THE EFFECTS OF EMBEDDING FORMATIVE ASSESSMENT MEASURES IN A PROBLEM--BASED LEARNING MATHEMATICS CURRICULUM FOR MIDDLE SCHOOL STUDENTS

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THE EFFECTS OF EMBEDDING FORMATIVE ASSESSMENT MEASURES IN A PROBLEM-BASED LEARNING MATHEMATICS CURRICULUM FOR MIDDLE SCHOOL STUDENTS

DISSEYATION

A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the College of Education at the University of Kentucky

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ABSTRACT OF DISSERTATION

THE EFFECTS OF EMBEDDING FORMATIVE ASSESSMENT MEASURES IN A PROBLEM-BASED LEARNING MATHEMATICS CURRICULUM FOR MIDDLE SCHOOL STUDENTS

Student performance in the area of mathematics is a topic of national concern in the United States, with several reports documenting the need for effective instruction to boost student achievement. However, what type of math instruction will most effectively raise student achievement for students with disabilities (SWD) remains a matter of debate. Problem-based learning (PBL) is a promising methodology for engaging and motivating students’ learning while increasing their math skills. Enhanced Anchored Instruction (EAI) is a form of problem-based learning, rooted in a constructivist framework, which guides students through complex problems through video anchors and context rich environments that has been shown to significantly improve math performance of SWD. Assessing student performance during PBL units is often difficult. Formative assessments supplement curriculum by allowing teachers to gather information and assess student learning during the course of instruction. However, despite the rise in formative assessment use, the effects of formative assessment in PBL curricula are rarely addressed. This study examined the effect of embedding formative assessments in the EAI curriculum on academic outcomes in middle school math classrooms. Results showed that problem solving performance did not improve with the addition of formative assessment and gains on computation performance were mixed.

KEYWORDS: Problem-Based Learning, Math Education, Enhanced Anchored Instruction, Formative Assessment, Learning Disabilities

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This dissertation is dedicated to my wife, Krissie, whose support and encouragement provided me with the motivation I required to accomplish this work. And also to my daughter, Avery Elizabeth, who is my greatest joy.
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INTRODUCTION

Introduction to Problem

Math education has been a topic of national concern for several decades. In 1983, the National Commission on Excellence in Education published *A Nation at Risk*, which brought attention to a decline in American educational performance and warned the country of the dire consequences of underachievement. The authors presented a rather dim outlook on the state of education when they wrote:

> If an unfriendly foreign power had attempted to impose on America the mediocre educational performance that exists today, we might well have viewed it as an act of war. As it stands, we have allowed this to happen to ourselves. We have even squandered the gains in student achievement made in the wake of the Sputnik challenge. Moreover, we have dismantled the essential support systems that helped make those gains possible. (National Commission on Excellence in Education, 1983, par. 2)

*A Nation at Risk* alerted the country to the educational crisis and laid the foundation for educational reform (Brandt, 2000; Ravitch, 1995). The National Council of Teachers of Mathematics (NCTM) was especially concerned with American underachievement in mathematics and published the *Curriculum and Evaluation Standards for School Mathematics* in 1989. This was the first set of published standards-based educational learning goals and launched the standards movement in American education.

However, despite the shift to standards-based instruction, a significant number of students still failed to achieve proficiency on standardized assessments administered at the state level. This issue was particularly critical when they began to investigate
performance across demographic groups (Gordon, Piana, & Keleher, 2000; Jacobson, Olsen, Rice, Sweetland, & Ralph, 2001). The inequities in education and poor achievement across demographic groups resulted in another major educational change with the authorization of the No Child Left Behind Act of 2001 (NCLB).

NCLB legislation has changed what states are expected to accomplish in their schools. Schools are responsible for providing access to more rigorous instruction and are held to higher levels of accountability for the academic achievement of every student, including students with disabilities (SWD). An accountability system was established for “improving the academic achievement of all students, and identifying and turning around low-performing schools that have failed to provide a high-quality education to their students” (NCLB, 2002, p. 1440). Despite linking achievement on state-administered tests to federally issued funds (i.e., Title 1) and mandating that 100% of students grades three through eight must achieve proficiency by 2014, American schools are still falling short of meeting their performance goals.

Schools nationwide are now entering the final year of the NCLB timeline and are facing mounting pressure to dramatically improve student performance and meet benchmarks or risk losing federal and state funding. While some evidence suggests that NCLB has had a positive affect on the performance of elementary-aged students in the area of mathematics, the positive effects are more evident in lower grades (Jitendra, Corroy, & Dupis, 2013). Educators continue to seek effective strategies for improving math performance. One promising instructional approach for improving student performance is problem-based learning (PBL). PBL is an approach to teaching mathematics that has effectively improved learning and reduced achievement gaps for
middle and secondary students (Bottge, Rueda, Serlin, Hung, & Kwon, 2007). Another instructional approach gaining increased use in schools is formative assessment. There is a growing body of evidence that suggests that when properly used, formative assessment is an effective method to accomplish these same goals of improved learning and reduced achievement gaps (Wiliam & Thomson, 2007). Each of these educational strategies provide schools with effective instructional strategies as they work to reach the proficiency goals established in NCLB.

**Background of the Study**

**Mathematics Achievement**

Between 4% and 10% of the school-aged population (K-12) has difficulties in mathematics and a large percentage of middle school students with disabilities are struggling in the area of mathematics (Fuchs, Compton, Fuchs, Paulsen, Bryant, & Hamlett, 2005; Geary & Hoard, 2005). According to the National Assessment of Educational Progress (NAEP) 65% of SWD scored below Basic level compared to only 23% of their peers without disabilities (Aud et al., 2011). To help raise standards, the Common Core State Standards for Mathematics (2010) describe for teachers performance expectations at each grade level. Yet, it has proven challenging to improve the math achievement of students with disabilities (Cawley, Parmar, Yan, & Miller, 1998). Two areas that are difficult for many students and factor significantly into students’ low math achievement are fractions and problem solving (Misquitta, 2011). SWD are especially poor problem solvers because they typically lack knowledge of the processes required for problem solving (Montague & Applegate, 1993).
Mathematics Instruction

The Principles and Standards for School Mathematics (National Council of Teachers of Mathematics, 2000) recommends that teachers “build new mathematical knowledge through problem solving” and that all students be given opportunities to solve quality problems that motivate and build mathematical confidence (n.p.). In order to facilitate such learning, teachers must understand the problem-solving process and provide students with guided instruction and a variety of problem-solving activities (Kroll & Miller, 1993). In problem solving, SWD often have the additional challenge of decoding text due to the co-morbidity of reading and math difficulties (Knopick, Alarcon, & Defries, 1997).

One educational strategy aimed at offering students authentic real world problems to improve their problem-solving ability is called Problem-Based Learning (PBL). PBL has historical roots back to Dewey (1916/1944) who believed that teachers should appeal to the students’ natural instincts of creativity and exploration. It was this belief that learning should be linked to “ordinary life” and that in doing so, students would naturally build their capacity to learn and think (Dewey, 1944, p.154). Although Medical Schools adopted this principle for teaching adult learners, it has only recently gained educational momentum in public schools. Barrows and Tamblyn (1980) define PBL as “the learning that results from the process of working toward the understanding or resolution of a problem” (p.18). According to Delisle (1997) PBL prepares today’s 21st century learners for success in a fast-changing world by developing skills in thinking, researching, problem solving, and technology.

One problem-based learning curriculum that has been shown to improve the math
skills of students with disabilities is Enhanced Anchored Instruction (EAI; Bottge, Heinrichs, Mehta, & Hung, 2002; Bottge, Rueda, & Skivington, 2006). EAI grew out of the Anchored Instruction model (AI) developed by the Cognition and Technology Group at Vanderbilt University (CTGV, 1990). AI is a video-based problem-solving curriculum designed to provide students with a motivating alternative to more traditional text-based word problems. EAI builds on the original AI concept by requiring students to utilize their problem solving skills to solve problems in practical contexts (e.g., building a hovercraft frame). Research on the effect of EAI curriculum has shown to genuinely engage and interest students who had previously shown a dislike for mathematics (Bottge et al., 2006). This confirms the belief of Dewey (1916/1944) that problems that students see as worthwhile will be motivating to solve.

While PBL models such as EAI offer strong support for improving the computation and problem-solving skills of students with disabilities, the role of explicit formative assessment in the curriculum has yet to be explored. PBL is often characterized as an individual or group activity that continues over a period of time that results in a product, presentation, or performance. It typically has a flexible timeline and other aspects of formative evaluation as the project proceeds (Blumberg & Michael, 1992). Instructors utilizing PBL instruction must be able to evaluate both the general progress toward the project conclusion and assess mathematical and problem-solving growth in students in order to inform instruction (Hosp, 2012). Although formative evaluation throughout the PBL unit provides for the first, it was not intended to do the latter. Given the increased emphasis of formative assessment over the past 15 years in the education of students and the significance of such assessment for academic performance of students who struggle
with mathematics (McIntosh, 1997), it is important to determine the effect of such
evaluations embedded in a PBL unit.

**Assessment in Mathematics**

Formative assessments are understood as assessment for learning (Stiggins &
Chappuis, 2006). While there are varying definitions of formative assessment offered by
experts in the field, they share some common elements. Formative assessment is a
systematic and continuous process used by educators during instruction in order to
evaluate student learning while it is still evolving (Black & William, 1998a; Clark, 2011;
Heritage, 2010). Formative assessment is linked to instructional objectives and integrated
within each aspect of teaching and learning at the classroom level. Both the teacher and
students are dynamically involved in formative assessment (Stiggins & DuFour, 2009).

One of the driving purposes of formative assessment is the opportunity to provide
teachers with a continuous feedback loop to adjust ongoing instruction and close gaps in
learning (Stiggins & Chappuis; Stiggins & DuFour). Kaminski and Cummings (2007)
define formative assessment as the process by which data are used to adjust teaching to
meet students’ needs.

**Statement of Problem**

Across the nation we face the problem of how to improve levels of student
achievement in mathematics, particularly for SWD. Despite federal legislation and
increased attention to the problem, students’ mathematics achievement levels continue to
fall below NCLB expectations. Although some progress has been made at the national
level for elementary aged students (Jitendra, Corroy, & Dupuis, 2013), most states and
schools will fail to reach the 100% proficiency goal established with NCLB. Educators
must provide effective math curriculum and interventions to improve student achievement for SWD.

PBL curriculum such as EAI (Bottge, et al., 2002; Bottge et al., 2006) has been shown to improve the computation and problem-solving skills of SWD on post-test measures. Formative assessment is another educational strategy for improving student achievement (Black & Wiliam, 1998a, 1998b; Wiliam, Lee, Harrison, & Black, 2004; Wiliam & Thompson, 2007) that has the potential of adding to the positive effects of EAI. (Black & Wiliam, 1998a; Sadler, 1989; Stiggins & Chappuis, 2006). The problem for many schools implementing PBL units in mathematics is finding an effective way to measure progress during the unit of study in order to ensure students are progressing in their foundational math skills as they work towards proficiency.

Purpose of the Study

The primary purpose of this study was to determine whether embedding formative assessment measures in a problem-based learning curriculum (i.e., EAI) could improve the computational and problem-solving performance of SWD in inclusive middle school settings. This study will do so by comparing student performance across two conditions using multiple outcome measures. A secondary purpose of the study was to determine the effect of embedding formative assessment on instructional variables. Given that formative assessment is often described as cumbersome to implement and time intensive, this study determined the impact of formative assessment on instructional decisions and curriculum pacing.
Research Questions and Hypothesis

The following research questions were developed to determine the extent and manner in which formative assessment measures embedded in the EAI curriculum affected student achievement in mathematics and teacher behaviors:

Experimental Research Questions

1. What effect will the addition of formative assessments to the EAI curriculum have on computational and problem-solving performance of students with and without learning disabilities in an inclusive classroom?

2. Is there an interaction effect between student status (e.g., SWD, Typical Student) and treatment status (EAI, EAI plus Formative)?

Qualitative Research Questions

3. What effect will the addition of formative assessments to the EAI curriculum have on the number of instructional days required to complete the unit(s) of study?

4. What effect will the addition of formative assessments to the EAI curriculum have on instructional decision making?

Hypotheses

The alternate hypotheses for this study were:

1. There are significant differences between the pre- and post test-score means of students taught using EAI Curriculum and EAI plus formative assessment.

2. There is an interaction effect between treatment status and disability status.

3. There are significant differences between the number of instructional days required to complete each unit between the EAI and EAI plus formative
assessment groups.

4. There are differences between the instructional decisions teachers make in EAI and EAI plus formative assessment conditions.

**Theoretical/Conceptual Framework**

This thesis primarily is based on the theoretical framework work of Bottge (2001), who draws on the educational theories of Dewey (1916) and Bruner (1960) among others. In addition, this thesis is supported by the theoretical framework of Black and Wiliam (1998a, 2006) on formative assessment. Integrated theoretical aspects of problem-based learning and anchored instruction in mathematics also support the work of this thesis. Bottge (2001) outlined the theoretical framework for EAI using the *Key Model* (p. 106) found in figure 1. In this model the teeth of the key represent six conditions that together foster problem solving in the area of math for students who are low-achieving. The six teeth are identified as “meaningful, explicit, informal, (de)situational, social, and teacher specific” (Bottge, 2001, p. 103). In the key model the lock pins represent learner qualities, which are enhanced by the curriculum. Specifically, Bottge identifies these learner qualities as “engagement, foundations, intuitions, transfer, cultural supports, and student-specific” (p. 103).

The conceptual framework for formative assessment is informed by Black and Wiliam’s definition of formative assessment (1998b):

All those activities undertaken by teachers, and by their students in assessing themselves, that provide information to be used as feedback to modify teaching and learning activities. Such assessment becomes formative assessment when the evidence is actually used to adapt the teaching to meet student needs. (p. 2)
This definition of formative assessment allows for interpretation of activities that might comprise a formative assessment, as the description refers more to the use of assessment data to drive instructional decisions than to any one type of assessment. This ambiguity has led to very diverse implementation of formative assessment. For example, there are multiple-choice assessments that are intended to quickly assess students on grade-level content either through paper-and-pencil tests (PPT) or Web-based tests (WBT). In comparison, there are formative assessments such as demonstrations, student journals, portfolios (Stiggins & Chappuis, 2006), and student work related to real-life applications and problem solving. These latter forms of assessment are often referred to as authentic assessments (Burke, 2005; Wiggins, 1990).

**Nature of Study**

The study utilizes a pretest-posttest randomized school-based trial to test the efficacy of two instructional conditions Enhanced Anchored Instruction (EAI) and Enhanced Anchored Instruction with formative assessment anchors (EAI/f) on students’ fraction computation and problem-solving abilities. Overall test scores will be analyzed to determine effects of the two conditions on students’ ability in those areas. According to Shadish, Cook, and Campbell (2002), the alternative treatment design with pretest allows the researcher to compare different treatments, and even if posttest differences are not detected, can allow for examination of pretest and posttest scores to determine if both treatment conditions improved or if neither did. Given that the standard treatment (e.g., EAI) has an established record of improving student performance in mathematics, a control condition is not necessary to prove the effectiveness of the treatment (Shadish, Cook, & Campbell, 2002).
Specifically, the study will use a randomized, two-group pretest–posttest design with multiple measures (Shadish, Cook, & Campbell, 2002). The randomized, two-group, pretest–posttest design with can be diagrammed as follows (Shadish et al.):

\[
\begin{array}{cccc}
R & O_{123} & X_A & O_{123} \\
R & O_{123} & X_B & O_{123}
\end{array}
\]

For the purpose of the research design, \(R\) is used to represent that the group was formed by random assignment. The pretest measures are represented with \(O\) with the numbers corresponding to three separate pretest measures. The alternate treatment groups are represented with \(X_A\) and \(X_B\) respectively, with \(X_A\) representing the EAI condition and \(X_B\) representing the EAI plus formative measures condition. The second \(O\) denotes the three posttest measures, which are identical to the pretest measures.

**Significance of the Study**

This study addresses educational issues of national concern, primarily improving mathematical skills for SWD. In addition, this study responds to a call for the educational community to better prepare students to enter the workforce and become productive citizens of society. Efforts to improve our current educational system are clear; however, student outcomes, particularly in middle and secondary mathematics are disappointing and achievement gaps between demographic groups remain (Balfanz & Byrnes, 2006; Klein, 2009). Problem-based learning curriculums foster deep levels of conceptual knowledge in mathematics and improve computational and problem-solving skills (Grant, 2010; Ferreira & Trudel, 2012; Walker & Leary, 2009). Formative assessment has also been shown to significantly improve test scores and to reduce achievement gaps (Black & Wiliam, 1998a, 1998b; Wiliam & Thompson, 2007). This study may demonstrate that embedding formative assessment measures in a problem-based learning curriculum can
produce significant improvement in mathematics achievement. It may contribute to evidence-based practices for teaching students with disabilities, mathematics achievement, and the goal of the *No Child Left Behind Act of 2001* that 100% of students demonstrate proficiency on state-administered mathematics tests in grades three through eight.

A large body of evidence exists that EAI curriculum can improve the computational and problem-solving skills of SWD (Bottge, 2001; Bottge & Hasselbring, 1993; Bottge, Heinrichs, Chan, & Serlin, 2001; Bottge, Heinrichs, Mehta, & Hung, 2002; Bottge, Ma, Gassaway, Toland, Butler, & Choo, in press). There is growing evidence that formative assessment can improve student learning and raise student achievement (Black & Wiliam, 1998a, 1998b, 2006; Chappuis, 2004; Shepard, 2000; Stiggins, 2005; Stiggins, Arter, Chappuis, & Chappuis, 2004; Stiggins & Chappuis, 2006; Wiliam, 2007a, 2007b). However, little research focuses on the potential effect of blending the problem-based learning of EAI with formative assessment of computational and problem-solving skills.

**Definition of Terms**

The following terms are used throughout this study:

*EAI.* EAI refers to the instructional package used to deliver fractions computation and problem-solving instruction, specifically using the instructional units Fractions at Work (*FAW*), Fraction of the Cost (*FOC*), and Hovercraft (*HC*). Participating teachers received training on implementing the curriculum and daily lesson plans specific to each unit.

*EAIf.* EAIf refers to the instructional package of EAI with embedded formative assessment anchors within each unit (i.e, *FAW, FOC, HC*). In the EAIf condition,
students will complete one formative assessment measure for every two to three days of instruction in each unit. Participating teachers have received previous training on implementing the curriculum and daily lesson plans specific to each unit. In addition, they received training on the delivery, scoring, and analysis of formative assessment measures.

*Formative Assessment.* Formative assessment refers to brief assessment tasks given at multiple points during each unit of study (see Appendix A). Formative assessment tasks are scored and analyzed by the teacher prior to continuation of instruction for instructional decision-making.

*Pre- and Post-test Measures.* The pre- and post-test measures include three separate instruments in this study. These include a researcher-developed Fractions Computation assessment (FC), a researcher-developed Problem-Solving assessment (PS), and two sub-sections of the mathematics section in the Iowa Test of Basic Skills (ITBS).

*SWD.* Refers to all student participants who have a diagnosed disability and are receiving special education services as outlined in their Individualized Education Program (IEP). These students receive math instruction in the inclusive (i.e., collaborative) classroom.

*Typical Students.* Refers to all students in the classroom who are not identified with a disability and receiving special education services.

*Instructional Decision-Making.* Instructional decision-making refers to the decision made by the teacher after scoring and analyzing formative assessment data. The teacher records the instructional decision on a researcher-developed form for qualitative analysis.
Assumptions

The following assumptions were made as part of this study

1. Student groups in both conditions were equivalent.

2. Teachers in both conditions were equivalent.

3. Students’ mathematics achievement can be measured using the Fractions Computation, Problem-solving, and Iowa Test of Basic Skills assessment protocols.

4. Each participant (e.g., teacher, student) provided accurate information with regard to demographic information and disability status.

5. The math teachers in each condition were equally effective instructors.

6. In participating classrooms, all teachers effectively taught the EAI curriculum.

7. All mathematics teachers were committed to improving every student’s math knowledge and problem-solving ability.

8. Students in each condition responded to pre- and post-test items to the best of their ability and the test scores accurately reflect their level of performance.

9. Students in EAI/f condition responded to formative assessment items to the best of their ability and their responses accurately reflect their level of performance.

10. Teachers in EAI/f condition accurately scored and analyzed formative assessment items and made the appropriate instructional decision based on that data.

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CHAPTER 2. LITERATURE REVIEW

Mathematics Instruction

According to the Trends in International Mathematics and Science Study (TIMSS; National Center for Education Statistics, 2007), students in other countries (i.e., Taiwan, South Korea, Singapore, Japan) continue to outperform students in the United States on measures of math proficiency. While more recent data suggests some improvement, interpreting the results of these assessments, which are administered in fourth grade and eighth grade, highlights the “relative weakness of U.S. students” (Woodward, 2013, p. 85) and underscores the need to analyze current teaching methods in mathematics. Historically, instruction in mathematics has gone through periods of focusing on improving basic math skills through explicit instruction and other eras that emphasized problem solving through more inquiry-based instruction (Jitendra, Corroy, & Dupuis, 2013; Lester, 1994; Woodward, 2013). For example, while the decade of the 1970’s focused on basic skills, the 1980’s shifted to instruction to problem-solving (Lester; Woodward).

In response, the National Council of Teachers of Mathematics (NCTM) issued its Principles and Standards for School Mathematics (2000), Professional Standards for Teaching Mathematics (1998), and Assessment Standards for Teaching Mathematics (1995) in which The Council included recommendations specific to teaching mathematics (2000). The NCTM, was founded in the 1980’s, by a group of individuals from across the U. S. committed to the mathematical education of students in K-12 schools. The primary focus of its work has been educational research and the publication of curriculum-guiding documents influencing math education and teacher preparation. This
work was initiated by the publication of *A Nation at Risk* (National Commission on Excellence in Education, 1983) which led educational leaders to seek more effective methods of instruction to better prepare American students for participation in a competitive global economy (NCTM). Since that time the council has worked to reform math education in the United States by focusing on the mathematics skills educators expect students to be able to use, the process by which students learn math, and how we go about assessing that progress. Currently, the NCTM recommends teaching to process standards based on the current needs of our students and based on several decades of research on mathematics methodology (NCTM; Wood, 1997). These recommendations for instruction are more aligned to inquiry-based instruction than direct instruction (DI) methods.

The NCTM references scores from the TIMSS (Gonzales et al., 2004) as support for emphasizing process and not just procedural understanding of math. Hmelo-Silver (2004) found that when compared to economically similar countries, U.S. math classrooms offered relatively few opportunities for students to problem solve, engage in math conversations, justify reasoning, and prove their answers were correct. These types of tasks, which align with NCTM process standards, are relatively unused in the majority of classrooms (Gonzales et al., 2004). In fact, according to Hiebert et al. (2003) 78% of math instruction utilized only aural statements or procedural demonstration by teachers in the traditional math classroom, with little attention given to development of mathematical process. Moreover, the observations revealed the majority of mathematical application (96%) consisted of practicing procedural tasks and independent seatwork without student engagement. These types of activities, emphasizing procedural learning while neglecting
process, lack the necessary rigor to advance students’ math achievement (Hmelo-Silver).

Traditionally, in U.S. classrooms mathematics instruction has focused on procedural understanding (e.g., direct instruction) with process approaches (i.e., inquiry-based) getting significantly less attention.

**Students with Disabilities in Mathematics**

Students with disabilities (SWD) regularly struggle in the area of mathematics. Several decades ago Kosc (1981) identified four variables that significantly impact an individual’s ability in the area of mathematics. The four variables include psychological factors (i.e., cognitive ability), education factors (i.e., the quality and quantity of education), personality factors (i.e., self-concept, attitude towards math), and neuropsychological patterns, such as perception or brain trauma (Kosc). Because students with disabilities (SWD), especially those with high incidence disabilities, are often impacted by each of these four factors, it is not surprising that many of them would perform poorly in the area of mathematics. The influence of those factors leads to six areas of math difficulty for SWD, including *perceptual skills, perseveration, language, reasoning, memory, and difficulty with symbolism* (Ginsburg, 1997). *Perceptual skills* refer to spatial awareness, sequencing, and size/distance and SWD need opportunities to explore objects and identify positional awareness (Tucker, Singleton, & Weaver, 2006). *Perseveration* is the inability to shift mentally from one operation or task to another and impacts an individuals’ ability to perform multiple operations or complete applied problems with multiple steps (Ginsburg). *Language* issues affect SWD when mathematical concepts are expressed in language (e.g., greater than, less than). *Reasoning* in mathematics requires abstract thinking and SWD are aided by “concrete materials and
real-life application whenever possible” (Weaver, 2012, p. 369). SWD often have difficulty with memory that necessitates teachers providing strategy instruction and increased exposure to material and opportunities to practice. Lastly, symbolism difficulty affects students when they fail to understand the meaning of mathematical operations expressed in symbols (Ginsburg).

Many SWD also have unique backgrounds that impact their performance in math. For example, Jitendra, Corroy, and Dupuis (2013) identified attention, socioeconomic status (SES), and reading as the most significant predictors of poor performance on solving mathematical word problems. Given these challenges, it becomes imperative that SWD receive quality instruction in mathematics that can lead to more successful outcomes. Unfortunately, math instruction for SWD is “often focused on computation, (and) they often have limited exposure to other elements of math, including measurement, time, and practical problem solving” (Weaver, 2012, p. 368).

The National Research Council (NRC; 2001) issued an extensive report that outlined issues with learning mathematics and included specific recommendations for effectively teaching SWD. First, the council recommended not altering content goals to differentiate instruction, but rather changing the type and speed of instruction. Second, the council recommended shifting the focus of instruction from teacher-centered models to student-centered models. Third, it advocated for students to verbalize ideas and explore mathematical ideas. Fourth, it endorsed frequent opportunities for students to use math in connection with real-life problems that connect to daily living. Fifth, it recommended a shift from paper-pencil activities to use of manipulatives, computers, and calculators. Sixth, it advocated teaching students to identify situations when estimates are appropriate
to use. Lastly, it endorsed problem-solving curriculum supported with computer technology and calculators (NRC). By designing instruction with these key elements, the NRC stated that SWD are appropriately supported as they work towards mathematical proficiency, as defined by conceptual understanding, procedural fluency, strategic competency, adaptive reasoning, and productive dispositions.

A variety of methods for teaching mathematics have shown the potential for improving the math outcomes of SWD. Among these are direct instruction approaches (Baxter, Woodward, & Olson, 2001; Gersten, & Carnine, 1990; Gersten, & Keating, 1987; Hasselbring, Goin, & Bransford, 1987; Hastings, Raymond, & McLaughlin, 1989; Hudson, Miller, & Butler, 2006; Kelly, Krosberger & VanLuit, 2004; Rivera & Smith, 1988), graduated instruction methodology (Gagnon & Maccini, 2007; Witzel, Mercer, and Miller, 2003), self-monitoring techniques (Deshler, Warner, Schumaker, & Alley, 1983; Ellis, Deshler, & Schumaker, 1989; Montague, 1992; Montague & Leavell, 1994), and inquiry-based instruction methods (Bell, 2010; Clements & Battista, 1990; Cognition and Technology Group at Vanderbilt, 1992; Grant 2010; Ferreira & Trudel, 2012; Walker & Leary, 2009). Of these, the direct instruction and inquiry-based approaches for teaching mathematics represent two common, yet distinct methodologies.

**Direct Instruction**

Direct Instruction (DI) is a method of teaching built on principles of behaviorism (Engelmann, 2005). In DI the teacher is the central figure in instruction and students experience a tightly controlled, sequential lesson. This teaching arrangement is grounded in the seminal works of behaviorists, such as Skinner (1938) who believed that individuals require reinforcement to maintain interest and that stimuli could be used to
effectively control behavior. Central to this concept is the belief that the environment
directly shapes behavior, and that complex learning necessitates small, systematic steps
(Engelmann). As the founder of DI wrote, it “…emphasizes well developed and carefully
planned lessons designed around small learning increments and clearly defined and
prescribed teaching tasks” (Engelmann, p. 1).

DI models of instruction emphasize standardized lesson plans and explicit
methods of instruction (Willis, 2001). Lessons are prescribed with highly structured
sequences of activities. DI frequently employs homogenous groupings of students to
allow for tightly controlled learning environments and tracking of student performance
(Engelmann, 2005). Standardized textbooks and scripted lessons are the primary teaching
tools in teaching mathematics. DI methods align with more standardized assessment
protocols, including state-authorized assessments given annually to track student progress
(Roh, 2003). Teachers utilize brief, repeated tests of discrete skills in DI with larger
intermittent tests to check for progress on overall progress (Engelmann). Much like
formative assessment measures, these data are then used to make instructional decisions
for the individual student and for the larger group. Assessments used in DI tend to focus
on accuracy of student responses and less on process as NCTM recommends.

DI lessons are structured around the following sequence of instructional activities
(Engelmann, 2005).

1. The teacher reviews prior learning,
2. The teacher explains short and long-term learning objectives with students.
3. The teacher leads a short demonstration (lecture) focused on discrete
   skills/concepts through intentional pacing and scripted prompts.
4. The teacher leads the whole class in guided practice of the skill/concepts including choral responding from students to assess understanding.

5. The teacher uses graduated scaffolding to transition students from guided to independent practice with expectations set for procedural operations and intended level of mastery (generally 90%). Independent practice is typically from the student textbook.

6. The teacher circulates throughout the room to check with individual students as independent practice occurs and provides remediation for students that failed to reach mastery on previous learning targets.

A typical DI lesson follows this order of activities and stresses individual student responding and the accuracy of those responses. This approach emphasizes procedural understanding focused on algorithms and rote memorization of steps assessed through standardized assessments, but often fails to develop the understanding of process that facilitates problem solving and the ability to apply students’ knowledge in meaningful ways. However, advocates of DI claim that increased achievement on standardized assessments should be the primary goal of instruction (Engelmann, 2005). Several studies have shown DI to be an effective method of instruction for improving academic performance of SWD in mathematics (Baxter, Woodward, & Olson, 2001; Hasselbring, Goin, & Bransford, 1987; Hastings, Raymond, & McLaughlin, 1989; Hudson, Miller, & Butler, 2006; Kelly, Gersten, & Carnine, 1990; Kroesbergen & VanLuit, 2004; Rivera & Smith, 1988).

DI has been referred to as a return to fundamentals approach to teaching mathematics and supporters promote it as the traditional method of instruction. Some
educators claim better test scores result from this procedural approach (Eley & Norton, 2003). Since much of the current emphasis is on improving state and national test scores for students who are not meeting proficiency standards, advocates of the approach hope it will regain acceptance as the preferred method of instruction for SWD often citing the *Project Follow-Through* study (Adams, 1996; Stebbins, St. Pierre, Proper, & Anderson, 1977). Between 1968-1979 the study examined 79,000 children across 180 communities and the results indicated the best instructional program for the elementary students was a true DI approach. In a more recent study, more than 10 years of research were analyzed and found “clear advantages for embedding steps in an explicit hierarchical goal structure and for teaching modeling of procedures for new concepts” (Eley & Norton, 2003, p. 864). The U.S. Department of Education (2005) highlighted the benefits of DI methods for not only students at-risk for math failure, but for the greater student population of students as well.

**Inquiry-based Instruction**

In comparison to DI, inquiry-based instruction is a teaching method that emphasizes student participation and exploration of mathematical processes through deep engagement with materials and exploration of mathematical concepts (NCTM, 2000). Importantly, it rejects the passive engagement of learners in the teacher-centered delivery of conceptual ideas. Inquiry-based instruction is built on the principles of constructivism whereby the learner constructs concepts by building on current and past knowledge (Dewey, 1916; Piaget, 1976; Vygotsky, 1978). Constructivists believe students are more likely to retain information and skills they learn through active learning and that social experience is deeply embedded in that process of learning (Piaget; Vygotsky).
Additionally, constructivists highlight the importance of prior knowledge and past experiences as students build new knowledge (Piaget).

Problem-based learning is an inquiry-based method of instruction rooted in constructivist learning theory that is aimed at engaging students in authentic problems. Students develop new knowledge through deep, meaningful engagement with problems. The theoretical constructs, essential components and characteristics of problem-based learning, as well as defining roles, are discussed with attention given to relevant research related to student outcomes.

**Theoretical Background**

Constructivism is a learning theory that emerged during the 1960’s out of the discovery learning approach to instruction (Jones & Southern, 2003). The central premise of constructivism is that students construct knowledge through active engagement in learning activities (Jones & Southern). Constructivists reject the belief that learning occurs through the transmission of knowledge from teacher to student, but rather, contend that knowledge is transmitted to the student through active, experiential learning. Therefore, from the constructivist’s point of view, the learner must be an active participant in the learning process and not a passive absorber of information (Mercer, Jordan, & Miller, 1994). According to Jones and Southern (2003), “Students acquire the most meaningful understandings and appreciations of their learning and problem-solving experiences if they are engaged in learning activities that allow them to discover relationships and solutions for themselves” (p. 7). When students fully engage in this level of instruction, they connect new knowledge with prior knowledge, resulting in the creation of personalized knowledge since each student possesses a distinctive prior
knowledge set (Mercer et al.). Personalized learning, in turn, leads to greater student ownership of learning.

Constructivist learning differs greatly from traditional approaches commonly seen across many educational settings. The traditional approach is described and understood as a lecture-recitation format, wherein the instructor lectures on new content and then assigns independent student practice for demonstration of understanding prior to the next lesson (Alsup, 2004). Constructivists argue that this traditional approach fails in the construction of knowledge primarily because students typically remain passive throughout instruction. Conversely, there are several distinctive characteristics of constructivism that make teaching and learning effective (Clements & Battista, 1990). To begin with, Clements and Battista (1990) clarified that knowledge is not passively received from the environment, but instead is actively created and invented by the student (Clements & Battista). The teacher does not lead instruction with the student following, the student leads instruction as the teacher facilitates. Secondly, students’ ideas are constructed and become meaningful when new knowledge is integrated with pre-existing knowledge (Clements & Battista). The third precept of constructivism is that there is not one true reality, but rather only individual interpretations of the world. Students in a constructivist environment are never required or asked to adopt someone else’s thinking, but are expected to create and refine their own (Clements & Battista). Lastly, students are engaged in a social context with peers where they are expected to negotiate, share, evaluate, and explain their thinking. Negotiating, sharing, explaining, and evaluating are all generic skills used in social contexts that are also used beyond the classroom in real life. Society places a high demand on students to acquire these generic skills (i.e.,
effective collaboration, communication, flexible and extensive learning, intrinsic motivation, problem solving skills) and be able to apply them to novel situations (Cheng, Lam, & Chan, 2008). However, in order to equip students with these skills, it is imperative that teachers transition from traditional teacher-centered methodology to more student-centered (i.e., constructivist) forms of instruction (Cheng et al.).

**Problem-Based Learning**

Problem-based learning (PBL) is a student-driven, teacher-facilitated method of instruction for learning that is constructivist in its approach (Bell, 2010; Yuen Lie Lim, 2011). PBL is based on having students encounter authentic scenarios that they find meaningful, developing a plan for addressing them, and then working collaboratively to create viable solutions (Baron, 2011; Belland, French, & Ertmer, 2009; Land & Green, 2000; Larmer & Mergendoller, 2010). PBL helps students become active and responsible learners through situating learning in authentic problems (Hmelo-Silver, 2004).

Advocates of PBL instruction recommend it because it has resulted in highly engaged students and high levels of student achievement (Barell, 2007; Mergendoller, Maxwell, & Bellisimo, 2007). Bender (2012) defines PBL as “using authentic, real-world projects, based on a highly motivating and engaging question, task, or problem, to teach students academic content in the context of working, cooperatively to solve the problem” (p.7). Often students are given some choice in selecting the project and/or the methods they use to solve it, which leads to students being highly motivated to work toward a resolution and leads to higher levels of academic achievement (Drake & Long, 2009; Grant, 2010; Maloney, 2010; Marzano, 2009). PBL is recommended as a 21st century teaching method
since it requires students to develop teamwork and collaborative skills (Cole & Wasburn-Moses, 2010; Partnership for 21st Century Skills, 2007).

This non-traditional approach originated from the work of educational reformer John Dewey, who believed in the importance of having applied experiences during learning (Cheng et al., 2008). Bell (2010) writes that PBL instruction employs multiple strategies critical for students to become proficient communicators and problem-solvers. Today, nearly all descriptions of PBL include teachers working cooperatively with students to develop meaningful, highly motivating driving questions related to authentic tasks (Barrell, 2007; Grant. 2010). PBL originated from medical school models practiced during the late 1960’s (Cote, 2007; Ferreira & Trudel, 2012). These models developed as a response to the realization that traditional methods of instruction (i.e., lecture and memorization) were having negligible effects on medical students’ performance during residency (Ferreira & Trudel).

Since that time, medical schools have continued use of PBL to facilitate greater levels of analytic thinking and problem-solving skills for medical students. Additionally, the educational community has begun using PBL in K-16 settings (Ferreira & Trudel, 2012). PBL is sometimes referred to as project-based learning, inquiry learning, authentic learning, or discovery learning. Some educators believe PBL is set to become the primary instructional methodology in the next century, particularly given the increasing demands of struggling students and educational changes with increased emphasis on differentiated instruction (Partnership for 21st Century Skills, 2007). PBL offers a unique alternative for educators working with students who lack motivation and possess poor problem-solving skills in the educational context of limited budgets and
instructional technologies that become quickly outdated (Belland, French, & Ertmer, 2009; Larmer & Mergendoller, 2010; Partnership for 21st Century Skills, 2007). PBL projects can be quite broad and may require flexible timeframes in order to facilitate students’ pursuit of unique pathways to possible solutions (Fleischner & Manheimer, 1997).

**PBL Terminology**

PBL literature provides the educational community with terminology specific to this instructional methodology (Barell, 2007; Bender, 2012; Grant, 2010). Defining the vocabulary commonly used in PBL research assists in understanding the components involved in this type of instruction. The following terms provide the operational terminology for understanding the language of PBL.

**Anchor** is the context in which the question is posed and serves to ground instruction in authentic situations. The anchor may take the form of a video or media presentation, or it could be text-based, such as a newspaper article (Cognition and Technology Group at Vanderbilt, 1992; Grant 2010). The anchor introduces the problem to students in an authentic and engaging way.

**Artifacts** are items developed by students in the course of solving the problem that represent potential answers. The term is used, in part, to stress that PBL units often do not result in traditional outcome measures, such as written reports. Although PBL units may result in a written report, they often result in items more aligned to real world scenarios, such as videos, portfolios of evidence, physical materials developed from hands-on activities, articles, or presentations (Grant, 2010). Given the emphasis on 21st-
century skills in PBL instruction, many artifacts are produced through technology (Bender, 2012).

**Authentic achievement** emphasizes learning that is embedded in work on authentic tasks that come from real world scenarios and are similar to the types of activities that adults complete in comparable situations (Barrell, 2007).

**Driving questions** in each PBL unit contains a principal issue or question that provides students with the task or goal of instruction (Larmer & Mergendoller, 2010). In order for the driving questions to be characterized as PBL, they should be both relevant and highly motivating to students (Grant, 2010; Larmer & Mergendoller).

**Expeditionary learning** is a form of PBL that involves students taking trips to locations in the community as part of instruction (Bender, 2012).

**Rubrics** provide structure to the PBL experience for both students and teachers. Rubrics should be detailed enough to give students a clear understanding of the goals of the unit, while still allowing students the ability to pursue diverse paths to solving problems (Bender, 2012).

**Student voice and choice** signify the essential role of student choice in selection of projects specific to the driving question or inquiry provided in PBL instruction. PBL often allows students to develop their own essential question(s) to pursue (Larmer & Mergendoller, 2010).

Given that PBL often employs various methods, Barrows (1986) promoted the development of educational goals for PBL in an effort to standardize educational outcomes (as cited in Walker & Leary, 2009). Barrows and Kelson (1995) added to the
taxonomy with five important educational goals of PBL: self-directed learning, problem solving skills, collaboration, extensive and flexible knowledge, and intrinsic motivation.

**Self-Directed Learning.** PBL is a powerful instructional strategy, which facilitates self-directed learning (SDL), and is becoming increasingly popular in Asian countries (Cheng et al., 2008). One of the benefits of PBL is that it equips students to become life-long learners through development of SDL skills (Hmelo-Silver, 2004). SDL facilitates the active development of explicit problem solving skills such as: identifying known information, creating and testing out theories, and developing solutions (Hmelo-Silver). The use of SDL skills becomes part of the problem solving process that guides learners to successful solutions.

**Effective Problem-Solving Skills.** Having the ability to transfer reasoning strategies to novel problems and being able to define problems from ill-structured information are indicators of effective problem-solving skills (Hmelo-Silver, 2004). When comparing gifted students in a PBL classroom versus traditional students, Gallagher, Stepien, and Rosenthal (1992) found that students with direct instruction in PBL were more likely to transfer problem-solving skills to new problems (as cited in Hmelo-Silver, 2004). Problem-solving skills are not inherent to all individuals and the nature of the learner can pose challenges for educators (Jonassen, 2011). There are both internal and external factors that affect problem solving; external factors include but are not limited to: structure, difficulty, and context; and internal factors include but are not limited to: prior knowledge, cognitive styles, experience, and reasoning skills (Jonassen). PBL instruction is intended to support all students in development of problem-solving skills despite any possible internal or external factors limitations.
**Collaboration.** Collaboration is a process where two or more people work cooperatively, with shared goals, towards an end product. Through PBL, students learn active listening skills, fundamental skills of proper communication, respect for others, and teamwork (Bell, 2010). Although effective collaboration is ideal, not all groups of people, in all settings, work together well. During PBL students are encouraged to reflect on the collaborative process through intentional thought (Dahlgren, & Dahlgren, 2002; Evensen, Salisbury-Glennon, & Glen, 2001). Reflection can be beneficial to both the individual and the group, and can be performed in several ways. Faidley, Evensen, Salisbury-Glennon, Glenn, and Hmelo (2000) evaluated collaboration by creating an observational and self-report instrument, the Learning Team Survey (LTS), to provide information on a group’s teamwork and processing. The checklist looks at group behaviors and attitudes that are important to collaborative learning, and each group member individually completed it to assess collaboration (Faidley et al.). PBL promotes collaborative teamwork in both design and explicit review of skills.

**Extensive and Flexible Knowledge.** Along with effective collaboration, communication and problem solving skills; PBL helps students construct a flexible and extensive knowledge base (Hmelo-Silver, 2004). According to Hmelo-Silver’s recent meta-analyses of research, students in PBL environments scored slightly lower than traditional medical students on multiple choice questions, but scored higher on tasks related to clinical problem solving. These results show that knowledge and skills attained by these students in PBL environments can be transferred to novel problem-solving situations (Hmelo-Silver, 2004).
Intrinsic Motivation. To be intrinsically motivated, students must seek motivation from within themselves rather than from any external or outside rewards. Although there is not significant research focused directly on intrinsic motivation, Hmelo-Silver (2004) says that PBL impacts intrinsic motivation “because learning issues arise from the problem (in response to students’ need to know)...therefore, intrinsic motivation should be enhanced” (p. 259). A group that functions well together is also important, because it affects the outcomes of learning and intrinsic motivation (Schmidt & Moust, 2000). PBL allows for differentiation of learning in the classroom, which allows students to develop their own interests and, therefore, pursue deeper learning and enhancement of intrinsic motivation (Bell, 2010).

Implementation of PBL

Over the years, research related to implementation of PBL has faced a number of challenges and obstacles due to the nature of curriculum design and other human factors (Hung, 2011). Consensus regarding the best research methodology for PBL in applied settings has not been reached. Hung (2011) wrote that research related to desired outcomes of PBL are “skewed” (p. 539) due to the high number of variables used in trying to compare PBL studies. Included among them are conflicting views of students’ interest, pursuing engagement in PBL classrooms, varying responsibilities and attitudes of facilitators, and differing roles of both teachers and learners across PBL environments (Taylor & Miflin, 2008).

There are several models of PBL, which researchers have attempted to classify. Barrows (1986) created a taxonomy that identified the level of self-directedness (i.e., teacher-directed, student-directed, partially student- and teacher-directed) as well as the
type of problem-structure (i.e., complete case, free inquiry, partial problem simulation). In another study, Hmelo-Silver (2004) outlined three distinct instructional approaches: PBL, anchored instruction, and project-based sciences. These models vary in their level of structure, from highly structured models with high levels of support to ill-structured models where students in the classroom work at their own pace and in their own direction (Hmelo-Silver). Bell (2010) defines PBL as a curriculum wherein students develop a question and then research the answer under the teacher’s supervision. This type of curriculum is underscored by student choice as the “key element in this approach” (Bell, p. 39). Students are permitted to choose which questions they pursue and how they choose to find and respond to them. These questions are commonly referred to as driving questions or inquiries in PBL, and development of an inquiry is the initial step in a PBL curriculum experience (Bell, 2010). Facilitators of such instruction may choose to develop inquires prior to introduction of the unit and make those available to students to guide learning or allow students to create their own problem within their group (Bell, 2010). However, according to Hung (2011) the key feature of PBL is that it is initiated and driven by a need to solve a real-world, ill-structured, authentic problem. These two approaches represent the extreme types of inquiries used in PBL: highly structured and ill-structured problems (Walker & Leary, 2009). Highly structured problems possess clear paths, optimal solutions, and context is of secondary concern, while ill-structured problems value assessment of student reasoning, are context crucial, and may not require specific solutions (Walker & Leary).

Small group instructional arrangements are commonly employed during PBL instruction with students being placed in small groups prior to introduction of the inquiry.
How these small groups are decided is a matter of some debate. Some who advocate for cooperative learning recommend heterogeneous ability grouping, where low achieving students are supported by high achieving students, which in turn improves high achievers’ cognitive abilities and presentation skills (Cheng et al., 2008). The PBL instructional arrangement allows teachers the opportunity to differentiate instruction through strategic collaborative groupings. However, researchers Fuchs, Fuchs, Hamlett, and Karns (1998) found that homogeneous grouping produced higher quality work and more effective collaboration among peers when compared to heterogeneous grouping. Whichever type of grouping is employed, Cheng et al. (2008) stated that effective PBL groupings contain elements of positive interdependence, individual accountability, equal participation, and social skills.

Scaffolded instruction supports student success (Bell, 2010). Scaffolded instruction is described as the level of support required for teachers to provide which will push students to a cognitive level just above their comfort zone (Bell). In order to assume the roles and tasks that PBL requires, appropriate scaffolding is necessary to develop students’ abilities and habits (Hung, 2011). Simons and Ertmer (2005) suggested that proper scaffolding could potentially lead to:

- Sparking students’ interest and reducing the tasks to a level deemed achievable by the students [which] could alleviate their difficulty in initiating the inquiry process;
- Engaging students in the scientific inquiry process (which) could help the students see their misconceptions;
- Providing prompts and modeling (which) could promote students’ reflective thinking about their solutions (p. 546).
Scaffolding can be used to differentiate instruction for students of all ability levels. However, at some point scaffolding needs to fade in the PBL learning environment. Pea (2004) believes that fading is necessary for the students to become problem-solvers, self-directed learners, and have flexible knowledge and skills.

How students learn the essential generic skills necessary for PBL and transfer those to applied problems in life is in the hands of the facilitator. Hmelo-Silver (2004) wrote that, “the facilitator is extremely important in modeling thinking skills and providing metacognitive scaffolding” (p. 246). The instructor’s role becomes central to student success in PBL instructional arrangements (Hung, 2011). While medical schools often have an instructor available for each small group, this is rarely the case in the traditional classroom where one instructor is often facilitating multiple groups simultaneously. Hmelo-Silver (2004) calls the one facilitator for multiple groups approach a “wandering facilitation model” (p. 246). The role of the facilitator is integral to the success of PBL, where it is possible to give too much guidance or not enough. Insufficient guidance can keep students from gaining effective problem solving skills, while excessive guidance can hinder students’ ability to develop SDL skills (Hung).

Jonassen (2009) noted that one of the potential shortcomings of PBL is that there can be a focus on problem solving without a simultaneous assessment of the underlying problems with which the students engage (as cited in Walker & Leary, 2009). In other words, it is important that students learn how to problem solve, but students also need to be assessed on the process and strategies used in solving problems. After instruction is initiated, assessment must be administered throughout PBL lessons in a dynamic and continuous
process, in which both the instructor and learner participate (Mercer, Jordan & Miller, 1994).

**Impact on Student Learning**

Research has regularly shown PBL to be a highly effective method of instruction (Gijbels, Dochy, Van den Bosche, & Segers, 2005; Grant, 2010; Thomas, 2000; Walker & Leary, 2008). In a longitudinal study by Hmelo-Silver (2004), over the first year of medical school, students involved in a PBL environment were compared to those in a traditional environment, and students who participated in the PBL curriculum were “more likely to produce accurate hypotheses and coherent explanations than the students in the traditional curriculum” (p. 250). This suggests that students in PBL environments are better able to construct knowledge and transfer it to new problem situations. In a study conducted by Schmidt, Loyens, Van Gog, and Paas (1996), a comparison of diagnostic accuracy for 30 case studies completed by students in PBL or traditional curriculums showed students in PBL environments were more accurate than their counterparts who participated in traditional curriculums. Research has consistently shown two consistent advantages to PBL instruction. First, PBL improves students’ motivation and engagement (Belland et al., 2009; Grant, 2010; Walker & Leary, 2008; Worthy, 2000). For example, Drake and Long (2009) found that students in a fourth-grade PBL classroom engaged in 4.27 more on-task minutes per 45 minutes of class time when compared to students in traditional instructional arrangements. This difference resulted in 12.80 additional hours of instruction over the course of the academic year (Drake & Long). In addition, participation in PBL units has led to better attitudes in particular subjects, which improves student engagement in those subjects (Boaler, 2002).
Secondly, student achievement is improved in PBL instruction as a result of increased engagement and motivation (Barell, 2007; Boaler, 2002; Bransford, Sherwood, Vye, & Rieser, 1986; Grant, 2010; Mergendoller et al., 2007; Strobel & van Barneveld, 2008). Gijbels et al. (2005) conducted a meta-analysis of research on the effectiveness of PBL instruction and determined that students improved their understanding of key concepts by up to 30 percent. Similar studies have found students improved academic performance as a result of PBL instruction across content areas (Geier et al., 2008; Scott, 1994; Strobel & van Barneveld, 2008; Walker & Leary, 2008). Additionally, research has shown that PBL resulted in higher levels of understanding, reflection, and critical thinking by focusing on deeper understanding (Boaler, 2002; Grant, 2010; Thomas, 2000). As a result of the PBL approach and a focus on understanding, students retain information at higher levels (Barell, 2007; Geier et al., 2008). Participation in PBL instruction has also resulted in improved problem solving across several subjects, including mathematics, science, and history (Strobel & van Barneveld; Walker & Leary, 2008). PBL was also found to be an effective methodology for differentiating instruction for students who were lower-achieving (Geier et al.; Mergendoller et al., 2007). Finally, research on PBL instruction showed students improved 21st century skills, such as instructional technology usage, collaborative work skills, and the ability to think critically (Barell; Cognition and Technology Group at Vanderbilt, 1992; Fleischner & Manheimer, 1997; Grant, 2010; Partnership for 21st Century Skills, 2007; Thomas, 2000).

Bell (2010) explained that the active learning process of PBL allows students to take various learning styles and preferences, use their tools of choice to research the problem, and choose a unique way to demonstrate their final product through a medium
of their choice. When PBL is implemented with student choice as a factor, children discover who they are as learners (Bell). In a study by Yuen Lie Lim (2011), results showed student’s reflective thinking developed from participation in a constructivist, PBL environment. Students in this study were required to take a 16-item questionnaire at the beginning and end of a PBL unit. The questionnaire measured four levels of reflective thinking habits as defined by Mezirow (1997): habitual action, understanding, reflection, and critical reflection (as cited by Yuen Lie Lim, 2011) and determined that students developed across these levels of reflective thinking in PBL environments, specifically in the area of critical reflection (Yuen Lie Lim).

PBL learning creates engaging experiences for authentic, real-world tasks (Bell, 2010). However, even though a PBL curriculum may be focused in one content area, the skills students gain impacts all areas of academic studies (Bell, 2010). As Bell writes, “research supports that students using PBL perform better on both standardized assessments and project tests than students in traditional direct instruction programs” (p. 42). Although many of the skills students acquire through participation in PBL curriculums are not measured on standardized tests, they are skills that must not be ignored if we are to equip students with twenty-first century skills in order to make them productive members of society (Bell). One form of PBL utilized in inclusive classrooms that supports students with disabilities is a form of anchored instruction: enhanced anchored instruction (EAI).

**Anchored Instruction**

Researchers have been examining curricular models that support students with disabilities in inclusive settings with higher-level mathematics skills, such as problem
solving (Bransford, Sherwood, Vye, & Rieser, 1986; CTGV, 1991). One approach to instruction developed from the Cognition Technology Group at Vanderbilt (CTGV), which is based on cognitive and constructivist theory, is called anchored instruction (CTGV 1990, 1991, 1992). Theory suggests that students do not learn to construct knowledge through traditional teaching methods. Instead, they require deep engagement in the exploration of meaningful problems and extended time to review and correct their ideas (CTGV, 1992). Anchored instruction is an example of how cognitive theory can be applied at the classroom level (CTGV, 1990). This type of instruction is in contrast to more traditional teaching methodologies, which tend to focus on rote memorization with little need for deep mathematical understanding.

Anchored instruction engages students by providing them with meaningful and complex problems to solve (CTGV, 1992). Curriculum anchors are developed in such a way that students have access to the resources available to experts while still developing mathematical proficiencies and learning new information (CTGV, 1996). The curriculum anchors are designed to engage students and motivate learning to solve problems as they investigate the context from different perspectives. As students explore these curriculum anchors, they discover their current knowledge is inadequate to solve the problem, and since the problems are meaningful, they pursue avenues to acquire the necessary information to solve them. This process of self-regulation leads to the construction of new mental models and beliefs (Lebow, 1993). In this arrangement, the instructor becomes a facilitator, rather than controller of the learning environment. At times, the educator will need to support the self-regulation of students by providing connections between their previous knowledge and the new understandings they pursue.
There are four principles to consider in supporting students with disabilities in higher-order thinking and instruction (Moore, Rieth, & Ebeling, 1993). These principles are “(a) considering students’ prior knowledge and preconceptions they bring regarding demands of the learning task, (b) developing students’ ability to form connections between new and existing knowledge so they can activate and apply the knowledge when appropriate, (c) promoting self-regulated learning, and (d) establishing a social context in the classroom that supports the development of active learning” (Moore, Rieth, & Ebeling, p. 2). These principles align with the design and intent of anchored instruction. Moore et al. noted that students with disabilities are often passive and unmotivated in their approach to learning and require direct teaching approaches (i.e. modeling, guided practice, and descriptive feedback). Providing students with meaningful and authentic problems to solve, directly addresses these tendencies.

The hallmarks of anchored instruction include: (a) complex and authentic problems, (b) embedding basic skills in meaningful contexts, (c) shared expertise/multiple roles and perspectives, (d) collaboration and self-regulated learning, and (e) multimedia research projects (CTGV 1990, 1991). Properties of anchored instruction can be readily identified in other approaches and theories, which are described below.

**Constructing knowledge.** Anchored instruction takes a similar approach to teaching and learning as constructivism (Jenkins, 1996). Constructivists tend to stress the importance of active construction of knowledge in the classroom (Harris & Graham, 1994). In a constructivist classroom students do not passively interact with the environment; rather, they are active, self-regulating learners. Through active, self-regulation, students construct knowledge in developmentally appropriate ways. The prior
knowledge and experiences that each student brings to the classroom serves as the starting point for new learning. Students construct new knowledge in terms of their prior knowledge, values, attitudes, and preferred ways of knowing (Jenkins, 1996).

Constructivists believe that true construction of knowledge and meaning only occurs when learners participate fully in their learning. That kind of complete participation is believed to lead to greater understanding and use of knowledge, thereby promoting application of what has been learned (Pressley, Harris, & Marks, 1992). For example, in a classroom setting, information presented to students may not be the same as students actively receive because information is not received exactly the same by any two individuals. The reliability of reception depends on several variables within each learner. In this way, learning is best understood as psychological rather than logical. Despite a consistent presentation of the curriculum, the student outcomes are determined by the learner’s previous knowledge, experiences, ability to process information, learning style, and level of development. From this belief, providing a situated activity that is enriched by practical and authentic contexts allows students to participate completely in their learning (Palincsar & Klenk, 1993; Reid, 1993).

**Situated cognition.** Situated cognition stresses that students should be engrossed in rich learning environments in order to participate fully in authentic, meaningful tasks for extended periods of time and from many different perspectives (Bransford, Vye, Kinzer, & Risko, 1990). This comes from a belief that learning is not meaningful if it is not situated in an authentic context. Advocates of situated cognition believe that in ideal learning situations, students will have a relationship with the teacher similar to the apprentice/master relationship: “Cognitive apprenticeship methods try to enculturate
students into authentic practices through activity and social interaction” (Brown, Collins, & Duguid, 1989, p. 37). These types of cognitive apprenticeships are believed to overcome the problem of passive knowledge by providing students the opportunity to acquire new knowledge in meaningful problem-solving situations. The teacher provides scaffolding to extend the learner’s growth within his or her zone of proximal development (Vygotsky, 1978). By involving students in the use of knowledge, by modeling the problem-solving process, and by tutoring students in questioning and other metacognitive skills, the teacher supports the students in taking over the learning process (Collins, 1985).

**Effects of Anchored Instruction**

Anchored instruction uses video-based anchors that contain rich multifaceted problems. This visual format allows students to develop pattern-recognition skills. Students can more easily formulate rich mental models of the problem situation, which is especially important for students with MD or low-achieving students. Researchers have studied the effects of anchored instruction across several academic areas including vocabulary, comprehension, story writing, and problem solving.

One series of studies employed a video anchor, *The Young Sherlock Holmes* (Bransford, Vye, Kinzer, & Risko, 1990; Risko, Kinzer, Vye, & Rowe, 1990). These studies took place in a fifth-grade classroom and were aimed at helping students learn language arts and social studies content. The experimental group consisted of both at-risk and average-ability students and utilized *The Young Sherlock Holmes* video anchor during instruction. The control group completed the same instruction but without the video anchor. These studies demonstrated that students in the experimental anchored
group were more likely to use the new-targeted vocabulary than were the students in the control group. Overall, students in the experimental anchored group used information learned during video-based instruction to assist in their interpretation and construction of narratives (Risko, Kinzer, Vye, & Rowe, 1990).

Sherwood and CTGV (1991) used the video-based anchor *Jasper Series*, which follows the adventures of a fictitious individual named Jasper Woodbury and his friends. The focus of the series is mathematical problem formulation and problem solving. The authors compared traditional text-based problem-solving instruction with instruction in the video-anchored context of the first Jasper adventure, *Journey to Cedar Creek* (JCC). The participants were members of a fifth-grade classroom who were all above average in achievement. Students in the anchored experimental group watched the video and explored the major questions the video posed. Students in the control group also watched the video, along with the experimental students, but did not receive instruction in solving Jasper’s problems. Instead, traditional teaching methods were used to instruct the control students in word problems. Students in the anchored experimental group were able to solve the traditional word problems as well as the control group, despite the fact that the control group had much more explicit practice in these types of problems (Sherwood & CTGV, 1991).

Bottge and Hasselbring (1993) compared the use of video-based curriculum to specific instruction in text-based word problems. Students were then assessed across both conditions. No differences were found between groups on the text-based word problems and the video-based problem. Therefore, video context appeared to facilitate the students’ ability to interpret problems in a video context, as well as the text-based word context.
The students, identified as remedial, scored comparably well to those of their typically developing peers on a test of fractions computations. However, the typically developing peers were still significantly better in their ability to accurately solve text-based word problems. The most important result of the study involved student performance on *The Houseboat Adventure* video transfer test. This activity was designed to assess students’ abilities to detect, explain, and solve problems comparable to those in the JCC.

Performance data were collected though individual interviews with the participants. Interview protocol scores of participants in the experimental group were significantly higher than those of the control group participants. In addition, the experimental students showed significantly more transfer of learning to a new, similarly complex problem, compared with the control students (Bottge & Hasselbring).

**Enhanced Anchored Instruction**

Enhanced Anchored Instruction (EAI) is a problem-based learning curriculum rooted in the Anchored Instruction units first developed by CTGV (1990, 1991, 1992). The theoretical background supporting the EAI curriculum is outlined by Bottge (2001) and explained using the “Key Model” (p. 103) found in figure 1. In this model the teeth of the key represent six conditions that together foster problem solving in the area of math for students who are low-achieving. The six teeth are identified as “meaningful, explicit, informal, (de)situational, social, and teacher specific”(Bottge, 2001, p. 103). In order for a key to open a lock, the teeth of the key must match up with a set of lock pins. Once in perfect position, the plug can rotate, and the lock will be opened. In the key model, the lock pins represent learner qualities, which are enhanced by the curriculum.
Specifically, Bottge identifies these learner qualities as “engagement, foundations, intuitions, transfer, cultural supports, and student-specific” (p. 103).

In the Key Model, each of the teeth in the key align with specific learner qualities. However, if the key (i.e., curriculum) is not an exact match and instruction does not meet student needs, then the lock (i.e., student learning) will not open. For example, if the first tooth of the key labeled meaningful does not fit an individual student’s lock pin, then engagement will not occur. This theoretical position is supported by the scholarship of Dewey and Bruner among others. Bruner (1960) wrote, “Students should know what it feels like to be completely absorbed in a problem” (p. 50) and this type of meaningful engagement is what the EAI curriculum intends. This stands in contrast to the text-based word problem approach typically presented to students during problem-solving instruction, which “rarely appear authentic and important to students with disabilities” (Bottge, 2001, p. 105). Secondly, the key model connects explicit instruction and foundations, a belief that although students need engagement with meaningful questions, they must also be provided with direct instruction on foundational skills necessary to solve problems. As Bottge wrote, “one of the most popular methods for helping diverse learners acquire automaticity is by directly teaching concepts and operations” (p. 106). This theory of learning is based on the assertion that without such instruction students will be ill equipped to solve complex and meaningful problems specified in the first tooth of the key.

The third tooth of the key is connection of what Whitehead (1929) refers to as “inert” knowledge or the inactive understanding students bring with them to the classroom setting and the connection between informal transmissions and intuitions (as
cited in Bottge, 2001, p. 105). The key model theory states that given that students with disabilities have struggled learning mathematics through traditional teaching methods and have therefore begun to doubt their mathematical intuition, teachers must find ways to “help students rediscover and make use of their informal networks in solving problems that require a combination of informal and formal knowledge” (Bottge, 2001, p. 106). These intuitions, once rediscovered, can assist students in solving meaningful and complex problems. The fourth key and pin of the model is the link between (de)situational cognition and transfer. Students often struggle transferring subject matter knowledge across subjects or to non-educational settings. This occurs in part because “knowledge is tied too closely to arenas in which it was learned” (Bottge, p. 107) and as Hatano and Inagaki (1993) argued, knowledge of procedures is dependent on context and is rigid (as cited in Bottge, 2001, p. 107). This type of situated cognition remains until students gain procedural proficiency and build mental models that allow them to envision other tasks to which the model can be applied.

Social learning and cultural supports is the fifth key and lock pin of the key model. This connection in the model is supported by the work of Vygotsky (1978) and his belief of “the prominence of language and discourse in the learning process”. Central to Vygotsky’s theory is the belief that higher levels of learning occur when students work collaboratively and cooperatively. Bottge wrote that problem-solving discussions (directed inquiry) allow teachers to determine what students are thinking and provide appropriate guidance, support student problem-solving through discussion of several plausible solutions, and build mathematical confidence for students with disabilities.
The sixth and final connection is teacher- and student-specific. This piece of the theory involves instructional variables such as teacher expectation, teacher self-efficacy, the ability to blend evidence-based practices in the delivery of content, and how students respond to such variables. As Bottge noted, “the challenge for teachers of students with disabilities is to find ways of delivering instruction that promote high expectations for all students” (p. 109). This intersection between the science and the art of teaching is centered on the teachers’ ability to utilize teaching theory in a customizable manner to meet the needs of the learners in ways that accentuate student strengths while supporting and strengthening known weaknesses.

When each of these six teeth fit their accompanying lock pins, the lock can be opened and student learning is maximized. Teachers must work to create meaningful learning environments in ways that promote the transfer of knowledge to novel contexts. At the same time, students require the support of explicit instruction in foundational skills to support intuitions and (re)build confidence. Students will also benefit from shared learning experiences that promote collaboration and cooperation. This theory of learning is supported by a century of educational theory and is sustained throughout the aims and goals of the EAI curriculum.

**Development of EAI Curriculum**

Bottge and Hasselbring (1993) discussed the importance of contextualizing word problems as opposed to the text-based problems that students traditionally solve in school. Building on previous research conducted using *The Adventures of Jasper Woodbury* (Learning Technology Center at Vanderbilt University, 1997), researchers examined the ways in which students explored possible solutions to video-anchored
problems in cooperative groups. These video anchors were designed to “provide a rich, realistic context from which students search for relevant clues to the challenge problem” (Bottge & Hasselbring, p. 37). The researchers noted that as students became engrossed in solving problems, their motivation and performance improved, even working outside of dedicated class time to continue working. This contextual approach to problem solving is recommended by the National Council for Teaching Mathematics (NCTM, 2000), yet is not commonly found in schools, particularly for students struggling with math. In 1998, the Relevance Counts Institute was developed in an effort to assist teachers with connecting classroom learning with job skills that students were likely to need upon graduation (Bottge & Osterman, 1998). One aim of the Relevance Counts Institute was to connect contextual problem solving to the workplace by assisting teachers in connecting job skills to classroom lessons (Bottge & Osterman). As a result of their participation, teachers realized that problem solving and collaborative work were important skills for students to possess. However, teachers were left to develop and initiate curricular changes independently and no determination of the effect on student outcomes was measured.

Bottge (1999) continued research on contextual problem solving in a quasi-experimental study involving students from resource classrooms and average-achieving students in a middle school setting. Remedial students were randomly assigned to contextual problem solving (CP) or word problem (WP) groups while the average-achieving classes were assigned altogether to the CP or WP group. The primary activities of the CP groups included watching 2 videos, *The 8th Caller* and *Bart’s Pet Project*, identifying the problem, discussing possible solutions, and working in cooperative groups
to solve the problem. The primary activities of the WP groups included “a series of standard single- and multistep word problems that paralleled the content of Bart’s Pet Project” (Bottge, p. 87). The results of the study showed that remedial and pre-algebra students in the CP groups benefited from situated problems. Statistically significant differences for the CP group were found on post-test contextualized problems and on a transfer task completed by students with the highest scores on test measures; which was the building of a skateboard ramp. This study utilized many characteristics found in later versions of EAI; namely, the use of video-anchors for contextual problem solving, use of collaborative work groups, and use of a transfer task using tangible materials (Bottge).

Bottge, Heinrichs, Chan, and Serlin (2001) explored more involved mathematical problems by extending the contextual problems to one of the more difficult problems in the Adventures of Jasper Woodbury series (Learning Technology Center at Vanderbilt University, 1997), Kim’s Komet. The Kim’s Komet problem included complex concepts such as “linear function, line of best fit, variables, rate of change (slope), measurement error, and acceleration” (Bottge et al., 2001, p. 69). The students with a history of poor achievement in mathematics were found to not only significantly improve scores on post-test measures, but also had less behavioral problems and demonstrated pride in their work (Bottge et al., 2001). The researchers found students would work to solve difficult and complex problems if they were given “challenging and meaningful” problems (Bottge et al., p. 71). This underlines a distinctive aspect of the EAI curriculum in that students are provided with challenging and meaningful problems.

In a 2002 study (Bottge, Heinrichs, Mehta, & Hung) the term Enhanced Anchored Instruction was used to describe the contextualized problem solving approach previously
addressed. Forty-two seventh-grade students, with and without disabilities, in the inclusive general education classroom participated in the study. Students were randomly assigned to EAI or traditional problem instruction (TPI) condition and effects were determined using pre- and post-test scores. The EAI curriculum centered on an 8-minute video entitled *Fraction of the Cost* (*FOC*; Bottge et al., 2002). The unit asks students to solve a multi-step contextual problem (i.e., building a skateboard ramp) after viewing the presentation of relevant information from individuals in a video format. Students are asked to problem solve, and also to calculate cost, use percentages, convert units of measurement, read a diagram (i.e., skateboard plans), and use mixed number fractions. Upon completion of the video-based problem, students were afforded the opportunity to extend these skills though construction of a wooden bench for a local school. The results of the study showed students with disabilities in the inclusive classroom did not perform as well as in previous studies (Bottge et al.). Several potential reasons offered for the performance of students with disabilities included the complex nature of the *FOC* unit, the time available for special educators to assist students during instruction, the high level of assistance that students received from peers without disabilities, and a lack of motivation to solve the contextualized problem. Future versions of the EAI curriculum share the characteristics of the curriculum designed by Bottge et al. (2002) by embedding rich problem solving in video-based anchors, while also providing students with hands-on extensions of the knowledge obtained in the classroom through transfer tasks.

Bottge, Rueda, and Skivington (2006) extended the EAI curriculum by adding additional video-based and hands-on applications to previous versions of the curriculum (e.g., Bottge et al., 2002). The study combined the *FOC* and *Kim’s Komet* units along
with two applied problems: the building of a skateboard ramp and the building of a hovercraft rollover cage from PVC pipe. This study, conducted in a public charter transition school (CT), employed 17 high school students with a history of serious behaviors that placed them at the school for students identified as at-risk. The results of the study revealed statistically significant gains for students involved in the study (Bottge et al., 2006). Bottge et al. explained the growth in achievement by describing student interest in the EAI curriculum, saying that “students considered the EAI problems relevant and important” (p. 402), thus generating increased motivation and engagement and leading to the higher post-test scores. However, one finding from classroom observations was that students rejected the teacher’s attempts at direct instruction of foundational skills, even when it was a computation skill with which they struggled. Participants temporarily refused to participate in instruction or applied problems when the teacher persisted with direct skill instruction. The issue of foundational skill development is of critical importance to problem solving curriculum such as EAI; how do teachers establish the basic computation skills that are needed to successfully solve complex, contextual problems? Bottge et al. (2006) highlighted the significance of this issue while adding to the characteristics of EAI by introducing multiple video-based problems and hands-on applications to the curriculum.

The EAI curriculum was then implemented with 128 seventh-grade students and two teachers across six classrooms: an inclusive class, a pre-algebra, and four typical classes (Bottge, Rueda, Serlin, Hung, & Kwon, 2007). The researchers again used FOC and Kim’s Komet for video-based contextual problem solving. However, the hands-on application consisted of building a hovercraft rollover cage from PVC pipe and
participation in a replication of the pentathlon activity seen in the *Kim’s Komet* video (Bottge et al., 2007a) The pentathlon included graphing of data and predictions of rate/speed on a full-sized ramp, straightaway track, and stunts assembled by the technical education teacher at the school. In this study, students in each of the classes, including those with learning disabilities “benefited from both sets of EAI problems” (p. 44). In a similar study, Bottge, Rueda, LaRoque, Serlin, and Kwon (2007) assessed the effect of EAI instruction on 100 students from three middle schools and one high school in four different classrooms, but this time with only the *Kim’s Komet* unit. This research employed 97 out of 100 students with disabilities taught by four different special educators. The findings again showed that students with disabilities increased significantly over students in the control group across several waves of testing (Bottge et al., 2007b), despite many special educators at the secondary level having much less formal knowledge of mathematics than their math counterparts (Maccini & Gagnon, 2006).

Gagnon and Bottge (2006) included EAI among the promising instructional methodology for work with at-risk students in alternative settings that offered teachers the chance to meet students’ diverse learning needs while keeping academically high standards. Instructional approaches for students in at-risk populations must be relevant and engaging, particularly because “65% of youth with ED and 38% of students with LD drop out of school” (Gagnon & Bottge, p. 40). An understanding of the population leads educators to pursue instructional approaches that embed computation skills in contextual problem solving scenarios. Student interviews provided some of the most meaningful data outside of empirical findings resulting from EAI curriculum implementation. The
most common theme that emerged from interviews with students was the relevancy and importancel to the students’ daily lives (Gagnon & Bottge). This finding echoed findings from Bottge et al. (2006) that students whose behaviors had previously prevented them from academic success were motivated during EAI instruction and learned much of what the teachers expected. In addition, post study interviews revealed students enjoyed learning and felt it met their unique educational needs.

In a 2009 study, Bottge, Rueda, Kwon, Grant, and LaRoque used a randomized pretest-posttest design to assess the problem-solving skills of high, average, and low achieving students to determine if paper-based or computer-based assessment moderated achievement for students. In addition, Bottge et al. (2009) tracked the movement and activities of students in each ability group during the computer-based testing through video analysis. The results of the study showed that there were no differences in type of assessment (i.e., paper-based vs. computer-based), but that all students, regardless of ability level, scored significantly higher on post-test and, therefore, benefited from EAI instruction. Tracking student movements allowed researchers to determine that the movements of low achieving students in many ways mirrored those of high and average achievers, suggesting that they followed similar problem-solving pathways. The results of this study supported the use of the curriculum for students of all ability ranges.

Bottge, Rueda, Grant, Stephens, and LaRoque (2010) examined the impact of formal fractions instruction combined with EAI curriculum by utilizing 54 middle school students, grades 6 through 8, across three different middle schools. Students were randomly assigned to one of two EAI conditions; however, all received instruction in resource math classrooms and most possessed an identified learning disability. Students
either received informal fractions instruction within the EAI curriculum or they received a unit of formal fractions instruction in addition to the EAI curriculum. The results revealed that students in the informal condition made gains in problem solving from pretest to posttest that were similar to those in the formal condition, and that formal fractions instruction produced an 11 point increase over students with only informal instruction in fractions (ES=0.81). Bottge et al. (2010) discussed that improvement in both problem solving and fractions computation was new to EAI curriculum and, therefore, the results were promising. This study provided the support for later versions of EAI curriculum that include formal fractions instruction.

Most recently EAI has been examined in a large-scale randomized study involving 31 middle school classrooms (Bottge, Ma, Gassaway, Toland, Butler, & Choo, in press). 335 students participated in the pretest-posttest cluster-randomized trial and those in the EAI condition outscored those assigned to the control condition in computation and problem solving (Bottge et al., in press). In addition, students in the EAI condition reduced the number of fractions computation errors related to combining and adding of numerators and denominators, suggesting an improvement in their conceptual understanding of fractions (Bottge, Ma, Gassaway, Butler, & Toland, 2014). These recent results from the complete EAI instructional package showed an increase in both foundational skills (i.e., fractions computation) and in advanced mathematical reasoning (i.e., problem solving).

**Distinctive Characteristics of EAI**

EAI curriculum currently includes five distinct units of study: *Fractions at Work (FAW)*, *Fraction of the Cost (FOC)*, *Hovercraft Unit (HC)*, *Kim’s Komet (KK)*, and the
Grand Pentathlon (GP). Although units have been added and developed over time, EAI now refers to the full instructional package. These units together are supported by the theoretical construct outlined within the “Key Model” (Bottge, 2001). EAI is distinguished by several characteristics, including foundational instruction of key mathematical concepts, multiple video-anchors, challenging and relevant problems, collaborative group work, and hands-on application of knowledge. The FAW unit contains explicit instruction on addition and subtraction of fractions and mixed numbers both with and without like denominators. This unit connects with the Key Model theory that direct instruction on foundational skills is necessary in order for students to solve meaningful problems they encounter in the curriculum. The FAW unit equips students solve the complex and meaningful problems they encounter throughout EAI.

The FOC unit incorporates the use of video-anchors for contextual problem solving and the use of collaborative work groups (Bottge, 1999). In the FOC unit students view a video-anchor that shows a group of students who want to build a skateboard ramp, but must first determine if they have the budget to purchase the necessary materials. Students work in cooperative groups to determine a solution that is economical and meets the budgetary restrictions contained in the video anchor. Students must gather information from the video and utilize accompanying plans. Computer software is included that provides a variety of learning scaffolds. Research related to EAI validated students would work to solve difficult and complex problems if they were “challenging and meaningful” (Bottge, 2001 p. 71). This emphasizes a distinctive of the EAI curriculum that students are provided with challenging and meaningful problems. This connects with the key model concepts of meaningful and social learning.
The HC curriculum examined by Bottge et al. (2002) embeds rich problem solving in collaborative groups, while also providing students with hands-on extensions of the knowledge obtained in the previous units. The HC unit involves using PVC pipe to design and construct a rollover cage for a hovercraft made of plywood and powered by leaf blower. Students use graph paper and their knowledge of ratios to determine pipe length all while staying within a pre-determined budget prior to construction of the final rollover cage. This transfer task of using tangible materials provides students with hands-on applications within the curriculum and connects with the (de)situational instruction addressed in the key model.

**Formative Assessment**

Educational assessment is an integral part of the search for improved education. Through assessment, educational stakeholders seek to determine how well students are learning and whether students and institutions are progressing toward the goals established for educational systems (Pellegrino & Chudowsky, 2003). Traditionally, assessment has been seen as a measurement act that occurs after learning has been completed and not as a necessary aspect of teaching and learning itself. This viewpoint, however, seems to be changing rapidly. External pressures of accountability on educational institutions are leading to innovations in instructional design, classroom practices, and in the ways educators utilize assessment.

Classroom assessments can generally be divided into two categories: summative and formative. Summative assessments, such as unit or final exams, large cumulative projects, standardized state/district exams, and report card grades have a sense of finality and are typically administered after a learning unit to provide feedback on how well
students have mastered the content or learning objectives (Garrison & Ehrinhaus, 2007). In addition, summative assessments are often used to evaluate the effectiveness of programs, school improvement goals, or curriculum alignment. Similarly, because they are administered at the conclusion of instructional periods, summative assessments do not provide information for teachers in making instructional adjustments and interventions during the learning process (Garrison & Ehringhaus). Summative assessments are also known as assessments of learning (Stiggins & Chappuis, 2006). Today, administrators and teachers face tremendous pressure for students to perform well on summative assessment measures (i.e., standardized tests) aimed at accountability or face potentially adverse consequences (Zimmerman & Dibenedetto, 2008). This has led some schools and districts to engage in repeated administration of such assessments throughout the year, solely to prepare students for the summative assessment at the conclusion of the year. Teachers have reported a feeling that this continuous cycle of testing diminishes instructional time, particularly in content areas outside of reading and mathematics (Dillon, 2006). Moreover, teachers rarely receive guidance for “using test results to improve instruction, and as a result, their motivation and that of their students can be easily undermined by adverse feedback” (Zimmerman & Dibenedetto, p. 206).

In contrast, formative assessments are thought of as assessment for learning (Stiggins & Chappuis, 2006). While there are differing definitions of formative assessment offered by experts in the field, there are common elements that run through them. Formative assessment is a systematic and continuous process utilized by teachers during instruction intended to evaluate student learning while it is still developing (Black & William, 1998a; Clark, 2011; Heritage, 2010). Formative assessment is directly linked
with instructional objectives of the lesson and is integrated within each aspect of teaching and learning at the classroom level. Both the teacher and the students are actively involved in the formative assessment process (Stiggins & DuFour, 2009). One of the driving purposes of formative assessment is the opportunity to provide teachers with a continuous feedback loop to adjust ongoing instruction and close gaps in learning (Stiggins & Chappuis; Stiggins & DuFour). Kaminski and Cummings (2007) define formative assessment as the process by which data are used to adjust teaching to meet students’ needs.

Formative assessment can include student self-assessment as well as peer-assessment and should inform and support instruction while learning is taking place (Black & William, 1998a; Clark, 2011; Heritage, 2010). Formative assessment is not a single event or measurement instrument, but rather an ongoing, planned practice that allows teachers to evaluate student learning. It also allows teachers to predict and make standardized judgments about student performance toward state content standards (Clark, 2011; Heritage, 2010). According to Cummings, Atkins, Allison, and Cole (2008) one type of formative assessment that is becoming increasingly prevalent in schools is the use of general outcome measures (GOM’s). GOM’s differ from teacher-made formative assessments in that they are standardized and possess psychometric properties that allow educators to track progress monitoring against comparative norms (Cummings et al.). One example of a GOM, is curriculum based measurement (CBM), an assessment that allows teachers to assess students’ growth in basic skills, such as early reading skills (Good & Kaminski, 2002). For this reason, Cummings et al. suggested that formative assessment is a necessary component of any successful Response to Intervention (RTI)
program, in that schools continuously monitor students and make instructional decisions based on their data.

Formative assessment is intended to (a) assist students in the identification of understanding; (b) to clarify what comes next in the learning process; (c) to become part of an effective system of intervention for struggling students; (d) to help students monitor their own progress towards attainment of standards; and (e) to motivate students by building confidence in themselves as learners (Stiggins & DuFour, 2009). Formative assessment also allows instructors to evaluate the effectiveness of their instructional practice (Stiggins & DuFour). Stiggins and Chappuis (2008) developed a model of formative assessment that provides students with clear standards, examples of strong and weak work, and feedback so that students can set personal learning goals. This model accentuates the active role of the student in the formative assessment process. Assessment for learning informs students about their learning and allows them to track their daily progress towards goals.

Formative assessment provides a focus on student progress as they navigate the curriculum from day-to-day. In order for assessment for learning to be successful, Stiggins and Chappuis (2006) developed five keys of formative assessment quality. First, assessment processes and results should serve clear and appropriate purposes. Second, assessments must reflect clear and valued student learning targets. Third, learning targets are translated into assessments that yield accurate results. Fourth, assessment results are managed well and communicated effectively. Finally, students are involved in their own assessment (Stiggins & Chappuis 2006). When each of these five conditions is present in the formative assessment process, the educator has succeeded in developing a quality
formative assessment. One characteristic of formative assessment is that teachers must respond to formative assessment (Dorn, 2010). Research has shown that when teachers base instructional decisions on formative assessment data, students’ academic performance increases by a significant amount and students who are low achieving can close the achievement gap (Deno, 1985, 2003; Fuchs, 2004).

**Formative Assessment and Instruction**

According to Conderman and Heden (2012), formative assessments can be employed at any of three distinct points in the instructional cycle: before instruction, during instructions, and after instruction. In using formative assessments before instruction, teachers can assess students’ prior knowledge of the subject matter. This prior knowledge then informs the teachers’ instructional decisions. For example, to assess students’ background knowledge a teacher may use the first two columns of a KWL chart indicating *What I Know* (K) and *What I Want to Learn* (W). Teachers may also utilize class discussions, pretests, anticipation guides, warm-ups, or admit slips (Conderman & Heden). Each of these data sources affords teachers the opportunity to determine the extent of prior knowledge possessed by students. Prior to the start of instruction it is also important to establish criteria for mastery of learning and set goals with students. These tasks engage students in the learning process by creating clear expectations and allowing them to actively prepare for instruction (Garrison & Ehringhaus, 2007).

During instruction, formative assessment requires that teachers ask relevant and thoughtful questions. Through intentional and meaningful questioning, teachers can make alterations to their instruction based on students’ responses (Garrison & Ehringhaus, 2007). Formative assessments require individual student responses and can take the form
of response cards, unison responses, or personal response (e.g., clicker) systems which provide immediate feedback on students’ knowledge (Conderman & Heden, 2012). In addition, both self- and peer-assessment can be used during teaching. Self-assessment in the form of student record keeping engages students by helping them see how much progress they are making toward learning goals (Stiggins & DuFour, 2009). When used formatively, these assessments help create a learning community within a classroom. Peer-assessment is also used to engage students in instructional dialogue with their classmates and provide them with opportunities to reflect on academic work. Research supports that students who are more reflective during instruction are more involved in their learning (Zacharis, 2010). As Cowie and Bell (1999) wrote, "the process involves them [the students] in recognizing, evaluating, and reacting to their own and/or others' evaluations of their learning. Students can reflect on their own learning or they may receive feedback from their peers or the teachers" (p. 539). Teachers can also use formative assessment at the conclusion of a lesson. These assessments can take the form of exit slips, the L column of the KWL chart, homework assignments, drafts of writing assignments, or projects competed in steps. Through gathering student data after several days of instruction, but before the end of the unit, teachers can identify student errors and reteach these misconceptions prior to administering summative assessments (Conderman & Heden, 2012). These data inform teachers’ instructional decisions for the remainder of the instructional unit.

**Impact of Formative Assessment**

Stiggins and Chappuis (2006) found that the ongoing formative assessment process encouraged student confidence. Reliance on summative assessments directly
impacts students’ motivation for learning by inducing test anxiety and the effect of low
scores on self-esteem and perceptions of themselves as learners (Harlen, 2005). The
formative assessment process allows students to immediately determine their confidence
level with academic material covered during instruction, whereas summative assessments
require students wait until the conclusion of a unit, which creates ambiguity in the
learning process and elevates feelings of anxiety and stress. Students benefit from
ongoing formative assessment for learning in several critical ways. First, they become
more confident learners because they get to experience success (Stiggins & Chappuis,
2006; Stiggins & DuFour, 2009). This confidence emboldens academic risk-taking and
supports perseverance in the learning process. The result is greater achievement for all
students, particularly low achievers, which helps reduce the achievement gap between
typically developing students and those with learning disabilities or a history of academic
failure. Secondly, students come to understand what it means to be in charge of their own
learning, monitor their own success, and make decisions that bring greater success.
Students’ ownership of their education increases motivation and thus, engagement during
instruction. The development of this ownership sets the foundation for students to pursue
lifelong learning.

Formative assessment, done well, represents one of the most powerful
instructional tools available to a teacher or a school for promoting student achievement.
(Stiggins & DuFour, 2009). In addition, formative assessment represents a more cost-
effective and efficient alternative when compared to other educational options (Yeh,
2008). Research has shown that specific formative assessment practices have a direct
impact on student learning and achievement (Black & Wiliam, 1998a). In a 1998 research
review, Black and Wiliam examined the research literature on assessment worldwide to
determine if formative assessments yielded higher student achievement as measured on
summative assessments. And if so, they asked, what kinds of improvements could be
made to classroom assessment practices in order to yield the greatest gains in
achievement? Black and Wiliam identified and analyzed more than 250 articles that
addressed these issues. Of these, several dozen directly addressed the question of impact
on student learning with sufficient scientific rigor and experimental control to allow firm
conclusions. Upon pooling the information on the estimated effects of improved
formative assessment on summative test scores, they described unprecedented positive
effects on student achievement. They reported effect sizes of one-half to one full standard
deviation in favor of formative assessments. Furthermore, Black and Wiliam reported
that improved formative assessment practices affected low achievers even more than
typically developing students and, therefore, reduced the range of achievement while
raising achievement across the board (Black & Wiliam, 1998a).

The research reviewed by Black and Wiliam (1998a) provided convincing
evidence that classroom assessment raised students’ attainment when it possessed several
key characteristics. First, information is gathered about the processes and products of
learning and is used to adapt teaching and learning. Second, learners receive feedback
that enables them to know how to improve their work and move forward in their learning.
Third, teachers and learners possess a shared understanding of the goals of particular
pieces of work assigned during instruction. Fourth, students are involved in assessing
their work (i.e., both self- and peer-assessment) and lastly, pupils are actively involved in
learning rather than being passive recipients of information before, during, and after instruction (Black & Wiliam).

However, formative assessments have not always been found to positively impact student achievement or motivation (Yin et al., 2008). Yin et al. examined the effect of embedding formative assessment in an inquiry-based science unit and found no statistically significant differences between formative assessment and control groups, although formative assessment did not negatively impact student performance either. The researchers suggested that teachers’ difficulty implementing formative assessment procedures with fidelity was the main contributing factor to the results (Yin et al.).

Despite the research that exists to support the use of formative assessment, there remain obstacles to implementation (Dorn, 2010). Dorn wrote that there are a number of political issues connected to high-stakes testing that impact the use and acceptance of formative assessment. Practically speaking, teachers must deal with the increased workload associated with administration of formative assessments, including planning, grading, and tracking progress (Dorn). Teachers must also reconcile the conflict between traditional planning, which is structured around time frames, and planning based on instructional data (Dorn). Educators must be willing to follow formative assessment data when these data show children are underperforming, and not simply by subscribing to the most common intervention of increasing the time students spend repeating the curriculum. Additionally, teachers face the increased pressure of standardized testing and an educational culture that believes it must teach to tests, as opposed to student understanding. In order for formative assessment to be most effective, teachers should
allow students the time and the resources to work hard on tests that have rather low stakes (Dorn).

**Formative Assessment and Students with Disabilities**

It is also recommended that formative assessment be considered for application with special populations, particularly students with disabilities and English language learners (ELL). Duke (2010) wrote with regard to students with disabilities, teachers should plan a range of options for all students to demonstrate their learning. Duke suggested that every child maintain a portfolio of work, and that each student should receive feedback about his or her achievement on every task in that portfolio. This would allow students to see how they are progressing toward a particular standard. Duke contended that students should also have the opportunity to resubmit items after feedback for a better mark. Teams of teachers should determine the criteria for these assessment items so that measurement is parallel across teachers, and the items should be judged against the standard being assessed. It is important that student achievement is compared against achievement of the standard and not against other students, which allows students to challenge themselves to increase personal performance rather than compete with each other.

The formative assessment process is uniquely structured to align with the educational trends of Response to Intervention (RTI), Universal Design for Learning (UDL), and differentiated instruction (Brand, Favazza, & Dalton, 2012; National Center on RTI, 2010; Tomlinson, 2000). Although no single definition of RTI exists, the term is generally used to describe the process in which schools identify students who are at-risk for poor learning outcomes, provide continuous monitoring of student progress,
implement evidence-based interventions, and adjust intervention intensity depending on the student’s responsiveness, all in an effort to identify students with learning disabilities (NCRTI). Formative assessment is utilized throughout the RTI process to the extent that RTI cannot meet its purpose without continuous formative assessment.

UDL is an instructional approach in which educators consider the scope of student abilities and learning styles while taking into account varying abilities (e.g., seeing, hearing, speaking, mobility, reading, writing, comprehension of English, attending, organizing, engaging, memorization) in order to create a collection of classroom resources that can be utilized as needed to meet the needs of students (Brand et al., 2012). UDL supports achievement through a combination of flexible materials and methods that allows students access to the curriculum and engages them in the learning process. In addition, UDL encourages multiple means of assessing student learning, including varying the methodology used in assessment, the format of the assessment, the scope of the assessment, the actual product resulting from learning, and the way feedback is provided to students (Brand et al.). These principles align with the aim and intent of formative assessment and provide educators with the framework for allowing students to express learning in whichever format students choose to utilize so that educators will have the data they require to shape instruction. Differentiated instruction is understood as any effort teachers make to respond to differences that exist among learners in the classroom (Tomlinson, 2000). Differentiation occurs anytime a teacher varies his or her teaching to meet the needs of an individual or group of students in his or her classroom in order to create the optimal learning experience (Tomlinson). In order for teachers to differentiate instruction, they require ongoing data on the effectiveness of their teaching,
which formative assessment can provide. In these ways formative assessment is uniquely equipped to facilitate learning in today’s educational climate of RTI, UDL, and differentiated instruction.

The formative assessment process has been described as a continuous feedback loop providing educators with the data they need to make instructional decisions and improve student outcomes. The research base supporting formative assessment is generally strong with numerous benefits reported for students including, achievement, motivation, and confidence. However, more research on embedding formative assessments in project-based learning units is needed.

Summary

Chapter Two presented an overview of mathematics instruction, with attention given to DI methods and inquiry-based approaches, such as PBL. Each method of instruction in mathematics provides evidence of effectiveness for teaching mathematics. This section was followed with the historical development of the EAI curriculum from AI models to its current state. A literature review revealed that problem-based learning curriculum, such as EAI can effectively motivate student learning and lead to greater levels of performance in mathematics. The theory of formative assessment was discussed next, and a gap in the literature regarding the use of formative assessment in PBL curriculums was identified. The use of formative assessment is a growing trend in education with potential strengths for supporting student learning in PBL curriculums. The application of theory leads to the development of formative assessment anchors developed for use in the EAI curriculum in response to this gap in the literature.
Figure 1.

The key model theory of teaching and learning (Bottge, 2001, p.4)

CHAPTER 3. METHOD

Introduction

This chapter discusses the methodology used to measure the effect of formative assessment measures used with the EAI curriculum in two inclusive middle school classrooms. It begins with a review of the purposes of the study and the research questions addressed by the study. This is followed by a description of the research design. The next two sections address sample selection and instrumentation. This is followed by a discussion of the data collection and analysis procedures used, and the chapter closes with a consideration of the ethical issues involved. The methodology, data collection, and analysis procedures are used to answer the proposed research questions.

Purpose of Study

This study had two main goals. The first was to determine the impact of formative assessment embedded in a problem-based learning curriculum on the mathematics achievement of middle school students. A second was to examine the impact of formative assessment measures on instructional variables such as pacing and instructional decision-making. Four measures were used to assess the mathematics achievement of students in each instructional condition: a researcher-developed fractions computation tests, a researcher developed problem-solving test, and two mathematics subsections of the Iowa Test of Basic Skills (ITBS). Classroom teachers administered these tests before and after treatment in both conditions. Student scores on these tests along with teacher reports were used to address the following research questions:
**Experimental Research Questions**

1. What effect will the addition of formative assessments to the EAI curriculum have on computation and problem-solving performance of SWD and typical students in an inclusive classroom?

2. Is there an interaction effect between student status (SWD, typical student) and treatment status (EAI, EAI)?

**Qualitative Research Questions**

3. What effect will the addition of formative assessments to the EAI curriculum have on the number of instructional days required to complete the unit(s) of study?

4. What effect will the addition of formative assessments to the EAI curriculum have on instructional decision making?

**Research Design**

The preliminary goal of researchers in the field of education is to examine advances in the field and report those findings to the larger community (Borg & Gall, 1989). Additionally, researchers in education aim to add to the existing body of knowledge (Lodico, Spaulding, & Voegtle, 2006). One goal specific to quantitative research is to prove or disprove claims through statistical analysis. Quantitative research is normally categorized as correlational, descriptive, or causal comparative (Borg & Gall, 1989). Though quantitative research methods share some commonalities, “they differ in their utility, comprehensiveness, and ability to establish cause-and-effect relationships among study variables” (Anderson, 1999, p. 82). Anderson further explains that certain methods are more appropriate than others depending on the situation and utility for responding to research questions.
The study used a randomized, two-group pretest-posttest design with multiple measures (Shadish, Cook, & Campbell, 2002) to test the efficacy of two instructional conditions, Enhanced Anchored Instruction (EAI) and Enhanced Anchored Instruction with formative assessment anchors (EAI/f) on students’ fraction computation and problem-solving performance. The researcher recruited two teachers who consented to being assigned to either condition.

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R & O_{123} & X_B & O_{123}
\end{array}
\]

According to Shadish, Cook, and Campbell (2002), the alternative treatment design with pretest allows the researcher to compare different treatments, and even if posttest differences are not detected, can allow for examination of pretest and posttest scores to determine if both treatment conditions improved or if neither did. Given that the standard treatment (e.g., EAI) has an established record of improving student performance in mathematics, a control condition was deemed unnecessary for establishing the effectiveness of the treatment (Shadish et al.).

**Sample Selection**

**Setting and Participants**

The population of interest in this study involved students with and without disabilities in inclusive middle school math classrooms in central Kentucky in 2014. One middle school is located in an urban setting with an enrollment of approximately 550 students. 60% of students qualify for free and reduced lunch and 2% are English Language Learners. The students are predominately white (47%) and African-American (36%), and the remaining students identify as Hispanic (11%) or other (6%). The second middle school is located in a rural setting with an enrollment of approximately 650
students. 63% of students qualify for free and reduced lunch and 3% are English Language Learners. The students are predominately white (90%), with the remaining students identifying as Hispanic (4%), African-American (2%), or Other (4%). Two math classrooms co-taught by a general math and special education teacher were recruited for the study. Selection criteria included: (a) previous training on EAI curriculum; (b) inclusion of students with disabilities in the inclusive (i.e. collaborative classroom) and (c) willingness to be randomly assigned to either treatment condition. Classrooms in both conditions included students with disabilities (SWD) and typical students.

The teacher pairs were randomly assigned to either the EAI plus formative (EAIf) assessment condition or the EAI only (EAI) condition. The classroom assigned to EAIf condition was located in a larger urban setting. The classroom assigned to EAI condition was located in a rural setting. Both special education teachers in the study participated in previous studies and had experience with teaching the EAI curriculum. All four teachers signed the teacher consent form (see Appendix B). Each participating student submitted signed assent and parent consent forms (See Appendix B).

**Instrumentation**

Teacher dyads assigned to EAIf and EAI used the same units of the EAI curriculum. The EAI curriculum unit consisted of the Fractions at Work (FAW), Fraction of the Cost (FOC), and Hovercraft (HC) units. Teachers in both conditions were provided the EAI curriculum consisting of daily lesson plans, a CD-rom with video anchors and interactive features, as well as materials required for the hands-on instructional units (HC). In addition, teachers in EAIf condition used embedded formative assessments
provided by the researcher to supplement the EAI curriculum. One formative assessment measure was given for every two to three days of lesson plans.

**Dependent Variables and Data Collection Measures**

The measures for this study included two researcher-developed criterion-referenced tests and two subtests of a standardized norm-referenced achievement measure. The measures assessed math performance of students before and after instruction. Tests were independently scored by the author who had scored more than 1,000 tests in two previous large scale studies. A second scorer, who also had previous experience scoring protocols, independently scored 19.2% of protocols using point-by-point agreement method.

**Quantitative Data Measures**

**Fractions Computation Test (FC).** The FC test consists of 20 items, including 14 addition and 6 subtraction, and is criterion-referenced. Fractions problems include items with common denominators, unlike denominators where the larger denominator could be the common denominator, and unlike denominators where neither could be the common denominator. Students were asked to work with simple fractions, mixed numbers, problems with 3 fractions, and reduce answers to the simplest form. Students could earn a total of 42 points on the test. Two points were possible for items 1 through 17 and number 19. Students could earn an additional point for items 18 and 20 if they reduced their answer to the simplest form. Interobserver agreement was 94%.

**Problem-Solving Test (PS).** Students in both conditions took Problem Solving Tests before and after instruction. These researcher-developed items tested the problem-solving performances of students. Each item on the tests was presented in open response
format asking students to interpret a figure, table, or graph. Students were asked to display their work for each item in a box provided. Students could earn full or partial credit on each item dependent on showing work and computing the correct answer. For items presented as standard word problems, the reading level was kept at or below the fourth grade. For the Problem Solving Test, students were allowed the use of calculators.

PS consisted of 12 items (10 open response items and two multiple-choice questions) worth 20 points, which assessed concepts closely aligned with the CCSSI-M Measurement and Data, Number and Operations – Fractions, and Ratios and Proportional Relationships. Internal consistency estimates were .76 at pretest and .82 at posttest (Bottge et al., in press). Interobserver agreement was 95%.

**Standardized Tests.** Students in all conditions took the ITBS (University of Iowa, 2008) math subsets (Form C, Level 12 - *Computation* and *Problem Solving*) before and after instruction. The ITBS test is a norm-referenced standardized achievement test. The *Computation* and *Problem Solving* math subtests of the ITBS were given utilizing the directions in the test administration booklet. Per ITBS instructions, students were not allowed to use calculators for the computation test but were allowed to use them for the problem solving test.

The ITBS *Computation* (ITBS-C) subtest consisted of 30 items. Students used one of four arithmetic operations (addition, subtraction, multiplication, or division) to solve problems with whole numbers, fractions, and decimals. Ten items assessed whole number operations. Of the 10 fraction computation items, there were 4 each of addition and subtraction and 2 of multiplication. Interobserver agreement was 99%.
The ITBS Problem-Solving and Data Interpretation (ITBS-PS) subtest consists of 28 items. Students solved problems presented in various formats with one or more steps required to answer the problem. This sub-test consists of 12 word problems and 4 requiring students to interpret data displays. The other items asked students to compute answers from interpreting graphs, charts, and tables. Sample KR20 estimates were .72 and .78 for Computation and .61 and .58 for Problem-Solving and Data Interpretation pretests and posttests, respectively (University of Iowa, 2008). Interobserver agreement was 99%.

**Qualitative Data Measures**

**Instructional Decision-Making.** The primary investigator collected a qualitative measure of the types of instructional decisions the participating teacher made based on formative assessment data. The teacher assigned to EAI reported the instructional decisions made after administering each formative assessment throughout the units of study. The instructional decisions were recorded on a researcher-developed form (see *Instructional Decision Making Form - Appendix C*).

The researcher collected qualitative instructional variable data related to instructional pacing and instructional decision-making. Instructional pacing data were generated through teachers reporting the number of days it took to complete each unit of study in both conditions. Having teachers select the instruction decision made and recording that for each formative assessment anchor given throughout the study generated instructional decision-making data.
Data Analysis Procedures

Data Collection

Data collected from the participating classes were recorded on a Microsoft Excel spreadsheet that functioned as the database. The Excel spreadsheet was used to record the pre- and post-test outcome measures on the FC, PS, ITBS-C, and ITBS-PS measures for the students who were tested in the spring of 2014. No student names were recorded on the spreadsheet. Only researcher-assigned ID numbers were used.

The first column of the spreadsheet contained assigned student ID numbers. The second column was used to indicate condition. The third column was used to indicate student disability status. The fourth, fifth, sixth, seventh, eighth, ninth, tenth, and eleventh columns were used to record each student’s total score on the FC, PS, and ITBS pretests and posttests respectively.

All scores were interval data and were coded using numerical values. The indicator for disability status was nominal data and were comprised of one letter descriptive terms, Y for yes the student had an IEP and N for no the student did not have an IEP.

Qualitative data on instructional pacing and instructional decision-making were recorded on a separate Microsoft Word document. The Word document was used to record the number of instructional days needed to complete each unit across conditions, a measure of instructional pacing. For the EAI condition, data on instructional decision-making were recorded using one letter descriptive terms, R for re-teach, P for proceed, D for re-teach with differentiation, A for additional practice, P² for peer-to-peer
remediation, N for no instructional decision noted, and O for other instructional decision (see Appendix C).

Numbers of instructional days were interval data and were entered using numerical values. The indicators for instructional decision-making status were nominal data and were coded using one letter descriptive terms described above.

**Data Analysis Approach**

The author used an Analysis of Covariance (ANCOVA) to answer the experimental research questions. ANCOVA allows the researcher to look at the influence of two or more independent variables (i.e., treatment, disability status) on a dependent variable (i.e., test scores) while removing the effect of the covariate factor. ANCOVA also permits the researcher to determine the variance explained by each of the independent variables (i.e., treatment, disability status) or the main effect, while also looking at the variance of all the independent variables together, or the interaction effect.

The researcher used a 2X2 Factorial Design ANVCOA. The factorial ANCOVA requires at least four variables. This case with two factors is referred to as a two-way ANCOVA. The four independent variables in the 2X2 ANCOVA are treatment status (EAI, EAIf) and disability status (SWD, Typical). Creating a dummy variable allowed the treatment status to be examined, treatment condition (i.e., EAIf) was equal to 1 and EAI only was equal to 0. Creating a dummy variable allowed disability status to be examined, as well; presence of disability (i.e., SWD) was equal to 1 and typical students with no disability status was equal to 0.

Qualitative data were generated during the course of the study and examined. Descriptive statistics are provided for instructional pacing. A more general review of
instructional decision-making was reviewed to examine if themes or patterns of
instructional response existed in the EAIf condition.

**Data Analysis Framework**

The previous section discussed what data were collected and how those data were organized for analysis. This section discusses how the collected data were used to address the five null hypotheses of the study.

The effectiveness of the EAIf treatment condition was examined by comparing the gain scores of the students involved in the treatment condition to scores from participants in the control (i.e., EAI) condition.

The first null hypothesis is: There are no statistically significant differences between the pre- and post-test scores of students taught using EAI Curriculum and those using EAIf curriculum. To test this hypothesis, an analysis of variance between groups was determined with ANCOVA.

The second null hypothesis is: There are no significant differences between the pre- and post test-score means of SWD and those typically developing students in the classroom. To test this hypothesis, an analysis of variance between groups was determined with ANCOVA.

The third null hypothesis is: There is no interaction effect between treatment status and disability status. To test this hypothesis, the researcher used a 2X2 factorial ANCOVA to determine if there was an interaction effect.

The fourth null hypothesis is: There are not significant differences between the number of instructional days required to complete each unit between the EAI and EAIf conditions. To test this hypothesis qualitative data were used, including descriptive
The fifth null hypothesis is: There are no significant differences between the instructional decisions made by teachers in EAI and EAI\textsuperscript{f} conditions. To test this hypothesis qualitative data were used, including a review of teacher-generated reports on the instructional decisions made throughout the course of the study.

**Ethical Considerations**

Ethical issues were reduced by the researcher’s ability to collect, evaluate, and report on student data obtained from the study without revealing the names of the school district, the school, or individual students. No teachers or students were interviewed or surveyed as part of this study.

There are four ethical principles in the conduct of social research: voluntary participation, informed consent, no harm to participants, and anonymity and confidentiality (DeVaus, 2001)

**Voluntary Participation**

Because the study sought to obtain information directly from the study subjects, voluntary participation was necessary. Respect for the privacy of individual teachers and students were maintained throughout this study by not referring to the school district, the school, or the individual students from whom data were obtained.

**Informed Consent**

This study recorded information on performance directly from students; therefore, individual assent forms from each student and consent forms from parents were necessary. Consent from the school district to conduct research within the district was sought and received.
No Harm to Participants

The study’s subjects were not harmed by their participation in this study. Students were not denied access to services or exposed to harmful interventions as a result of their participation in this study. The study’s researchers examined the effect of educational interventions with proven effectiveness and school administrators agreed to implement the intervention in these classrooms.

Anonymity and Confidentiality

The researchers of this study were very careful to maintain the anonymity and confidentiality of the study’s subjects. Student names were not recorded in the building of the database of student scores. It was not possible for anyone related or tangential to the study to cross-reference the student ID numbers to student names using the materials, files, or computer records of the study’s researchers. All data, records, and analyses were saved and stored on a password-protected computer.

IRB Approval

IRB approval for this study was sought and received (see Appendix B).
CHAPTER 4. RESULTS

Students who participated in the study were from two inclusive mathematics classrooms located in two middle schools in central Kentucky. One school, which implemented the EAI curriculum, was located in a rural setting and the other school, which taught with the EAI plus formative curriculum, was located in a rural setting. All 39 participants were in the seventh grade and received instruction in inclusive math classrooms. The majority of the participants were in the EAI condition (61%) while the remaining 15 participants were taught with EAI\textit{f} (39%). Students were almost evenly split between SWD (n=19) and typical students (n=20), with the EAI condition having 46% SWD (n=11) and 54% typical students (n=13) and EAI\textit{f} condition having 53% SWD (n=8) and 47% typical students (n=7). Students were almost evenly split between male (n=18) and female (n=21), with EAI condition having 50% male (n=12) and 50% female students (n=12) and the EAI\textit{f} condition having 40% male (n=6) and 60% female students (n=60%). Table 1 shows pretest and posttest scores for students by disability status and instructional condition.
Table 1

Pre and Posttest Scores by Student Type Across Conditions

<table>
<thead>
<tr>
<th></th>
<th>SWD</th>
<th>Typical Student</th>
<th></th>
<th>SWD</th>
<th>Typical Student</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pretest</td>
<td>Posttest</td>
<td>Pretest</td>
<td>Posttest</td>
<td>Pretest</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
<td>M</td>
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<td>FC</td>
<td>5.45</td>
<td>6.10</td>
<td>17.27</td>
<td>13.98</td>
<td>10.00</td>
</tr>
<tr>
<td>PS</td>
<td>8.27</td>
<td>5.01</td>
<td>12.27</td>
<td>4.69</td>
<td>12.54</td>
</tr>
<tr>
<td>ITBS-C</td>
<td>14.64</td>
<td>3.56</td>
<td>15.45</td>
<td>6.67</td>
<td>20.00</td>
</tr>
</tbody>
</table>

*Note. Tests include Fraction Computation (FC), Problem Solving (PS), Iowa Test of Basic Skills, Computation (ITBS-C), Iowa Test of Basic Skills, Problem Solving (ITBS-PS) for Students with Disabilities (SWD) and Typical Students by instructional condition.*
Data were analyzed to answer four questions:

1. What effect, if any, did the addition of formative assessments to the EAI curriculum have on computation and problem-solving performance of SWD and typical students in an inclusive classroom?

2. Is there an interaction effect between student status (SWD, typical student) and treatment status (EAI, EAIf)?

3. What effect, if any, did the addition of formative assessments to the EAI curriculum have on the number of instructional days required to complete the unit(s) of study?

4. What effect, if any, did the addition of formative assessments to the EAI curriculum have on instructional decision making?

Questions 1 and 2

To examine the first two research questions, four 2 X 2 ANCOVAs were conducted to assess if there were differences in posttest FC, PS, ITBS COMP, and ITBS PS scores by condition and by IEP after controlling for pretest scores. Prior to analysis, the assumption of normality was assessed for all four scores. Normality was not met for FC ($p = .015$) or for PS ($p = .005$), although it was met for both ITBS scores ($p > .050$). Levene’s tests were conducted to assess for equality of variance. Significance was found for PS scores ($p = .032$) only, and thus a more stringent alpha level of .025 was used when conducting the 2 X 2 ANCOVA for PS (Pallant, 2010).

On the FC no significant difference was found by condition, $F(1, 34) = 2.35, p = .134$, partial $\eta^2 = .07$ or for IEP, $F(1, 34) = 0.02, p = .894$, partial $\eta^2 = .00$. However, a
significant interaction of condition by IEP was found, $F(1, 34) = 8.48, p = .006$, partial $\eta^2 = .20$. Pairwise comparisons were conducted to assess where the differences lie. Scores for non-IEP participants were significantly higher for EAI students ($M_{adj} = 31.33$) compared to EAIf students ($M_{adj} = 16.33$). Additionally, the performance of students in the EAI condition was significantly higher for non-IEP students ($M_{adj} = 31.33$) compared to IEP students ($M_{adj} = 21.03$) (see Table 2).

On the PS test, there were no significant differences by condition, $F(1, 34) = 3.60, p = .066$, partial $\eta^2 = .10$, nor were significant differences found by IEP, $F(1, 34) = 0.35, p = .561$, partial $\eta^2 = .01$. A significant interaction of condition and IEP was not found, $F(1, 34) = 0.11, p = .746$, partial $\eta^2 = .00$. Results of the ANCOVA are presented in Table 2.

There were significant differences in ITBS COMP scores by condition, $F(1, 34) = 8.12, p = .007$, partial $\eta^2 = .19$. Since significance was found, pairwise comparisons were conducted. ITBS COMP scores for the EAIf participants ($M_{adj} = 21.49$) were significantly larger than ITBS COMP scores for EAI participants ($M_{adj} = 18.06$). Significant differences were not found by IEP, $F(1, 34) = 2.09, p = .157$, partial $\eta^2 = .06$. A significant interaction of condition and IEP was not found, $F(1, 34) = 3.54, p = .068$, partial $\eta^2 = .09$. Results of the ANCOVA are presented in Table 2.

There were no significant differences in ITBS PS scores by condition, $F(1, 34) = 0.28, p = .602$, partial $\eta^2 = .01$, nor were significance differences found by IEP, $F(1, 34) = 0.53, p = .472$, partial $\eta^2 = .02$. A significant interaction of condition and IEP was not
found, $F(1, 34) = 1.75, p = .194$, partial $\eta^2 = .05$. Results of the ANCOVA are presented in Table 2.

Table 2

ANCOVA for Test Scores by Condition and IEP

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>P</th>
<th>Partial $\eta^2$</th>
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<tbody>
<tr>
<td>FC pre</td>
<td>1764.55</td>
<td>1</td>
<td>212.50</td>
<td>1955</td>
<td>.001</td>
<td>.37</td>
</tr>
<tr>
<td>Condition</td>
<td>212.50</td>
<td>1</td>
<td>1.62</td>
<td>2.35</td>
<td>.134</td>
<td>.07</td>
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<tr>
<td>IEP</td>
<td>1.62</td>
<td>1</td>
<td>765.23</td>
<td>0.02</td>
<td>.894</td>
<td>.00</td>
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<tr>
<td>Condition*IEP</td>
<td>76523</td>
<td>1</td>
<td>90.28</td>
<td>8.48</td>
<td>.006</td>
<td>.20</td>
</tr>
<tr>
<td>Error</td>
<td>3069.43</td>
<td>34</td>
<td>90.28</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PS pre</td>
<td>271.65</td>
<td>1</td>
<td>271.65</td>
<td>30.83</td>
<td>.001</td>
<td>.48</td>
</tr>
<tr>
<td>Condition</td>
<td>31.70</td>
<td>1</td>
<td>31.70</td>
<td>3.60</td>
<td>.066</td>
<td>.10</td>
</tr>
<tr>
<td>IEP</td>
<td>3.04</td>
<td>1</td>
<td>3.04</td>
<td>0.35</td>
<td>.561</td>
<td>.01</td>
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<tr>
<td>Condition*IEP</td>
<td>0.94</td>
<td>1</td>
<td>0.94</td>
<td>0.11</td>
<td>.746</td>
<td>.00</td>
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<tr>
<td>Error</td>
<td>299.61</td>
<td>34</td>
<td>8.81</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>ITBS COMP pre</td>
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<td>504.50</td>
<td>38.05</td>
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<td>.53</td>
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<td>107.69</td>
<td>8.12</td>
<td>.007</td>
<td>.19</td>
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<td>IEP</td>
<td>27.74</td>
<td>1</td>
<td>27.74</td>
<td>2.09</td>
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<td>46.98</td>
<td>3.54</td>
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<tr>
<td>Error</td>
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<td>34</td>
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<tr>
<td>ITBS PS pre</td>
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<td>311.47</td>
<td>36.01</td>
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<td>.51</td>
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<td>.602</td>
<td>.01</td>
</tr>
<tr>
<td>IEP</td>
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<td>4.57</td>
<td>0.53</td>
<td>.472</td>
<td>.02</td>
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<tr>
<td>Condition*IEP</td>
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<td>1</td>
<td>15.16</td>
<td>1.75</td>
<td>.194</td>
<td>.05</td>
</tr>
<tr>
<td>Error</td>
<td>294.04</td>
<td>34</td>
<td>8.65</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. Separate 2X2 ANCOVA analysis for each measure including Fraction Computation (FC), Problem Solving (PS), Iowa Test of Basic Skills, Computation (ITBS-C), and Iowa Test of Basic Skills, Problem Solving (ITBS-PS).

Note 2. Alpha level of .025 was used for PS 2 x 2 ANCOVA.
Questions 3 and 4

To examine research question 3, the number of days required to complete each unit was examined for EAI and EAI$^f$. When the formative assessments were added to the EAI curriculum, the time of instruction increased from 14% to 60% compared to when it was non-formative. The HOC unit increased the least (14%) while the FOC unit increased the most (60%). On average, the number of days increased by 41%.

To examine research question 4, the type of instructional decision-making was examined for EAI and EAI$^f$ teachers. Teachers in EAI$^f$ condition reported instructional decisions after each formative assessment measure. The researcher developed the instructional options based on professional judgment and the current research base. No prescriptive was given prior to the study and teachers were asked to make their decision based on the results of the formative assessments. For EAI only teachers, the instructional decision making was not changed with the exception of re-teaching content in the original lesson on the FAW unit at day 7. For EAI$^f$ teachers, they re-taught content in the original lesson four of the eight times listed, and re-taught content utilizing one or more differentiation strategies two of the times listed. The teachers elected to proceed with instruction without mediation twice as well. The percent correct on the formative assessment was at its highest for during the FOC unit (82%), while at its lowest during the FAW unit (67%) and HC unit (67%). Instructional decision-making is presented in Table 3.
Table 3

Instruction Decision Making Made by EAI and EAlf Teachers

<table>
<thead>
<tr>
<th>Unit</th>
<th>EAI</th>
<th>EAlf</th>
<th>% Correct on Formative Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>FA1 (FAW - Day 3)</td>
<td>None</td>
<td>Re-teaches content in the original lesson</td>
<td>72%</td>
</tr>
<tr>
<td>FA2 (FAW - Day 5)</td>
<td>None</td>
<td>Re-teaches content utilizing one or more differentiation strategies</td>
<td>73%</td>
</tr>
<tr>
<td>FA3 (FAW - Day 7)</td>
<td>Re-teaches content in the original lesson</td>
<td>Re-teaches content utilizing one or more differentiation strategies</td>
<td>67%</td>
</tr>
<tr>
<td>FA4 (FOC - Day 3)</td>
<td>None</td>
<td>Re-teaches content in the original lesson</td>
<td>72%</td>
</tr>
<tr>
<td>FA5 (FOC - Day 5)</td>
<td>None</td>
<td>Teacher has elected to proceed with instruction without mediation</td>
<td>82%</td>
</tr>
<tr>
<td>FA6 (HC - Day 3)</td>
<td>None</td>
<td>Re-teaches content in the original lesson</td>
<td>79%</td>
</tr>
<tr>
<td>FA7 (HC - Day 5)</td>
<td>None</td>
<td>Teacher has elected to proceed with instruction without mediation</td>
<td>80%</td>
</tr>
<tr>
<td>FA8 (HC - Day 7)</td>
<td>None</td>
<td>Re-teaches content in the original lesson</td>
<td>67%</td>
</tr>
</tbody>
</table>

Summary of Analysis of Data

The results of each research question were analyzed using statistical analysis as well as descriptive statistics. The next chapter explores the results of the statistical tests performed in this chapter, including possible interpretations and inferences.
CHAPTER 5. DISCUSSION

The purpose of this study was to determine whether embedding formative assessment measures in a problem-based learning curriculum (i.e., EAI) could improve the computation and problem-solving performance of SWD and typical students in inclusive middle school settings. The study’s overall goal was to enrich the research in the area of problem-based learning, specifically how assessment can impact the conceptual frameworks developed by Bottge (2001) and Black and Wiliam (1998a, 1998b). The secondary purpose of the study was to determine possible effects of formative assessment on instructional variables, such as on instructional decision-making and pacing.

Results showed that the addition of formative assessment to the EAI curriculum did not lead to substantial differences in student performance, except for computation scores on ITBS-C. In addition, including formative assessment with EAI curriculum did not lead to substantial differences for SWD. These findings fail to support the current research that formative assessment can be highly effective in improving student achievement (Wiliam et al., 2004; Wiliam & Thompson, 2007). However, the findings from this study do support current research that EAI improves computation and problem-solving performance of students (Bottge et al., 2002, Bottge et al., 2007, Bottge et al., in press). The analysis of descriptive data from this study showed that the addition of formative assessment to the EAI curriculum did impact instructional pacing and instructional decision-making. Teachers in EAI/f condition did some form of re-teaching after 6 of 8 formative assessment measures and overall, teaching the EAI/f curriculum
took longer than the EAI curriculum. These findings support the concern made by Heffernen and Koedinger (2012) that teachers are being asked to use assessment to drive instruction, yet every minute spent on assessments is a minute lost or added to instruction.

**Implications for Practice**

This research study addresses the need to identify evidence-based practices for raising math proficiency of students in the United States to those of international competitors (National Center for Education Statistics, 2007). EAI and EAI/ supported student learning through engaging them in learning activities that enabled them to discover relationships and solutions for themselves (Mercer, Jordan, & Miller, 1994) while also helping teachers meet the recommendations of the NCTM (2000) to focus on process and not just procedural understandings of math. PBL curriculum, such as EAI and EAI/, provided teachers a student-driven, teacher-facilitated method of instruction that improved the math proficiency of students (Bell, 2000; Bottge et al., 2007).

Because students, particularly those with disabilities, often lack the foundational math skills required to find the complex solutions found in PBL, Bottge (2001) recommended providing “explicit instruction” (p. 107) on foundational math skills alongside problem solving instruction. This study supports that recommendation as students performed equally well on the ITBS-C test across conditions after receiving explicit instruction in the FAW unit. They also performed comparably on both measures of problem solving. Therefore, educators interested in teaching with PBL curriculum should include explicit instruction on foundational math skills.
In this study, students in EAI\textsuperscript{f} did significantly better on the FC test suggesting that formative assessment may provide benefits to students on foundational math skills, such as computation, but not in problem solving. Part of the explanation for these findings may be that as students in EAI and EAI\textsuperscript{f} became “completely absorbed in problem(s)” (Bruner, 1960, p. 50). Language and discourse (Vygotsky, 1978) became central to the problem solving process and students did not require the support of ongoing formative assessment. Computation skills are well suited to a continuous feedback loop that allows teachers to adjust ongoing instruction and close gaps in learning (Stiggins & Chappuis, 2008: Stiggins & DuFour, 2009). However, continuous review of and checks on ideas are natural characteristics of problem solving processes. Some researchers contend that the issue of context and problem solving transfer is an issue that must be addressed by instruction (Catambone & Holyoak, 1989; Sweller, 1988). Gick and Holyoak (1983) found that using multiple exemplars, even without providing explicit instruction in generalized rules, could facilitate transfer to novel tasks across contexts.

In this study, students in EAI\textsuperscript{f} condition were provided opportunities throughout PBL units to apply problem-solving skills to novel tasks, but these opportunities did not lead to improved performance on posttest measures of problem solving. This repeated practice could have pushed students to their cognitive processing capacity and hindered their ability to acquire the schemas necessary to support learning transfer beyond what they gained from the EAI curriculum alone (Sweller, 1988). This study suggests that problem solving instruction, with or without formative assessment, should include some form of explicit instruction to help students recognize and apply problem-solving
schemas to novel tasks, as repeated opportunities and re-teaching alone did not lead to improved performance. The findings also suggest that teachers should be careful not to overload students with multiple transfer tasks.

This study showed that teachers’ use of formative assessment for informing instructional decision making within the framework of a problem-based learning curriculum is not straightforward (i.e., EAI/). These decisions led to significant increases in the time it took to complete units. The EAI/ condition completed posttest measures 17 instructional days after students in EAI condition, but that increased instructional time did not lead to statistically significant gains over the use of PBL alone. Therefore, if teachers are providing appropriate scaffolding (Bell, 2010), differentiating through grouping of students (Cheng et al., 2008), and/or are using highly structured problems that possess clear paths (Walker & Leary, 2009), formative assessments may not be necessary in order for students to achieve at high levels in PBL units (Bell, 2010; Walker & Leary, 2009).

In this study formative assessment was used in EAI/ to adjust teaching to meet perceived student needs (Kaminski & Cummings, 2007) and theoretically should have led to greater achievement for all students, especially those that were low achieving and SWD according to Stiggins and Chappuis (2006). The instructional decision-making based on formative assessment data used in this study included proceeding with instruction, re-teaching content, and re-teaching with differentiation, yet those instructional decisions, did not lead to greater achievement when compared to the EAI curriculum alone. This is explained in part by Hmelo-Silver (2004) who describes the
role of teacher as facilitator in PBL instruction. According to Hmelo-Silver the effective facilitator is continually assessing student progress and adjusting the level of guidance to respond to student needs. Failure to do so could prohibit students from gaining effective problem solving skills (Hung, 2011). The ongoing instructional decision-making of the facilitator is similar to the instructional decision-making based on formative assessment, albeit based on intuition as opposed to data. Therefore, it is recommended that teachers implementing PBL curriculum assume active roles of facilitation and adjust the level and type of support to meet student needs. By doing so, they can adequately inform their instructional decision-making and may make additional formal formative measures unnecessary.

Suggestions for Future Research

The review of research and findings from this study suggest several areas to consider for future research. First, would refining the formative assessment measures so they more closely align with larger driving questions of the PBL unit improve student achievement? The formative assessments given to students in EAIf during the FOC and HC units were developed using released NAEP problem solving items. These items were designed to determine if students could transfer emerging problem solving skills to novel tasks and were intentionally not linked to the EAI curriculum. Because this type of formative assessment was not effective in improving student achievement, it would be of interest to see if ongoing assessment that more closely aligns to the schemas of the driving question would yield higher levels of student achievement as advocates of formative assessment contend (i.e., Wiliam & Black, 1998a, Stiggins & Chappuis, 2007).
Conducting a similar study with refined assessments would offer valuable insight into the usefulness of formative assessments within PBL curriculum.

Another question related to the implementation of formative assessment measures in PBL curricula is, what effect do formative assessments have on students' perceptions of self-efficacy in the area of problem solving? Stiggins and DuFour (2009) have stated that formative assessment measures should not only motivate student learning, but also build confidence in students as learners. The unique properties of the EAI curriculum also serve to motivate student learning and promote math proficiency by facilitating the development of a productive disposition (Bottge, et al., 2014; NRC, 2001). What effect would the combination of formative assessment and EAI curriculum have on students’ perception of themselves as capable mathematicians?

Lastly, what does instructional decision-making look like for effective facilitators of PBL? In this study, the author asked teachers in EAI to report each instructional decision made based on formative assessment data. In EAI teachers were also asked to report instructional decision-making from the same list of possibilities, but were given no directives outside of that. Hemlo-Silver (2004) has discussed the importance of the teacher as facilitator during PBL instruction. It is important to collect more qualitative data on the types of instructional decisions, frequency of decisions, and data sources that teachers use when facilitating PBL and use that in combination with quantitative data on student achievement to determine what constitutes effective teacher behavior in PBL instruction.
Limitations

There are several limitations noted of the study. First, the absence of a true control group limited the ability of the author to determine the impact of EAI and EAI/ over more traditional forms of instruction. Second, throughout the study both participating school districts incurred significant delays due to inclement weather. These delays increased the number of calendar days between pretest and posttest and could have impacted student performance. Participating schools missed 13 and 17 days, respectively during the course of the study. Third, the EAI/ condition experienced an attrition of five students from pretest to posttest. Three students failed to return signed parent consent forms, one student was removed from the school, and one student refused to complete posttests. No student attrition occurred in the EAI condition. Lastly, due to inclement weather delays the posttests for EAI/ were administered the week before state testing. The increased attention given to state testing preparation may have impacted student performance for EAI/.

Conclusion

This study determined that embedding formative assessment measures in a problem-based learning curriculum (i.e., EAI) did not improve the problem-solving performance of SWD and typical students in inclusive middle school settings and had only a mixed impact on computation performance. The study augmented the current research in the area of PBL by providing evidence that formative assessment measures not directly linked to the EAI curriculum do not support the development of problem solving skills for middle school students in mathematics. This study provides further
evidence that EAI is an effective strategy for improving the computation and problem-solving skills of SWD and typical students. This study adds to the body of research in the area of formative assessment by providing descriptive information of how formative assessment impacts instructional decision-making and pacing, both important considerations for practitioners.
Appendix A – Formative Assessment Measures

Formative Assessment #1 (*FAW Day 3*)

Student Name: ____________________________

1. If you have $\frac{1}{4}$ of a candy bar and your partner has $\frac{3}{4}$ of a candy bar, which of you has more?

2. How much more?

3. How much do you have altogether?

4. Suppose you have a piece of wood that is $\frac{15}{16}$ foot long. If you cut $\frac{3}{16}$ of a foot of wood from this piece, how much is left?

5. List 2 equivalent fractions for $\frac{2}{3}$:
Formative Assessment #2 (*FAW Day 5*)

Student Name: ______________________________

1. If you have $\frac{7}{8}$ of a candy bar and your partner has $\frac{3}{4}$ of a candy bar, which of you has more?

2. How much more?

3. How much do you have together?

4. Circle all of the fractions that are equivalent to $\frac{1}{4}$:

   \[
   \frac{2}{8} \quad \frac{5}{20} \quad \frac{4}{7} \quad \frac{1}{8} \quad \frac{4}{16}
   \]

5. 

   \[
   \frac{4}{9} + \frac{1}{3}
   \]
Formative Assessment #3 (FAW Day 7)

Student Name: ______________________________________

1. \[ \frac{5}{16} \quad \frac{1}{8} \quad ? \]

2. When adding fractions \( \frac{1}{3} \) and \( \frac{1}{2} \), which of the following numbers could NOT be used as the common denominator if the numerators are to be whole numbers?
   a. 6 \hspace{1cm} b. 9 \hspace{1cm} c. 12 \hspace{1cm} d. 18

3. Identify the least common multiple of 3 & 4.

4. Identify the least common multiple of 9 & 6.

5. Identify the least common multiple of 3 & 15.
Formative Assessment #4 (FOC Day 3)

Student Name: __________________________

1. What fraction of the figure is shaded?

<p>| | | |</p>
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<tr>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

A. $\frac{1}{4}$  
B. $\frac{3}{10}$  
C. $\frac{1}{3}$  
D. $\frac{3}{7}$  
E. $\frac{7}{10}$

2. Tyler drinks 24 fluid ounces of milk each day for 7 days. How many quarts of milk does he drink in the 7 days? Do not round your answer. (1 quart = 32 fluid ounces)

Answer: ____________________ quarts

3. Raynold had 31 baseball cards. He gave the cards to his friends. Six of his friends received 3 cards each. Seven of his friends received 1 card each. The rest received 2 cards each.

4. How many of his friends received exactly 2 cards from Raynold?

5. Explain how you found your answer.
Formative Assessment #5 (FOC Day 5)

Student Name: ______________________

A high school orders 11 buses to transport 418 students. If each bus can seat 35 students, will the number of buses ordered be enough to provide a seat for each student?

1. Yes or No

2. Explain your answer.

Jill needs to earn $45.00 for a class trip. She earns $2.00 each day on Mondays, Tuesdays, and Wednesdays, and $3.00 each day on Thursdays, Fridays, and Saturdays. She does not work on Sundays. How many weeks will it take her to earn $45.00?

3. Answer: ______________________

4. Which picture shows that \( \frac{3}{4} \) is the same as \( \frac{6}{8} \)?

A.  

B.  

C.  

D.  

Formative Assessment # 6 (HC Day 3)

Student Name: ______________________________

1. The floor of a room shown in the figure above is to be covered with tiles. One box of floor tiles will cover 25 square feet. Use your ruler to determine how many whole boxes of these tiles must be bought to cover the entire floor.

_______ boxes of tiles.

2. Explain your reasoning in the space below.

3. Robert has $30 and wants to buy as many bags of peanuts as possible. He does not have to pay any sales tax on the food that he buys.

Based on the prices given in the chart above, how many bags of peanuts can Robert buy? Answer: ________________

4. Robert buys all the bags of peanuts that he can. What is the most expensive single item on the chart that he can buy with the money he has left?

Answer: ________________

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yogurt</td>
<td>$0.95 each</td>
</tr>
<tr>
<td>Pretzels</td>
<td>$2.50 per bag</td>
</tr>
<tr>
<td>Cheese Cubes</td>
<td>$2.19 per bag</td>
</tr>
<tr>
<td>Bagel</td>
<td>$0.89 each</td>
</tr>
<tr>
<td>Fruit Drink</td>
<td>$1.85 each</td>
</tr>
<tr>
<td>Peanuts</td>
<td>$2.55 per bag</td>
</tr>
</tbody>
</table>
Formative Assessment #7 (HC Day 5)

Student Name: ________________________

The linear graph below describes Josh’s car trip from his grandmother’s home directly to his home.

1. Based on this graph, what is the distance from Josh’s grandmother’s home to his home?

2. Based on this graph, how long did it take Josh to make the trip?

3. What was Josh’s average speed for the trip? Explain how you found your answer.

4. Explain why the graph ends at the x-axis.
Formative Assessment #8 (HC Day 7)

Student Name: ________________________

You need to cut three (3) pieces of pipe out of one large pipe that is 12 feet long. The first needs to be $4\frac{1}{4}$ feet long, the next piece needs to be $5\frac{9}{12}$ feet long, and the last one needs to be $1\frac{1}{3}$ feet long.

1. How much total pipe do you need?

2. Do you have enough pipe to cut all three pieces out of the 12 foot piece? Explain.

Your group is trying to decide if you have enough money to build your Hovercraft design. You only have $4.25 remaining in your budget. Your plan calls for 13 T’s.

3. If T’s cost 0.32 cents each – do you have enough to build your design?

4. What if the T’s cost 0.34 cents each?
Appendix B – IRB Approval Forms

TO: Mark Badger
Special Education & Rehabilitation Counseling
103 Callie Circle
Wilton, KY 40590
P: phone: 8 (859) 227-1770

FROM: Chairperson/Vice Chairperson
Non-medical Institutional Review Board (IRB)

SUBJECT: Approval of Protocol Number: 13-0935-PR8

DATE: January 17, 2014

On January 14, 2014, the Non-medical Institutional Review Board approved your protocol entitled:

The Effects of Embedding Proactive Assessment Measures in a Problem-Based Learning Mathematics Curriculum for Middle School Students

Approval is effective from January 14, 2014 until January 13, 2015 and extends to any consent/assent forms, cover letters, and/or phone scripts. If applicable, attach to the IRB approved consent/assent document(s) to be used when enrolling subjects. If consent/assent forms have a valid "IRB Approval" stamp when consent/assent forms have been obtained from the IRB. Prior to the end of this period, you will submit a Continuation Review Report Form which must be completed and returned to the Office of Research Integrity so that the protocol can be reviewed and approved for the next period.

In implementing the research activities, you are responsible for complying with IRB declarations, conditions, and requirements. The research procedures should be implemented as approved by the IRB protocol. If the research has not been submitted for review and approval by the IRB prior to implementation, Protocol changes made without prior IRB approval to eliminate apparent hazards to the subject(s) should be reported in writing immediately to the IRB. Furthermore, discontinuing a study or completion of a study is considered a change in the protocol's status and therefore the IRB should be promptly notified in writing.

For information describing investigator responsibilities after obtaining IRB approval, download and read the document "PI Guidance to Responsibilities, Qualifications, Records and Documentation of Human Subjects Research" from the Office of Research Integrity's Guidance and Policy Documents webpage [http://www.research.uky.edu/ohr/PI%20Guidance%20to%20Responsibilities%20Qualifications%20Records%20and%20Documentation%20of%20Human%20Subjects%20Research.pdf]. Additional information regarding IRB review, federal regulations, and institutional policies may be found through ORI's website [http://www.research.uky.edu/ohr]. If you have questions, need additional information, or would like a paper copy of the above mentioned document, contact the Office of Research Integrity at (859) 257-9428.

Chairperson/Vice Chairperson

[Signature]
Teacher Consent to Participate in Research Study
The Effects of Embedding Formative Assessment Measures in a Problem-Based Learning Mathematics Curriculum for Middle School Students

WHY ARE YOU BEING INVITED TO TAKE PART IN THIS RESEARCH?

You are being invited to take part in a research study about the effectiveness of embedding formative assessment probes in the Enhanced Anchored Instruction curriculum. Enhanced Anchored Instruction is a math curriculum designed to develop math skills of low-achieving adolescents, including those students with disabilities. You are being invited to take part in this study because you are teaching math in an inclusive classroom containing students with and without disabilities and have had previous experience with the Enhanced Anchored Instruction curriculum. You will be one of two participating classrooms in this study.

WHO IS DOING THE STUDY?

The person in charge of this study is Mark D. Butler, a doctoral candidate at the University of Kentucky in the Department of Early Childhood, Special Education, and Rehabilitation Counseling. He is working under the direct supervision of Dr. Brian Bottge of the University of Kentucky in the same department. All people involved in this study are affiliated with the University of Kentucky.

WHAT IS THE PURPOSE OF THIS STUDY?

Based on a pedagogical approach called Anchored Instruction, Enhanced Anchored Instruction extends or enhances Anchored Instruction by affording students additional opportunities to practice their skills as they solve new, but analogous problems in applied and challenging contexts. Students first solve a problem in multimedia format and then apply what they learn in related hands-on problems (e.g., building skateboard ramps, designing and manufacturing hovercrafts).

I am testing the effectiveness of Enhanced Anchored Instruction and Enhanced Anchored Instruction embedded with formative assessment measures. If this study shows effectiveness it may lead to a blending of problem-based learning in mathematics with formative assessment practices. If the study does not show positive effects, it will give me an opportunity to improve the teaching method for future studies.

ARE THERE REASONS WHY YOU SHOULD NOT TAKE PART IN THIS STUDY?

Teachers participating in this study will not be exposed to any harm, either physically or mentally. If you teach math with Enhanced Anchored Instruction you will have received training on implementing the curriculum. Enhanced Anchored Instruction is designed to be motivating and fun for students. If you are part of the Enhanced Anchored Instruction plus
Formative assessment you will have received training on implementing the curriculum and formative assessment measures.

WHERE IS THIS STUDY GOING TO TAKE PLACE AND HOW LONG WILL IT LAST?

The research will be conducted in the math classroom at the school where you teach. You will not need to come to the University of Kentucky for any reason during the course of this research study. The study will last approximately 5 weeks.

WHAT WILL YOU BE ASKED TO DO?

This project will evaluate two ways of teaching the Enhanced Anchored Instruction curriculum for the purpose of improving students’ math skills. Teachers in each condition will be teaching math using the Enhanced Anchored Instruction curriculum. Your classroom will be randomly chosen to be in Enhanced Anchored Instruction or Enhanced Anchored Instruction plus formative assessment condition. Therefore, you will not have a choice as to which type of instruction you use during the study.

Teachers in schools chosen to use Enhanced Anchored Instruction will be asked to use the curriculum in one collaborative math classroom using the research materials (e.g., lesson plans, software, materials). The learning materials are aligned to Kentucky Core Academic Standards. Teachers in schools chosen to use Enhanced Anchored Instruction plus formative assessments will be asked to use the curriculum in one collaborative math classroom using the research materials (e.g., lesson plans, software, materials), as well as administering researcher-developed formative assessment probes every two days throughout the study.

You will be asked to help administer math pretests and posttests to students prior to and following the instructional period (approx. 5 weeks). These tests are similar to the ones you give as part of your usual teaching methods. The math tests take about 60 minutes. Teachers in the Enhanced Anchored Instruction plus formative condition will be asked to administer formative assessment probes every two days. Teachers will be asked to score these, analyze the results, and select an instructional decision based on the data. These are all activities you would do in the course of your regular teaching duties.

The research will be responsible for distributing and collecting parent permission and student assent forms. These forms will be placed in a collection box on the teacher’s desk.

WHAT ARE THE POSSIBLE RISKS AND DISCOMFORT?

To the best of our knowledge, the teaching activities you will engage in as part of this research project have no more risk or harm than you would experience in everyday teaching activities.
WILL YOU BENEFIT FROM TAKING PART IN THIS STUDY?

Teachers may benefit from this study by learning a new teaching method to help them work with low-achievers including students with learning disabilities in math. In general, your willingness to participate may help our schools better educate our children in math in the future.

DO YOU HAVE TO TAKE PART IN THIS STUDY?

If you decided to take part in this study, it should be because you want to volunteer. You will not lose any benefits or rights you would normally have if you choose not to volunteer. You can stop at any time during the study and still keep the benefits and rights you had before volunteering. If you decided not to take part in this study, your decision will have no impact on your employment or the quality of care, services, etc., you receive.

IF YOU DON'T WANT TO TAKE PART IN THIS STUDY, ARE THERE OTHER CHOICES?

If you don't want to be in this study, there are no other choices except to not take part in this study.

WHAT WILL IT COST YOU TO PARTICIPATE?

There are no costs associated with taking part in the study.

WILL YOU RECEIVE ANY REWARDS FOR PARTICIPATING IN THIS STUDY?

Teachers who participate in this study will not receive payment.

WHO WILL SEE THE INFORMATION THAT YOU GIVE?

When I write about this study, you will not be personally identified in these written materials. I may publish the results of this study; however, I will keep your name and other identifying information private.

I will keep private all research records that identify you to the extent allowed by law. However, there are some circumstances in which we may have to show your information to other people. For example, the law may require me to show your information to a court, or to tell authorities if you report information about a child being abused or if you pose a danger to yourself or someone else. Also, I may be required to show information that identifies you to people who need to make sure I have done the research correctly; these would be people from such organizations as the University of Kentucky.
CAN YOUR PARTICIPATION IN THIS STUDY END EARLY?

If you decide to take part in this study, you will have the right to decide at any time that you no longer want to continue. You will not be treated differently if you decide to stop taking part in this study.

WHAT IF YOU HAVE QUESTIONS, SUGGESTIONS, CONCERNS, OR COMPLAINTS?

Before you decide whether to accept my invitation to participate in this study, please contact the investigator, Mark D. Butler, at 859-227-1770 and ask any questions that might come to mind. Later, if you have questions, suggestions, concerns, or complaints about this study, you can still contact the investigator. If you have any questions about your rights as a volunteer in this study, please contact the staff in the Office of Research Integrity at University of Kentucky at 859-257-9428 or toll free at 1-866-400-9428.

If you want to participate in this study, please sign and return one copy of this consent form to the investigator and keep one copy for your records. We request that you keep a copy for your records in order to have the contact information for both the investigator and University of Kentucky Office of Research Integrity as listed above.

WHAT ELSE DO YOU NEED TO KNOW?

This research study will be used to complete my doctoral degree at the University of Kentucky.

TEACHER PERMISSION FORM

By signing below and returning this form to the investigator, you are agreeing to participate in this research project.

__________________________________________  ________________________________
Teacher Name                                             Teacher Signature

__________________________________________   _____________________________
Phone Number                                              Date
Parent Consent to Participate in Research Study

The Effects of Embedding Formative Assessment Measures in a Problem-Based Learning Mathematics Curriculum for Middle School Students

WHY IS YOUR CHILD BEING INVITED TO TAKE PART IN THIS RESEARCH?

Your child is being invited to take part in a research study about the effectiveness of embedding formative assessment probes in the Enhanced Anchored Instruction curriculum. Enhanced Anchored Instruction is a math curriculum designed to develop math skills of adolescents, including those students with disabilities. Your child is being invited to take part in this study because they are a student in an inclusive math classroom containing students with and without disabilities. If you give permission to your child to take part in this study, your child will be one of about 50 students.

WHO IS DOING THE STUDY?

The person in charge of this study is Mark D. Butler, a doctoral candidate at the University of Kentucky in the Department of Early Childhood, Special Education, and Rehabilitation Counseling. He is working under the direct supervision of Dr. Brian Botte at the University of Kentucky in the same department. All people involved in this study are affiliated with the University of Kentucky.

WHAT IS THE PURPOSE OF THIS STUDY?

Based on an approach called Anchored Instruction, Enhanced Anchored Instruction extends or enhances Anchored Instruction by affording students additional opportunities to practice their skills as they solve new but analogous problems in applied and challenging contexts. Students first solve a problem in multimedia format and then apply what they learn in related hands-on problems (e.g., designing and manufacturing hovercrafts).

I am testing the effectiveness of Enhanced Anchored Instruction and Enhanced Anchored Instruction embedded with formative assessment measures. If this study shows effectiveness it may lead to a blending of problem-based learning in mathematics with formative assessment practices. If the study does not show positive effects, it will give me an opportunity to improve the teaching method for future studies.

ARE THERE REASONS WHY YOU SHOULD NOT TAKE PART IN THIS STUDY?

Students participating in this study will not be exposed to any harm, either physically or mentally. Your child will be receiving the new math instruction either with or without formative assessment measures.
WHERE IS THIS STUDY GOING TO TAKE PLACE AND HOW LONG WILL IT LAST?

The research will be conducted in your child’s math classroom at the school where your child attends. He/she will not need to come to the University of Kentucky for any reason during the course of this research study. The study will last approximately 5 weeks.

WHAT WILL YOUR CHILD BE ASKED TO DO?

This project will evaluate two ways of teaching math for the purpose of improving students’ math skills using Enhanced Anchored Instruction (EAI). Students in both schools will be taught math in this new way. Your child’s classroom will be randomly chosen to use the EAI curriculum or the EAI curriculum plus formative assessments. Thus, you will not have a choice as to which type of math instruction your child receives.

To measure what students have learned, students in both classes will be asked to take math tests at the beginning and at the end of the study during their regular math instruction. The tests take about 60 minutes. If you do not give permission to use the test results, your child will still take the tests, but I will not use the results for research purposes.

By granting permission for your child to participate in the study, you are consenting to allow the researcher to access information in your child’s records about their categorization as receiving special education services or not. This information will remain confidential and academic records will only be accessed for students whose parents give permission.

WHAT ARE THE POSSIBLE RISKS AND DISCOMFORT?

The learning activities your child will be participating in have no more risk of harm than the learning activities in typical middle school math classrooms.

To help describe the students involved in the study, researchers may review information in your child’s academic records such as their special education categorization. Only the researchers will have access to the individual’s information. Number rather than name will reference students. The research data will be stored on password-protected computers and locked in cabinets at the University of Kentucky. Neither your name nor your child’s name will appear in any reports on the research.

In some instances, students may experience mild anxiety completing the math tests. If that happens, the teacher will tell your child that he/she will not have to finish the tests.

WILL YOU BENEFIT FROM TAKING PART IN THIS STUDY?

There is no guarantee that your child will benefit from this study. However, I do expect that most children who participate will improve their math knowledge and skills. This improvement may be reflected in their standardized math exams. We also expect that most
children will improve their attitude toward mathematics once they experience the learning activities.

IF YOU DON'T WANT YOUR CHILD TO TAKE PART IN THIS STUDY, ARE THERE OTHER CHOICES?

If you don't want your child to be involved in the study, your child will still receive the math instruction and take the tests. If your child withdraws from participation, I simply will not use the information from your child's tests in the analysis.

WHAT WILL IT COST YOU TO ALLOW YOUR CHILD TO PARTICIPATE?

There are no costs associated with taking part in the study.

WILL YOUR CHILD RECEIVE ANY REWARDS FOR PARTICIPATING IN THIS STUDY?

No.

WHO WILL SEE THE INFORMATION THAT YOUR CHILD GIVES?

Your child's information will be combined with information from other children taking part in this study. When I write about this study to share with other researchers, I will write about this combined information we have gathered. Your child will not be personally identified in these written materials. I may publish the results of this study, but I will keep your child's name and other identifying information private. I will make every effort to prevent anyone who is not directly involved in the study from knowing that your child has provided me information or the content of the information. I will keep private all research records that identify your child to the extent allowed by law. However, there are some circumstances in which I may have to show your child's information to other people. For example, the law may require me to show your child's information to a court, or to tell authorities if your child reports information about a child being abused or if your child poses a danger to himself/herself or others. Also, I may be required to show information that identifies you and your child to people who need to make sure I have done the research correctly. These would be people from such organizations as the University of Kentucky.

CAN YOUR PARTICIPATION IN THIS STUDY END EARLY?

If you decided to allow your child to take part in this study, you and your child will have the right to decide at any time that you no longer want to continue. You will not be treated differently if you decide to stop taking part in this study.
WHAT IF YOU HAVE QUESTIONS, SUGGESTIONS, CONCERNS, OR COMPLAINTS?

Before you decide whether to allow your child to accept my invitation to part in the study, please contact the investigator, Mark D. Butler, at 859-227-1770 and ask any questions that might come to mind. Later, if you have questions, suggestions, concerns, or complaints about this study, you can still contact the investigator. If you have any questions about the rights of your child as a volunteer in this study, please contact the staff in the Office of Research Integrity at University of Kentucky at 859-257-9428 or toll free at 1-866-400-9428.

If you want to give permission to your child to participate, please sign and return one copy of this consent form to the investigator and keep one copy for your records. We request that you keep a copy for your records in order to have the contact information for both the investigator and University of Kentucky Office of Research Integrity as listed above.

WHAT ELSE DO YOU NEED TO KNOW?

This research study will be used to complete my doctoral degree at the University of Kentucky.

Parent PERMISSION FORM

By signing below and returning this form to the investigator, I am agreeing to my child’s participation in this research project. I understand that this participation will involve the use of my child’s pretest and posttest results and access to their student records.

(Child’s Full Name) _____________________________

(Printed Parent/Guardian Name) _____________________________

(Date) _____________________________
Assent Form

The Effects of Embedding Formative Assessment Measures in a Problem-Based Learning Mathematics Curriculum for Middle School Students

You are being asked to be in a research study with Mark Butler from the University of Kentucky. The study will take place in your math class. The purpose of this project is to look at 2 ways of teaching math for helping you in math. Students in both schools will be taught math in a new way.

Students will take math tests at the beginning and at the end of the study during school hours. By agreeing to participate, you are allowing me to use the results. You will still take the tests either way. The tests take about 60 minutes.

Only the researcher will have access to the test scores. Your name will be used only to match the two sets of tests. I won't use your name for any other reason and it will never appear in any reports.

Your participation in this project is up to you. There is no penalty for not participating. Your grade will not be affected. If you decide not to participate, you will still receive math instruction and you will still take the tests. However, we will not use your test results in the research project.

If you feel uncomfortable while you are in this study, please tell your math teacher. If you decide at any time you do not want to finish the study, you may stop. You will still be in the math class and take the tests, but I won't use your results.

You can ask Mark Butler (859-227-1770, mark.butler@uky.edu) questions at anytime about anything in this study. You can also ask your parent any questions you might have about the study.

Signing this paper means that you have read this or had it read to you, and that you want to be in this study. If you do not want to be in this study, do not sign this paper. Being in this study is up to you, and no one will be angry if you do not sign this paper or even if you change your mind later. You agree that you have been told about this study and what you need to do.

Printed Student Name  Student Signature  Date

IRB Approval 13-0925  THIS FORM VALID 1/14/14 - 11/3/15

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Appendix C

Instructional Decision-Making Form

<table>
<thead>
<tr>
<th>Instructional Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>Represents re-teaching option, where the teacher re-teaches the content presented in the original lesson(s)</td>
</tr>
<tr>
<td>P</td>
<td>Represents that the teacher has elected to proceed with instruction without remediation</td>
</tr>
<tr>
<td>D</td>
<td>Represents that the teacher has elected to re-teach the content utilizing one or more differentiation strategies (i.e., modifying content, altering process)</td>
</tr>
<tr>
<td>A</td>
<td>Represents that the teacher has chosen to assign additional practice problems for students to complete</td>
</tr>
<tr>
<td>$P^2$</td>
<td>Represents that the teacher will differentiate content through the use of peer-to-peer remediation</td>
</tr>
<tr>
<td>N</td>
<td>Represents that the teacher has not noted that any instructional-decision was made</td>
</tr>
<tr>
<td>O</td>
<td>Represents that the teacher has elected to implement an instructional strategy not specified in the instructional coding. Teacher will provide a description to the researcher of the selected strategy.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Formative Assessment</th>
<th>Percentage Correct</th>
<th>Instructional Decision</th>
</tr>
</thead>
<tbody>
<tr>
<td>FAW Day 3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FAW Day 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FAW Day 7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FOC Day 3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FOC Day 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HoverCraft Day 3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HoverCraft Day 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HoverCraft Day 7</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Instructional Decision-Making Form (Completed)

<table>
<thead>
<tr>
<th>Instructional Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>Represents re-teaching option, where the teacher re-teaches the content presented in the original lesson(s)</td>
</tr>
<tr>
<td>P</td>
<td>Represents that the teacher has elected to proceed with instruction without remediation</td>
</tr>
<tr>
<td>D</td>
<td>Represents that the teacher has elected to re-teach the content utilizing one or more differentiation strategies (i.e., modifying content, altering process)</td>
</tr>
<tr>
<td>A</td>
<td>Represents that the teacher has chosen to assign additional practice problems for students to complete</td>
</tr>
<tr>
<td>P²</td>
<td>Represents that the teacher will differentiate content through the use of peer-to-peer remediation</td>
</tr>
<tr>
<td>N</td>
<td>Represents that the teacher has not noted that any instructional-decision was made</td>
</tr>
<tr>
<td>O</td>
<td>Represents that the teacher has elected to implement an instructional strategy not specified in the instructional coding. Teacher will provide a description to the researcher of the selected strategy.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Formative Assessment</th>
<th>Percentage Correct</th>
<th>Instructional Decision</th>
</tr>
</thead>
<tbody>
<tr>
<td>FAW Day 3</td>
<td>72.2%</td>
<td>Re-teach (R)</td>
</tr>
<tr>
<td>FAW Day 5</td>
<td>73.3%</td>
<td>Re-teach w/ Differentiation (D)</td>
</tr>
<tr>
<td>FAW Day 7</td>
<td>66.6%</td>
<td>Re-teach w/ Differentiation (D)</td>
</tr>
<tr>
<td>FOC Day 3</td>
<td>72%</td>
<td>Re-teach (R)</td>
</tr>
<tr>
<td>FOC Day 5</td>
<td>82%</td>
<td>Proceed (P)</td>
</tr>
<tr>
<td>HoverCraft Day 3</td>
<td>79.14%</td>
<td>Re-teach (R)</td>
</tr>
<tr>
<td>HoverCraft Day 5</td>
<td>79.50%</td>
<td>Proceed (P)</td>
</tr>
<tr>
<td>HoverCraft Day 7</td>
<td>66.6%</td>
<td>Re-teach (R)</td>
</tr>
</tbody>
</table>
References


doi:10.1037/0022-0663.93.4.659


doi:10.1080/09585170500136093

doi:10.1177/002246699402800301


Montague, M. (1992). The effects of cognitive and metacognitive strategy instruction on the mathematical problem solving of middle school students with learning
doi:10.1177/002221949202500404


*ERIC Digest.* ERIC Clearinghouse on Elementary and Early Childhood Education.


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CURRICULUM VITA
Mark D. Butler
Department of Early Childhood, Special Education, and Rehabilitation Counseling
University of Kentucky

EDUCATION

Ph.D. Department of Early Childhood, Rehabilitation Counseling, and Special Education, University of Kentucky, Lexington, KY
2014 (expected) Emphasis: Learning and Behavior Disorders

M.A. Asbury University
2009 Wilmore, KY
Emphasis: Learning Disabilities, Behavioral Disorders

B.A. Asbury University
2002 Wilmore, KY
Major: Religious Studies

PROFESSIONAL EXPERIENCES

2010- 2014 Graduate Assistant, Department of Early Childhood, Special Education and Rehabilitation Counseling, University of Kentucky, Lexington, KY
Funding Source: Institute of Education Sciences, Goal 3, Cognition and Student Learning in Special Education
Title: Evaluating the Efficacy of Enhanced Anchored Instruction for Middle School Students with Learning Disabilities in Math
PI: Professor Brian Bottge

2011-Present Faculty Member & Coordinator of the Support Program for Students with Learning Differences. School of Education Faculty, Asbury University, Wilmore, KY
• Behavioral Interventions, Exceptional Learner, and Introduction to Students with Learning and Behavior Disorders
• Math for Special Populations
• Methods and Assessment
• Interventions for Differentiation
• GEN 110 Seminar for students in the support program
2008-2010  *Special Education Teacher*, West Jessamine High School, Nicholasville, KY. Developed and implemented intensive behavioral support program for students at risk for failure, drop-out, and/or expulsion; served as caseload manager for special education students at a traditional high school in Jessamine County; nominated for Teacher of the Year award during 2008-09 school year.

2007-2008  *Science Teacher, Special Education Caseload Manager*, Providence Alternative Middle School, Wilmore, KY

2002  *Youth Counselor*, Kentucky United Methodist Children’s Home. Provided therapeutic services for at-risk students in the residential and school settings; conducted group sessions, processed new intakes; facilitated completion of the resident’s daily schedules and tasks in residential setting

**RESEARCH AND PUBLICATIONS**

**Journals**


**Presentations/Conference Papers**


Instruction: Mathematics Curriculum for Struggling Middle School Students invited presentation at the annual Council for Exceptional Children (CEC) conference in Philadelphia, PA.


Butler, M., & Horn, C. (2013, March). Examining Collaborative Teaching in Rural and Urban Settings across the state of Kentucky presentation at the annual American Council on Rural Special Education (ACRES), Orlando, FL.


Butler, M. & Roller, T. (2012, September). *Cross Collaboration to Support Clinical-based preparation for Special Educators in the area of Mathematics* presentation at the annual meeting of the Kentucky Association of Teacher Educators (KATE), Georgetown, KY.


Butler, M. (2011, October). *Behavioral Assessment in Schools: Recommendation for Process and Practice & Implications for Teacher Prep Programs* at the Kentucky Association of Teacher Educators (KATE) Annual Conference, Georgetown, KY.


Butler, M. (2010, June). *Tertiary/Tier III Support at a Second Year PBS School: Identification, Implementation, & Reflection* presentation at the Kentucky Center for Instructional Discipline (KYCID) Annual Conference, Richmond, KY.

Butler, M. (2010, April). *Designing and Developing Tier II & Tier III Supports at the school-wide level* professional development session for Jessamine County School District, Nicholasville, KY.
RESEARCH

Research Assistant:


PI Dr. Brian Bottge
University of Kentucky

Co-PIs
Dr. Xin Ma
Dr. Michael Toland
Dr. Jane Jensen
University of Kentucky

Dr. Allen Cohen
University of Georgia

Sun-Joo Cho
Vanderbilt University

Duties include:

• Conduct and coordinate classroom observations
• Assist in training cooperating teachers
• Oversee/monitor scoring test protocols
• Oversee/monitor data entry
• Prepare manuscripts and deliver presentations

UNIVERSITY TEACHING
Asbury University

• SEG 630: Behavioral Interventions, Fall 2010, Fall 2011, Spring 2013, Spring 2014
• SEG 638: Introduction to Learning and Behavioral Disorders, Summer 2011, Summer 2012, Fall 2012, Summer 2013, Fall 2013
• EDG 628: Interventions and Differentiation, Fall 2011, Spring 2012, Summer 2012, Fall 2012, Summer 2013
• SEG 320/520: Special Populations, Spring 2011, Summer 2012, Fall 2012, Spring 2014
• SEG 642: Mathematics for Special Populations, *Spring 2012, Spring 2013*
• SEG 660: Methods and Assessment, *Fall 2011 and Fall 2012*
• SEG 672: Methods and Assessment, *Spring 2012 and Spring 2013*
• SEG 632: Collaboration and Advocacy, *Summer 2013*
• ED 405/505: Learning Performance & Assessment, *Summer 2013, Fall 2013*
• ED 428: Interventions and Differentiation, *Summer 2013, Fall 2013, Spring 2014*
• Gen 110: Seminar for Students in Support Program at AU, *Fall 2011 and Spring 2012*

*Online Course Developer for the following undergraduate and graduate level course at Asbury University*
• EDG 628: Interventions and Differentiation
• EDA 320/520: Exceptional Learner
• SEG 638: Introduction to Learning & Behavioral Disorders
• EDA 428: Interventions and Differentiation
• SEG 660: Methods & Assessment I
• SEG 632: Collaboration and Advocacy
• SEG 670 (co-developer): Research Stats/Single-Subject Design
• SEG 672: Methods & Assessment II

*Funded Grants/Awards*

*Arvle and Ellen Thacker Research Fund,* Mark D. Butler, Dissertation Award, Spring 2014, $350.00 USD

*School of Education Faculty Mini-Grant Fund,* Mark D. Butler, Research Funding, Spring 2014, $ 610.00 USD

2013 WHAS Crusade for Children Grant, Channon Horn & Mark D. Butler on behalf of Asbury University, $35,000.00

2012 WHAS Crusade for Children Grant, Channon Horn & Mark D. Butler on behalf of Asbury University, $30,000.00

2011 WHAS Crusade for Children Grant, Channon Horn, Mark D. Butler, & Barbara Kennedy on behalf of Asbury University, $25,000.00

*Affiliations/Memberships*

Teaching license in State of KY, Learning and Behavior Disorders, P-12
Member of Council of Exceptional Children (CEC)
Member of Kentucky Council of Exceptional Children (CEC)
Member of American Council on Rural Special Educators (ACRES)
Member of American Educational Research Association (AERA)
Member of Kentucky Association of Teacher Educators (KATE)