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UTILITY OF AN ERROR ANALYSIS AND PERFORMANCE DEFICIT  
ASSESSMENT FOR SELECTING BRIEF INTERVENTIONS TO  
INCREASE MATH FLUENCY

by

Aaron Denison

A thesis submitted in partial fulfillment  
of the requirements for the degree

of

EDUCATIONAL SPECIALIST

in

Psychology

Approved:

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Logan, Utah

2013

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**ABSTRACT**

Utility of an Error Analysis and Performance Deficit Assessment for Selecting  
Brief Interventions to Increase Math Fluency

by

Aaron Denison, Educational Specialist

Utah State University, 2013

Major Professor: Donna Gilbertson, Ph.D.  
Department: Psychology

The purpose of this study was to examine the utility of a brief assessment for the selection of an effective instruction to increase fluency performance on computation math problems. Participants were four general education third-grade students who performed below the median score on a classwide administered multiple math skills probe. Students first participated in a brief assessment within a mini-withdrawal design to compare the relative effects of a contingent reward (CR) condition to a baseline condition on math fluency performance using a multiple skills probe. All four students increased performance when given an opportunity to earn an incentive for meeting a performance goal. Increased performance indicated a performance deficit to explain low math performance and that the students would positively respond to a contingent reward intervention on single math skills. To validate this hypothesis, the effects of baseline, CR, and instruction plus CR on fluency performance over time was assessed using a multiple

baseline design across three single target skills for each student. Of the 12 skills assessed, results from the extended analysis demonstrated that the CR was effective on one skill, instruction plus CR was effective on five skills, and performance improved during baseline on six skills. Post results showed improved performance on the multiple probe for all students but performance was retained over 2 to 4 weeks on 5 of the 12 skills mastered during the study. Discussion focuses on considerations of the utility of a brief assessment approach in the application decision making and for future research.

(88 pages)

## PUBLIC ABSTRACT

### Utility of an Error Analysis and Performance Deficit Assessment for Selecting Brief Interventions to Increase Math Fluency

by

Aaron Denison, Educational Specialist

Utah State University, 2013

Children who struggle with math fluency are typically not provided with the appropriate motivation and instruction for their needs in the regular education classroom. Because of their lack of math fluency skills, these children can be negatively affected throughout their education and can continually fall further behind their peers. It is clear that children who struggle with math fluency should be provided with interventions specific to their needs in order to thrive in a school environment. Thus, it is critical that school psychologists and researchers develop effective strategies for children who are struggling with math fluency in order to help them gain the necessary skills and speed to thrive at school. It is also important to support a child with a brief intervention to limit the amount of time the student misses ongoing classroom instruction.

Research on one approach called brief assessments has shown this approach to be effective in identifying interventions. In this study, the validity of a brief assessment that may be used identify two possibilities about the cause of the problem was examined: (1) a *can't do* problem due to lack of skill ability or mastery or (2) a *won't do* problem due to lack of motivation. Identifying the cause helps to select an intervention. A *can't do* problem would require more intense instruction and practice and a *won't do* problem requires an incentive for improved performance. Some children require both instruction and incentives.

Four general education third-grade students participated in a classwide 2-minute math probe that consisted of multiple third-grade math problems. All students were referred by teachers for math support, performed below the majority of their peers, and fell below a mastery criterion on the classwide assessment. The four students participated in a brief assessment to determine the cause of the problem. Students were given the math probe again but were told that if they increased their score on the classwide assessment, they would be allowed to pick a prize. Because all students increased their score by more than 30%, it was hypothesized that all students had a *won't do* problem and would

positively respond to an incentive intervention to learn single math skills. To validate this hypothesis, students were then given three different math sessions on three different skills until the student reached benchmark levels for two sessions: an assessment-only condition, an incentive 5-minute condition, and an instruction plus incentives 10-minute condition. All children reached a mastery criterion on three single math skills. Of the 12 skills assessed, incentives was an effective intervention for one target skill, instruction plus incentives was effective for five target skills, and the assessment-only was effective for six target skills. Growth on the assessment-only condition may potentially be due to practice effects, feedback, or motivation due to increased scores. Performance improved on the classwide multiple probe administered to all students at the end of the study; however, performance was retained for 2 to 4 weeks on half of the 12 target skills mastered during the study.

In sum, students responded differently to the interventions and each student responded differently to interventions across the three skills. The low response on the intervention with incentives only did not validate the *won't do* hypothesis that was developed from the brief assessment results. Thus, although the multiple probe may be more efficient, the results suggested it was not effective selecting correct hypotheses across skills and this brief assessment may need to be administered for each skill.

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Aaron Denison



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## CHAPTER I

### INTRODUCTION

Mathematical skills are necessary to solve daily real-life problems and to perform numerous jobs, yet many students in United States schools struggle with learning math skills and approximately 6% of these students have a learning disability in the area of mathematics (Carson & Eckert, 2003). Additionally, 66% of students who have a mathematical learning disability identified before fifth grade continue having math skill problems in subsequent grades (Mazzocco, 2005). Although knowledge of multiple skills contribute to a student's ability to solve math problems, a recent report from the National Mathematics Advisory Panel (NMAP, 2008) purports that high accuracy and rates, or fluent performance, on math facts and computational skills is a critical factor that influences successful math progress when learning more complex skills in subsequent school years. A lack of accurate and fluent performance may limit students' ability to understand and proficiently perform higher level math concepts or more applied math problems (Gersten & Chard, 1999). Given that studies suggest that early interventions that target fluency building can effectively increase skill proficiency (Gersten, Jordan, & Flojo, 2005), the selection and application of appropriate math interventions that remediate individual student problems are necessary for students who struggle with math.

The selection of an appropriate intervention depends on the function or reason for poor performance (VanDerHeyden & Witt, 2007). Reasons for poor math performance may first be simply categorized into two different types of problems: a performance deficit (*won't do* problem) or a skill deficit (*can't do* problem). A performance deficit is

defined as a problem that is caused by a lack of motivation by the student, meaning that the behavioral effort that is needed to do the assignment is not supported by the consequential outcome or reward that the student receives for completing the work.

General interventions used to address performance deficits are contingent reinforcement, goal setting, and timed sprints (VanDerHeyden & Witt, 2007). A skill deficit is defined as a problem which is caused from failed attempts to learn the instructional skills, suggesting that the student needs further instruction, or a new way of delivering the information. Some typical interventions used to address skill deficits are cover-copy-compare and performance feedback (Coddington et al., 2009a).

One promising method, brief experimental analysis (BEA), has been employed by researchers as an assessment tool to select an academic intervention that would best match academic problems for an individual student over time (Daly, Witt, Martens, & Dool, 1997). Generally, BEA is used when a student is not progressing at the same rate as the other students of his/her class and the student's current performance is below the expected performance of the class. BEA is a method to quickly apply and compare the effects of multiple intervention options on an identified student's performance to select the most optimal intervention that meets individual needs or address different reasons for poor math performance. Thus, direct measurement of a student's academic performance is combined with the selection of an academic intervention. Researchers have often used curriculum-based measurement (CBM), a psychometrically validated progress monitoring assessment tool, to measure students' academic performance rates (Deno, 1985, 2003; Shinn, 1989). A CBM assessment on mathematic skills is conducted by

having students complete problems on a math worksheet for one to five minutes to obtain math fluency (i.e., number of digits correct per minute [dcpm]) on single or multiple skills. Due to the sensitivity to treatment changes, CBM can be used as a tool which will quickly and efficiently determine the effectiveness of an intervention. Evaluating and comparing the effects of different interventions on fluency rates obtained from a brief CBM assessment provides an empirically supported method that allows the direct assessment and selection of an intervention that may best meet a student's specific needs over time.

Research efforts have been primarily focused on the development and validation of experimental analysis methods that will allow practitioners to briefly test instructional interventions in the area of reading (Daly, Bonfiglio, Mattson, Persampieri, & Foreman-Yates, 2005; Daly, Bonfiglio, Mattson, Persampieri, & Foreman-Yates, 2006a; Jones & Wickstrom, 2002). Findings from studies on the predictive validity of BEA in the area of reading have shown that the effects of selected interventions may be idiosyncratic across students (Daly, Martens, Dool, & Hintze, 1998) and improve reading fluency performance over time (Eckert, Ardoin, Daly, & Martens, 2002). Moreover, the distinction between skill-based versus performance-based deficits has proven useful in identifying effective instruction in several studies that have used BEA methods to discriminate between students' performance-based and skill-based instructional needs (Duhon et al., 2004; Eckert, Ardoin, Daisey, & Scarola, 2000; Eckert et al., 2002; Noell, et al., 1998). With BEA identified interventions reading performance can increase, which shows the importance and necessity to continue research on BEA methods that provide

brief techniques to discern individually appropriate interventions for students struggling with math concepts. Although there have only been a few studies conducted on BEA concerning math interventions, the results have shown successful selection of effective interventions that facilitated math performance and met the idiosyncratic needs of the participating students (Carson & Eckert, 2003; Coddling et al. 2009a; Gilbertson, Witt, Duhon, & Dufrene, 2008; VanDerHeyden & Burns, 2009). Given these promising results, the purpose of this study was to further examine the feasibility of conducting experimental analyses of math skills with elementary students for individual decision making.



## **CHAPTER II**

### **LITERATURE REVIEW**

#### **Math Performance in American Schools**

Research concerning effective academic progress monitoring assessment and intervention has garnered a considerable amount of awareness in the past several years primarily due to the No Child Left Behind Act (NCLB) and the Individuals with Disabilities Education Act (IDEA) amendments of 2004. The focus in these two federal laws on progress monitoring and preventative intervention as effective methods to improve the education of all children has resulted in an increase in research on the assessment and intervention of reading in elementary aged students (McCurdy, Daly, Gortmaker, Bonfiglio, & Persampieri, 2006). However, mathematics has not received the same amount of attention that reading has been given (Coddington et al., 2009a). Swanson, Hoskyn, and Lee (1999) found that only 10% of the academic intervention studies conducted in the classroom with students with disabilities over a 20-year span examined intervention effects on math performance. Still, mathematics are viewed as a skill that is necessary for successful functioning in a variety of life situations, such as employment, home and family, and community involvement (Carson & Eckert, 2003). The lack of research in mathematics assessment and intervention should not be attributed to a low prevalence of math disabilities given that up to 6% of school-aged children experience learning disabilities in mathematics (Carson & Eckert, 2003; Fleischner & Manheimer, 1997). Research suggests that 66% of children who have a mathematic disability in

elementary school continue with that disability into subsequent grades (Mazzocco, 2005). Moreover, many students in the general population are also exhibiting math deficits. In a recent review of students' national test scores on a yearly administered math proficiency test, only 39% of students in grade 4 performed to a minimum standard of proficiency in mathematics, while 69% of students in grade 8 and 61% of students in grade 12 scored above the basic level (National Center for Education Statistics [NCES], 2009). Students from families living in poverty seem to be especially at risk for poor math performance (NCES, 2009). Given the prevalence of students who are struggling in math, future research should focus on effective strategies to identify interventions to increase more students' math performance.

### **Problem Identification in the Area of Math**

Identifying the type of problem that is occurring is essential in determining the intervention needed to resolve the problem. For academic problems, an important step in problem identification is to determine whether the student lacks the skills to correctly complete the work, termed a skill deficit or a *can't do* problem, or whether the student simply lacks the motivation to do the work, which is termed a performance deficit or a *won't do* problem. This is a necessary and important distinction because interventions useful for skill problems may not be useful for performance problems and vice-versa (VanDerHeyden & Witt, 2007).

A *can't do* or a skill deficit problem may be caused due to a lack of skill acquisition, where the student never completely learned the skill and cannot successfully

complete the work that is expected in the classroom (VenDerHeyden & Witt, 2007).

However, Skinner (1998) noted that this was not the only reason students may exhibit a skill problem. This may also be due to generalization deficits, where the student properly acquires a skill but is unable to generalize it to a different environment. Another possible reason is that students may be unable to determine which skills are necessary for the appropriate context.

For skills deficits, instructional interventions have been selected based on the conceptual framework termed the instructional hierarchy (IH). This framework proposed by Haring, Lovitt, Eaton, and Hansen (1978) suggested that there were four different learning stages: acquisition, fluency building, generalization, and application. Each of these stages may require distinct instructional variables to promote student outcomes. The first stage, skill accuracy, is when students first learn a skill function and how to appropriately follow the procedures to gain the correct response. This is accomplished with effective teaching practices such as previewing material, explicit step by step instruction, modeling, the use of prompts, guided practice with feedback for promoting skill acquisition and accuracy. Once the skill is acquired, the next stage is fluency building such that students can quickly and automatically perform the skill. Fluency building strategies provide practice opportunities in a rapid manner on a daily basis followed by performance feedback, to increase the rate of correct responses. Next, students are able to generalize the fluent skills to more novel setting or tasks. To enhance generalization and application, learning of new strategies are sequentially hierarchically presented such that all skills needed to complete more complex skills are fluent. The IH

framework provides several distinct levels of learning that corresponds to specific instructional procedures to help identify functional variables to add to an intervention designed to remediate skill deficits.

A *won't do* or a performance deficit problem is due to the student's lack of motivation to complete the skill. Examples of interventions for performance deficit problems are goal setting and contingent reinforcement (VanDerHeyden & Witt, 2007). Additionally to a lack of consequential outcomes that supports behavior use, Skinner (1998) purported that *won't do* problems may also be related to fluency performance. From a behavioral perspective, when given a choice, students will choose to perform the behavior which requires the least amount of effort or the behavior that produces the quickest and/or higher rates of reinforcement. Fluent performance that is automatic requires little cognitive effort and time, which may result in more immediate reinforcement than slower performance. Slower performance that requires more cognitive effort and time may result in the student choosing not to participate in the assignment unless the student is offered a valued reward which will increase the desire to perform the task. Students who are fluent with a skill will spend less effort and therefore may be more willing to participate in the behavior for less reinforcement than students who struggle with the skill and display much more effort.

According to a recent report from the NMAP (2008), lower proficiency on math facts and computational skills is one key factor that explains why many American students' math test scores are lower than students from other countries. In addition, the absence of computational fluency is commonly observed among students identified as

having a specific mathematical learning disability (Gersten et al., 2005). Instructional time, however, is generally focused on developing accurate skill performance. Once an adequate level of accuracy is obtained, further instructional strategies generally stop (Skinner, 1998). Although accuracy is critical, instruction to promote fluency building is essential in developing the skill to the point where it is efficient and more likely to generalize its use to novel contexts and more able to modify the skill when needed to adapt its use to new demands (Gersten & Chard, 1999). Several studies suggest that early intervention can effectively increase skill proficiency and can avoid further setbacks in academic progress (Gersten et al., 2005). And using conceptual frameworks such as skill or performance deficits or the IH could assist in intervention selection that would most likely have a positive effect on students. Thus, it is important to identify the intervention options available to improve student outcomes that may address various types of math problems. A brief review of research on empirically based mathematics computation interventions that may be implemented to supplement the general education curriculum to increase math performance follows.

### **School-Based Interventions to Address Mathematics Difficulties**

Although research on mathematics computation interventions is limited, several recent reviews have identified several effective intervention options that can be selected to implement with students needing additional mathematics support. Coddling, Hilt-Panahon, Panahon, and Benson (2009b) reviewed 37 studies investigating intervention effects on math computation rates to identify interventions of simple and moderate

intensity. Simple interventions were defined as interventions that improved the academic environment with no change in the process of instruction. Intervention components included contingent reinforcement, performance feedback, goal setting, cue cards, altering instructions or timing, or changing the form of practice opportunities. Moderate interventions were defined as interventions that enhanced the existing classroom instruction such as direct instruction on the weakest skills, increased skill opportunities, or increased pace of instruction. Studies published between 1980 and 2007 included 914 kindergarten to 12<sup>th</sup>-grade students experiencing difficulties in math. Identified simple interventions that included earning free time, flash card practice, goal setting with contingent reinforcement, and count-bys resulted in large effects sizes for most participants (range,  $d = 0.33$  to  $4.74$ ). Moderate interventions that included peer tutoring, cover-copy-compare self-instruction, review of taped problems, and incremental rehearsal, resulted in mostly large effects sizes for most participants (range,  $d = 0.17$  to  $8.59$ ).

Based on the assumption that a student's performance level within the IH four learning phases (acquisition, fluency, generalization, and application) may determine the most relevant intervention for individual students, Burns, Coddling, Boice, and Lukito (2010) reviewed the intervention literature to further investigate the link between skill proficiency level and the effect of an intervention on math performance. Seventeen single-subject studies were reviewed to examine the extent of which acquisition and fluency interventions increased accuracy and rate of completed math computation problems. Studies published between 1989 and 2007 included 55 second- to sixth-grade

students who exhibited low math performance. The effects of these two types of interventions were examined for subjects who were performing in the frustrational level range (i.e., median baseline dcpm scores falling below 14 for second- and third-graders and 24 for fourth- through sixth-grade students) or instructional level range (i.e., baseline median score between 14-31 dcpm for second- and third-graders and 24-49 dcpm for fourth- through sixth-grade students). Percentage of all nonoverlapping data (i.e., the number of intervention points that overlapped the highest baseline data point divided by the total number of data points) was converted to a mean phi coefficient. Acquisition interventions included incremental rehearsal of math facts, strategic math series, and modeling the task through cover-copy-compare. In this review, 21 acquisition interventions applied to frustration-level skills resulted in large effect sizes for most participants (phi coefficient range, 0.76 to 0.93) whereas 15 acquisition interventions applied to instructional-level skills resulted in a small to moderate effect size for instructional level scores (phi coefficient range, 0.29-0.70). Fluency interventions included taped problems, explicit timing, contingent reinforcement for faster completion and independent practice of easier items. These interventions also resulted in higher effect sizes for frustration-level skill than the instructional-level. Twelve fluency interventions with frustration-level skills resulted in small to moderate effect sizes for most participants (phi coefficient range, 0.25 to 0.68) whereas four fluency interventions for instructional-level skills resulted in percentage of all nonoverlapping data of 0%. These results suggested that acquisition interventions were found to be suitable for children who perform below the frustration level. However, fluency interventions for

instructional-level skills resulted in inconclusive results because of the limited number of studies. Although more research is warranted, an assessment of skill performance when identifying math problems might be helpful for matching skill levels with a specific intervention.

Clearly, these reviews indicate some intervention options that may remediate math deficits. Although limited, there is some evidence that the level math performance of struggling students may be linked to interventions that have a high likelihood for success for resolving specific types of math learning problems or stages. Individual differences between students emphasize the need to identify which intervention components may be necessary for a particular student. A review of the research on an approach, brief experimental analysis, which combines the direct measurement of a students' academic performance with the selection of an academic intervention, follows.

### **Brief Experimental Analysis Using CBM**

There is an emerging area of study in which researchers employ brief experimental analysis (BEA) to predict an academic intervention that would optimally address the academic concerns that have been raised for individual students (Daly et al., 1997). BEA may be used when a student is not learning at the same rate as other students and there is a discrepancy between a student's current and expected performance.

Because diverse individual needs makes it difficult to predict what intervention would work best, BEA is a method to briefly test out and compare various treatment effects on academic performance before an intervention is implemented over time. Treatments are



selected prior to the BEA based on a conceptual framework, such as skill verses performance deficits or IH. The source of an identified academic problem is then explored by observing and comparing change in academic performance between a series of planned motivational and instructional variables that are directly administered with a student (Jones, Wickstrom, & Daly, 2009).

Curriculum-based measurement, or CBM, is typically used to assess student academic performance. CBM is a reliable, sensitive, efficient, and validated assessment method for monitoring student using standardized directions and brief repeated fluency timings. This measure can be used to evaluate growth over time (Fuchs, Fuchs, Hamlett, Walz, & Germann, 1993) and to provide information about when to modify instruction (Deno, Fuchs, Marston, & Shin, 2001). For math, students complete problems on a worksheet for one to five minutes and the change in number of dcpm is monitored (Shinn, 1989). For the BEA process, using a single-case experimental design, each selected treatment is administered to the student on a skill(s) for one session for 5 to 15 minutes. Immediately following the intervention, a CBM is readministered to assess the effect of the intervention on academic performance relative to the no treatment assessment. Results of the CBM assessment conducted after each intervention trial is compared to the no treatment CBM assessment (i.e., baseline) to determine which administered intervention was the most effective relative to baseline. Thus, the CBM data can be used to determine how to effectively modify instruction. Experimental control is also demonstrated when a clear, immediate change in behavior is replicated when the most effective and least intrusive intervention is readministered a second time with the

student being evaluated (Martens & Gertz, 2009). Data showing the most effective intervention tested provides preliminary data regarding the treatment that will most likely produce the greatest academic gain over time.

Although there has largely been empirical based support for the predictive utility of the BEA approach for identifying individualized intervention to increase reading (e.g., Daly et al., 1998; Daly, Murdoch, Lillenstein, Webber, & Lentz, 2002; Jones & Wickerstrom, 2002), only a few researchers have investigated the effects of the BEA procedures to select interventions to increase math performance. The selection of math intervention strategies to implement and assess within the context of BEA have relied largely on functional reasons why students are not performing as expected. For example, Duhon and colleagues (2004) investigated a BEA approach for differentiating between skill and performance deficits. The study included four male students aged 8 to 10 years old, referred for intervention by teachers for poor academic performance. At the onset of the study, students and their classmates were administered a classwide math CBM assessment in reading, math, and writing. All participants were performing below a preset mastery dcpm criterion and within the lower 16<sup>th</sup> percentile of the class in one academic area. An incentives condition was administered with the students that provided an opportunity to earn an incentive if they performed at a specified level. If a student demonstrated an appropriate skill level with incentives, then this result suggested that the child was exhibiting a performance deficit and would most likely benefit from an intervention providing reward for academic improvements. Alternatively, when a student did not respond to incentives, then it was hypothesized that the child was exhibiting a

skill deficit and would benefit from an instructional intervention. Results from this study showed that when an instructional intervention and a contingency-based intervention developed with teacher input were alternatively implemented, two of the four students who exhibited skill deficits academically benefited from the instructional intervention, whereas the other two students exhibiting performance deficits benefited from an intervention involving a contingency based on improved performance. These results suggest that this assessment process is useful for predicting what type of intervention is needed for individual students based on the skill and performance deficit framework.

Although providing contingent reinforcement for performance gains is one effective intervention for improving skills for both fluency and motivational problems, other motivational strategies include providing performance feedback (e.g., Daly et al., 1997), setting performance goals (e.g., Eckert et al., 2000), using explicit timing for task completion (e.g., Rhymer, Skinner, Hennington, D'Reaux, & Sims, 1998), and giving students' choices (e.g., Cosden, Gannon, & Haring, 1995). Given these intervention options, Carson and Eckert (2003) examined the utility of BEA for identification of an intervention that meets individual needs of three elementary-aged students who were students exhibiting performance deficits when learning to master math skills. A performance deficit in this study was defined as low fluency performance (i.e., less than 20 dcpm) and high accuracy (i.e., greater than 85%) on three single-digit math CBM tests. Moreover, differences in student gains in math performance were compared between interventions chosen by students and intervention selected using the BEA approach. First, an empirically based intervention was selected using the BEA approach

in the context of a multielement design with the three participants. The intervention with greatest gains was selected by comparing the effects of a baseline (no treatment) session with four interventions: contingent reinforcement, goal setting, feedback on digits correct, and timed sprint condition. Results revealed that the timed sprint intervention was the BEA selected intervention that showed greatest increase in math fluency (range, 3 to 10 dcpm) relative to the baseline for all three participants. For the student selected intervention, participants ranked the intervention that he or she thought would be the most to least effective in solving mathematical problems. All three participants selected the contingent reinforcement intervention although the rankings of the remaining interventions varied across students. In the second phase of the study, the effect of the BEA selected intervention was compared with a student-selected intervention on math rates using an alternating treatments design. For all students, greatest gains in rate performance were observed with the BEA selected intervention (range, 39 and 42 dcpm) as compared to the student selected intervention (range, 30 to 33 dcpm). Two of the three students scored in a mastery fluency level of performance (i.e., > 40 dcpm) with the BEA selected intervention and the results showed little improvement with the student selected interventions relative to baseline. This research further supports that empirically selected treatments, selected using results from the BEA method, produces gains in mathematical fluency for students exhibiting a performance deficit.

The utility of a brief assessment approach for identifying a potentially effective intervention to improve on-task behavior as well as to improve fluency performance on computation math problems was investigated by Gilberston and colleagues (2008).

Participants in this study included four elementary students referred for intervention services in the general education classroom. A brief individual assessment was conducted with each participant to compare the relative effects of incentives and instruction on math fluency. For all students, fluency performance increased from baseline performance during a contingent reinforcement condition (range, 23% to 42%), but performance fell below a preset mastery criterion. A second assessment condition was administered to examine the additive influence of instruction in the form of fluency practice with contingent reinforcement. Instruction and reward resulted in even greater gains for all students (range, 42% to 86%). Given the performance increased with both reinforcement and instruction, the authors hypothesized that a combination of a skill and performance deficit would be the most effective for all participants. Following the brief assessment, the effects of a baseline condition followed by a reward plus instruction intervention condition on math fluency was evaluated over time using a multiple baseline design across subjects. The intervention consisted of 5 minutes with practice opportunities learning math skills with immediate error correction. Immediately after practice, the student completed a six minute math probe and earned tokens or a reward if he or she met or exceeded a fluency goal. Furthermore, to observe the students' on-task behavior, the experimenters directly observed the four participants while they independently worked on math computation problems taught during the intervention in math class. Greater percentages of on-task were obtained with intervention (range, 60% to 100%) on a moderate difficulty level task for all participants relative to baseline (range, 30% to 65%). Slope of math performance were greatest for three of the four students during the

intervention sessions (range, .3 to 3.0) relative to baseline (range, -1.1 to 0). These results suggest that BEA selected interventions not only increase math fluency, but also increase on-task behavior for at-risk children.

Interventions to be examined within a BEA may also be selected a priori using the IH conceptual framework (Haring et al., 1978). For example, Coddling and colleagues (2009b) investigated the effects of a BEA method to improve math performance that included interventions providing motivational, skill acquisition, and fluency building components. Moreover, procedures were used in this study to examine the generalization effects of the selected treatment on a CBM probe with different but similar problems than the problems practiced and presented on the CBM probe administered after each intervention was given. In this study, a BEA was administered with four students identified as at-risk in math performance using a multielement design to examine the relative effect of four interventions on math fluency as compared to a baseline (no treatment) session. The four interventions included incentive for increased performance (contingent reinforcement), performance feedback on math progress, goal setting, and cover-copy-compare. An extended analysis was conducted using an alternate treatment design to compare the effects of the BEA selected intervention and a no treatment condition on math fluency over time. Similar to the BEA approach, a math CBM probe was administered immediately after the intervention or during a baseline condition. To examine generalization of treatment to different problems, a CBM generalization probe was also conducted after each session during the extended analysis without incentives or treatment. This probe consisted of 50% same and 50% similar but different problems than

the CBM administered to examine the learning of skills taught in the intervention session. Coddling and colleagues found individual differences between student responses to the interventions applied during the BEA such that one student exceeded baseline by 60% with the CCC condition, a second student exceeded baseline by 40% with performance feedback, and the third and fourth exceeded baseline by 20% and 56% with goal setting. During the extended analysis, greater gain in math fluency performance was consistently observed with intervention relative to baseline conditions for all participants. Two of the four participants reached mastery levels ( $>40$  dcpm). However one participant showed greater dcpm levels with intervention than baseline, but did not increase over time during both conditions. Moreover, gains on the generalization assessment relative to baseline were observed for only one of the four students. The authors suggested several reasons why generalizability of BEA in mathematics was low. First, overlap of targeted problems on the treatment assessment and the generalization assessment was 50%. Second, the intervention was administered, at most, twice a week. Third, when the math problem is due to a performance deficit, the student may not be motivated to increase performance on the generalization probe given under baseline condition. Ultimately, these results further support that BEA can be effectively used to identify interventions for students lacking in mathematical skills, however, this study found weak generalization effects.

VanDerHeyden and Burns (2009) explored fluency levels obtained on math CBM probes administered during the BEA and intervention process that would likely predict retention of a fluent skill over time and generalization of skill in a related but more complex problem. In this study, the effect of a classwide peer tutoring intervention on

math computation fluency was assessed for 432 second through fifth-grade elementary school students. A peer mentoring intervention was implemented 4 days a week during the school year. This intervention included three minutes of guided peer practice on one math skill in which prompts and immediate corrective feedback was given during guided practice (to build accuracy), a 2-minute independent practice probe (to build fluency), scoring of probe and error correction, and a group contingency for improved performance. A series of computational math skills were presented weekly in a hierarchical simple to complex sequential order. Three CBM probes were administered: a weekly intervention probe consisting of the weekly single skill taught, a weekly retention probe consisting of previously taught skills, and a monthly progress monitoring probe consisting of all skills. Results showed that, at all grade levels, performing at a mastery fluency level (i.e., 10 dcpm for second to third graders or 20 dcpm for fourth to fifth graders) on an early skill in the skill sequence related positively to mastery of a later more complex skill with small to moderate effect sizes (range,  $\eta^2 = .16$  to  $.35$ ). Results also showed that students in the second and third grades retained fluency performance on the skills learned several months later after they performed at 30 dcpm or higher. Likewise, fourth- and fifth-grade students retained the skills learned after they performed at 60 dcpm or higher. These benchmarks can be beneficial for setting student fluency performance goals that would likely predict retention of the learned skill over time.

Although research on BEA approaches suggests utility for predicting which intervention would most likely produce positive outcomes in math fluency when the selected intervention is applied over time, many questions remain. A review of the BEA



literature targeting reading fluency conducted by Burns and Wagner (2008) cited limitations similar to BEA targeting math outcomes including inconsistent criterion to select optimal BEA interventions and inconsistent extended analysis methods. Due to fewer BEA studies investigating math outcomes, it is less clear if BEA produces differential responding to different interventions between students. The extent that interventions generalize on different math subskills also remains uncertain.

Although motivational strategies have been a primary focus in BEA math outcome studies, results from BEA reading outcome studies show that fewer students respond to the contingent reward condition as compared to an instructional intervention condition or instructional plus a reward condition. Results from Burns' meta-analysis showed that of 11 interventions evaluated for at least five sessions, greatest gains were achieved with a combination of strategies designed to increase accuracy and fluency with and without incentives. Jones and colleagues (2009) reported that of 35 students in nine BEA reading studies, 9%, 51% and 40% were classified as exhibiting a performance deficit, skills deficit, or both, respectively. Unsurprisingly, more intense intervention is more effective for more students but feasibility is just as important in school settings. Thus, intensive treatment factors applied within a BEA approach must consider administration time, student's time away from ongoing regular educational instruction, training issues, and personal availability both during the administration of the BEA and implementation of the selected intervention. Given this concern, Daly, Persampieri, McCurdy, and Gortmaker (2005) conducted a BEA method that first evaluated the effect of an intense intervention and then sequentially reduced instructional and motivational

components to identify the simplest intervention that produces similar performance gains as the strongest treatment package. Daly and colleagues (2005) conducted BEA in three phases with two elementary students experiencing reading difficulties. The first phase included a treatment package consisting of both skill- and performance-based strategies and a control condition. Then, the treatment was simplified by evaluating the effect of single skill-based and performance-based instructional components. Using this approach, the most intense intervention was set as a comparative criterion to compare if similar effects are obtained with less intensive treatments. Results of this BEA method revealed a reinforcement-only for one student and the treatment package for the other student as the most effective treatment that led to increases in reading performance over time. Given the disruption of learning when behavior problems occur, additional conditions or intervention variables may also be examined to reduce problem behaviors that often occur when administered to a group of students. Some example of these types of components may include error-less teaching, providing choice, or contingent escape (Daly, Garbacz, Olson, Persampieri, & Ni, 2006b).

Given that schools are focusing more on the identification and evaluation of math interventions that remediate math deficits for diverse student populations within the general education setting and using the data to make special education eligibility decisions, more research is warranted to guide the predictive utility of BEA for treatment selection to improve math outcomes. Because math consists of many skills, an efficient BEA targeting math outcomes would be one that could identify one intensive intervention that quickly boosts accurate and fluent performance across computational math skills.

### **Utility of Skills Analysis for Selecting Effective Instruction**

The type of probe used in BEA may also enhance the utility of the process. For example, Fuchs, Fuchs, Hamlett, and Stecker (1990) investigated the utility of a skills or error analysis approach which was incorporated into a CBM probe on math performance on instructional modifications. Thirty randomly selected special educators participated in this study with a total of 91 students in grades three through nine. Each student was classified as either learning disabled or emotionally disturbed and had a current IEP with mathematics goals. Teachers were randomly assigned to one of three groups: (1) CBM monitoring with graphed math performance goals and skills analysis, (2) CBM monitoring with graphed math performance goals only, or (3) a control group with CBM monitoring only. All students in the treatment conditions were administered a grade-level skills-analysis CBM probe twice weekly for 15 weeks using a computer program to administer and score probes. For each student in the two treatment groups, teachers calculated a median baseline performance from three baseline measurements and set a performance criterion that the student could achieve by the end of the year. After collecting eight data points teachers reviewed student data, graphed with a line of best fit and a goal aim line. Based on this data teachers selected and received feedback on the corrective choice of one of four decisions: make a teaching change, raise the goal, move to a higher grade level for measurement, or insufficient data for analysis. For each student in the skills analysis group, teachers were also given the information on student scores on specific skill objectives on the probes indicating if the skill was not attempted, non-mastered, partially mastered, or mastered. Results indicated that students in the goal

review plus skills analysis condition significantly outperformed students in both the goal review condition and control condition on the CBM ( $p < .05$ ) and on a state-wide math assessment. Differences between the Goal plus Skills analysis review and the Control groups, Goal plus Skills analysis review and Goal only groups, and Goal only and Control groups were associated with effect sizes of .67, .55 and .26 dcpm, respectively. Although results suggest that teachers may have implemented instructional modifications after reviewing the skill analysis CBM results, teacher instruction was not observed in this study. Thus, additional research is needed to ascertain the degree that the inclusion of skills analysis type of CBM data lead to optimal interventions that improve student outcomes.

Given that skills analysis may enhance the quality of information about student progress by pinpointing specific skills for instruction, use of a CBM probe that allows a skill or error analysis of a series of skills when administering a BEA may enhance the utility of BEA for remediating math deficits. Given that the BEA method allows direct observation of behavior change with various types of remediation instructional and motivational components, a skill analysis probe administered to evaluate treatment effects may also provide useful information about intervention effectiveness across skill domains. The goal of an error or skill analysis is to identify the patterns of errors made by a student in order to understand why students make the errors to help develop instruction to correct the errors. According to Tindal and Marston (1990), there are common computational errors that may be examined in a multiple skill CBM probe. For example, errors in regrouping, carrying 10s, incorrect operation, or ignoring place value in

division. These types of errors are simple steps within a math problem that may be quickly remediated with additional instruction or practice when identified. However, individual differences may influence what type of instruction or motivational strategy would be most effective across skills.

### **Purpose of the Study**

Students struggle in math for various reasons. Poor math performance may be due to low motivation, poor accuracy and/or low fluency rates on computational math skills. There is strong evidence supporting that early intervention targeting the reason for the poor performance prevents severe math deficits from developing over time. Further, VanDerHeyden and Burns (2009) provided evidence that early math skills must be learned before more complex skills are mastered. Potential individual differences in math deficits emphasize the need to identify which intervention may be necessary for a particular student. Several studies have empirically demonstrated how brief experimental analysis (BEA) may be a useful and cost-efficient assessment approach for making treatment decisions about students who are not responding to regular classroom instruction (Martens & Gertz, 2009). A number of these studies have examined the effects of instructional and motivational variables on math computational fluency (Carson & Eckert, 2003; Coddling et al., 2009a; Gilbertson et al., 2008; VanDerHeyden & Burns, 2009). Math fluency is a legitimate indicator of student progress given that it is a sensitive measure for students' skill proficiency that seems to predict skill retention and generalization (VanDerHeyden & Burns, 2009). However, few studies have applied

results of a BEA approach across different math subskills. Although BEA is effective for reading, math differs from reading in that many skills are taught and evaluated.

Moreover, there are common math errors that may be corrected with minimal effort and time, that may improve performance on more complex skills. Using a skills analysis approach may facilitate the appropriate selection of instruction that enhances student learning over time (Fuchs et al., 1990). Thus, the purpose of this study was to replicate and extend previous research that evaluated treatment effect on math fluency within the BEA framework (Carson & Eckert, 2003; Coddling et al., 2009a; Gilbertson et al., 2008; VanDerHeyden & Burns, 2009). Specifically, procedures were used to examine the effect of interventions addressing skill- and performance-based reasons for mathematic calculation problems that incorporate a skill analysis approach and to examine the impact of the selected intervention on the fluency and retention of at least two different math subskill deficits based on result of a brief assessment approach on a progress monitoring assessment. Specific research questions included the following.

1. To what extent do four students experiencing difficulties with math skills show individual differences on the performance or skill deficit hypotheses suggested by a brief contingent reward assessment to distinguish between a *won't do* and *can't do* problem?
2. What are the effects of the selected functionally relevant intervention on math fluency across computational skills and time during the extended analysis?
3. How many interventions sessions are required to remediate computational skill deficits to a benchmark rate criterion across all skills?

## **CHAPTER III**

### **METHODS**

#### **Setting**

Participants involved in this study were recruited from a public elementary school located in a rural district in a western state. The school population consisted of approximately 543 students from kindergarten through fifth grade consisted of 2% Latino, 1% Asian, 1% Black, 82% Caucasian, and 14% race/ethnicity unknown students. Approximately 33% of these students qualified for federal free or reduced lunch program and 7% for special education services.

Experimental sessions were implemented by trained psychology graduate and undergraduate students who conducted experimental procedures at a small table in an empty classroom setting at the school.

#### **Participants**

Three male and one female third grade general education Caucasian students, who met the following criteria, were included in this study. Participants were (a) reported by the teacher as not performing as expected in math class and elected as a student who may benefit from supplementary instructional support, (b) performed below peer median score and performance benchmark standards on a classwide math curriculum based measurement screening measure that may have been given to all students by school personnel prior to the study as part of a classwide assessment, and (c) provided parental

written informed consent and student assent for participation. Four students (Robert, Lenny, Steven, and Jenna) were asked to participate in the study and all four participants agreed. No student had received additional supports in addition instruction in the general education classroom during the school year.

### **Math Measures and Materials**

Two different math CBM measures were used in this study: a skill analysis (SA) measure consisting of multiple skills and a subskill (SS) measure consisting of one skill. Each measure consisted of problems that were presented vertically on 8½ by 11-inch worksheets with about five problems per row. Reliability for computation outcome measures has been shown to be adequate ( $r = .83-.93$ ; Shinn 2004). Criterion validity ranged from .36 to .62 (Thurber, Shinn, & Smolkowski, 2002). The test-retest ( $r = .79$ ) and parallel forms (.61-.79) of reliability for single or multiple computation problem probes are adequate (Foegen, Jiban, & Deno, 2007). Each measure was timed using standardized direction according to Shinn (1989). A description of the amount of time that each measure was administered and types of problems on each of the three math measures follows.

#### **Skills Analysis Measure**

A skills analysis (SA) measured math CBM measure in this study consisted of a page of problems addressing grade level computational math skills (e.g., adding single digit or double numbers, multiplying single digit numbers) in hierarchical order of skill difficulty (Skinner, 1998). These measures were created to enable the identification of



possible areas of intervention for math computation skills using skills analysis (Fuchs et al., 1990). This measure was also designed to minimize mastery of basic facts to focus on mastery of computation steps. To accomplish this, each problem represented a skill step that can be taught within a brief (i.e., 5-minute) lesson using a coach card. Moreover, all problems were comprised of facts that would require minimum finger counting or mental counting to reduce the lack of fluency of basic facts that would influence performance on more complex math computation skills. For example,  $21 + 13$  rather than  $45 + 36$  can be used for a double digit addition problem with no regrouping. The problems were selected from third grade level basic math skills as determined by district curriculum requirements, content of classroom math book, and teacher input. The number of problems on each measure was selected such that correctly written answers would have ample number of digits correct to ensure that all students who had mastered the skill would not finish during a two or three minute timed session. See Appendix A as an example of this type of probe.

### **Subskill Math Measures**

The subskill (SS) math CBM measures were constructed to consist of individual problems consisting of one of the skills presented on the above SA measures. The number of problems on this measure were selected such that correctly written answers would equal 50 or more digits correct to ensure that all students who had mastered the skill would not finish during a 30-second timed administration. SS skill measures were created for each skill using a Microsoft Excel spreadsheet configured to generate a different problem order for each measure to control for the influence of possible ordering

effect of problems and learning due to memorization of answers if problems were given in a constant order. See Appendix B as an example of this type of probe.

### **Dependent Variables or Response Definitions**

The primary dependent variable in this study was math computational fluency, which was calculated as the total number of digits correctly written and placed correctly per minute (dcpm). A digit was scored as correct if the digit is the correct answer and in the correct place even if the number was reversed or rotated. Alternatively, digits were scored as incorrect if the digit was an incorrect digit, a correctly written digit appeared in the wrong place value, or the correct digit was omitted (Shapiro, 2004).

### **Independent Variables or Experimental Conditions**

#### **Baseline**

An SS measure was administered during baseline to monitor participants' math performance without supplemental intervention. During baseline sessions, a researcher administered a timed SS measure to a student then calculated the math fluency performance score and shared the score with the student. No incentives or instruction were offered during baseline (see protocol in Appendix C).

#### **Contingent Reinforcement**

The contingent reinforcement (CR) condition was designed to evaluate performance with incentives by providing incentives upon meeting a math goal on a CBM measure. Before completing a timed measure, students were told that they could

earn a reward if the student's score on the measure met or exceeded a goal. The first goal presented was the highest score obtained during baseline followed by any higher score obtained on any subsequent probe. After the researcher scored the measure and shared the results with students, the students earned the reward. Possible rewards included small toys, games, edibles, and books (see protocol in Appendix D).

### **Instruction Plus Contingent Reinforcement**

In this condition, CR and instructional strategies were used. This began with the instruction designed to provide step-by-step talk-aloud rule guidelines, practice opportunities with immediate error correction to promote accuracy, and fluency on a specific math skill on a CBM measure (Schuster, Stevens, & Doak, 1990). In addition time-delayed prompting, an error-less learning technique, was employed to prevent problem behaviors (Touchette & Howard, 1984). More specifically, the researcher began the session by giving a goal to earn a prize. Second, math rules required to complete problems on the measure were given, the researcher completed two problems while talking out loud, explaining how he or she is completing the problem using the rule(s) to the student. Third, students were asked to verbally repeat the rules while completing problems until the rule and problem is correct for two problems. The errorless learning strategy was also applied as students complete problems. That is, whenever a student hesitated more than 5 seconds or wrote an incorrect digit, the correct digit was immediately provided to the student and the student corrected the problem. Fourth, the student practiced independently with immediate feedback using the cover-copy-compare technique. At this time, the student was given a copy of the answers to the current

worksheet. The student worked on four problems and then turned the answer sheet over and compared the answers. Finally, the student was administered a 30-second timed SS measure following the same procedures described in the CR condition to earn a prize if he or she met or exceeded the goal. This condition was administered about 10 minutes per session (see protocol in Appendix E).

## **Procedures and Experimental Design**

### **Recruitment of Participants and Classwide Preassessment**

Participant recruitment procedures began with asking two third-grade teachers to refer students who were not performing as expected in math class and would benefit from supplementary instructional support. The teachers each referred two students and agreed to administer a classwide 2-minute timed SA probe to further confirm student performance levels relative to peers. SA measures were administered to students and classmates by a researcher in the classroom with the teacher for a 2-minute timed assessment. Probes were administered using procedures described in Shinn (1989) and in the VanDerHeyden and Burns (2009) study, such that the researcher instructed students to try to complete every problem and not to skip around, set and start a timer, and then telling student to begin. Students were prompted to move on if they stopped to work on a problem (see protocol in Appendix F). The timed measure was scored to determine dcpm and each skill problem was scored to determine correct and incorrect answers.

Four students that were identified based on low scores relative to class mean and teacher referral were provided with a consent form to give to his or her parents and

earned a small prize for returning the form (with or without consent) to the teacher or researcher (see Appendix G). When the students returned the form with parent consent, a verbal and written summary of the study rationale and procedures were provided to request informed assent from the student. This was done with IRB approval from the Utah State University and Cache County School District approval.

### **Brief CR Assessment**

A brief CR assessment was individually conducted outside of class with each participant to generate one of two hypothesis: (1) performance was related to incentive or (2) performance was related to a combination of incentive and insufficient instruction and practice (Duhon et al., 2004; Gilbertson et al., 2008). During this condition, each student was readministered an SA measure with similar skills presented in the same order as the SA measure given in the preassessment but with slight variation in numbers within each problem (e.g., changing the problem  $21 + 13$  to  $12 + 31$ ). Prior to the administration of each math measure, the researcher informed each student that a reward of his or her choice (e.g., small toys, edibles) could be earned by meeting or exceeding a goal. Similar to prior studies (Coddling, Archer, & Connell, 2010; Jones & Wickstrom, 2002), the goal criterion was set by multiplying the student's score obtained on the SA measure during the above pre-assessment of math skill performance by 30%. The criterion of 30% was set to reduce the likelihood that a student identified as exhibiting a *won't do* problem is, in fact, a *can't do* problem who needs a more intensive instructional intervention. Students were allowed to briefly examine a box filled with approximately 20 different prizes before the SA measure was administered. After the researcher scored the measure

and shared the results with the student, a reward was given if the goal was exceeded. For each student, the brief assessment was completed in five minutes or less.

Based on the results of the brief assessment, one of two hypotheses was developed based on assessment results. First, if a student met or exceeded the preset criterion for performance with contingent reward, then it was hypothesized that the student required an intervention with incentives for meeting performance goals. If a student did not exceed the preset criterion, then it was hypothesized that the student required an instructional intervention on missed skills.

Finally, a mini-withdrawal design was used to compare the relative effects of the CR intervention condition to the SA baseline, on math fluency, for each participant (Martens, Eckert, Bradley, & Ardoin, 1999). That is, the students were re-administered a SA probe without incentives (baseline) and an SA probe with incentives (CR) to replicate results between the above pre-assessment and CR results.

### **Extended Analysis**

A multiple-baseline design (MBD) across math skills and participants was used to analyze the effect of a baseline, CR, and CR + I treatment on math fluency on three different SS skill measures (Barlow & Hersen, 1984). Three incorrect skill problems on the SA probe administered during the preassessment of math skill performance was the computation skills that were presented on the SS skill measures. Following a stable or decreasing baseline performance, the BEA intervention was implemented using a staggered approach across three math skills for each participant. A skill was considered to be mastered when math fluency performance was at or above the 30 dcpm score that

predicted math skill retention over time in the VanDerHeyden and Burns (2009) study for third grade students. Two to three experimental conditions were administered to each student for 5 to 20 minutes at the end of a school day with a two minute break immediately after the administration of a condition.

### **Follow Up**

The three SS skill probes were administered at least 1 week after the end of the study to estimate retention of fluency performance over time. Also, a post assessment that was identical to the pre EA assessment was administered to assess for generalization of mathematics skills.

### **Integrity of Experimental Procedure**

Adherence to the experimental procedures (i.e., administration of pre-assessment, brief assessment, baseline, and intervention) was evaluated for 50% of each student's sessions by an independent trained observer. Integrity of experimental procedures was calculated as a percentage of the correct steps completed, divided by the total number of procedure steps multiplied by 100. All experimental procedures were conducted with 100% integrity for each participant.

### **Interrater Agreement**

Interrater agreement of the dependent variable was evaluated by two independent raters for 30% of the administered math measures across all participants and experimental phases. Scorer agreement was calculated on an item-by-item basis: agreements (i.e., both raters agreed that the digit was correct) were divided by agreements plus disagreements

with the remainder multiplied by 100%. The mean inter-rater agreement on the probes was 100%.

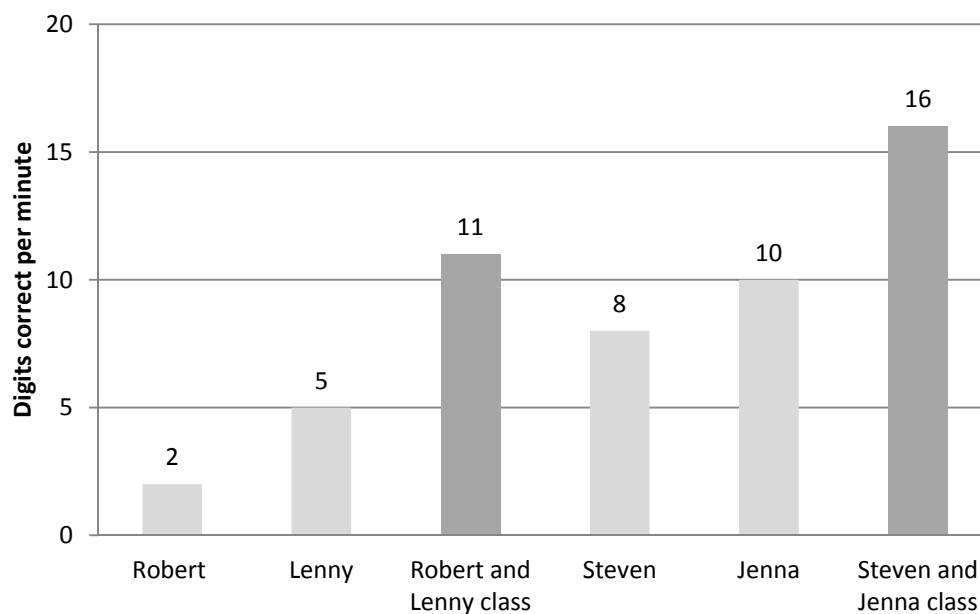


## CHAPTER IV

### RESULTS

#### Preintervention Assessment of Academic Skills

Each participant's dcpm score and the median dcpm score of all student scores in the class on the SA probe administered to the entire class are presented in Figure 1. Results from the classwide screening revealed that the scores of the four participating students fell below the class median and the grade level benchmark criterion (i.e., 30 dcpm; VanDerHeyden & Burns, 2005). There were a total of 24 out of 29 students in Robert and Lenny's class and 11 out of 24 students in Steven and Jenna's class that fell below the benchmark criterion. However, percentile rank scores of all four participants fell below the 16<sup>th</sup> percentile when compared to the class performance.



*Figure 1.* Participant and class mean digits correct per 2 minutes scores on the classwide subskill analysis measure.

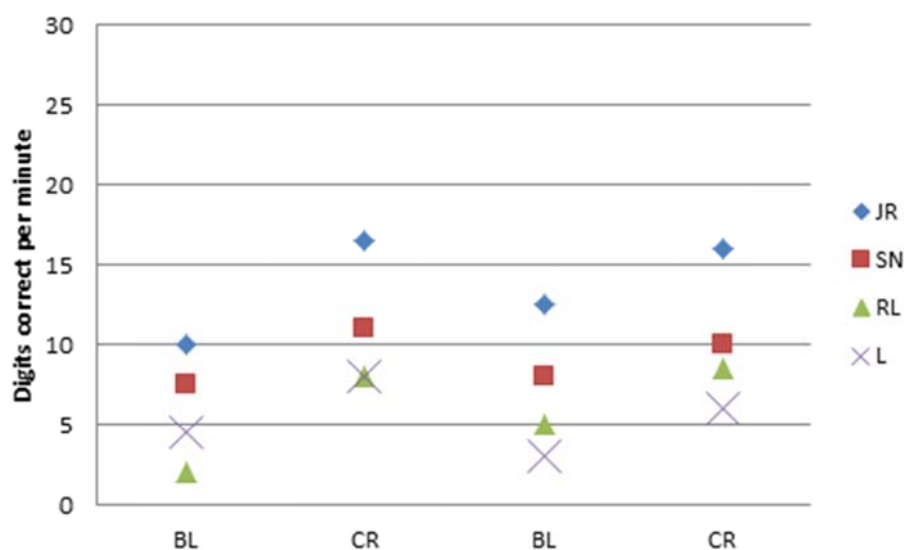
### Brief CR Assessment

Results of the brief CR assessment were used to answer the first research question regarding the extent that the four participants showed individual differences on the performance or skill deficit hypotheses suggested by a brief contingent reward assessment. As shown in Table 1, the brief CR assessment resulted in a dcpm score improvement of 38% or more for all four participants relative to the score on the classwide SA probe. Given that each student scored at least 30% more dcpm than his/her previous best performance on the SA probe, it was hypothesized performance was influenced by a performance deficit requiring a motivational strategy for all participants. As shown in Figure 2, improvement with reward relative to baseline was replicated on subsequent baseline and CR conditions on a SA probe. However, the scores of Steven, Robert, and Lenny remained below both the grade level benchmark criterion (i.e., 30 dcpm) and the class mean. Jenna increased performance above the class mean yet remained below the benchmark criterion. Thus, there were no individual differences

Table 1

*Results from Class and Out of Class Brief Assessment of Academic Performance on the Skills Analysis Measure Including Percent of Improvement and Hypothesized Deficit*

Variable	Steven	Robert	Lenny	Jenna
In-class dcpm score	8	2	5	10
Out-of-class dcpm score with CR	11	8	8	17
Percent increase between CR and in-class score	38%	300%	60%	70%
Hypothesized deficit	Performance deficit	Performance deficit	Performance deficit	Performance deficit



*Note.* BL = baseline and CR = Contingent Reward.

*Figure 2.* Brief experimental assessment results for all participants.

between the hypothesis developed and it was predicted that all student would positively respond to a CR intervention applied over time on single math skills.

### Extended Analysis

Results from the extended analysis were used to validate the effects of the selected functionally relevant intervention on math fluency across computational skills and time. As described in the method section, baseline, CR, and intervention procedures were sequentially administered on three different skills that were incorrect on the classwide and CR administered SA probes. An intervention was considered effective when meeting the benchmark criterion for two sessions. The problem number on the SA probe and the type of problems that were presented on each student's three SS probes are listed in Table 2.

Table 2

*Skills Practiced on Subskill Math Measures for Each Student*

Steven	Robert	Lenny	Jenna
Skill 7 (double digit subtraction no regrouping)	Skill 9	Skill 9	Skill 9
Skill 9 (double digit subtraction no regrouping)	Skill11	Skill11	Skill11
Skill 11 (three digit subtraction no regrouping)	Skill 14 (double digit multiplication)	Skill 14	Skill 14

The effects of experimental conditions on dcpm were evaluated using visual inspection of the time-series data and by comparing scores to a benchmark criterion. Figure 3a-d depicts each participant's fluency rates on math skill probes administered during baseline and treatment conditions for three different skills. Means, standard deviations, and ranges for each experimental condition are displayed in Table 3.

As shown in the Figure 3a-d, student response to experimental conditions differed between the four participants and also differed between the three skills for each individual. Although performance was evaluated on a total of 12 skills that were administered to the four participants, growth on one (8%) skill was gained with reward which corresponded to the performance deficit hypothesis and growth on five (42%) skills was gained on the instructional interventions which corresponded to the alternative skill deficit hypothesis. Additionally, gains on six (50%) skills occurred without intervention in the baseline condition. Given the variability in performance level and trends between subjects, further discussion of study outcomes will be presented for each participant.

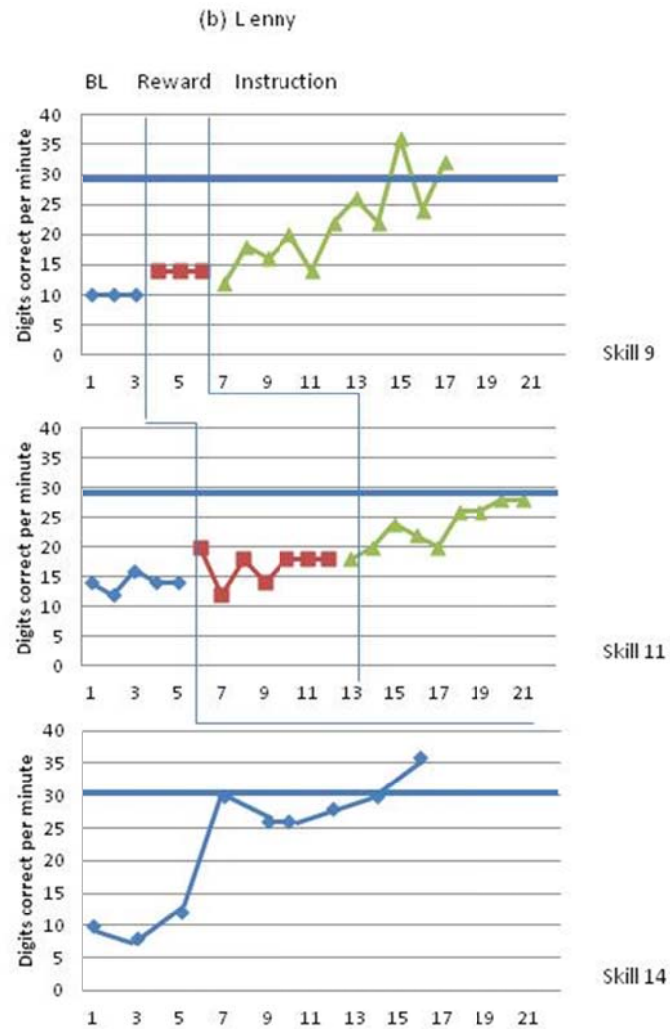
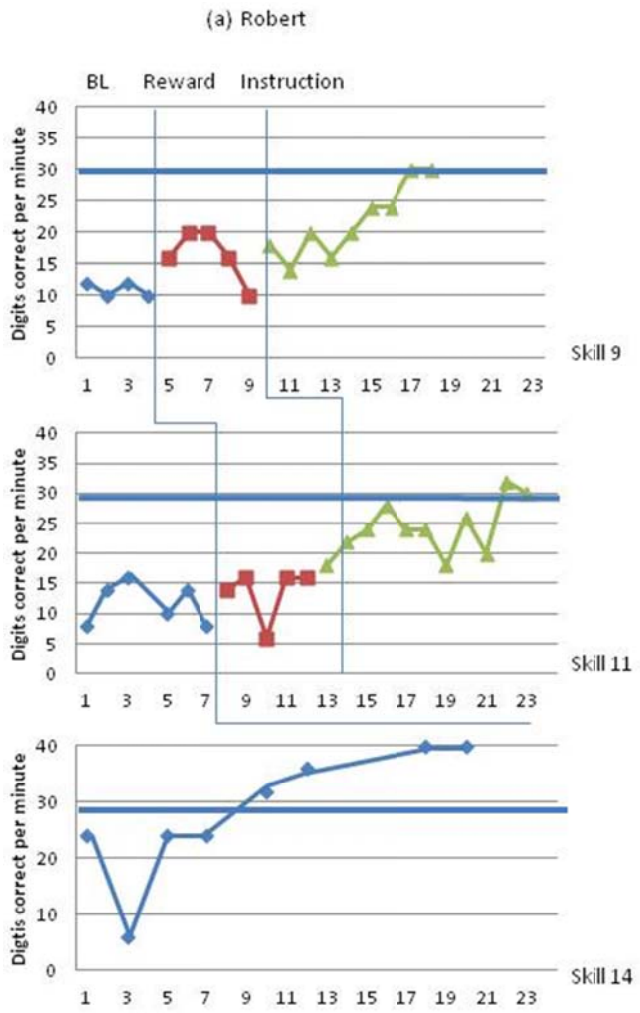


Figure 3. Digits correct per minute (dcpm) for each participant (a to d) during baseline (BL), contingent reward (CR), and contingent reward plus Instruction (CR + I) sessions.

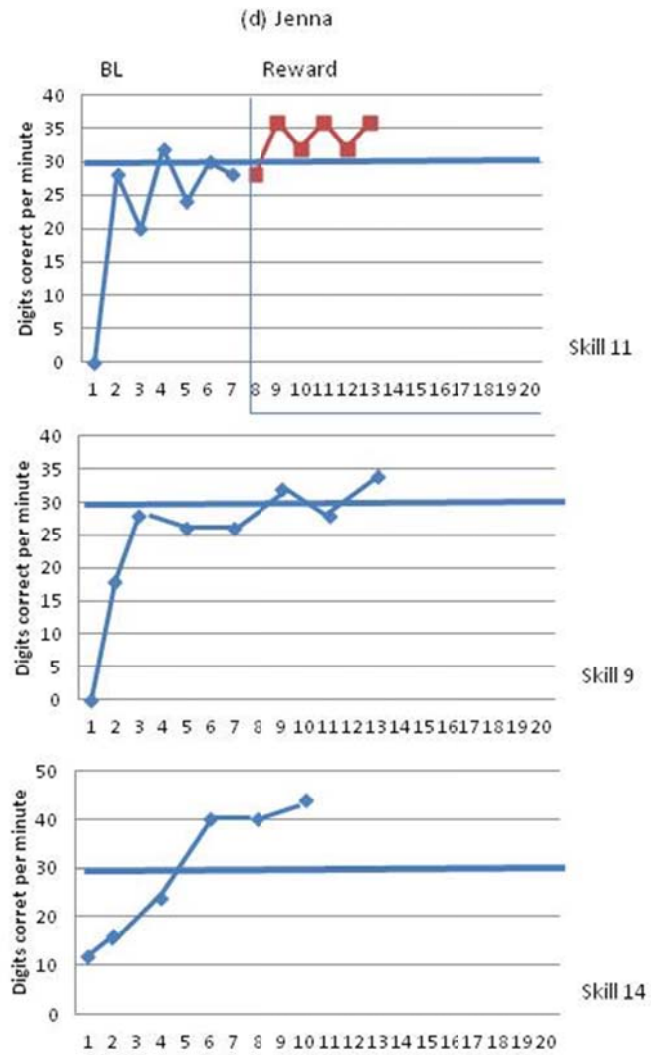
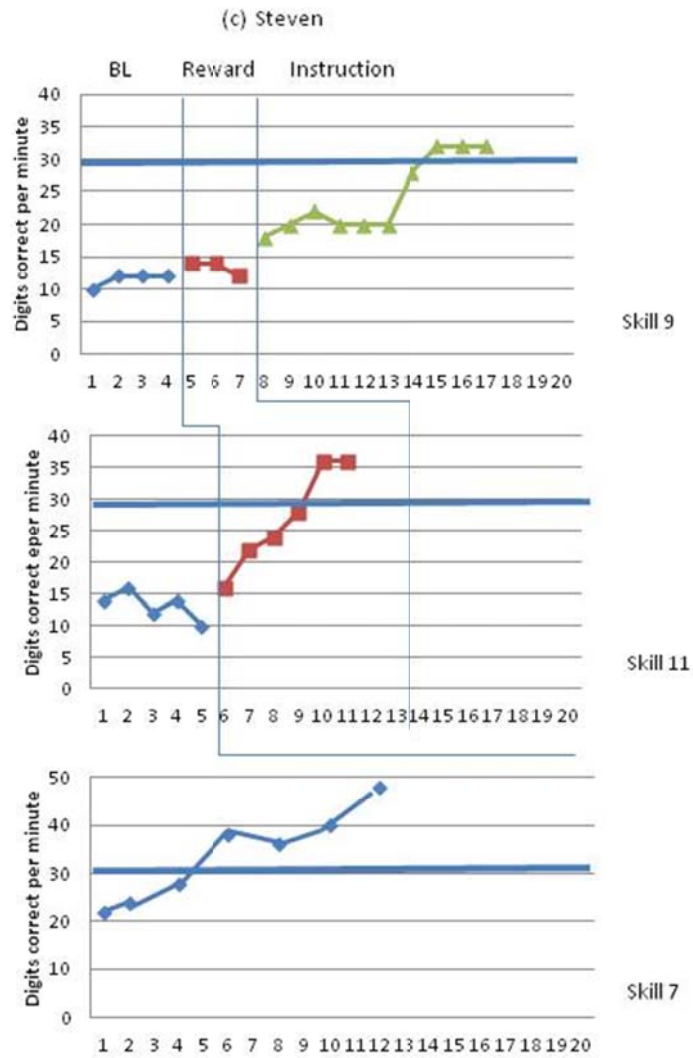


Figure 3 (cont.)

Table 3

*Descriptive Statistics for the Four Participants During Administered Experimental Conditions*

Student/condition	Digits correct per minute			Digits correct per minute			Digits correct per minute		
	Mean	<i>SD</i>	Range	Mean	<i>SD</i>	Range	Mean	<i>SD</i>	Range
Robert	Skill 9			Skill 11			Skill 14		
Baseline	11.00	1.15	2	11.67	3.44	10	31.20	11.78	44
CR	16.40	4.10	6	13.60	4.34	-2			
CR + instruction	21.78	5.70	22	24.18	4.60	26			
Lenny	Skill 9			Skill 11			Skill 14		
Baseline	10.00	0.00	0	14.00	1.41	4	22.89	10.15	28
CR	14.00	0.00	0	16.89	2.79	8			
CR + instruction	22.00	7.32	12	23.56	3.71	10			
Steven	Skill 7			Skill 9			Skill 11		
Baseline	33.71	9.41	26	11.50	1.00	2	13.20	1.6	6
CR				13.33	1.15	2	27.00	7.97	20
CR + instruction				24.40	5.87	14			
Jenna	Skill 9			Skill 11			Skill 14		
Baseline	23.14	10.95	32	27.43	5.13	8	29.33	13.78	32
CR	33.33	3.27	8						
CR + instruction									

As shown in Figure 3a and b, both Robert and Lenny did not show positive trends in academic performance on skills 9 and 11 with the introduction of CR relative to baseline as hypothesized. Positive trends toward benchmark were demonstrated with the administration of CR + Instruction on the two skills. Performance increased to benchmark on skill 14 during the baseline condition.

As shown in Figure 3c, Steven demonstrated a steady positive trend during baseline on skill seven probes meeting and remaining above benchmark after three practice sessions. Alternatively, no growth or a decreasing trend was observed on skill 9 and 11 during baseline. During the contingent reward condition, math performance increased to benchmark within four sessions on skill 11 but remained low on skill 9. Performance increased to benchmark on skill 9 after 6 sessions of CR + Instruction.

As shown in Figure 3d, Jenna responded to practice and feedback during the baseline condition on all three skills although she more steadily performed at or above benchmark on skill 11 as hypothesized with the administration of a CR condition.

In summary, only one participant, Steven, responded to the CR treatment to address the hypothesized performance deficit and he responded on only one of the three skills. Alternatively, Steven required CR + I on one skill and Robert and Lenny required CR + I on two of the three skills administered. All participants met benchmark on at least one of the skills during baseline with practice and feedback.

The third research question was to examine the number of interventions sessions required to remediate computational skill deficits to a benchmark rate criterion across all skills. An examination of trials to criterion showed a steady increase in required trials to



reach benchmark as each phase became more complex. That is, trials to mastery criterion ranged from three to five for Baseline ( $M = 3.5$ ,  $SD = 0.8$ ), was four trials for CR that was not replicated, and seven to nine trials for CR + I ( $M = 8.0$ ,  $SD = 0.9$ ). Given that interventions varied for three of the four participants, time lines to criterion varied for these individuals and skills requiring more intensive effective interventions resulted in longer time lines.

### Post Data

Post data were also collected on the SA probe and the three SS probes. As shown in Table 4, although post SA + CR scores did improve relative to the score obtained on the classwide SA administered prior to interventions (range between a 12% to 50% increase), all scores remained below benchmark. Post scores on the SS probes reveal that scores at or above benchmark was retained on 42% (5/12) skills. Specifically, Jenna scored above benchmark on all three skills and Steven and Robert each scored above benchmark on one skill.

Table 4

#### *Digits Correct Per Minute on Post Subskill Math and Skills Analysis Measures*

Student	Pre SA + CR	Post SA + CR	Skill 7	Skill 9	Skill 11	Skill 14
Robert	8	12		18	28	46
Lenny	8	10		24	24	28
Steven	11	13	31	24	26	
Jenna	17	19		32	30	44

## **CHAPTER V**

### **DISCUSSION**

#### **Findings**

BEA is a well-supported effective strategy to identify interventions to increase reading performance for elementary-aged students; however, additional research on the potential for using BEA to develop hypotheses that are used to select effective individualized math interventions is needed. These findings widen the growing research literature regarding the treatment utility of a brief assessment to improve math computation skills for students for whom classwide was not sufficient to improve performance. Prior studies have supported the utility of this type of assessment to distinguish between low performance due to lack of motivation, practice, and/or instruction on a single target math skill (Carson & Eckert, 2003; Coddling et al., 2009a; Gilbertson et al., 2008); whereas, in this study, the utility of a brief CR assessment was examined on a SA multiple probe to determine a motivational problem on multiple target skills per individual. Although all students in this study showed gains with the brief CR assessment on the SA multiple probe and met the criteria to be considered a performance deficit, results during the extended analysis demonstrated that the CR intervention addressing a motivation problem was an effective intervention for one skill and CR + I was effective for five skills of the 12 skills assessed. For the remaining six skills, no treatment other than a few sessions of 30-second practice followed by feedback was needed during the extended analysis.

In sum, although all students had similar outcomes during the brief CR assessment, students responded differently to the applied conditions in the extended analysis and each student responded differently to interventions across the three skills. But the low response on the CR intervention did not validate the *won't do* hypothesis that was developed from the brief assessment results across skills. Thus, the brief assessment on a SA multiple probe did not support the successful selection of an effective treatment selection in prior studies that applied the brief assessment procedures on a single skill probe. Although the multiple probe may be more efficient to identify skills to target, this brief assessment may need to be administered for each skill to distinguish between a *can't do* or *won't do* problem.

The brief CR assessment examined in this study is to be used as part of an assessment system to guide intervention program decisions (VanDerHeyden & Witt, 2007). The more positive responses to the CR + I intervention also suggests a more complex assessment is needed to determine a combined *can't do/won't do* problem. In a similar study, Noell and colleagues (2001) assessed three conditions (a baseline, a CR, and an instructional condition) during the brief assessment on a skill by skill basis in the area of reading. Reward was combined with the instructional procedure when the CR condition improved reading performance. An intervention was predicted to be effective over time when oral reading fluency increased by 20% or more above the previous baseline. Each intervention was applied over time in an extended analysis to validate the brief treatment outcomes. Overall, results showed that the brief assessment accurately identified an effective intervention for 83% of the skills (10 out of 12) assessed.

Interestingly, on 50% of the skills, both the brief CR condition and CR + I condition increased oral reading rates relative to baseline in the brief assessment, but rates improved at a steeper growth rate with CR + I compared to CR during the extended analysis. In this present study, an instructional intervention condition was not applied as part of the brief assessment because a brief instruction on one skill would not result in a substantial change in score on the SA assessment and thus be sensitive enough to predict the most effective instruction across different types of skills on a multiple probe (McComas et al., 2009). Clearly the most intensive intervention, CR + I, would have reliably produced positive effects on all skills in this study but this intervention required the most time. Selecting CR + I for all skills would decrease efficiency in terms of time as the less intensive CR and baseline conditions were effective on over half the skills. Alternatively, applying the CR intervention based on the performance deficit hypothesis would have produced positive outcomes for seven of the 12 skills within four sessions.

Despite the limited findings of the brief assessment for treatment selection in this study, these results were consistent with previous research in showing differences between individual's responses to interventions (Coddling et al., 2009a) and showing individual's response differences between academic target skills (Noel et al., 2001). There may be several plausible explanations for the mixed findings across individuals and skills in the area of math. First, mixed results may be due to different causes for poor performance on individual problems on the SA multiple probe and then the student responded to the condition that best addressed the specific cause on the single skill presented on the SA probe. For example, a skill that was never adequately acquired

would have increased with instruction, practice, and motivation (CR +I), a skill that was acquired but not yet proficient would have increased with practice and motivation (CR), and a skill that had been fluent at one time would be quickly boosted back to a fluent level with a few practice sessions (baseline). Differences in causes for poor performance across skills makes the assessment process for identifying effective interventions in the area of math more complex and perhaps more time consuming than the area of reading.

One finding different to prior studies was that half of the skills showed gains during baseline possibly due to practice and performance feedback provided in this condition. This result may be due to differences in task difficulty across skills for each student. Another plausible explanation may be that initial gains on a single probe may have motivated students to keep working to make even greater gains. In fact, there are several research based math intervention options that may have been used to motivate students. Carson and Eckert (2003), for example, compared math fluency gains for motivational problems with various strategies including CR, performance feedback, goal setting, and timing sprints for students exhibiting performance deficits. Optimal growth on single digit addition problems for three fourth-grade participants was observed during a timed sprints intervention relative to other interventions and baseline (with no feedback). During the timed sprint condition, the students were told to work fast for 30 seconds on two probes and given immediate feedback on their performance. It is possible that the baseline condition in this study that included a brief timing and feedback may have also played a similar motivational role that led to improved fluency gains. Jenna's scores, for example, improved with baseline on all three skills. Performance was more

consistent on one skill, however, with CR suggesting that incentives was a stronger motivational strategy needed on a perhaps more difficult skill.

Mixed findings across skills may also be due to treatment interference across phases. That is, change in one skill led to changes in a second skill even without prompting or treatment on the second skill. Treatment interference was a risk given that the SA probe was designed to evaluate small computation steps that may have required brief instructional interventions. Skills 7 (subtract two columns with no trading), 9 (subtract two columns with trading), and 11 (subtract 3 columns with trading from ones) were more complex yet similar steps using subtraction one digit facts to complete, whereas skill 14 (multiply two digit with no regrouping) differed in fact knowledge base and steps. For example, treatment interference may be a plausible explanation for the observed congruent increase on Steven's skill 11 (subtract 3 columns w/ trading from ones) after making gains on skill 9 with treatment. Although the probe for skill 14 had less content overlap than other skill probes used in this study, carryover of treatment effect or classroom instruction may have also explained baseline growth on skill 14 (two-digit multiplication) since students were in two classes. The teachers, however, did not report any additional attention to this skill in their classrooms when queried at the end of the study. Of course, generalization of treatment on more complex skills is a desirable and efficient outcome and ways to enhance generalization of the SA probe should be further investigated in future studies.

### **Implications for Practice and Directions for Future Research**

Given that a primary purpose of this study was to investigate an efficient assessment method to identify effective intervention, implications of these findings on time and resources is worth discussing. First, a multiple math probe consists of a number of different types of problems that could require extensive teaching for each problem. The probes used in this study attempted to break complex problem types into small steps that would involve brief and few remedial teaching sessions. Although the effective experimental conditions varied, all students met criterion on every skill in less than 10 sessions that were conducted in 10 minutes or less. Moreover, students in this study had similar target skills which may have been conducted with small group rather than individual instruction.

Enhancing the detection of a true performance deficit may be further explored by examining alternative criteria to use to develop a performance deficit hypothesis. Currently, variable percent increases between baseline and intervention scores have been used to predict a performance deficit in the literature. Percent increases used in prior studies include 20% (Petursdottir et al., 2009), 15% (Carson & Eckert, 2003), and 30% (Gilbertson et al., 2008). For all percentages used in prior studies, however, the performance deficit hypothesis would remain the same for all students in this study because the highest percentage criterion was used. Benchmarks provided in the literature are a second criterion that may be added to predict performance deficits. Potential benchmarks include scores that predict retention (i.e., at or above 30 dcpm for third grade; VanDerHeyden & Burns, 2009), within instructional level (i.e., 10 dcpm for third

grade; Deno & Mirken, 1977), meeting the class median, and/or meeting the grade level median. The performance deficit hypothesis would not have varied for any of the four participants based on the 30 dcpm benchmark used in this study. Alternatively, an instructional intervention would be the predicted effective intervention for all participants based on meeting the 10 dcpm or the class median. Thus, requiring one or both of these levels would have resulted in the brief analyses on the SA multiple probe accurately predicting the effective intervention for 42% of the single skills.

Finally, results found in this study also have implications for data based decision making to determine termination of an intervention. In this study, an intervention was evaluated as effective when student fluency met the 30 dcpm benchmark on the single skill probe. Yet, retention data suggests that student performance showed gains relative to baseline but may need more treatment or practice sessions to maintain fluency benchmark scores before terminating the intervention or a few booster sessions to regain it (Binder, 1996). Gains on the SA multiple probe were observed for all participants. As expected, sensitivity to growth over time was not as steep as performance on the SS probes, but results on the SA probe demonstrated that students were able to generalize accurate performance on the targeted single skills presented on the SA probe with different types of computational problems.

### **Limitations**

There are several limitations to this investigation that warrant consideration. First, although brief assessments are designed to examine within-subject data to identify



effective individualized interventions, the small sample size in one grade level that targeted only subtraction and multiplication computation problems limits generalizing conclusions to larger populations and other skills. Second, differences in intervention responses prevented the same sequence of conditions from appearing in all of the multiple baseline sequences for all participants. Further, the impact of the potential sequence effects is unknown. For example, CR and CR + I are likely to have taken more trials to criterion without the prior baseline condition. Third, as noted above, baseline condition contained elements such as feedback and timings that may have functioned as a motivation strategy. Fourth, only one instructional intervention was implemented and this intervention targeted both acquisition and targeted fluency building using multiple strategies. Specific instructional strategies included: task analysis, teacher modeled and student practice talk aloud problem solving, independent overt problem solving and immediate feedback, and a brief 30-second timed independent assessment with goal setting. Perhaps a less intensive instruction was needed. Finally, it cannot be ascertained to the degree that there were carry over treatment or practice effects on one skill that produced or increased gains on another skill.

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**APPENDICES**

## Appendix A

### Example Skills Analysis Measure (SA)



**Example Skills Analysis Measure (SA) Part 1**

Student Code: \_\_\_\_\_ Date: \_\_\_\_\_

$$\begin{array}{r} 1) \quad 21 \\ \quad +43 \\ \hline \end{array}$$
$$\begin{array}{r} 2) \quad 125 \\ \quad +72 \\ \hline \end{array}$$
$$\begin{array}{r} 3) \quad 26 \\ \quad +5 \\ \hline \end{array}$$
$$\begin{array}{r} 4) \quad 92 \\ \quad +18 \\ \hline \end{array}$$
$$\begin{array}{r} 5) \quad 347 \\ \quad +123 \\ \hline \end{array}$$

$$\begin{array}{r} 6) \quad 215 \\ \quad +495 \\ \hline \end{array}$$
$$\begin{array}{r} 7) \quad 54 \\ \quad -12 \\ \hline \end{array}$$
$$\begin{array}{r} 8) \quad 367 \\ \quad -121 \\ \hline \end{array}$$
$$\begin{array}{r} 9) \quad 51 \\ \quad -22 \\ \hline \end{array}$$
$$\begin{array}{r} 10) \quad 40 \\ \quad -11 \\ \hline \end{array}$$

$$\begin{array}{r} 11) \quad 651 \\ \quad -215 \\ \hline \end{array}$$
$$\begin{array}{r} 12) \quad 932 \\ \quad -167 \\ \hline \end{array}$$
$$\begin{array}{r} 13) \quad 301 \\ \quad -177 \\ \hline \end{array}$$
$$\begin{array}{r} 14) \quad 34 \\ \quad \times 2 \\ \hline \end{array}$$
$$\begin{array}{r} 15) \quad 12 \\ \quad \times 24 \\ \hline \end{array}$$

$$\begin{array}{r} 16) \quad 67 \\ \quad \times 2 \\ \hline \end{array}$$
$$\begin{array}{r} 17) \quad 503 \\ \quad \times 5 \\ \hline \end{array}$$
$$\begin{array}{r} 18) \quad 234 \\ \quad \times 5 \\ \hline \end{array}$$
$$\begin{array}{r} 19) \quad 21 \\ \quad \times 13 \\ \hline \end{array}$$
$$\begin{array}{r} 20) \quad 20 \\ \quad \times 52 \\ \hline \end{array}$$

$$\begin{array}{r} 21) \quad 36 \\ \quad \times 12 \\ \hline \end{array}$$
$$\begin{array}{r} 22) \quad 37 \\ \quad \times 25 \\ \hline \end{array}$$

## Skills Analysis Measure (SA) Part 2

Student Code: \_\_\_\_\_ Date: \_\_\_\_\_

SKILL: Add checks to correct answers. Any blanks will suggest a specific basic skill deficit.	Item no.			
STUDENT NAME:				
ADDITION				
Add two columns no regrouping	1			
Add three columns no regrouping	2			
Add one column regrouping	3			
Add two columns regrouping	4			
Add three columns regrouping from ones	5			
Add three columns regrouping from ones and 10's	6			
SUBTRACTION				
Subtract two columns no trading	7			
Subtract three columns no trading	8			
Subtract two columns with trading	9			
Subtract three columns with trading from ones	9			
Subtract three columns with trading from ones with zero	10			
Subtract three columns with trading from ones	11			
Subtract three columns with trading from ones and tens	12			
Subtract three columns with trading from ones and tens with zero	13			
MULTIPLICATION				
Multiply one digit no regrouping	14			
Multiply two digits no regrouping	15			
Multiply two and one digit with regrouping	16			
Multiply three and one with regrouping ones	17			
Multiply three and one with regrouping ones and tens	18			
Multiply two digits with no regrouping	19			
Multiply two digits with no regrouping and zero	20			
Multiply two digits with regrouping ones	21			
Multiply two digits with regrouping ones and tens	22			

Appendix B

Example Subskill (SS) Probe

$$\begin{array}{r} 30 \\ x \underline{\quad 2} \end{array}$$

$$\begin{array}{r} 13 \\ x \underline{\quad 2} \end{array}$$

$$\begin{array}{r} 31 \\ x \underline{\quad 2} \end{array}$$

$$\begin{array}{r} 84 \\ x \underline{\quad 1} \end{array}$$

$$\begin{array}{r} 76 \\ x \underline{\quad 1} \end{array}$$

$$\begin{array}{r} 34 \\ x \underline{\quad 2} \end{array}$$

$$\begin{array}{r} 10 \\ x \underline{\quad 2} \end{array}$$

$$\begin{array}{r} 42 \\ x \underline{\quad 2} \end{array}$$

$$\begin{array}{r} 12 \\ x \underline{\quad 2} \end{array}$$

$$\begin{array}{r} 40 \\ x \underline{\quad 2} \end{array}$$

$$\begin{array}{r} 41 \\ x \underline{\quad 2} \end{array}$$

$$\begin{array}{r} 24 \\ x \underline{\quad 2} \end{array}$$

$$\begin{array}{r} 32 \\ x \underline{\quad 2} \end{array}$$

$$\begin{array}{r} 39 \\ x \underline{\quad 1} \end{array}$$

$$\begin{array}{r} 43 \\ x \underline{\quad 2} \end{array}$$

$$\begin{array}{r} 50 \\ x \underline{\quad 1} \end{array}$$

$$\begin{array}{r} 40 \\ x \underline{\quad 2} \end{array}$$

$$\begin{array}{r} 13 \\ x \underline{\quad 2} \end{array}$$

$$\begin{array}{r} 32 \\ x \underline{\quad 2} \end{array}$$

$$\begin{array}{r} 74 \\ x \underline{\quad 1} \end{array}$$

Appendix C  
Baseline Assessment

**30 sec : Timed Assessment**

**Say** *“This is a math worksheet. All of the problems are \_\_\_\_\_ (addition, subtraction, multiplication, division, etc.). When I say ‘start,’ you may begin answering the problems. Start on the first problem on the left on the top row (point). Work across and then go to the next row. Do you have any questions?”*

Set timer for 30 seconds. **“Start.”** Student should not skip around.

When timer rings say **“Stop.”**

**Score and Feedback**

Count the number of digits correct and tell the score to student

## Appendix D

### Contingent Reinforcement Intervention Protocol for Earning Reward

### Contingent Reinforcement Intervention Protocol for Earning Reward

**Student Code:** \_\_\_\_\_ **Date:** \_\_\_\_\_

1. *Greet student.* “We’re going to do some math today.”
2. “The last time you did this math worksheet, you scored \_\_\_\_\_ digits correct.”
3. “Today, I’m going to give you an opportunity to do this worksheet again. If you can beat your score, then you can pick anything you like from the treasure chest.” **Show student the treasure chest. Allow student to briefly sample items in the treasure chest.**
4. *Ask the student* “Do you see anything in there that you would like to earn?” **If the student does not seem excited about any of the items in the treasure chest, offer free time, outside time, visit with favorite teacher, or ask the student to nominate something reasonable.**
5. **“This is a math worksheet. All of the problems are \_\_\_\_\_ (addition, subtraction, multiplication, division, etc.). When I say ‘start,’ you may begin answering the problems. Start on the first problem on the left on the top row (point). Work across and then go to the next row. Do you have any questions?”**
6. Set timer for 30 seconds. **“Start.”**
  1. Monitor student performance to ensure that the student works the problems in rows and does not skip around or answer only the easy problems.
  2. When timer rings say **“Stop.”**
  3. Count the number of digits correct. If the student increased his/her score by one digit or more, allow student to select something from the treasure chest. If the student did not increase his/her score by one digit or more, do not allow the student to make a selection from the treasure chest.



Appendix E

Instruction Plus Contingent Reward Intervention Protocol

## Instruction plus Contingent Reward Intervention Protocol

**Student Code:** \_\_\_\_\_ **Date:** \_\_\_\_\_

**Give Goal:** *“Today, I’m going to give you an opportunity to do earn free time. If you can beat your last best score, then you throw a dice to earn free time minutes. You can have your free time on the day that you earn a total of 10 minute. But first we are going to review and practice the skill before you will have the chance to earn free time.”*

### **Give Student step-by-step rule card**

Example for subtraction regrouping:

- A. Look at the ones column.
- B. Is the top number smaller than the bottom? Yes, means we need to make the top number bigger.
- C. Borrow a 10 from the tens column. Cross out the top number in the tens column. Subtract 1 from the top number (i.e.,  $5-1=4$ ). Write the number on the top.
- D. Add the 10 to the one column (i.e.,  $4+10=14$ ). Write in the 1 next to the top number.
- E. Subtract the ones column.
- F. Subtract the tens column.

### **2 min/2 problems: Teacher Step-by-step rule Talk-Aloud**

Hand the student the step-by-step card to use as reference while you complete two problems using the words and talking about the steps out loud.

### **2 min/ 2 problems:**

#### **Student Teacher Step-by-step Talk-Aloud and 5 sec Timed Delay Error Correction**

Ask student to do problems also using the talk aloud procedure

Provide feedback on the correct and incorrect completed problem steps.

Say correct digit when a student hesitates more than 5 seconds or writes an incorrect digit- say the relevant rule - and have the student correct the problem.

Continue until the student says the correct rules and writes the correct digits for 2 consecutive problems.

### **2 min/ 4 problems: Cover-Copy-Compare practice with immediate feedback:**

Give a worksheet and copy of the answers.

Turn the correct answer sheet over.

Student completes 4 problems on worksheet.

Uncover the correct answers.

Compare answers with the correct answer and correct incorrect problems.

**30 sec: Timed Assessment**

**Say** *“This is a math worksheet. All of the problems are \_\_\_\_\_ (addition, subtraction, multiplication, division, etc.). When I say ‘start,’ you may begin answering the problems. Start on the first problem on the left on the top row (point). Work across and then go to the next row. Do you have any questions?”*

Set timer for 1 min.

**“Start.”** Monitor student performance to ensure that the student works the problems in rows and does not skip around or answer only the easy problems.

When timer rings say **“Stop.”**

**1 -10 min: Score and Reward**

Count the number of digits correct. If the student increased his/her score by one digit or more from the last session, allow student to throw a dice for free time minutes. Write number of minutes on chart. Give free time when the student earned 10 or more minutes.

Appendix F

Classwide Skills Analysis Multiple Probe Assessment Protocol

### Classwide Skills Analysis Multiple Probe Assessment Protocol

1. Pass out papers face-down, instructing students not to turn them over until you tell them to do so.
2. **“Please write your first and last name on the back of your paper.”** Pause briefly to allow students to write their names.
3. **“This is a math worksheet. There are several types of problems on this work sheet. Some are addition, subtraction, multiplication, and division problems. Look at each problem carefully before you answer it. When I say ‘start’ turn the paper over and begin answering the problems. Start on the first problem and work across the page (point). Then go to the next row. If you cannot answer the problem, mark an ‘X’ through it and go to the next one. Are there any questions?”**
4. Set timer for two minutes. **“Start.”** Begin timer.
5. Monitor student performance to ensure that students work the problems in rows and do not skip around or answer only the easy problems.
6. When timer rings, say, **“Stop. Raise your papers and put your pencils down.”**
7. Collect math sheets and give to service provider/consultant

Appendix G  
Informed Consent



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USU IRB Approval: April 19, 2011  
Approval Terminates: 04/18/2012  
Protocol #2911  
IRB Password Protected per IRB Administrator

## INFORMED CONSENT

### Utility of an Error Analysis and Performance Deficit Assessment for Selecting Brief Interventions to Increase Math Fluency

**Introduction/ Purpose:** Professor Donna Gilbertson and graduate student Aaron Denison, both in the Department of Psychology at Utah State University are conducting a research study to find out more about a way to find the best type of instruction that helps students to learn important math skills. You have been asked to take part because you are a parent of a child who may benefit from more help in learning math skills. There will be approximately three students who participate in this research.

**Procedures:** If you agree to be in this research study, the following will happen to you and your child.

1. You will be asked to complete the attached sheet about your child. This completed sheet may be turned in with this form if you wish for your child to participate in this program.
2. Your child will work with researchers for about 4 weeks on the following steps.
  - a) Your child will be asked to work on a 2 to 5 minute math worksheet that has a number of important math skills on it that your child is learning in his or her class.
  - b) Your child will complete another worksheet but this time will be given the chance to earn a reward of his or her choice (i.e., small activity, toy, or school supply) by meeting or beating a goal.
  - c) Your child will be given one on one instruction to learn at least three math skills that were missed on the math worksheet. That is, your child will be given step-by-step rules to complete the math problems, modeling of the steps, and a practice session with feedback from the researcher to help with any errors. Finally, your child will be given a timed worksheet and will earn free time minutes when he/she meets or beats a goal. This instruction will be given for 10 minutes on 4 days a week.
3. This math instruction will be given on three different math skills until the student has mastered all three skills.

**Risks:** Participation in this research study may involve some added minimal risks or discomforts. Because we are teaching a subject which may not be your child's strength, he/she may experience slight discomfort from participating in the lessons. Your child will also miss about 10 minutes of class time for 4 days a week. However, we will also work closely with teachers to determine the best time to work with children so that no school work will be missed. Each working session is also very brief and students will be earning small toy or school supply to help reduce frustrational behaviors.

**Benefits:** This program is likely to directly benefit your child by giving him/her the opportunity to gain further instruction on math skills. Some students may also experience improved on-task behavior in math class after learning the math skills. Results of intervention will be shared with parents, and with your consent, with the student's math teacher such that the intervention may continue to be used to promote other math skills. Also, the information gained by this study may potentially help educators learn more about how to support children to master important math skills that are necessary skills for later math instruction.



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## INFORMED CONSENT

### Utility of an Error Analysis and Performance Deficit Assessment for Selecting Brief Interventions to Increase Math Fluency

**Explanation & offer to answer questions** Aaron Denison or Donna Gilbertson has explained this research study to you and answered your questions. If you have other questions or research-related problems, you may reach Professor Gilbertson at 435-797-2034.

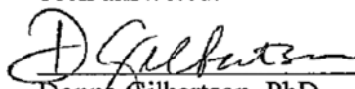
**Voluntary nature of participation and right to withdraw without consequence:** Participation in research is entirely voluntary. You may refuse to participate or refuse to have your child participate in this study at any time. You may withdraw or your child may ask to be withdrawn from the study at any time without consequence or loss of benefits.

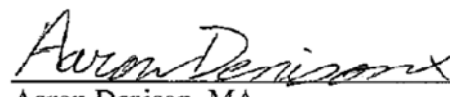
**Confidentiality:** Research records will be kept confidential, consistent with federal and state regulations. To protect your privacy, personal, identifiable information will not be included on any study documents. A code will be used to replace your name and the name of your child on all documents. The code will be kept separate from the data throughout the study and it will be destroyed one year after the study is completed. Only the principal investigator and student researcher will have access to the coded data. To protect your confidentiality, the data will be kept in a locked file cabinet or on a password protected computer in a locked room. A report will be prepared at the end of this study with no individual results reported in the summary.

**IRB Approval Statement** The Institutional Review Board for the protection of human participants at USU has approved this research study. If you have any pertinent questions or concerns about your rights or a research-related injury, you may contact the IRB Administrator at (435) 797-0567 or email [irb@usu.edu](mailto:irb@usu.edu). If you have a concern or complaint about the research and you would like to contact someone other than the research team, you may contact the IRB Administrator to obtain information or to offer input.

**Copy of consent** You have been given two copies of this Informed Consent. Please sign both copies and keep one copy for your files.

**Investigator Statement** "I certify that the research study has been explained to the individual, by me or my research staff, and that the individual understands the nature and purpose, the possible risks and benefits associated with taking part in this research study. Any questions that have been raised have been answered."

  
\_\_\_\_\_  
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**INFORMED CONSENT**  
**Utility of an Error Analysis and Performance Deficit Assessment for Selecting Brief Interventions to Increase Math Fluency**

**Signature of participant's parent or legal guardian** By signing below, I agree to allow my child to participate.

\_\_\_\_\_  
Parent or Guardian

\_\_\_\_\_  
Date

**Relationship to Participant:** \_\_\_\_\_ **Name of Child** \_\_\_\_\_

**Child/Youth Assent:** I understand that my parent(s)/guardian is/are aware of this research study and that permission has been given for me to participate. I understand that it is up to me to participate even if my parents say yes. If I do not want to be in this study, I do not have to and no one will be upset if I don't want to participate or if I change my mind later and want to stop. I can ask any questions that I have about this study now or later. By signing below, I agree to participate.

\_\_\_\_\_  
Name

\_\_\_\_\_  
Date