgel, A. (2010). Spacing and testing effects: A deeply critical lengthy, and at times discursive review of the literature. *Psychology of Learning and Motivation, 53,* 63-147.

Dempster, F. N. (1988). The spacing effect: A case study in the failure to apply the results of psychological research. *American Psychologist, 43*(8), 627-634.

Dempster, F. N. (1989). Spacing effects and their implications for theory and practice. *Educational Psychology Review, 1*(4), 309-330.

Dettmers, S., Trautwein, U., Ludtke, O., Kunter, M., & Baumert, J. (2010). Homework works if homework quality is high: Using multilevel modeling to predict the development of achievement in mathematics. *Journal of Educational Psychology, 102*(2), 467-482.

Dougherty, K. M., & Johnston, J. M. (1996). Overlearning, fluency, and automaticity. *The Behavior Analyst, 19,* 289-292.

Driskell, J. E., Willis, R. P., & Copper, C. (1992). Effect of overlearning on retention. *Journal of Applied Psychology, 77*(5), 615-622.

Dunlosky, J., & Nelson, T. O. (1992). Importance of the kind of cue for judgments of learning (JOL) and the delayed-JOL effect. *Memory & Cognition, 20*, 374-380.

Ebbinghaus, H. (1913). *Memory*. (H. A. Ruger & C. E. Bussenius, Trans.). New York: Teachers College. (Original work published in 1885; paperback ed., New York: Dover, 1964).

Egan, K. L., & Schneider, M. C. (2008). Exploring the test construct equivalence of the 2006, 2007, and 2008 Missouri Assessment Program in communication arts and mathematics for English language learners, students with disabilities, accommodated students. Retrieved February 11, 2012, from http://dese.mo.gov/divimprove/assess/tech/documents/MAPConstructEquivalence .pdf.

Field, A. (2009). *Discovering statistics using SPSS* (3rd ed.). Los Angeles: Sage.

Frost, J. H., Coomes, J., & Lindeblad, K. (2009). Collaborating to improve students' transitions from high school mathematics to college: Characteristics and outcomes of a cross-sector professional development project. *NASSP Bulletin, 93*(4), 227-240.

Ganter, S., & Barker, W. (2004). *The curriculum foundations project: Voices of the partner disciplines.*Washington, DC: Mathematical Association of America. Retrieved November 21, 2011, from, http://www.maa.org/cupm/crafty/Chapt1.pdf.

Gay, L. R., & Airasian, P. (2000). *Educational research: Competencies for analysis and application* (6th ed.). Upper Saddle River, NJ: Prentice Hall.

Gilbert, T. F. (1957). Overlearning and the retention of meaningful prose. *Journal of General Psychology, 56*, 281-289.

Gill, S. J. (2010). *Developing a learning culture in nonprofit organizations.* Los Angeles: Sage.

Gill, B. P., & Schlossman, S. L. (2004). Villain or savior? The American discourse on homework, 1850-2003. *Theory Into Practice, 43*(3), 174-181.

Goettl, B. P., Yadrick, R. M., Connnolly-Gomez, C., Regian, W., & Shebilske, W. L. (1996). Alternating task modules in isochronal distributed training of complex tasks. *Human Factors, 38*(2), 330-346.

Gorgievski, N. (2011). The impact of the spacing effect and overlearning on student performance in calculus. Ph.D. dissertation, University of Connecticut, United States -- Connecticut. Retrieved December 27, 2011, from ProQuest (UMI Number 3464319).

Grote, M. G. (1995). Massed versus distributed practice in high school physics. *School Science and Mathematics, 95*(2). 97-101.

Herbert, M. (2010). ACT sets new goals for college readiness. *District Administration, 46*(1), 10.

Hichens, L. (2009). College readiness of 11th grade students: Identifying characteristics related to success on the ACT. Ed.D. dissertation, Aurora University, United States -- Illinois. Retrieved March 6, 2011, from Dissertations & Theses: A&I. (Publication No. AAT 3381288).

Ingalls, V. A. (2008). A mixed methods comparison study of placement strategies for college mathematics courses. Ed.D. dissertation, Ashland University, United States-- Ohio. Retrieved October 19, 2011, from http://etd.ohiolink.edu/view.cgi?acc_num=ashland 1227036887. (Document No. Ashland 1227036887).

Karpicke, J. D., & Roediger, H. L., III. (2007). Expanding retrieval practice promotes short term retention, but equally spaced retrieval enhances long-term retention. *Journal of Experimental Psychology, 33*(4), 704-719.

Kaur, B. (2011). Mathematics homework: A study of three grade eight classrooms in singapore. *International Journal of Science and Mathematics Education, 9,* 187-206.

Kelly, A. E. (2008). Reflections on the national mathematics advisory panel final report. *Educational Researcher, 37*(9), 561-564.

Koenig, K. A., Frey, M. C., & Detterman, D. K. (2007). ACT and general cognitive ability. *Intelligence, (36)*2008, 153-160.

Kornell, N., & Bjork, R. A. (2008). Learning concepts and categories: Is spacing the "enemy of induction"? *Psychological Science, 19*(6), 585-592.

Krueger, W. C. F. (1929). The effect of overlearning on retention. *Journal of Experimental Psychology, 12*, 71-78.

Langer, E. J., & Imber, L. G. (1979). When practice makes imperfect: Debilitating effects of overlearning. *Journal of Personality and Social Psychology, 37*(11), 2014-2024.

Lee, B. B., & Lee, J. (2009). Mathematics and academic success in three disciplines: Engineering, business and the humanities. *Academy of Educational Leadership, 13*(3), 95-105.

Leicht, K. L., & Overton, R. (1987). Encoding variability and spacing repetitions. *American Journal of Psychology, 100*(1), 61-68.

Madison, B. L. (2010). Mathematics at the school-to-college transition. Retrieved November 23, 2010, from http://apcentral.collegeboard.com/apc/members/features/9394.html.

Magee, P. A. (2010). College mathematics placement tests: student perceptions of preparation and appropriateness of placement. Ed.D. dissertation, University of California, United States--California. Retrieved March 6, 2011, from Dissertations & Theses: A & I. (Publication No. 3437531).

McNabb, T. (1990). *Course placement practices of American postsecondary institutions*. (ACT Research Rep. No. 1990-10). Iowa City, IA: ACT, Inc.

Mertens, D. M. (2005). *Research and evaluation in education and psychology: Integrating diversity with quantitative, qualitative, and mixed methods* (2nd ed.). Thousand Oaks, CA: Sage.

Midwestville High School (MHS). (2012). Midwestville high school class offerings and course descriptions. Retrieved February 17, 2012, from http://wpr7.schoolwires.net/cms/lib2/MO01001590/Centricity/Domain/89/2011-2012%20WPHS%20Course%20Descriptions%20%20V%20final%20cut%20%20revised.pdf.

Missouri Department of Elementary and Secondary Education (DESE). (n.d.). The Missouri assessment program: Score use, meaningfulness, and dependability. Retrieved on July 8, 2011, from http://dese.mo.gov/divimprove/fedprog/discretionarygrants/ReadingFirst/DMAP.pdf.

Missouri Department of Elementary and Secondary Education (DESE). (2006). Missouri assessment program: Technical report. Retrieved on July 8, 2011, from http://dese.mo.gov/divimprove/assess/tech/2006_mo_tech-report.pdf.

Missouri Department of Elementary and Secondary Education (DESE). (2012). Missouri school directory. Retrieved on October 4, 2012, from http://dese.mo.gov/directory/.

Missouri State University (MSU). (2010). Math placement at Missouri State University. Retrieved November 23, 2010, from http://www.missouristate.edu/generaleducation/34602.htm.

Missouri State University (MSU). (2011). Department of mathematics. Retrieved December 27, 2011, from http://www.missouristate.edu/registrar/catalog/dept_ma.html.

Mitchell, C. (2011). ACT college and career readiness workshop. Missouri State University Campus, Springfield, MO.

Mullis, V. S. I., Martin, M. O., & Foy, P. (2008). *TIMSS 2007 international mathematics report.* Chestnut Hill, MA: TIMSS & PIRLS International Study Centre, Boston College.

Murphy, J., & Decker, K. (1989). Teachers' use of homework in high school. *Journal of Educational Research, 82*(5), 261-269.

National Mathematics Advisory Panel (NMAP). (2008). *Foundations for success: The final report of the National Mathematics Advisory Panel.* U.S. Department of Education: Washington, DC.

Nelson, T. O. (1982). Overlearning and the feeling of knowing. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 8*(4), 279-288.

Nonis, S. A., Hudson, G. I., Philhours, M. J., & Teng, J. K. (2005). Changes in college student composition and implications for marketing education: Revisiting predictors of academic success. *Journal of Business Research, 58*, 321-329.

Patton, M. Q. (2008). *Utilized-focused evaluation* (4th ed). Thousand Oaks, CA: Sage.

Preskill, S., & Brookfield, S. D. (2009). *Learning as a way of leading: Lessons from the struggle for social justice.* San Francisco: Jossey-Bass.

Rayburn, L. G., & Rayburn, J. M. (1999). Impact of course length and homework assignments on student performance. *Journal of Education for Business, 74*(6), 325-331.

Rohrer, D. (2009a). Avoidance of overlearning characterizes the spacing effect. *European Journal of Cognitive Psychology, (21)*7, 1001-1012.

Rohrer, D. (2009b). The effects of spacing and mixing practice problems. *Journal for Research in Mathematics Education, 40*(1), 4-17.

Rohrer, D., & Pashler, H. (2010). Recent research on human learning challenges conventional instructional strategies. *Educational Researcher, 39*(5), 406-412.

Rohrer, D., & Taylor, K. (2006). The effects of overlearning and distributed practice on the retention of mathematics knowledge. *Applied Cognitive Psychology, 20,* 1209-1224.

Rohrer, D., & Taylor, K. (2007). The shuffling of mathematics problems improves learning. *Instructional Science: An International Journal of the Learning Sciences, 35*(6), 481-498.

Rohrer, D., Taylor, K., Pashler, H., Wixted, J. T., & Cepeda, N. J. (2005). The effect of overlearning on long-term retention. *Applied Cognitive Psychology, 19*(3), 361-374.

Ronning, M. (2011). Who benefits from homework assignments? *Economics of Education Review, 30*(2011), 55-64.

Rose, R. J. (1992). Degree of learning, interpolated tests, and rate of forgetting. *Memory & Cognition, 20*(6), 621-632.

Rossi, P. H., Lipsey, M. W., & Freeman, H. E. (2004). *Evaluation: A systematic approach* (7th ed.). Thousand Oaks, CA: Sage.

Sawyer, R. (1989). *Validating the use of ACT assessment scores and high school grades for remedial course placement in college.* (ACT Research Rep. No. 1989-4). Iowa City, IA: ACT, Inc.

Sawyer, R. (2010). Usefulness of high school average and ACT scores in making college admission decisions. Retrieved on July 8, 2011 from http://www.act.org/research/researchers/reports/pdf/ACT_RR2010-2.pdf.

Saxon, J. H., Jr. (2003). *Algebra 1: An incremental development* (3rd ed). Norman, OK: Saxon Publishers.

Scott, M. C. (2009). STEM (science, technology, engineering, and mathematics). *Technology and Children, 14*(1), 3.

Seabrook, R., Brown, G. D. A., & Solity, J. E. (2005). Distributed and massed practice: From laboratory to classroom. *Applied Cognitive Psychology, 19*, 107-122.

Simon, D. A., & Bjork, R. A. (2001). Metacognition in motor learning. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 27*(4), 907-912.

Sladky, L. (2010). One-third of students need remedial college math, reading. *USA Today.* Retrieved November 29, 2010, from http://www.usatoday.com/news/education/2010-05-11-remedial-college_N.htm.

Southwest Baptist University (SBU). (2011). General education. Retrieved December 27, 2011, from http://www.sbuniv.edu/academics/SBU_Catalog_PDFs/general_education_requirements.pdf.

Trautwein, U. (2007). The homework-achievement relation reconsidered: Differentiating homework time, homework frequency, and homework effort. *Learning and Instruction, 17*(3), 372-388.

Trautwein, U., & Koller, O. (2003). The relationship between homework and achievement—still much of a mystery. *Educational Psychology Review, 15*(2), 115-145.

Trautwein, U., Koller, O., Schmitz, B., & Baumert, J. (2002). Do homework assignments enhance achievement? A multilevel analysis in 7th-grade mathematics. *Contemporary Educational Psychology, 27*, 26-50.

Trautwein, U., Niggli, A., Schnyder, I., & Ludtke, O. (2009). Predicting homework effort: Support for a domain-specific multilevel homework model. *Journal of Educational Psychology, 98*, 438-456.

University of Missouri (MU). (2011a). General education requirements. Retrieved December 27, 2011, from http://generaleducation.missouri.edu/requirements/.

University of Missouri (MU). (2011b). Campus institutional review board (IRB). Retrieved June 25, 2012, from http://research.missouri.edu/cirb/.

Willingham, D. T. (2002). How we learn. Ask the cognitive Scientist: Allocating student study time. “Massed” versus “distributed” practice, *American Educator, 26*(2), 37-47.

Zhu, Y., & Leung, F. K. S. (2011). Homework and mathematics achievement in hong kong: Evidence from the TIMSS 2003. *International Journal of Science and Mathematics Education.* Retrieved February 12, 2010, from http://www.springerlink.com.proxy.mul.missouri.edu/content/r75g787k83661379/
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APPENDIX A

Informed Consent

I,___________________________________, Superintendent, agree my district may participate in the study of best practices in mathematics instruction based on a comparison of mixed practice lessons to blocked practice lessons being conducted by Tamara J. DuBois, a doctoral student at the University of Missouri-Columbia.

I understand that:

District archival data will be used in the dissertation study.

Participation is voluntary and the district may withdraw at any point in the study.

The identity of all students, faculty, and staff of the district will be protected in the reporting of the findings.

All collected data will be secured. The key connecting student names with test score data will be destroyed immediately upon collection of all data. Remaining data will be destroyed three years after the completion of the dissertation.

I have read the information above and any questions I asked have been answered to my satisfaction. I agree my district may participate in this activity, realizing it may withdraw without prejudice at any time.

Signed:____

Date: ____

Informed Consent

I,____________________________________, Principal, agree my district may participate in the study of best practices in mathematics instruction based on a comparison of mixed practice lessons to blocked practice lessons being conducted by Tamara J. DuBois, a doctoral student at the University of Missouri-Columbia.

I understand that:

District archival data will be used in the dissertation study.

Participation is voluntary and the district may withdraw at any point in the study.

The identity of all students, faculty, and staff of the district will be protected in the reporting of the findings.

All collected data will be secured. The key connecting student names with test score data will be destroyed immediately upon collection of all data. Remaining data will be destroyed three years after the completion of the dissertation.

I have read the information above and any questions I asked have been answered to my satisfaction. I agree my district may participate in this activity, realizing it may withdraw without prejudice at any time.

Signed:____

Date: ____

VITA

Tamara (Roberts) DuBois was born February 25, 1975, in Poplar Bluff, Missouri. After attending public schools in rural southern Missouri, she received the following degrees: B.S.ed. in Mathematics (1997) and M. S. ed. in Mathematics (2003) from Missouri State University and Ed.D. in Educational Leadership and Policy Analysis from the University of Missouri-Columbia (2012). She is married to Geoff DuBois and together they have four children, Hayden, Jathan, Zeb, and Jessa. Dr. DuBois is dedicated to mathematics education. She is currently employed at West Plains High School in West Plains, Missouri.