USING ASSESSMENT DATA AND PROBLEM ANALYSIS TO MATCH INTERVENTIONS TO SKILL DEFICITS

by

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This study investigated the potential advantages of using Curriculum Based Measurement (CBM) and problem analytic frameworks when selecting early numeracy interventions. One kindergarten student was evaluated across treatment phases that were either matched or un-matched to the participant's skill deficits. The Instructional Hierarchy (IH) and conceptual and procedural heuristic were applied to problem analytic procedures. The participant was identified as having an acquisition deficit in number identification skills. These deficits were determined to be both conceptual and procedural in nature. Therefore, interventions were only matched along the lines of the IH, with the acquisition intervention being selected as matched, and the fluency intervention being selected as un-matched. Baseline and treatment phases were delivered in a hybrid ABAB reversal design with an alternating treatments component. Since skill deficits were found to be both conceptual and procedural, hypotheses regarding matched and un-matched conceptual/procedural interventions could not be tested. Conceptual and procedural interventions were both provided as matched interventions and potential differences were still explored in the study. The study hypothesized that matched interventions would lead to greater growth on the dependent variable -- number identifications per min. However, no differences were found between matched- acquisition and un-matched- fluency interventions. Interpretations of the findings and study limitations are discussed, as well implications for practice and research.

Using Assessment Data and Problem Analysis to Match Interventions to Skill Deficits

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CHAPTER 1: PROBLEM FORMULATION

Mathematics Under-Achievement in America

There has been growing concern over the years that the United States is falling behind other nations in mathematics achievement. In 2011, Harvard's Program on Education Policy and Governance and Education reported only 32% of the 2011 high school graduates nationwide were proficient in mathematics, ranking 32nd among nations participating in the Program for International Assessment (Program for International Assessment [PISA], 2011). The National Assessment of Educational Progress reported that 18% of all students were below basic level of achievement by 4th grade, and 29% were below basic level by eighth grade (National Assessment of Educational Progress [NAEP], 2009). High stakes testing has emphasized the responsibility of individual teachers and schools for the achievement of their students. Problem solving models and problem analytic frameworks provide an objective method for identifying deficits, generating hypotheses, and selecting appropriate interventions (Christ, 2008). Moreover, problem solving approaches are compatible with modern educational practices that increasingly emphasize measurable student outcomes and data driven instructional methods.

Identifying Skill Deficits in Early Numeracy

There is growing evidence from experimental and factor analytic studies that arithmetical ability is not a unitary skill, but encompasses a broad range of skills, including counting, memory for arithmetic facts, the understanding of concepts, and the ability to follow procedures (Dowker, 2007). If mathematical knowledge involves separate abilities as some research suggests, then specifying skill deficits provides valuable information for intervention planning (Seethaler & Fuchs, 2010). Researchers have acknowledged that basic mathematical concepts attained in early childhood create the foundation for later math skills. By the end of kindergarten students should be able to verbally count and discriminate quantities, and by age six, these concepts should be coordinated within a mental number line (Okamato & Case, 1996). These skills are critical building blocks for developing math competencies, and predictive of future math performance.

Curriculum Based Measurement (CBM)

Curriculum Based Measurement (CBM) are brief assessments that are designed to be easy to administer and score, technically adequate with regards to reliability and validity, and capable of multiple administrations due to alternate forms that are readily available and easy to construct (Deno, 1985). Additionally, CBM is designed to assess skills that are relevant to classroom learning objectives, and can be used for a wide variety of purposes including, screening, progress monitoring, and diagnosis of academic skills deficits (Fuchs, Fuchs, Hosp, & Hamlet, 2003). The Tests of Early Numeracy (TEN) are CBMs that measure skills in early numeracy development. These measures include tests of Oral Counting (OC), Number Identification (NI), Quantity Discrimination (QD), and Missing Number (MN) (Shinn, 2004). The TEN, and similar Early Numeracy Curriculum Based Measurements (EN-CBMs) are sometimes adopted by schools as a method of screening and identifying students who are risk of not meeting grade level expectations in a some critical academic skill (Martinez, 2009). CBM is also capable of progress monitoring student responses to interventions and can be administered frequently (e.g. 1-3 times per week). In more recent years however, EN-CBM has been increasingly applied to diagnostic assessment “for intervention” (Seethaler & Fuchs, 2011). This type of EN-CBM focuses on diagnosing skill deficits for the purpose of determining which intervention strategy might be most successful in addressing a particular skill deficit.

Problem Analytic Frameworks

Instructional hierarchy. The four phases that define the Instructional Hierarchy (IH) are called acquisition, fluency, generalization, and application. The IH, as described by Haring and Eaton (1978), is a series of phases in which skills (e.g., reading, math) initially develop as slow and inaccurate, then become accurate but slow (acquisition stage), and are eventually performed quickly and accurately (fluency stage). Finally, newly acquired skills are applied in novel contexts (generalization stage) and flexibly integrated into new learning (application stage). Reading research has demonstrated that the IH is a useful tool when combined with CBM, and has been used to inform instructional strategies for students within various phases of learning (Daly & Martens, 1994). In recent years there has been an attempt to bridge knowledge gained from reading research to advances in early numeracy instruction. CBM and problem analytic frameworks can help generate hypotheses and inform the selection of an appropriate intervention strategy (Burns, et al., 2010). More research is needed in this area, and one of the goals of this study is to investigate how applying the IH to CBM data can help facilitate the process of identifying skill deficits and lead to more targeted and effective interventions.

Conceptual and procedural heuristic. Another problem analytic framework that can be applied to intervention selection in early numeracy is the conceptual and procedural heuristic. Conceptual knowledge is comprehension of the relationships that underlie math problems, whereas procedural knowledge is an understanding of the rules and steps required to solve math problems (Burns, 2011). Some students may have difficulty understanding the underlying principles of a math problem, whereas some may have difficulty with recalling arithmetic math facts (Burns, 2011). Conceptual knowledge reflects an understanding of why a procedure works and whether a procedure is appropriate (LeFevre et al., 2006). It is possible for a student to comprehend a math concept but still have difficulty retrieving basic facts in order to solve math problems (Jordon, et al., 2009). Problem analysis has the potential to identify and differentiate between these types of skill deficits. Burns (2011) demonstrated how problem analysis can help better diagnosis, and treat math problems caused by conceptual and procedural deficits. The conceptual and procedural heuristic is based upon years of early numeracy research, yet the conceptual and procedural heuristic as a problem analytic framework is still in the early stages of research. One of the goals of this study was to replicate and extend previous research by applying the conceptual and procedural heuristic to problem analysis and intervention selection.

The conceptual and procedural heuristic and IH were both used as problem analytic frameworks in this study. The TEN were administered to a kindergarten student struggling with early numeracy skills. Problem analysis was used to identify and select interventions that were considered to be matched, or un-matched to the student's skill deficit. Matched and un-matched interventions were compared across study phases in order to investigate whether interventions indicated by the problem analysis were more effective than interventions which were un-matched to the problem analysis.

Summary of the Problem and Study Rationale

With 18% of all students falling below basic level of achievement by 4th grade and 29% falling below basic level by eighth grade, there is clearly a need for quality early intervention in mathematics (National Assessment of Educational Progress [NAEP], 2009). Yet, math interventions are commonly selected and implemented in schools without problem analysis, which is a critical component necessary to solve and prevent problems efficiently and effectively (Young & Gaughan, 2010).

Furthermore, there is evidence to suggest that number sense is not a unitary concept or ability, but a complex set of distinct skills and abilities (Dowker, 2007; Barody, Eiland, & Thompson, 2009). More research studies are necessary in order to improve early intervention and prevention efforts. This is especially true for children coming from economically disadvantaged backgrounds who are most at risk of falling below basic levels of achievement by the fourth grade (National Assessment of Educational Progress [NAEP], 2009). The goal of this study was to contribute to research on using problem analytic frameworks and CBM data in early numeracy interventions, with a general aim of improving early prevention and intervention practices.

Purpose, Research Questions, and Hypotheses

The first objective of the study was to administer EN-CBM for diagnostic purposes, using selected probes from the TEN. This provided a way of establishing which early numeracy sub-skill to target (e.g. number identification). Next, the IH was used as a problem analytic framework in order to help identify the type of skill deficit (e.g. acquisition, or fluency). Then the conceptual/procedural heuristic was used as a problem analytic framework in order to identify skill deficits that were conceptual, procedural, or both. A hybrid, ABAB reversal design, with alternating treatments component, was used to compare student progress across intervention phases that were either matched to the student's skill deficit, or un-matched. Study outcomes were assessed through regular progress monitoring in Number Identification (NI), one of the TEN measures. During each baseline and intervention phase, three timed (1 min) administrations of NI were given to the participant, and the median score was used to calculate the DV score for that session.

First, it was hypothesized that greater levels of the DV would appear during matched intervention phases than un-matched. In other words, NI per min (median score) would be greater during the unmatched phases than un-matched phases. Visual analysis of graphed data points (DV) would clearly demonstrate that data points in the matched phases were appearing at greater values along the y axis compared to un-matched phases. Additionally, there would be little to no overlap between data points in the matched and un-matched phases, suggesting that data points were consistently higher in the matched condition across study phases. In other words NI per min (median score) would be greater during intervention phases that were considered matched to skill deficits identified by the two problem analytic frameworks (IH, conceptual and procedural heuristic).

Next, it was hypothesized that data points (DV) would show greater increases in trend during matched phases than un-matched phases. Greater trend increases during matched phases would be determined by visually analyzing a split middle line of progress for each treatment phase. Matched phases were predicated to have a split middle line of progress that was more inverted than un-matched phases. In other words, matched phases were predicated to show greater increases in NI per min (median score), than the un-matched phases.

CHAPTER 2: REVIEW OF THE LITERATURE

Instructional Hierarchy & Skill by Treatment Interaction Approach

Burns et al. (2010) advocated for a skill by treatment interaction approach as a method of generating and verifying hypotheses using curriculum-based measurement (CBM). This approach can be used to identify skill deficits that are based along the continuum of skill growth and development, from inaccurate and slow, to accurate and slow (acquisition phase), to skills that can be performed quickly and accurately (fluency phase). The last two phases of the IH, (generalization and application) have not played as much of a role research applying the IH to intervention strategies. The skill by treatment interaction approach is focused on skill proficiencies and deficits that are deemed to be either acquisition or fluency based. Along with the concepts of acquisition and fluency based proficiencies/deficits, are the related concepts of instructional, and frustrational levels of performance. Instructional and frustrational levels represent a student's level of proficiency on a skill or skill set, and are defined as percentage correct per unit time. For example, in the case of reading, a number of correct words read would be calculated for a specific time period (e.g. one minute). In reading, an "instructional level" would be around 93 to 97 percent accuracy on words read aloud during a one minute oral reading probe (Gickling & Thompson, 1985). However, for mathematics, the instructional level is typically represented by lower accuracy criteria than for reading, with accuracy ranging between 70 and 80 percent of items answered correctly (Gickling & Thompson, 1985). Scores falling below this percentage are defined as frustrational. This level of performance represents inaccurate performance, and as the name implies, a frustrational range falls within the range of skills that are not yet acquired by the individual (Burns et al., 2010). These different performance levels have been associated with different types of interventions. For example, an accuracy deficit is best matched to an intervention that promotes acquisition of a new skill. Cover-copy-compare is an example of an acquisition based intervention that promotes learning through the process of providing models of math problems with answers provided, covering the model, then instructing the student to complete the problem without the model, and then uncovering the model and comparing the answers (Burns, et al., 2010). Codding, Shiyko et al. (2007) found that cover-copy-compare was more effective than explicit timing for students whose performance was in the frustrational, or acquisition phases of learning. In contrast, interventions that emphasized explicit timing and independent practice drills were more effective for students falling within the instructional level, or fluency stage of learning. Burns, et al. (2010) evaluated the different effects of acquisition and fluency interventions in a meta-analysis of studies coded as "using assessment data" such as CBM. For studies that were coded as acquisition based interventions, seven used cover, copy, compare procedures, and three used flash card drills such as incremental rehearsal. Interventions that emphasized practice opportunities, goal setting, and contingent reinforcement were coded as fluency interventions. A total of 11 studies used acquisition interventions, and five used fluency based interventions. Additionally, assessment data collected prior to the implementation of each intervention was coded as either instructional or frustrational. Results from the meta-analysis found that acquisition interventions, such as cover, copy, compare resulted in large effect sizes for students scoring within the frustrational ranges on pre-intervention skills assessments. In contrast, students' scoring within instructional level ranges demonstrated effect sizes within moderate ranges, indicating that the acquisition based intervention was less effective for students within the fluency stage of learning. A similar finding was demonstrated for fluency interventions; effect sizes were within the small to moderate ranges when provided to students who were coded as performing within frustrational levels on the skill (Burns, et al., 2010). These data lend support to the skill by treatment interaction approach. Acquisition interventions that were characterized by explicit modeling of concepts and frequent corrective feedback were most effective for students scoring within frustrational ranges of performance. In contrast, students scoring at instructional levels demonstrated greater progress when a fluency intervention was used in the study, indicating that more independent practice was necessary to enhance the skill (Burns et al., 2010).

Conceptual and Procedural Heuristic Case Study

Burns (2011) investigated the benefit of the conceptual and procedural heuristic, a new problem analytic framework that has recently emerged from early numeracy research. Conceptual knowledge is comprehension of the relationships that underlie math problems, whereas procedural knowledge is an understanding of the rules and steps required to solve math problems (Burns, 2011). The conceptual and procedural deficit heuristic is a method for selecting functionally related interventions in mathematics. Using a single subjects case design, two students—a second grader, and a fourth grader, were first identified as having low performance in conceptual or procedural skills. One participant was identified as having acceptable conceptual knowledge, but low procedural knowledge, whereas the other participant was identified as having acceptable procedural knowledge, but low conceptual knowledge. First, an intervention that was "mismatched" to the student's deficit was delivered so that the student with the conceptual deficit would receive a procedural intervention, and vice versa. Finally, each participant was given the "appropriate" intervention that was matched to his or her skill deficit (i.e., procedural intervention for procedural deficit). The study found that the matched intervention was more effective, with a mean percentage of non-overlapping points of 100%.

This is in contrast to the mismatched intervention, which resulted in only 16.5% of non-overlapping data points. Although study findings demonstrate potential for this problem analytic framework, more data is clearly needed in these early stages of research. One of the goals of the present study was to replicate and extend this line of research; first by using a younger participant (kindergartner), and also by adding the IH to problem analytic and matching procedures.

CHAPTER 3: METHOD

Participants and Setting

The research participant selected for the study was a five-year-old boy recruited from a school in a medium sized rural district in the southeastern United States. IRB approval was obtained prior to participant recruitment and study implementation (appendix I).The selection process began with teacher nomination. The researcher sent emails to two kindergarten teachers at the school, explaining the nature of the study and the selection criteria. The criteria required that potential participants be aged 4-6 years, struggling in math, but not identified as a student with a disability. Once the teacher had nominated a student, the primary researcher screened the student using standardized administration procedures for the TEN (Clarke & Shinn, 2004). The inclusion criteria for the study required that the student score at or below the 25th percentile on Number Identification (NI) and/or Quantity Discrimination (QD). National norms during the fall of the kindergarten school year were used to determine percentile ranking (norms can be retrieved at http://www.aimsweb.com). The 25th percentile ranking on grade norms has been recommended as a cutoff point when selecting students for additional instructional support within a Response to Intervention (RTI) model (Gerston, Jordan, & Flojo, 2005). Screening, problem analysis, and intervention sessions took place in a conference room located at the school. Signed parental consent was obtained prior to data collection (appendix J).

Materials

Dependent measures. The Tests of Early Numeracy were retrieved from http://www.aimsweb.com. The TEN are CBM tests that cover four domains that reflect skills being taught in the math curriculum during kindergarten and parts of first grade (Clarke & Shinn, 2004). Oral Counting (OC), which targets the ability to count aloud from one, was excluded in the study. Research suggests that OC is not as predictive of math performance as the other TEN measures (Clarke & Shinn, 2004). Additionally, MN was not used in the study because there was strong evidence during screening that this skill was well beyond the participant's skill level. Scores on MN during the fall of kindergarten tend to be low and beyond the instructional level of many students during the fall of kindergarten (Lembke & Foegen, 2009; Martinez et al., 2009). Therefore, only NI was used to assess changes to the DV in response to the IV (e.g. progress monitoring.)

NI measures the ability to name numerals (0-10) during a one-minute interval. Clarke & Shinn (2004) have reported correlation coefficients of .99 for inter-scorer reliability, .93 for alternate form reliability, and .85 for test retest reliability. Martinez et al. (2008) reported a correlation coefficient of .92 for test-retest and .91 for delayed alternate forms reliability. Using the Woodcock Johnson Applied Problems (WJ-AP) as a criterion, a predictive validity correlation coefficient for NI was reported as .68 (Clarke & Shinn, 2004). Using the Stanford 10 Achievement Test (SAT-10*)*, a concurrent validity correlation coefficient was reported as .44, and .31 for predictive validity (Martinez et. al, 2008).

There is also evidence to suggest that the TEN is sensitive to growth and suitable for progress monitoring. Among the TEN measures, NI demonstrates the most sensitivity to growth. Additionally, growth rates in NI skills are highest during kindergarten, and especially for students scoring in the lower percentile ranges. For example, for students scoring below the 25th percentile, the average growth rate between the fall and winter of kindergarten is one unit, or one digit per week (Clarke & Shinn, 2004.)

Problem analysis, maintenance & generalization measures. Quantity Discrimination and Quantity Array measures were administered during the problem analysis to help diagnose skill deficits in early numeracy. These measures were also administered approximately three weeks after the last day of intervention. Scores at pre and post intervention were used to assess generalization and maintenance of early numeracy skills.

QD is a measure of an examinee's ability to compare two numerals and identify which is larger. Studies investigating the technical adequacy of the TEN have consistently reported reliability and validity statistics that support the use of QD as technically adequate screening measure (Lembke & Foegen, 2009; Martinez et al., 2009; Clarke & Shinn, 2004). Clarke & Shinn (2004) reported a correlation coefficient of .99 for QD inter-scorer agreement, and a correlation of .92 between alternate forms of the measure. Martinez et al. (2008) reported a correlation coefficient of .77 for delayed alternate forms reliability and .80 for test retest reliability. Using the WJ-AP as a criterion, a predictive validity correlation coefficient for QD was reported as .79. Using the SAT-10, Martinez et al. (2008) reported a concurrent validity correlation coefficient of .63, and .46 for predictive validity.

Another CBM measure, Quantity Array (QA) was administered as part of the problem analysis. This measure was used diagnostically to assess conceptual and procedural skills deficits. It was also administered at post intervention approximately three weeks after intervention. QA measures are presented as a series of dots that can be estimated or counted. This measure has demonstrated potential in evaluating early numeracy skills that are not captured in the TEN. Additionally, Quantity Array measures provide a way to assess estimation skills (conceptual) and procedural counting using one to one correspondence (procedural). Lemke and Foegen (2009) used a quantity array measure along with NI, QD, and MN to predict first grade math performance. Using the TEMA-3 as criterion, predictive validity correlations of

.35 were found between quantity array scores and the criterion. This level of predictive validity was comparable to NI and QD measures, which ranged from .34 to .37 (Lemke & Foegen, 2009).

Procedure

Establishing baseline. NI scores were used for determining stability in baseline and for progress monitoring. Although NI was the single DV used to establish baseline and monitor responses to different study treatments (IV), generalization of early numeracy skills was also considered relevant to the study's overall purpose. Therefore, QD and QA measurements were administered at baseline and post-intervention. Since QD was beyond the instructional level of the student it would have been unethical to spend time progress monitoring a skill that was clearly inappropriate for the child and likely to produce a floor effect (i.e. scores of zero, or no score.) The participant consistently missed the first five items administered on QD probes during baseline testing, thereby meeting the discontinue criteria outlined in the TEN administration and scoring manual. Although QD and QA were not used for progress monitoring purposes, measuring these skills at pre and post intervention periods provided data about potential generalization and maintenance of early numeracy skills.

CBM procedure. Administration procedures began with placing a copy of a NI probe in front of the examinee. The examiner placed another copy on a clipboard and positioned it so the participant was unable to see what the examiner was writing down. Next, the examiner provided the examinee with the following instructions: "Look at the paper in front of you. It has a number on it (demonstrate by pointing). What number is this?" Similarly, the instructions given for QD include the following statements: "Look at the piece of paper in front of you. The box in front of you has two numbers in it (demonstrate by pointing), I want you to tell me the number that is bigger." Once the examiner gave the participant the instructions a stopwatch started timing for one minute. If the participant did not answer the first problem after three seconds, he was told to "try the next one." If he failed to get any items correct within the first five items the test was discontinued and a score of zero was recorded. As the participant responded to each item on the probe set, the examiner followed along and places a slash (/) through incorrect responses. Credit (score = 1) was given for correct responses, whereas skipped or incorrectly answered items were given no credit (score = 0). Cumulative scores on each measure were calculated as the total number of correctly identified numerals during a one-minute administration period. At the end of the one minute interval a bracket was placed around the last item completed and the examiner told the participant to stop (instructions can be retrieved at http://www.aimsweb.com).

Quantity Array administration took place during the problem analysis and again approximately three weeks after the last intervention session. The following instructions were given to the participant: "The paper in front of you has boxes with dots in them. When I say begin, I want you to tell me how many dots are in each box. Start here and go across the page. If you come to one that you don't know, I'll tell you to go on to the next one. Are there any questions?" Responses were recorded as the student said the answers aloud. The administration was untimed and scores were calculated as the percentage correct out of 42 items.

Problem analysis procedure. Prior to data collection, a set of problem analytic procedures were administered to determine which interventions best matched the student's skill deficits. Problem Analysis took place during one session and lasted approximately 45 minutes. The steps are also outlined in Appendix A. Curriculum based measures (NI, QD) were administered according to standardized administration instructions (Clarke & Shinn, 2004). The problem analysis started with NI because these skills are considered prerequisite to QD skills. The study criteria for determining a skill deficit was a median score falling at or below the 25th

percentile on national AIMSweb norms. During the fall of kindergarten, the 25th percentile corresponded to the criterion of 15 correctly identified digits per minute (retrieved from: http://www.aimsweb.com.) The participant obtained a median score of 1 on standardized NI probes. Therefore, a skill deficit was identified in NI. Although the participant also obtained a score below the 25th percentile on QD, this is a more advanced skill, so NI was chosen as the skill deficit to target in the matched intervention. Although, a completely un-matched intervention would theoretically target the contraindicated skill area (e.g. QD instead of NI), doing this would likely reduce the educational benefit to the participant, and would have moved beyond the more relevant questions of the study. Therefore all interventions in the study targeted the area of NI, including the un-matched intervention.

The next step in the problem analysis was determining whether or not the deficit in NI was a fluency or acquisition deficit. In order to answer this question, the participant was administered an untimed NI probe. If the participant scored below 80% correct (accuracy) the deficit would be considered an acquisition deficit. This criterion was based on the Gickling and Thompson (1985) criteria that suggest 70%-85% accuracy reflects an instructional level in math, and that accuracy below this represents a frustration range. The participant's score on the untimed probe of 56 items was 21% accurate; therefore the skill deficit was defined as an acquisition deficit in NI.

The next goal of the problem analysis was to determine whether or not the acquisition deficit in NI was related to conceptual skills, procedural skills, or both. The participant was shown quantity arrays on a worksheet and asked to tell the examiner the number of dots presented. The criteria set aside for determining the existence of a conceptual deficit was accuracy falling below 80 percent correct. Examples of theses Quantity Array forms can be found in Appendix H. The participant was administered 42 Quantity Arrays, with each item featuring a range of dots (1-10) arranged similarly to dice, or dominoes. The participant correctly identified five out of 42 items (12% accuracy), meeting the study criteria for a conceptual deficit in number identification skills. Error analysis also revealed that the student struggled with estimating quantities, a skill that is believed to be conceptual in nature (Dowker, 2007). For example, when presented with a Quantity Array with less than three dots, the participant was inconsistent with responses. Additionally, the participant would sometimes attempt to "recount" dots on a new item, even when the same Quantity Arrays were in close proximity (i.e. separated by one or two items on the probe.) The ability to estimate quantities, and understand the "same number" concept is one way that conceptual deficits in early numeracy are identified (Dowker, 2007; Burns, 2011.) Error Analysis also revealed deficits in procedural counting skills such as using one to one correspondence to count objects in an array. For example, during some items it was noted that the participant would "double count" certain dots and fail to count others. These types of errors indicate skill deficits in counting procedures (Dowker, 2007). Therefore the participant was identified as having both procedural and conceptual deficits in number identification skills. Since both conceptual and procedural deficits were indicated by the problem analysis, the matched condition included both conceptual and procedural interventions. Although an un-matched intervention was originally proposed for the study, the existence of deficits in both conceptual and procedural skills made matching and un-matching on this dimension difficult. Burns (2011) makes the suggestion that when both conceptual and procedural deficits are implicated by problem analysis, the conceptual deficit should be targeted first because conceptual skills are more fundamental. However, there is little elaboration on why conceptual knowledge is considered more fundamental to skill acquisition.

Overall, there appears to be no clear consensus in the literature regarding how conceptual and procedural skills should be treated when both are identified as skill deficits (Dowker, 2007; Ketterlin-Geller, Chard, & Fien, 2008). As such, it seemed unwise to assume that a conceptual or procedural intervention would be more or less matched to the participant's needs. Comparing conceptual and procedural interventions was a prudent and necessary approach since both deficit types were implicated during problem analysis. However, it did create an opportunity to compare conceptual and procedural interventions when both were implicated as skill deficits. One of the major objectives of the study was to investigate how the conceptual and procedural heuristic might be applied in problem analysis. However, it may not always be apparent in an initial problem analysis which type of intervention is going to lead to the most growth in the targeted skill, especially if the student is missing many prerequisite skills. Understanding any potential differences between the two intervention types is important to making the conceptual and procedural heuristic a useful tool for problem analysis, especially in cases of low performing students who present both types of deficits.

The only dimension in which interventions were matched and un-matched was along the lines of the IH. The un-matched intervention selected for the study was a fluency-based intervention in NI. The matched interventions were both acquisition based interventions, one targeting conceptual knowledge deficits in NI, and the other addressing procedural knowledge deficits in NI (e.g. using one to one correspondence to count and identity numbers.)

Intervention procedure. The participant was picked up from his classroom around 1:30-2:00 in the afternoon each day. This occurred at a time when other students were doing independent learning activities at classroom centers. The intervention took place in one of the school's conference rooms, and the student was escorted to and from the intervention location each day. Sessions lasted approximately 30 minutes, and included time for progress monitoring. The first 15-20 minutes was spent on instructional activities, and the last five minutes was spent administering progress monitoring probes in NI. Approximately five minutes of each session was spent redirecting the child as necessary, and providing small rewards (e.g. stickers) at the end interventions sessions contingent upon the participant's hard work and cooperation.

Matched intervention #1: NI/acquisition/conceptual. Lessons began by presenting a worksheet and demonstrating or explaining the task to the participant. Information for the matched acquisition/conceptual intervention can also be located in Appendix C. Worksheet items included numbers (1-9), presented as words, numerals, and a series of dots. Worksheets activities included drawing dots next to numerals, and writing numerals next to dots. The goal of the activity was to write the correct numeral next to the corresponding number of dots, and vice versa. During initial sessions, the interventionist modeled the task by first completing the item, covering up the answer, and then instructing the participant to complete the item again. After the first intervention session, the participant appeared to be familiar with the task and was asked to begin working on the first item. Familiarity of the task was determined by the participant's ability to draw dots or numerals for worksheet items without the researcher providing examples or verbal instructions. In these instances, the student was provided the worksheet and would begin working on the first item after a simple prompt from the examiner, such as "go ahead with the first one." Modeling and error correction occurred if the response given by the participant was incorrect. If the participant wrote down an incorrect response, the researcher would make a statement such as "that's not quite right," and make the correction to the worksheet. This was followed by additional explanation and feedback. The correct response was then covered by a piece of folded paper, and the participant was asked to correct the item before moving on to the next one. If the participant produced a correct answer to an item he was provided verbal statements, such as, “great job” and “that’s right” in order to provide immediate feedback on performance. He was then asked to complete the next item on the worksheet. When incorrect responses were given, the correction and modeling procedures would occur and were repeated as necessary before moving on to the next item.

In addition to DotMath worksheets, a card matching game was implemented as part of the matched conceptual intervention. This intervention was employed on separate intervention days than worksheet activities. The card game was designed to address the same conceptual skill deficits as the worksheet activities. Producing written responses on worksheets takes more time than identifying correct card matches, especially for a young child with limited proficiency using a pencil. The purpose of the game intervention was to increase opportunities to respond with the notion that matching a number/numeral card pair would take less time than a comparable worksheet item covering similar information (e.g. three objects identified as “3”).

Cards with numbers (1-10) were presented in ascending order in front of the participant who was seated at a table. Cards featuring pictures of objects and Disney characters were shuffled and then placed in random order above the row of number cards. The participant was instructed to match each numeral card to the card picturing the same number of objects. The participant was told that he would get a sticker at the end of the session for every correctly matched card. When the student incorrectly matched a card, the researcher immediately corrected the error and provided the correct match. These cards were then removed, and used later to provide new opportunities to match cards previously missed by the participant. For correct matches, the participant was given verbal praise, and the match was placed in a pile and removed from the game.

Matched intervention #2: NI/acquisition/procedural. DotMath worksheets were also used during the matched procedural intervention, and included the same modeling and feedback strategies described for the conceptual intervention, such as immediate error correction and modeling of correct responses. A description of the matched acquisition/procedural intervention can also be located in Appendix D. The DotMath activities for the procedural intervention differed from the conceptual intervention by providing explicit instruction and modeling in the area of procedural counting (e.g. rules for one-to-one correspondence and cardinality). Two strategies were incorporated during the completion of worksheets that were not incorporated during the conceptual intervention. The first strategy was instructing the participant to use a pencil to cross out each dot as it was counted aloud. This was used to emphasize the concept of one-to-one correspondence and to prevent procedural counting errors, such as counting a dot more than once, or failing to count one of the dots pictured. For items that required translation of dot quantities into a numeral, the participant used the crossing out strategy with his pencil while counting aloud. Once he finished counting, he was instructed to write the numeral that corresponded to number of dots. The second strategy was applied to items that required the participant to draw dots corresponding to the pictured numeral. On these items, he was instructed to draw in the number of dots corresponding to each numeral while counting aloud. Once he reached the correct number of dots he was instructed to drop his pencil. Dropping the pencil was done to emphasize the concept of one to one correspondence and cardinality. By dropping his pencil the participant was prevented from drawing additional dots after the target number had been reached. If the student forgot to implement one of these strategies appropriately, he was prompted to use the procedural strategy taught to him.

Un-Matched intervention: NI/ fluency. During the un-matched fluency intervention, the student completed DotMath worksheets- the same instructional materials used in the two matched interventions. The difference between the matched and un-matched intervention was that during un-matched sessions, the worksheets were administered in timed formats, and feedback was delayed until the participant completed as many items as he could in one minute. A description of the un-matched/fluency intervention can be found in Appendix B. During timed drills the participant was instructed to work independently and complete as many items as possible during a one minute interval. He was also provided with a target goal and told that he could earn candy as a reward for meeting target goals (e.g. a specified number of correct items). Prior to the intervention, the participant was asked what his favorite candy was so that the reward would be sufficiently reinforcing to him. After he completed the timed drill, the researcher reviewed the items with the participant and provided feedback on each item with regards to the accuracy, and modeled correct responses for items missed.

After reviewing the items completed during the first drill, another drill worksheet was provided to the participant with the same instructions to complete items independently and obtain as many correct answers as possible. Target goals and criteria for reinforcement were adjusted based upon performance on the first drill. If the student failed to receive reinforcement on the first drill, targets were lowered to meet his previous level of performance. If the student met or exceeded expectations, target goals were increased to a greater number of items correct per minute. When target goals were not met during a drill, the goal for the next drill was adjusted to match the number of items correctly identified on the most recent trial. For example, if the target goal was originally set to six correct items per minute, but the participant only got four, the goal was lowered to four items on the next drill. If the participant reached the target goal during a drill, the goal for the next drill was increased to the current level of performance "plus one," thereby increasing the threshold for positive reinforcement by "one more" correct response per min for the next trial. The rationale was to increase criterion goals by small increments which were more likely to allow positive reinforcement to continue, rather than increase goals to levels that would be difficult to reach. If the participant reached his target goal, positive reinforcement (e.g. candy) was delivered after each worksheet was reviewed and scored.

Procedural integrity. Integrity checklists for each intervention are listed in Appendices E, F, and G. Procedural integrity checklists were completed by the researcher for 100% of the sessions. Checklists were filled out after the researcher returned from escorting the student back to class, approximately five minutes after each session ended. Intervention start and stop times were recorded on checklist forms immediately before the intervention started and ended. However, for three of the sessions, start times were recorded after the intervention had ended. For those days, session start times were estimated, and therefore coded as a "missed" step on the procedural checklist for that session. Fidelity for each intervention session was calculated by dividing the total number of steps implemented correctly by the total number of steps listed on the checklist, multiplied by 100. The percentage of implemented steps observed ranged from 86% to 100%, with a mean implementation of 91.2%.

Permanent product data were used to assess treatment integrity with regards to immediate corrective feedback and error correction procedures. This step was also included as step five on treatment integrity checklists for the matched interventions. Since corrective feedback procedures are central to delivering acquisition interventions with integrity, analysis of work products was considered a worthwhile analysis (Burns, Codding, Boice, Luikito, 2010). This step was counted as "complete" if there were written signs of correction found for an attempted worksheet item (e.g. changing a numeral, erasing dots). In other words, corrective feedback was defined as a completed step (i.e. “complete”) whenever corrections were made in response to a wrong answer given by the participant. If the worksheet item was answered correctly by the participant, and no error correction was necessary, the step was also coded as “complete.” If the participant provided an incorrect response and no signs of error correction were evident, the step was coded as “incomplete” for that item. After all attempted worksheet items were reviewed and coded as “complete” or “incomplete,” a percentage was calculated for the implementation of this step (i.e. corrective feedback). Fidelity of corrective feedback procedures used during the matched acquisition interventions was calculated by dividing the total number of worksheet items demonstrating complete implementation of corrective feedback (i.e. “complete”), by the total number items attempted, multiplied by 100. There were 71 total items attempted by the participant that could be analyzed. Corrective feedback was appropriately delivered for 100% of these items.

The researcher had another observer who was trained in CBM administration procedures rescore NI probes. Inter-observer agreement was calculated at 99%. One scoring error was detected during the rescoring process.

Data Analysis

Changes in level and trend were analyzed within and between study phases in an evaluation of whether the phase changes may have impacted the direction and level of the data. Since the participant had both conceptual and procedural deficits, both acquisition interventions were coded as being matched to participant skill deficits. The fluency intervention was coded as un-matched since the problem analysis did not implicate a fluency-based intervention as being appropriate for the participant. Visual analysis was used to compare the level of data points and the amount of overlap between data in the matched and un-matched phases. This was done in order to evaluate the study hypothesis that matched intervention phases would result in higher NI scores (DV) compared to un-matched intervention phases.

Comparison of data trends in the matched and un-matched conditions were evaluated using the split middle line of progress. The purpose of this analysis was to evaluate the hypothesis that matched study phases would demonstrate greater trend increases than un-matched phases. A split middle line of progress was also determined for each type of matched intervention. Since both conceptual and procedural interventions were matched to skill deficits, un-matching procedures could not be applied to the conceptual and procedural heuristic. However, split middle analysis was used to evaluate potential differences in data trends which might suggest that a conceptual or procedural intervention was more effective, and therefore a better match to student needs.

Split middle trend lines were determined using a four step process of splitting data points. First, data were split into equal parts, then the intersection of the mid-rate and mid-dates were identified for each half. After the intersecting points were identified for each half, a line was drawn connecting the points in order to find the quarter intersect line of progress. The line was then adjusted so that there were an equal number of data points falling on or above the line as there were falling on or below the line. During this adjustment the line was moved slightly up or down, ensuring that the line remained parallel to the original line (Cooper, Heron, & Heward, 2007).

Design

The study implemented a hybrid single-case design, beginning with a reversal design (A-B-C-B-C-B/C), followed by an alternating treatments design. Changes between the study phases were assessed using multiple data analytic techniques supported for these types of single-case design. To evaluate hypothesized outcomes, phases were implemented as follows; A was baseline, B was the matched intervention, and C was the “un-matched/fluency” intervention. Each phase lasted approximately three to four sessions. The baseline phase took place across three consecutive days when no intervention occurred. Intervention phases initially lasted three to four sessions before phase changes were made. This allowed the participant to become acclimated to each intervention as it was initially introduced. After all intervention conditions had been introduced into the study, phase changes became more rapid in a manner consistent with an alternating treatments design. The alternating treatments design, or repeated acquisition design (RAD), can be used to identify the intervention that leads to the greatest growth. Boren (1963) proposed that this type of design could be used to examine how quickly skills are acquired under different conditions.

The table below provides a timeline and sequence for baseline and intervention phases, as well as events relevant to the study’s methodology, design, and data analysis.

Table 1
Screening, problem analysis, and intervention activities

DATE	DESIGN PHASE	ACTIVITIES	INTERVENTION TYPE
10/4/12	n/a	eligibility screening	n/a
10/12/12	n/a	problem analysis/deficits identified	n/a
10/15/12	A	baseline	baseline (none)
10/16/12	A	baseline	baseline (none)
10/17/12	A	baseline	baseline (none)
10/22/12	B1	matched intervention	acquisition/conceptual
10/31/12	B1	matched intervention	acquisition/conceptual
11/5/12	B1	matched intervention	acquisition/conceptual
11/7/12	B1	matched intervention	acquisition/conceptual
11/13/12	C1	un-matched intervention	fluency drills
11/14/12	C1	un-matched intervention	fluency drills
11/15/12	C1	un-matched intervention	fluency drills
11/16/12	B2	matched intervention	acquisition/procedural
11/19/12	B2	matched intervention	acquisition/conceptual
11/28/12	B2	matched intervention	acquisition/conceptual
11/29/12	B2	matched intervention	acquisition/procedural
12/5/12	C2	un-matched intervention	fluency drills
12/12/12	B3	matched intervention	acquisition/procedural
12/14/12	B3	matched intervention	acquisition/procedural
12/17/12	C3	un-matched intervention	fluency drills
01/9/13	n/a	Post intervention follow-up (23 days)	n/a

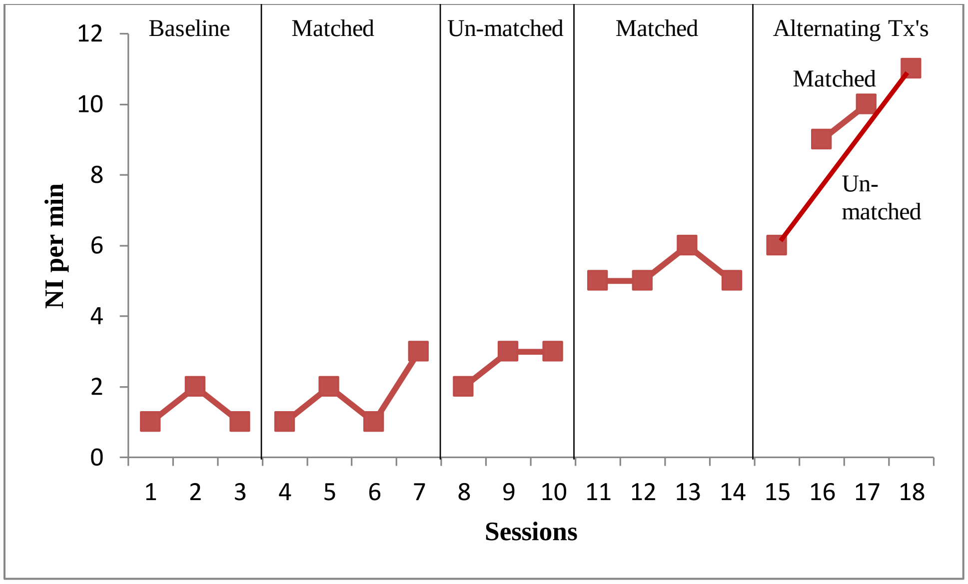
CHAPTER 4: RESULTS

In Figure 1, the number of correctly identified digits per minute is presented across baseline, matched and un-matched phases. Data points corresponding to the A-B-C-B reversal design phase of the study are separated by phase lines indicating changes in treatment. The last four data points represent alternating treatments in which matched and un-matched phase changes were made in more rapid succession. These data points are connected by treatment type (i.e. matched/unmatched), and labeled accordingly. During baseline, the participant obtained scores ranging from 1-2 on NI probes, indicating that he was able to correctly identify 1-2 digits (numerals 0-10) during a 1-min probe. In the first matched intervention phase, NI scores ranged from 1-3, resulting in overlap with data points in the baseline phase. Only one data point in the first matched phase was a non-overlapping data point. In the first unmatched phase there was complete overlap with data points from the matched phase, and NI scores ranged from 1-3. However, there was no overlap between any of the data points in the un-matched phase and the second matched phase. Scores in the un-matched phase ranged from 2-3, and scores in the second matched phase ranged from 5-6. This was the last intervention delivered in reversal fashion before switching to an alternating treatments design. Alternating treatments occurred on the last four intervention sessions (15-18), and consisted of two matched and two unmatched intervention sessions. The participant obtained a NI score of six during the first unmatched session of the alternating treatments portion of the study, and a score of nine during the first matched session. Although the level of data points in the matched sessions was initially higher, there was an increase in performance during the next un-matched phase. In the final un-matched phase, the participant obtained a NI of 11, which was the highest score obtained during the study period.

Scores on the dependent variable were consistently low across all phases as well, suggesting that the participant continued to struggle with NI skills throughout study phases. The visual analysis of the level of data points across study phases did not support the hypothesis that matched interventions would result in higher NI scores than un-matched interventions. In fact growth in NI skills (DV) was slow and steady across time, in a manner consistent with typical skill maturation. However, in order to get a better sense of how much growth might be expected in the DV in the context of typical maturation and skill growth, AIMSweb norms were consulted (norms can be retrieved at http://www.aimsweb.com.). Average rates of improvement are published in the TEN norms manual and estimated weekly growth rates can be viewed by skill type (e.g. NI), score and percentile rankings, grade, and time of school year (e.g. fall to winter). Overall growth in NI skills during intervention periods was determined by subtracting the score obtained at baseline (NI=1) from the highest DV score obtained on the last day of the study (NI=11). The participant increased his NI score by 10 units during eight to nine week period he received interventions. Therefore, his average weekly rate of improvement during the intervention period (including weekends, holidays, etc.) was calculated as approximately 1.0 unit or digit per week. This is the same growth rate that AIMSweb reports for kindergarten students scoring below the 25th percentile in NI between the fall and winter months, thus supporting the maturation hypothesis.

Figure 1

NI per min across matched and un-matched interventions



Split Middle Analysis

Figure 2.0 depicts a split middle line of progress for matched and un-matched interventions. A split middle line of progress was drawn to help analyze any potential differences in data trends between the matched and un-matched intervention phases. First, data from the un-matched phases were split into two equal halves. The dividing line was drawn through the un-matched data point corresponding to session number ten on the x-axis. This left two un-matched data points remaining on each half. Next, the intersections of the mid-rates and mid-dates were identified for the left and right halves. A quarter-intersect line was drawn by connecting point 2.5 (y axis) and point 8.5 (x-axis), to the intersection of point 8.5 (y axis) and point 16.5 (x-axis). The data points were then counted and the line adjusted as necessary to ensure that equal numbers of data points on or above the line, as on or below the line.

Next, a split middle line of progress was found for matched intervention phases. First, matched data points were split into two equal parts, with data being split at point 11.5 on the x axis. This left five matched intervention data points in each half. Then the intersecting mid-rates and mid-dates were identified for each half of the data. A quarter-intersect line was then made by connecting point 2 (y axis) and point 6 (x-axis), to the intersection of point 6 (y axis) and point 14 (x-axis). The line was then adjusted so that that equal numbers of data points were falling on or above the line, as on or below the line.

Split middle analysis revealed gradual increases in data trends in the matched and un-matched phases over time. NI scores increased from a baseline of 1-2 correct digits per minute up to 11 digits per minute on the last day of intervention. However, visual analysis of data trends for each type of intervention did not support the hypothesis that data trends would demonstrate greater increase during matched intervention phases than un-matched phases.

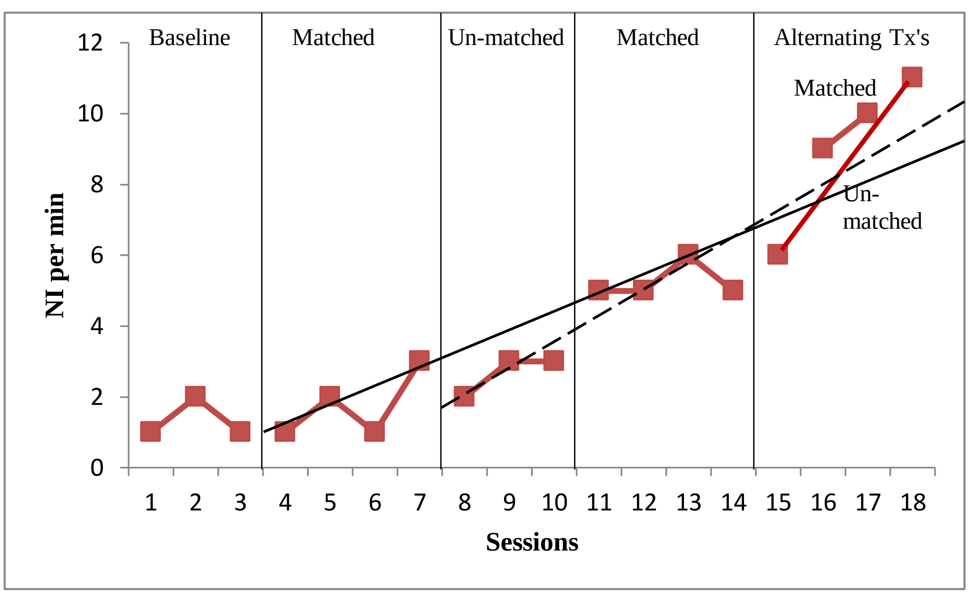
In Figure 2.1, the data trends for the two matched interventions were compared using split middle analysis. First, procedural intervention data points were split into equal halves by dividing data at point 14.5 on the x-axis. Two procedural data points remained in each half. Next, the mid-rates and mid-dates were identified for the left and right halves of the data. The quarter-intersect line connected point 5 (y-axis) and point 12.5 (x-axis), to the intersection of point 9.5 (y-axis) and point 16.5 (x-axis). After the quarter-intersect line was then drawn, the line was adjusted slightly to ensure that equal numbers of data points fell on or above the split middle line as on, or below the line.

The process developing a split middle line of progress was repeated for the conceptual data. Conceptual data points were first divided into separate halves along the x- axis at point 6.5, leaving three conceptual data points in each half. Then the mid-rates and mid-dates were identified for each of half of the data. The quarter-intersect line was drawn by connecting points 1 (y-axis) and 5 (x-axis), to the intersection of points 5 (y-axis) and 12 (x-axis). After the quarter-intersect line was then drawn, the line was adjusted as necessary to ensure equal numbers of data points above and below the line.

Split middle analysis did not reveal any notable differences in the trend of data points across conceptual and procedural intervention phases. Although no differences in data trends were ever hypothesized, split middle analysis provided a useful way of potentially uncovering differences that may have been overlooked if interventions were coded and analyzed as "matched" only. Data trends were similar with regards to the direction of data, as well as growth across respective study phases. The participant obtained a score of one on the DV during the first conceptual intervention session. This score increased to five by the last conceptual intervention session. A DV score of five was obtained on the first day of the procedural intervention. This score increased ten by the last day of the procedural intervention. It should be noted that the conceptual intervention was introduced earlier in the study and also ended earlier, which is why scores were generally lower in the conceptual phase.

Figure 2

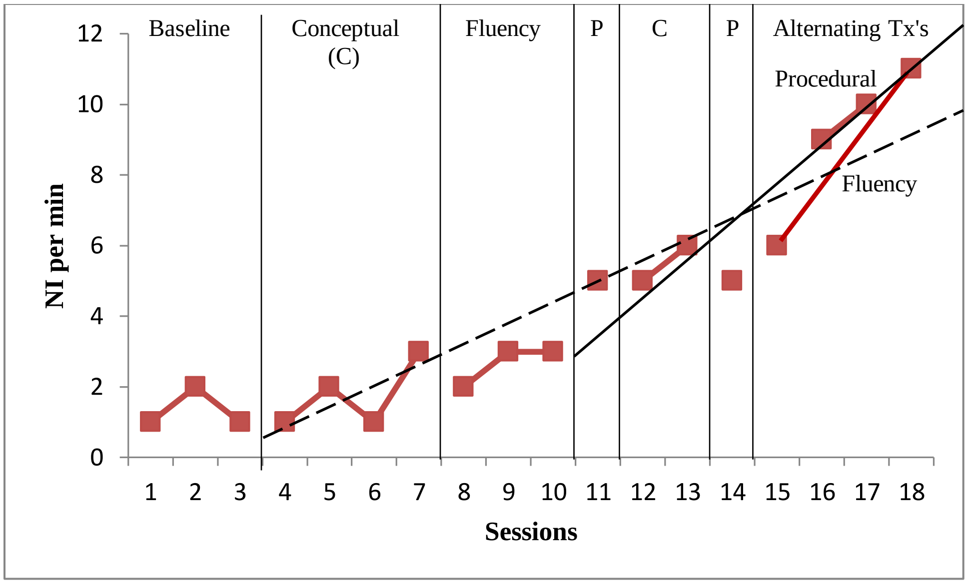
Spilt middle line of progress for matched and un-matched conditions



Solid=matched, Dashed=un-matched

Figure 3

Spilt middle line of progress for conceptual and procedural interventions



C=Conceptual, P=Procedural

Solid line=conceptual intervention, Dashed lined= procedural intervention

Maintenance & Generalization

In order to investigate potential generalization of NI skills, QD scores were compared at pre and post intervention. QD data were collected once at baseline, again on the last day of intervention, and 23 days post-intervention. Median scores for QD at baseline ranged from 0-1. On the last day of data collection, a median QD score of 4 was obtained. The median QD score of 2 was obtained at 23 day follow-up. Quantity Array measures were also administered at pre and post intervention phases. During problem analysis, QA probes were scored for accuracy in untimed administrations. Accuracy on QA probes was equal to 12% accuracy, or 5 out of 42 correctly identified quantity arrays. At 23 day follow-up, quantity arrays were administered again, and scored for accuracy. At follow-up, the participant obtained an accuracy percentage of

76%, or 32 out of 42 items correct. Maintenance of NI skills was also assessed by administering NI probes 23 days after intervention. A median score of 11 was obtained, the same score obtained on the last day of intervention.

CHAPTER 5: DISCUSSION

There has been growing concern over the years that the United States is falling behind other nations in mathematics achievement. The National Assessment of Educational Progress reported that 18% of all students were below basic level of achievement by 4th grade, and 29% were below basic level by eighth grade (National Assessment of Educational Progress [NAEP], 2009). High stakes testing has emphasized the responsibility of individual teachers and schools for the achievement of their students. Problem solving models and problem analytic frameworks provide an objective method for identifying deficits, generating hypotheses, and selecting appropriate interventions (Christ, 2008). The study examined whether using a problem analytic approach resulted in interventions that were better matched to individual student needs in early numeracy (i.e. skill deficits.)

Interventions were matched based upon the problem analytic framework of the Instructional Hierarchy (IH). Interventions in the matched condition were acquisition-based, whereas interventions in the un-matched condition were fluency-based. The determination of whether an intervention was matched to the participant's skill deficits was made during problem analysis phase of the study. Although the study initially sought to match interventions along the conceptual and procedural heuristic, this did not occur due to the student's low ability in both of these areas. However, study procedures did employ both conceptual and procedural interventions within the matched condition. Dependent outcomes were assessed by regular progress monitoring in Number Identification (NI). Quantity Discrimination and Quantity Array probes were also administered at pre and post intervention periods to assess potential generalization and maintenance of early numeracy skills.

The study incorporated an A-B-C-B-C-B/C design, incorporating elements of both reversal and alternating treatments designs. Changes between the study phases were assessed using multiple data analytic techniques. To evaluate hypotheses, phases were implemented as follows; A was baseline, B was the matched intervention, and C was the un-matched/fluency intervention. It was hypothesized that score increases on the DV (median of three NI probes) would be greatest during phases when the intervention was matched to the student's skill deficits.

However, study hypotheses predicting greater increases in the level and trend of data points in the matched intervention were not supported by study data. It is possible that the level and trend of data was related to factors such as maturation or classroom instruction. For example, the participant's estimated weekly growth rate in NI during the intervention period was one unit per week, which was also the same weekly growth rate reported by AIMSweb norms for kindergarten students scoring below the 25th percentile between the fall and winter months. This suggests that growth in NI skills was related to maturation and typical patterns of growth observed for same grade peers, performing at a similar level on this skill.

Several study limitations may have impacted study outcomes. Problem analytic procedures proposed for the study were not prepared to address the lower skill levels of the research participant. He had not yet mastered one to one correspondence and procedural counting skills. This limited how much the problem analysis could be used to differentiate between matched and un-matched conditions, similar to the way floor effects might reduce the utility of an assessment instrument. Additionally, the presence of both conceptual and procedural deficits limited the scope of study since hypotheses relating to the conceptual and procedural heuristic were based upon the idea of matching and un-matching interventions to skill deficits. This limited the aims of study to the IH. Additionally, the use of a single participant was a limitation which prevented comparison across participants. Order effects may have impacted scores on the DV across different treatment phases. Without another participant in the study, there was no clear way of assessing how order effects might have impacted scores on the DV.

Implications for Practice and Directions for Future Research

Although applying problem analytic frameworks to intervention selection did not produce the hypothesized effects, there were promising findings. In particular, the maintenance and generalization measures produced some interesting outcomes with potential implications for practice. Quantity Array (QA) measures may have demonstrated growth in procedural counting skills that were not reflected in the dependent variable (NI). Analyses revealed substantial growth in quantity array skills that increased from 12% accuracy to 76% accuracy at post intervention follow-up.

Future research is needed in order to better understand how the conceptual and procedural heuristic can be applied to the diagnosis and treatment of early numeracy skill deficits. In particular, it might be interesting to examine the technical adequacy of QA probes for progress monitoring, as well as their practical applications within problem analytic frameworks such as the conceptual and procedural heuristic. QA probes have potential to assess procedural counting skills, and potentially conceptual skills, such as estimation. Studying how QA can be used within the conceptual and procedural heuristic is a future research question that is both compelling from the perspective of understanding how early numeracy concepts are developed, and practical with regards diagnostic purposes and progress monitoring.

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APPENDIX A: PROBLEM ANALYSIS STEPS

- **Step 1:** Administer NI using standardized procedures
- **Q1:** Is the score below the 35th percentile on kindergarten norms?

  If yes, go to step 2. If no, skip to step 4.

- **Step 2:** Administer NI using untimed procedures
- **Q2:** Is accuracy below 80%?

  If yes, go to step 3. If no, problem analysis ends. The matched intervention is <u>NI/Fluency</u>.

- **Step 3**: Administer Quantity Array/NI version
- **Q3:** Is accuracy below 80%?

  If yes, the matched intervention is <u>NI/Acquisition/Conceptual</u>. If no, problem analysis ends. The matched intervention is <u>NI/Acquisition/Procedural</u>.

- **Step 4:** Administer QD using standardized procedures
- **Q4:** Is the score below the 35th percentile on fall kindergarten norms?

  If yes, go to step 5. If no, problem analysis ends. The participant is does not meet criteria for study and is disqualified.

- **Step 5:** Administer QD using untimed procedures
- **Q5:** Is accuracy below 80%?

  If yes, go to step 6. If no, problem analysis ends. The matched intervention is <u>QD/Fluency</u>.

- **Step 6:** Administer Quantity Array/QD
- **Q6:** Is accuracy below 80%?

  If yes, a <u>QD/acquisition/procedural deficit</u> is identified. Problem analysis continues to assess for a conceptual deficit. Go to step 7.

  If no, go to step 7.

- **Step 7:** Administer Quantity Array/QD. Ask the student to count the total number of dots shown for each item. Afterwards, ask the examinee "how many dots are there when you start counting from the other side?"
- **Q7:** Does the examinee proceed to count the dots again?

  If yes, a <u>QD/acquisition/conceptual deficit</u> is identified

APPENDIX B: UN-MATCHED INTERVENTION/FLUENCY

1. *Objective:* Increase opportunities to respond with immediate corrective feedback *Method of instruction:* Monitored practice using worksheets that require students to fill in the appropriate number of dots corresponding to numerals and vice versa (numerals from dots). The participant will fill out the worksheet independently and receive corrective feedback after task completion. Student is given rewards for faster performance.	Dot Math for Kids Worksheets

APPENDIX C: MATCHED INTERVENTION/ACQUISITION/CONCEPTUAL

Instructional Activities	Materials
1. *Objective:* Explicit instruction/modeling and immediate feedback *Method of instruction*: Modeling tasks using worksheets that require students to fill in the appropriate number of dots for each numeral.	Dot Math for Kids Worksheets
2. *Objective:* Increasing opportunities to respond while still providing frequent modeling and immediate feedback *Method of instruction:* Game based strategy using cards that match quantities to numerals. Each player takes turns allowing the interventionist to model correct responses.	Mickey Mouse Club Learning Game Cards

APPENDIX D: MATCHED INTERVENTION/ACQUISITION/PROCEDURAL

Instructional Activities	Materials
1. *Objective:* Explicit instruction/modeling and immediate feedback *Method of instruction*: Model procedures for counting dots using one to one correspondence. Provide immediate corrective feedback on procedural counting errors (e.g. counting a dot more than once.) Model correct procedures and then have the student correct any errors before moving on to the next item.	Dot Math for Kids Worksheets

APPENDIX E: INTEGRITY CHECKLIST/UN-MATCHED/FLUENCY

Student____________ Date____________ Session number___________

Start time___________ End time_________ Observer________________

Please indicate N (NO) or Y (Yes) if step was completed, or N/A if not applicable.

1. Did the session start and end on time?
2. Did the interventionist clearly state the goal was to increase speed of performance?
3. Were specific target goals (e.g., numbers/minute) clearly communicated to the student?
4. Did the interventionist offer incentives (e.g., stickers) for faster performance?
5. Was positive feedback (e.g., praise) provided even when target goals were not met?
6. Were incentives provided immediately after the task was completed?
7. Was performance feedback provided after each challenge (e.g., timed worksheet)?
8. Was the student engaged at least 80% of the time?

Total number of Y's divided by N's= total intervention fidelity

APPENDIX F: INTEGRITY CHECKLIST/AQUISTION/CONCEPTUAL

Student: ____________ Date: ____________ Session number___________

Start time___________ End time: _________ Observer________________

Please indicate N (NO) or Y (Yes) if step was completed, or N/A if not applicable

1. Did the intervention start and end on time?
2. Were the intervention materials/worksheets clearly visible to the student during demonstrations?
3. Did the person conducting the intervention take pauses while explaining concepts in order to ensure the student understood what was being modeled?
4. Were correct responses given affirmative or positive feedback (e.g., "that's correct", or "good job"?)
5. Were incorrect responses immediately corrected?
6. Were explanations provided for why the previous answer had been incorrect and why the correct answer was in fact correct?
7. Was the student engaged at least 80% of the time

Total number of Y's divided by N's= total intervention fidelity

Questions applicable to objective #2 only, do not include these if objective #2/Card game was not played.

8. Did the interventionist clearly explain the way to play the matching card game?
9. Were numerals and quantity cards randomly displayed so that the student would need to match them to their correct pair?
10. Did the interventionist take turns with the student and model correct responses?

11. Did the interventionist take a turn at a ratio of 5:1 when beginning the game (one time per one turn for the child)
12. Did the interventionist correct incorrect matches by the student?
13. Did the intervention increase the ratio of modeled responses when the student got two or more wrong in a row (i.e., take more turns)
14. Did the interventionist decrease modeled responses (i.e., turns) in response to improved performance by the child (two or more correct in a row)?

Total number of Y's divided by N's= total intervention fidelity

APPENDIX G: INTEGRITY CHECKLIST/ACQUISITION/PROCEDURAL

Student____________ Date____________ Session number___________

Start time___________ End time _________ Observer________________

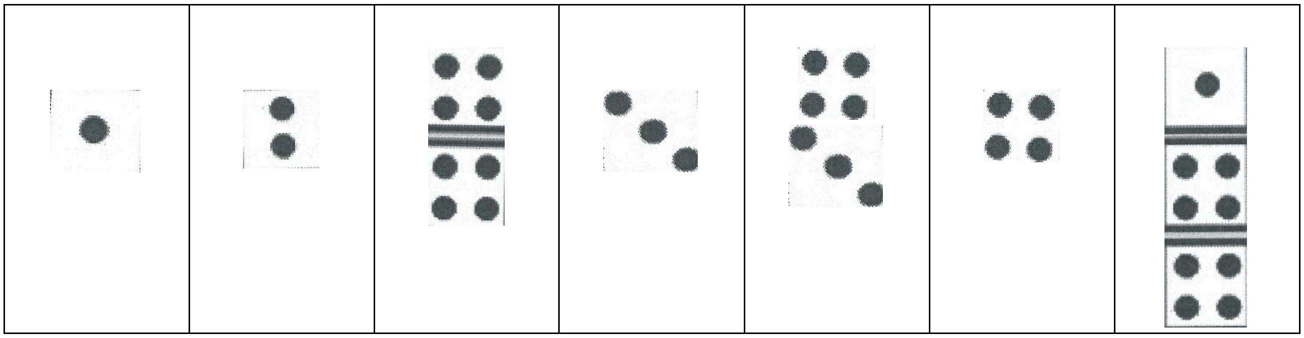
Please indicate N (NO) or Y (Yes) if step was completed, or N/A if not applicable

1. Did the intervention start and end on time?
2. Were the intervention materials/worksheets clearly visible to the student during demonstrations?
3. Did the person conducting the intervention take pauses while explaining concepts in order to ensure the student understood what was being modeled?
4. Were correct responses given affirmative or positive feedback (e.g., “that’s correct”, or “good job”?
5. Were incorrect responses immediately corrected?
6. Were explanations provided for why the previous answer had been incorrect and why the correct answer was in fact correct?
7. Was the student engaged at least 80% of the time?

Total number of Y’s divided by N’s= total intervention fidelity

APPENDIX H: QUANTITY ARRAY ASSESSMENT

Given to: ____________________ Given by: _______________________Date: ______________



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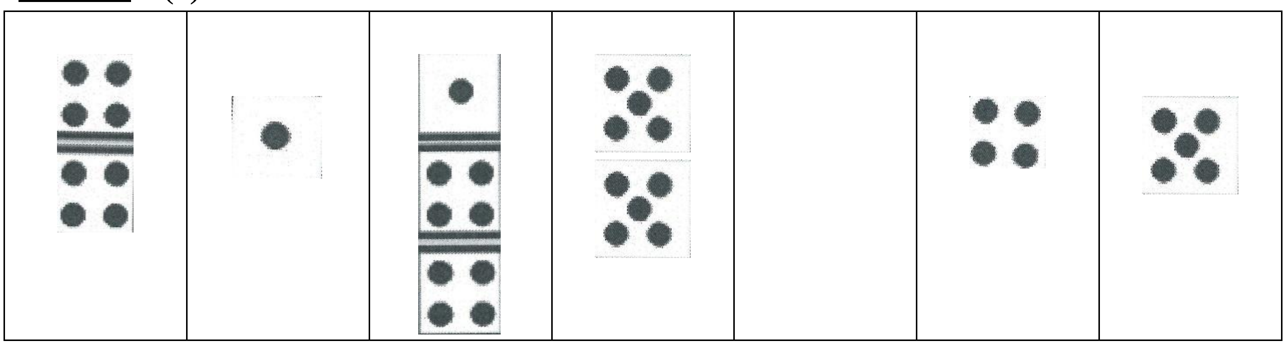

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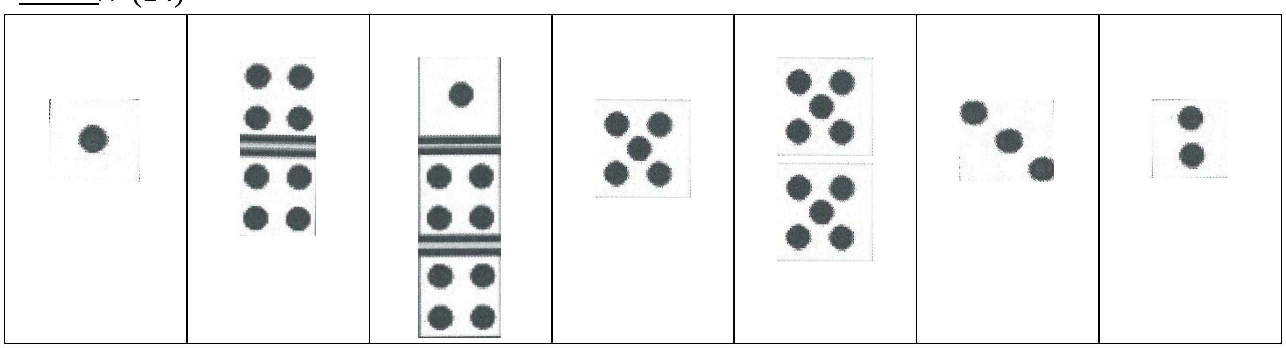

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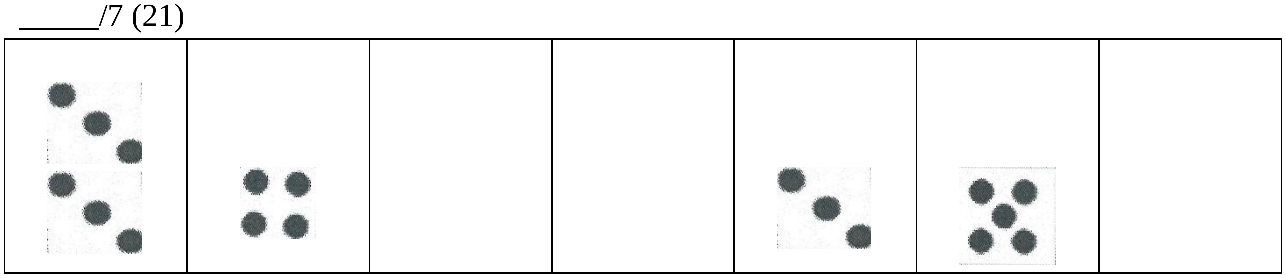

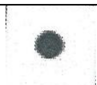						

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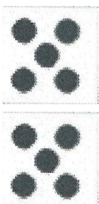	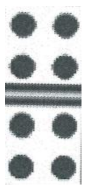		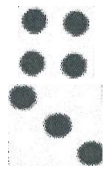	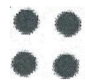		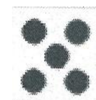

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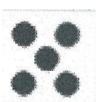			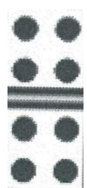	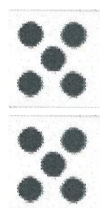		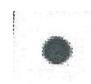

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APPENDIX I: IRB APPROVAL LETTER

EAST CAROLINA UNIVERSITY
University & Medical Center Institutional Review Board Office
1L-09 Brody Medical Sciences Building· Mail Stop 682
600 Moye Boulevard · Greenville, NC 27834
Office **252-744-2914** · Fax **252-744-2284** · **www.ecu.edu/irb**

Notification of Exempt Certification

From: Social/Behavioral IRB

To: Heather Serling

CC: Scott Methe

Date: 4/23/2012

Re: UMCIRB 12-000792
Matching Interventions to Skill Deficits

I am pleased to inform you that your research submission has been certified as exempt on 4/20/2012. This study is eligible for Exempt Certification under category #1.

It is your responsibility to ensure that this research is conducted in the manner reported in your application and/or protocol, as well as being consistent with the ethical principles of the Belmont Report and your profession.
This research study does not require any additional interaction with the UMCIRB unless there are proposed changes to this study. Any change, prior to implementing that change, must be submitted to the UMCIRB for review and approval. The UMCIRB will determine if the change impacts the eligibility of the research for exempt status. If more substantive review is required, you will be notified within five business days.
The UMCIRB office will hold your exemption application for a period of five years from the date of this letter. If you wish to continue this protocol beyond this period, you will need to submit an Exemption Certification request at least 30 days before the end of the five year period.
The Chairperson (or designee) does not have a potential for conflict of interest on this study.

IRB00000705 East Carolina U IRB #1 (Biomedical) IORG0000418
IRB00003781 East Carolina U IRB #2 (Behavioral/SS) IORG0000418 IRB00004973
East Carolina U IRB #4 (Behavioral/SS Summer) IORG0000418

Study.PI Name:
Study.Co-Investigators

APPENDIX J: PERMISSION LETTER

Dear Parent/Guardian,

I'm presently working on my Masters of School Psychology at East Carolina University. As part of my degree requirements, I am planning an educational research project to take place at your child's school that will help me to learn more about ways to improve math interventions for kindergarten children. The fundamental goal of this research study is to investigate how problem solving models and data based decision making can improve upon intervention selection.

As part of this research project, your child will participate in approximately 20 intervention sessions lasting 30 minutes each. As this study is for educational research purposes only, the results of each writing activity **will not** affect your child's grade.

I am requesting permission from you to use your child's data (e.g. tests of early numeracy skills) in my research study. Please understand that your permission is entirely voluntary.

If you have any questions or concerns, please feel free to contact me at school at **919-724-9976** or by emailing me at serlingh10@ecu.edu. If you have any questions about the rights of your child as a research participant, you may contact *The University and Medical Center Institutional Review Board* at 252-744-2914.Please detach and return the form at your earliest convenience. Thank you for your interest in my educational research study.

Heather Serling

Researcher/Investigator

--

As the parent or guardian of ____,

(write your child's name)

☐ **I grant my permission for Ms. Serling to use my child's data in her educational research project regarding writing instruction. I voluntarily consent to Ms. Serling using any of the data gathered about my student in her study. I fully understand that the data will not affect my child's grade, will be kept completely confidential, and will be used only for the purposes of her research study.**

☐ **I do NOT grant my permission for Ms. Serling to use my child's data in her educational research project regarding math interventions.**

Signature of

Parent/Guardian:____Date: