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AN EXPLORATION OF THE MATH NAMES FOR NUMBERS: AN EARLY CHILDHOOD MATHEMATICS INTERVENTION

by

SUZANNE DEAN MAGARGEE

A DISSERTATION

Presented to the Faculty of the University of the Incarnate Word
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

UNIVERSITY OF THE INCARNATE WORD

May 2017

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ACKNOWLEDGEMENTS

Thank you is not nearly enough for my dissertation chair, mentor, research partner, and friend, Dr. Judy Beauford. Without your brilliant mind and masterful teaching, none of this would have been possible. Also, a sincere thank you to Dr. Absael Antelo, Dr. Elda Martinez, and Dr. Mary Ruth Moore, for your gracious support of the Number Names Research Project as well as serving on this dissertation committee. To Duncan Hayse at UIW for your patient editing and support. To my friends and support group through the doctoral program at UIW, most especially Sr. Eucharia Gomba, Leo Peirera, and Paul Foster. To my children, Rachel and Austin – you are the loves of my life. Thank you more than you will ever know for your support and patience. And finally, to Max and Fil, whose daily motivation was instrumental in the completion of this dissertation.

DEDICATION

To Mom, Dad, Rachel, Austin, Judy, my family, and all of my students whom I've had the joy of serving. We are all a part of something much greater than ourselves.

AN EXPLORATION OF THE MATH NAMES FOR NUMBERS: AN EARLY CHILDHOOD MATHEMATICS INTERVENTION

Suzanne Dean Magargee, PhD

University of the Incarnate Word, 2017

A longitudinal study of the effects of an early childhood mathematics intervention was conducted in 2 private elementary schools in a large city in central Texas. The study included 377 participants in prekindergarten through fifth grades. Explicit non-inverted number names were taught in English and Spanish to prekindergarten and kindergarten students, with formative assessments conducted during this timeframe. Summative assessment results from standardized achievement tests were collected in grades 1 through 5 from 341 of the participants. Normal curve equivalent scores of total mathematics achievement, problem solving, and mathematics procedures were compared among groups of children with no or up to 2 academic years of experience using explicit non-inverted number names. Children in Grade 1 who had no experience with the intervention, scored significantly higher than the other children in mathematics procedures. After the first grade, a means trend emerged, showing children with the most experience demonstrated higher overall mean scores within the three measures. In Grade 3, children with the most experience using the intervention demonstrated significantly higher scores in mathematics procedures.

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Early Childhood Numeracy

"Pure mathematics is, in its way, the poetry of logical ideas."

—Albert Einstein

In the United States, the *Common Core State Standards* are leading a nationwide transformation, due in part to the *No Child Left Behind Act* (NCLB) of 2001 and the *Race to the Top Program* of 2010. NCLB mandates that high schools will graduate more college-ready high school students without clearly demonstrating how students will achieve this lofty goal. Response to the NCLB mandate and *Race to the Top Program* in mathematics include adoption of national standards, focus on early childhood learning outcomes, and a vertical re-alignment of curriculum which the introduction of place value concepts earlier in elementary grades (U.S. Department of Education, 2009).

In an effort to reach the advanced levels of achievement demonstrated by students in the highest performing nations, *Common Core State Standards of Mathematics* (CCSSM) learning objectives introduce place value at lower grade levels (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010). The *Mathematics Framework for the 2011 National Assessment of Educational Progress* report (2010) describes assessment of vertically aligned standards, expected learning outcomes in an average educational setting. The frustration lies in the progression of skills and knowledge acquisition from the earliest entry into formal education.

Effective curriculum and instruction in number sense during early childhood directly impacts future mathematics achievement (Baroody, 2001; Clements & Sarama, 2008; Greenes, Ginsburg & Balfanz, 2004; Kamii, Kirkland, & Lewis, 2001; Moeller, Pixner, Zuber, Kaufmann & Nuerk, 2011; Toll & Van Luit, 2013). Connecting quantities, number names and numerals in

early childhood is essential to the successful transition from informal to formal mathematics (Purpura, Baroody, & Lonigan; 2013). Among the many contributing factors of student success is the language of instruction and its effect on efficiently mapping quantity to numeral (Salillas & Carreiras, 2014; Spelke & Tsivkin, 2001).

Cheng, Li, Kirby, Qiang, and Wade-Woolley (2010); Macizo and Herrera (2010); Miura, Okamoto, Kim, Steere, and Fayol (1993); Miura (2001); Pixner, Moeller, Hermanova, Nuerk, and Kaufmann (2011a); Ryoo et al. (2014); and Salillas and Carreiras (2014) reported evidence supporting the linguistic relativity hypothesis posit of language shaping numeracy cognition. These researchers found vocabulary, syntax, and semantics play a role in development of numeral cognition. Recent research established a connection of language to mathematics achievement in elementary grades and is now turning attention to early childhood place value acquisition. In a recent investigation of the role of the Chinese explicit non-inverted number naming system in mathematics achievement, Mark and Dowker (2015), found a specific connection to place value knowledge in early childhood.

Context of the Study

Historically, children who use Asian explicit non-inverted number naming systems, outperform all other children on *Trends in International Mathematics and Science Study* (TIMMS), an international test of mathematics achievement. Results from the *TIMMS 2011* administration showed that United States eighth graders made some progress with a slightly above average score of 508 (international average 500). Korea was still the top scoring nation with an average of 613, far above the United States (Loveless, 2013). United States students also scored closer to the international intermediate level benchmark score of 475, than the high international benchmark score of 550 (TIMMS & PIRLS International Study Center, 2011).

Children from Asian language heritages outperformed every other participating nation on both the fourth and eighth grade benchmarks (TIMMS & PIRLS International Study Center, 2011).

In the Organisation for Economic Co-operation and Development (OECD) report *Lessons from PISA 2012 for the United States*, Strong Performers and Successful Reformers in Education, United States performance of 15-year-olds in mathematics ranks 26th out of 34 participating nations, far below the top performing nations with significant Asian populations. According to their findings, 26% of U.S. 15-year-olds fall below Level 2 in mathematics proficiency, the threshold for future socio-economic success (OECD, 2013). Further, research solidly establishes the connection between early numeracy acquisition and continued advancement and mastery of abstract mathematics concepts (Charlesworth, 2005; Dehaene, Molko, Cohen, & Wilson, 2004; Moeller et al., 2011; Sophian, 2012).

A consistent pattern of Asian language heritage was identified within the highest achievers on *TIMMS* mathematics assessments. Alsawaie, (2004), Browning (2008), Cotter (2000), Fuson, Grandau, and Sugiyama (2001), Ho and Fuson (1998), Miura (1987), Miura and Okamoto (1989), Pagar (2013) and Uy (2003) describe Asian number names as explicit non-inverted labels for numerals that are congruent with numeric representations. Explicit non-inverted number names clearly state the number of tens units first and then state the number of single ones units, thus the exact quantity in place value order. This pattern continues through each successive place value.

Explicit non-inverted number naming systems consistently demonstrate facilitation of children's acquisition and understanding of numeracy and place value (Campbell & Xue, 2001; Cankaya, 2013; Dowker, Bala, & Lloyd, 2008; Imbo & LeFevre, 2009; Miura, 1987; Ng & Rao, 2010; Sousa, 2008). Sousa (2008) discussed the early childhood impact of reduced vocabulary of

the explicit non-inverted number naming system requiring far less working memory to retrieve and map to Arabic numerals. Chen, Cowell, Varley, and Wang (2009) also found native Mandarin speaker's higher mathematics performance to be due in part to more efficient use of working memory. This advantage is maintained during the subsequent formal schooling years (Beauford, 2005; Browning, 2008; Browning & Beauford, 2011; Sousa, 2008). Bugden and Ansari (2011) and De Smedt, Noel, Gilmore, and Ansari (2013) found that children who possessed numeric magnitude processing in early childhood demonstrated higher mathematics achievement in first and second grades. Accelerated ability to process magnitude comparisons as 3- to 5-year-olds also led to higher mathematics achievement scores. Browning (2008), Campbell and Xue (2001), Cotter (2000), Fuson et al. (2001), Ginsburg, Choi, Lopez, Netley, and Chao-Yuan, (1997), and Miura (2001) all found strong evidence to suggest explicit non-inverted number names facilitated acquisition of place value concept.

Research conducted over the past two decades has demonstrated the efficacy of explicit non-inverted number names with early childhood and elementary aged children. When working with the names for numbers from 1 to 100, children are much better able to both remember the number name and attach it to the correct symbolic and physical representation (Dowker et al., 2008; Imbo & LeFevre, 2009; Sousa, 2008). Browning (2008), Cotter (2000), Fuson et al. (2001), and Alsawaie (2004) found that kindergarten and early elementary children achieved greater mastery of numeracy concepts through the use of explicit non-inverted number names in the children's natural language. In addition to this, children have the added benefit of learning that a group of 10 ones can also be named as a single tens unit. Children can also learn how to physically and symbolically compose and decompose tens units in order to scaffold their

understanding trading and borrowing concepts in two-digit addition and subtraction (Fuson, 1990; Miura, 2001; Miura & Okamoto, 1989).

The *Common Core State Standards of Mathematics* (CCSS) addressing place value acquisition begin in first grade, requiring children to successfully map concrete units of tens and ones to abstract two-digit numerals. Children should understand that a tens unit is composed of 10 ones units, that numbers in the teens are composed of a tens unit plus successive ones units, and that each consecutive decade is composed of additional tens units. Second grade standards extend this concept to three-digit numerals and specifically require knowledge of hundreds, tens, and ones units (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010). With early elementary acquisition of base-10 numeracy and place value set as primary objectives of the Common Core State Standards of Mathematics, supports for meeting these objectives may be provided in prekindergarten and kindergarten (Charlesworth, 2005) through explicit non-inverted number names.

Languages are most effectively learned in the 3- to 5-year-old timeframe with numeracy concepts directly connected to language development (Hart & Risley, 2003; Sousa, 2008). Through early childhood learners' use of explicit non-inverted number names, this concept may be addressed in prekindergarten and kindergarten, thus advancing acquisition of this foundational concept by as much as two years (Beauford, 2005; Browning, 2008; Beauford & Browning 2011). Current Kindergarten learning standards focus on rote counting to 100 by tens and ones units (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010). Prekindergarten children may be taught this using explicit non-inverted number names.

Statement of the Problem

Jones et al. (1996) described three levels of base-10 place value acquisition as pre-place value (single digit understanding), emergent (understand 10 as a single unit), and developing (apply knowledge of tens and ones units). Beauford (2005) found that children from Mandarin language heritages enter first grade at emergent and demonstrate developing place value abilities by the end of first grade. Children in the United States were found to begin first grade with pre-place value understanding and to move into emergent understanding near the end of second grade.

The current Common Core mathematics learning standards requires a concept leap from first to second grade, expecting knowledge and application of place value through 20 in first grade and then full comprehension and ability to apply place value concepts up through 1,000 in second grade. Currently, no early childhood mathematics learning objectives specifically address place value as tens units and ones units. Instead, counting focuses on memorization of unique names and quantities.

Very little research has been conducted exploring a classroom intervention using explicit non-inverted number names in early childhood as a means of learning numeracy concepts including place value. A significant gap in the literature exists using explicit non-inverted number names to teach numeracy and place value in early childhood. Scant literature traces children's use of explicit non-inverted number names and mathematics achievement trajectory from early childhood through elementary grade levels in the United States. Numerous studies have established the benefits of early childhood mathematics instruction with multiple modes of input, mastery of counting principals as a prerequisite to learning formal mathematics, vertically aligning learning objectives that address place value, and a significant link between explicit non-

inverted number names and place value concept acquisition. A gap in the literature exists connecting explicit non-inverted number names in early childhood and place value concept acquisition.

Purpose of the Study

The purpose of this study is to examine the efficacy of prekindergarten and kindergarten children's learning explicit non-inverted number names as tool to meet respective grade level mathematics learning objectives and first grade place value learning objectives, and to track mathematics achievement as measured by nationally normed standardized tests through fifth grade. This study seeks to address a gap in the body of knowledge specifically addressing the use of explicit non-inverted number names in prekindergarten and kindergarten, subsequent learning trajectories in first through fifth grades, and comparison to peers who use only traditional number names.

Research Question

The hypothesis of this study is explicit non-inverted number names facilitate prekindergarten and kindergarten children's mastery of grade level mathematics learning objectives, address future grade level base-10 composition and place value learning objectives, and improve learning trajectories through fifth grade. This study will seek to answer the following research question through extant standardized test data measuring first through fifth grade mathematics achievement of children who learned explicit non-inverted number names in prekindergarten and kindergarten, as well as children who used only traditional number names.

Research question. *Do children who learn explicit non-inverted number names in prekindergarten and kindergarten demonstrate different levels of mathematics achievement in*

first through fifth grades than children without experience with explicit non-inverted number names?

Research Design

This quantitative longitudinal quasi-experimental study explores numeracy and place value acquisition using explicit non-inverted number names with prekindergarten and kindergarten children in early childhood formal education. Conducted on two campuses within a private school system between 2003-2009 and 2011-2014, the study spans a total of nine school years. It examines number sense development (specifically place value acquisition) of children in prekindergarten and kindergarten using an explicit non-inverted number names intervention. Learning trajectories in Grades 1 through 5 were examined of children both with and without experience.

Children enrolled in prekindergarten and kindergarten formed the intervention group. Students in first through fifth grades who did not learn explicit non-inverted number names served as a comparison group. Formative assessments were conducted in prekindergarten and kindergarten, measuring and comparing mathematics achievement to learning objectives. Standardized test scores as summative assessments were collected from both schools in the first through fifth grades. Within and between groups comparisons of mathematics achievement were conducted.

Formative assessments were used to measure progress with grade level objectives. A brief task interview format (Figure 1) was designed that led children through the levels of Bloom's Taxonomy and provided for dialog and observation. Children were observed for self-correction and problems solving skills as well as the number naming system used for the different tasks. Tasks were presented in the following order: rote counting, identifying the

number of tens units and the number of ones units in a numeral, reading numerals, modeling numerals with manipulatives. Formative assessments served as benchmarks by tracking individual progress while affording the opportunity to compare with established mathematics learning outcomes.

Counting mastery in early childhood establishes the foundation of numeracy development and future mathematics achievement (Ng & Rao, 2010). Using five two-digit numerals, Miura (1987) and Miura, Kim, Chang, and Okamoto (1988) measured children's numeracy development and knowledge of base-10 concepts through their ability to read, identify place-vale, and model place value using base-10 blocks. Formative assessments of rote counting, identifying place value in two-digit numerals, reading two-digit numerals aloud, and modeling two-digit numerals using tens units and ones units in varying combinations, to determine levels of mastery.

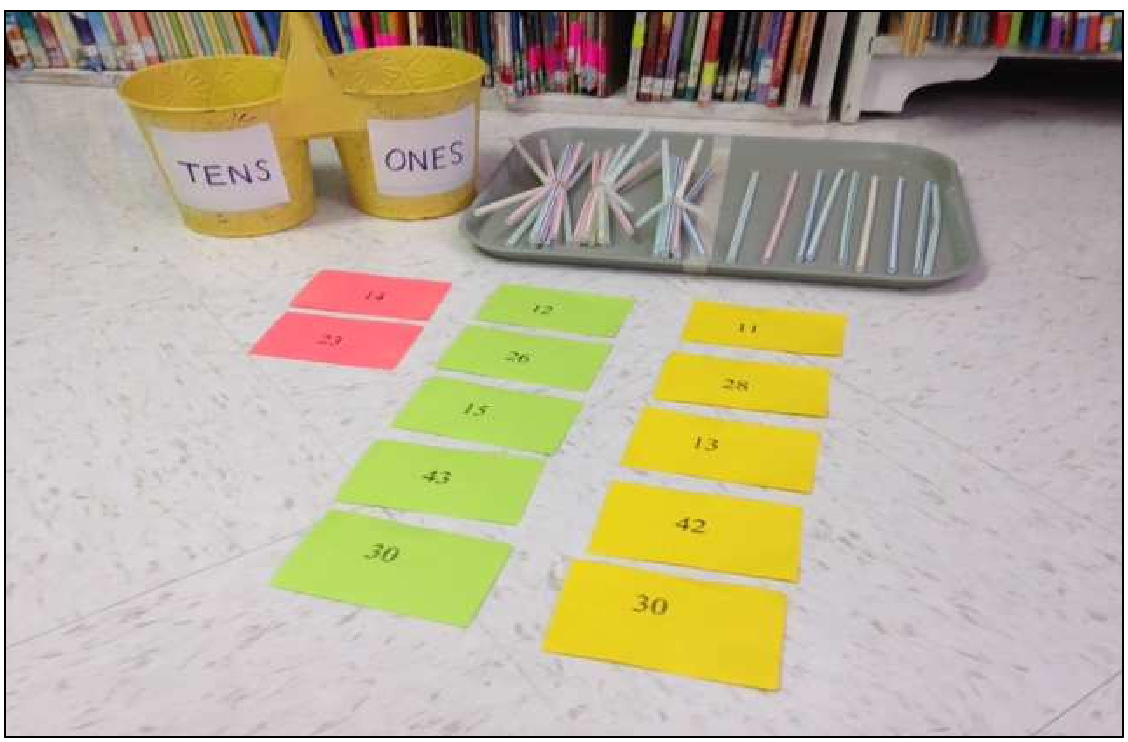

Figure 1. Formative interview task assessments. Front (left to right): place value identifying cards, number reading cards, and number modeling cards. Rear (left to right): place value modeling containers and modeling manipulatives.

This study will analyze extant data of the summative assessments collected from the first through fifth grades over a period of nine years. Research exploring the implementation of an explicit non-inverted number names intervention in early childhood was conducted at two accredited, private elementary schools within a private school district in a large city in central Texas. Prekindergarten and kindergarten children were taught to name numbers and count using explicit non-inverted number names. During the school years from fall 2003 through spring 2009, Beauford (2011) conducted research of prekindergarten and kindergarten aged children learning to count using explicit non-inverted number names at School A, In the spring of 2009, kindergarten students were formatively assessed and standardized test scores were collected from first through fifth grades in the spring semesters of 2005 - 2009. Magargee and Beauford conducted a second, similar study at School B, from fall 2011 through spring 2014. Informal formative assessments were conducted twice each school year prekindergarten and kindergarten classes. Standardized test scores were collected in the spring semesters of 2013 and 2014 for kindergarten, first and second grades (Magargee & Beauford, 2014).

Theoretical Framework of Study

Baroody (2001) and Fuson (1990) outline the process of numeracy development from birth through approximately seven years of age. Their work recognized the complexity of individual learning abilities, teaching methods, and educational settings, as well as the imperative of a comprehensive model encompassing diverse learning theories. Children's numeracy acquisition through learning and understanding counting principals of number naming, one-to-one correspondence, stable count order, and cardinality principal were all identified as precursors to place value understanding. Sophian (2012) presents learning trajectories rooted in

constructivism with researchers, teachers and children, curriculum and instruction sharing a symbiotic relationship.

Recent studies have demonstrated the efficacy of structured mathematics instruction in early childhood. *Big Math for Little Kids*, *Building Blocks*, *Math Worlds* and *Head Start* early numeracy curriculum and instruction focus on teaching counting principals using multiple modalities. Children who participated in structured direct instruction learned rote counting, one-to-one correspondence, stable count order, and cardinality at higher rates than children not in these types of programs (Baroody, 2001; Clements & Sarama, 2008; Geist, 2009; Greenes et al., 2004; Griffin, 2004; Kamii et al., 2001; Puma, Bell, Cook, Heid, & Lopez, 2005).

Contrary to conventional learning theory, more recent research has established that young children are capable of more sophisticated understanding of number. In addition to one-to-one comparisons, they are capable of part-to-whole comparisons. Counting is the gateway to understanding number and the manner in which counting development occurs impacts future understanding of number. Research has also established that the more experience young children have with part-to-whole number comparison, the better developed their future numeracy (Kato, Kamii, Ozaki, & Nagahiro, 2002; Libertus, Marschik, & Einspieler, 2014; Purpura et al., 2013; Sophian, 2012). Moeller et al. (2011) found in addition to the early numeracy positively impacting learning trajectories, flawed early understanding lead to later learning difficulties.

Research conducted over the past several decades has established a language connection between cultures using explicit non-inverted number naming systems, early place value acquisition, and an accelerated mathematics achievement trajectory compared to cultures with non-explicit number naming systems. Children who learn to count using explicit non-inverted number names conceptualize part-whole and how to group tens and ones units in quantities and

numerals. Since place value is embedded in the number naming system, children enter formal education with a working knowledge of this foundational concept. Children who learn non-explicit number names must be taught understanding of place value in numerals with instruction beginning towards the end of the second grade with kindergarten and first grade focusing on memorization of procedures. An achievement gap of at least two grade levels exists when these children enter formal education.

Explicit non-inverted number names have been identified as a significant factor in place value understanding and subsequent mathematics achievement. Children whose primary language uses explicit non-inverted number names, acquire numeracy concepts prior to formal education because they are embedded in language. Children who learn this type of number naming system in early childhood enter formal education with foundational place value understanding, positively impacting their mathematics achievement trajectories.

Chang (2008) and Wang, Lin, Tanase, and Sas (2008) found while language is a part of the numeracy acquisition process, it does not act in isolation. Cankaya (2013) identified explicit non-inverted number names within a larger structure of effective early experiences as a factor in canonical base-10 understanding. In 2013, Pagar presented evidence of canonical base-10 manipulatives also playing a role in place value understanding. In these studies, an explicit non-inverted number naming system was the common factor positively affecting numeracy development.

Researchers have explored the relationship of explicit and non-inverted number names and numeral processing in a variety of languages and cultures. Macizo and Herrera (2010) and Salillas and Carreiras (2014) demonstrated Spanish only (semi-explicit and semi-inverted number naming system) and Spanish bilinguals use language to connect quantity to Arabic

numerals. Dowker et al. (2008) studied the Welsh (explicit non-inverted) and Tamil (semi-explicit) number naming systems, found even with limited exposure a significant correlation to counting and limited effects with other numeracy concepts. Spelke and Tsivkin (2001) examined the role of Russian language and found a significant relationship of language with mapping quantity to numeral. Pixner et al. (2011b) linked explicit non-inverted number names to accurate Arabic numeral processing. In order to explore the linguistic relativity hypothesis within a single language and culture, Pixner et al. (2011b) studied two Czech number naming systems, one inverted and one non-inverted. Children who used inverted number names were found to make significantly more errors than those who used the non-inverted number names. All found explicit non-inverted number names more efficient in numeral processing.

Significance of Study

The study contributes to the body of literature in both early childhood and mathematics education. Findings are significant to three groups of stakeholders. Developers of learning standards may utilize connections found between early childhood use of explicit non-inverted number names and early childhood acquisition of place value. Early childhood classroom educators may draw from this research when designing curriculum and pedagogy that builds on children's innate ability to connect concrete language and abstract numeracy concepts. Educators of students with special learning needs may examine the use of explicit non-inverted number names as an additional mode of input in differentiated curriculum.

Delimitations of the Study

Teacher efficacy, socioeconomic status, parental involvement, educational environment, individual learning differences, and culture were not studied. Research has demonstrated that

these factors play roles as well in student achievement with lasting effects to varying degrees. Rather than attempt to correlate them, this study focuses on the efficacy of explicit non-inverted number names in learning outcomes of counting, number recognition, place value understanding, and long term achievement through standardized test scores.

Definitions of Terms

Explicit non-inverted number names identify quantity and Arabic numerals according to the number of tens units and the number of ones units, in place value order. Two-digit numbers from 10 to 99 are grouped by decades with only ten words used for 99 numbers. For example, the numbers 20 to 29 begin with “two-ten” and end with the number of digits. This pattern continues through 99. Three-digit numbers follow the same pattern with bundles of hundreds stated first. For the purpose of this study, explicit non-inverted number names are the Math Names for numbers.

Mapping in this study is defined as the process of cognitively connecting concrete quantities to abstract Arabic numerals through language (Miura, 1987). Ability to fluently and accurately identify quantity through symbolic representation is fundamental to formal mathematics operations (Dehaene et. al., 2004; von Aster & Shalev, 2007).

Place value refers to the location of digits in a numeral and their subsequent meaning and the quantity they represent such as the “1” in “15” representing a quantity of one tens unit and the “5” representing five ones units. Arabic numerals represent quantities bundled by tens units in descending order and naming ones units last (Miura, 1987).

Review of the Literature

This study seeks to explore the efficacy of a single intervention, the use of explicit non-inverted number names, in facilitating place value acquisition in early childhood and subsequent mathematics achievement in first through fifth grades. For this reason, the review of the literature focuses on the significance of numeracy and place value understanding in early childhood, the connection of explicit non-inverted number names and place value, symbolic mapping, numeracy, and place value acquisition.

Humans are born with an innate sense of number, first developing through informal learning of manipulating and observing physical quantities (Feigenson, Dehaene, & Spelke, 2004). As thought processes develop, we begin to connect concrete quantity to abstract symbols, or numerals (Dehaene, 2009). We use numerals in formal education to manipulate numbers through operations and in order to do this well, we must understand the place value of the digits within the numerals. Language is a factor mediating the mapping process (Canobi & Bethune, 2010). A significant body of evidence has established that explicit non-inverted number names are more efficient at facilitating mapping of quantity to symbols and consequently, to place value, than non-explicit number names (Ho & Fuson, 1998; Miura, 1987; Miller, Major, Shu, & Zhang, 2000).

Children from Asian language heritages historically demonstrate mathematics concepts mastery superior to their non-Asian peers. Research spanning over half a century exposes the tenacity of this learning discrepancy (Lee, 2006; Miura, 1987). Formal education curriculum and instruction, parental involvement in the learning process, and culture have been shown to contribute to the mathematics success of Asian children. The structure of the explicit non-inverted number naming systems is highly significant. While many theories seek to explain the

contributing factors of mastery of mathematics concepts, perhaps one of the most prevalent theories addresses the *acceleration* of place value concept acquisition.

This review of the literature is divided into six sections: Learning Trajectories, Numeracy Acquisition, Place value Acquisition, Symbolic Mapping, Linguistic Relativity, and Mathematics Learning Standards**.**

Learning Trajectories

Children who acquire foundational concepts of counting, numeracy and place value in early childhood are in a much better position to learn two-digit addition and subtraction in early elementary. They advance in mastery of concepts at a faster pace are able to move on to advanced concepts at earlier stages (Clements & Sarama, 2008; Dehaene et. al., 2004; LeFevre et al., 2010; Locuniak & Jordan, 2008). Further, children who demonstrate mastery of numeracy concepts in kindergarten retain advantages through first grade and into second grade, while children who lagged in kindergarten were later found to have difficulty acquiring formal mathematics operations in second grade (LeFevre et al., 2010; Locuniak & Jordan, 2008). Using longitudinal data from the United States Department of Education, Bodovsky and Youn (2011) conducted a study of mathematics and literacy of 11,813 children from kindergarten through fifth grade. Their findings not only supported the premise that high levels of early mathematics skills acquisition positively affected later mathematics achievement, they revealed that poor early skills acquisition correlated to lower performance in later grades.

Symbolic Mapping

Children begin the process of mapping, or connecting, quantity to numerals through number names and the process of learning to count (Figure 2). Herrera and Macizo (2010 and 2012) demonstrated that non-inverted number names and Arabic numerals could be recalled with

relative ease. Quantity and traditional number names were not recalled as rapidly. Numbers, language, and calculation centers are mapped to specific regions of the brain (Butterworth, 2005; Dehaene, 2009). Both visual and auditory pathways are used as the intraparietal sulcus area of the brain is activated, more specifically the right lobe for non-symbolic (non-numeral) stimuli and the right parietal lobe for numerals (Holloway, Price, & Ansari, 2010). Dehaene (2009) and Dehaene et al. (2004) identified a verbal component to symbolic identification.

Siegler and Opfer (2003) described several different mapping systems, the most fundamental being an innate sense of number and then growing with complexity as children encounter greater magnitudes and map to numerals. Sousa (2008) discussed how through the process of mapping, young children store information connecting quantity and number names in the language center of the brain. As cognitive processes transition from concrete to abstract, quantity and symbolic representation are stored in other parts of the brain. This ability to connect concrete to abstract is essential and developed in early childhood (Brankaer, Ghesquiere, & De Smedt, 2014; Cantlon et al., 2009; von Aster & Shalev, 2007).

Role in developing numeracy. Mapping of concrete quantity to abstract numerals via number names is an encoding process (Holloway et al., 2010). Humans are born with an innate sense of number that develops into more complex systems of mathematical operations as the brain develops (Baroody, 1985; Locuniak & Jordan, 2008; Siegler & Opfer, 2003; Verguts & Fias, 2004). The structure of the language plays a significant role in children's successful mapping as well as possibly determining *when* this process takes place (Miller et al., 2000; Miura, 1987).

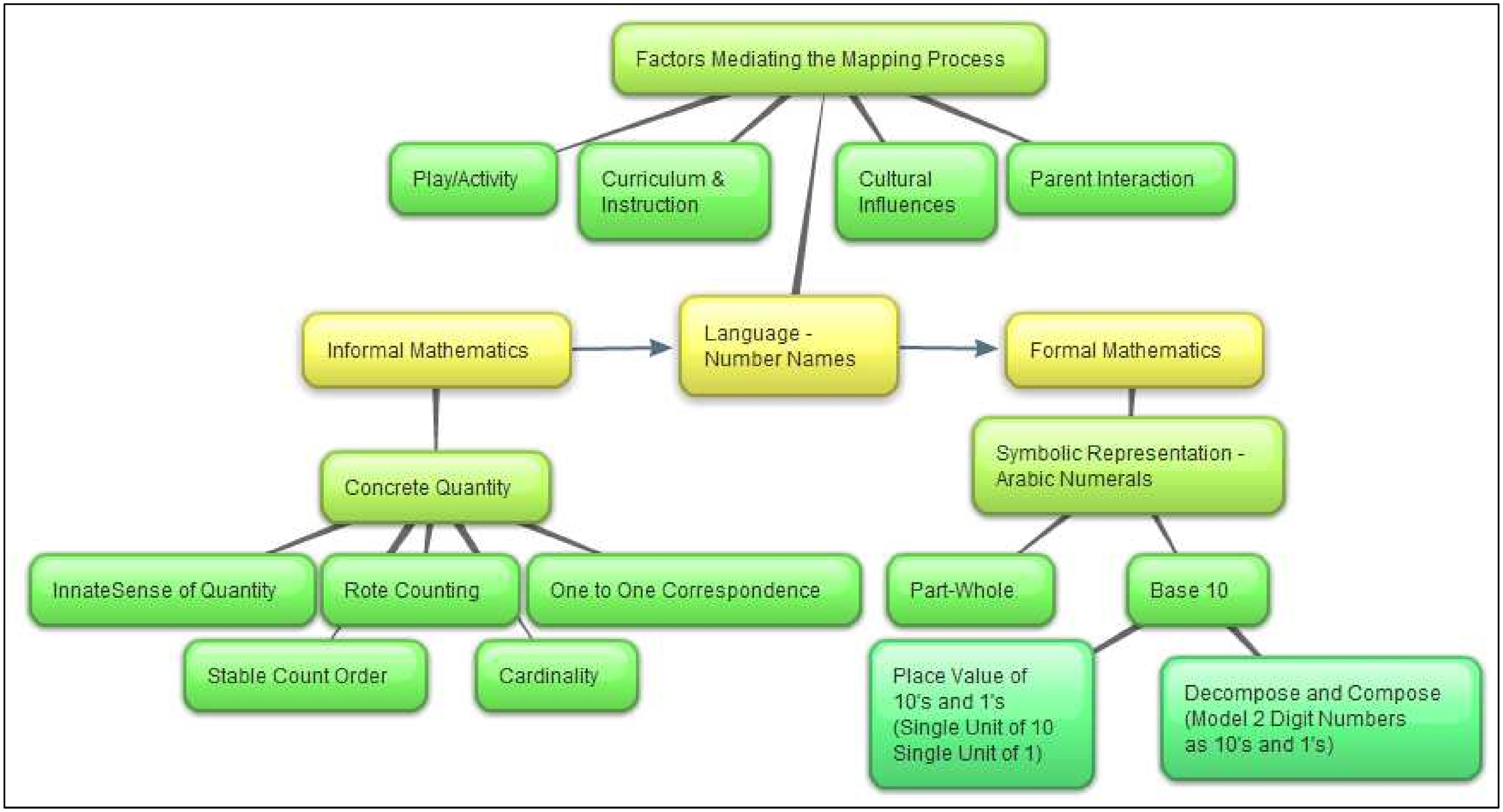

Figure 2. Factors mediating the mapping process. A model of the role of language in bridging informal mathematics to formal mathematics by connecting concrete quantity to abstract numerals.

Multiple representations – multiple words, symbols, and mapping strategies. According to Baroody (1985), children who are exposed to multiple representations of number are better able to identify quantity and connect to Arabic numerals. Number processing was found to be non-abstract in nature with multiple representations, both verbal and numeric, supporting number recognition and processing (Dehaene et. al., 2004; Kadosh & Walsh, 2009; Siegler & Opfer, 2003). Garrett (2010) also found that multilingual children were more adept at selecting words in context, benefitted from a richer vocabulary and when considering mathematics as a language in and of itself, were more highly skilled in acquiring mathematics language.

Siegler and Opfer (2003) studied second and fourth grade children's representations of numbers, and found that mapping strategies were connected to participants' experiences with number. In a study exploring cross-modulation of languages when retrieving number names, Macizo, Herrera, Paolieri, and Roman (2010) found that Italian/German bilinguals used their primary language. Ultimately, children used the languages and the strategies with which they had the most experience. In 2013, Michael-Luna reported on parents' concerns regarding prekindergarten bilingual education and the effect of dual language learning in early childhood. Her qualitative study revealed how adept the young children in the study were at selecting languages according to context, as well as their ability to learn multiple languages from each other in linguistically diverse environments. In the classroom, English was used for instruction and rather than displaying confusion, the children demonstrated adaptability. Bloch (1999) shared observations of multilingual instruction in early childhood classrooms in South Africa. Children were found to derive benefit from multilingual oral and written curriculum and pedagogy. The study revealed the importance of multiple representations and modeling of

literacy in multiple languages. Children benefitted from this diversity of languages at home and in formal education.

In their comprehensive study examining the emergent vocabularies of 269 20-month-old children, Bornstein et al. (2004) found a predominance of nouns in early vocabularies. American English, Dutch, French, Hebrew, Italian, Korean, and Spanish language acquisitions in their respective countries, showed that children tend to learn nouns first. Hypothesizing this could be connected to the labeling of objects, they also found that early Korean vocabularies contained nearly equal amounts of verbs. The early vocabularies of American English and Korean contained roughly equal numbers of quantifier words. The results supported the argument that number names are acquired in early childhood.

Numeracy Acquisition

Sood and Jitendra (2011) studied an early childhood number sense intervention in a United States kindergarten for effect on numeracy acquisition, assessing for rote counting, counting from, number identification, and number sense abilities. In their study of 101 5-year-olds from low income families, children made gains in all areas, indicating the interventions to be effective tools for developing number sense. Providing young children with guided experiences with number allowed them opportunities to explore new vocabulary and connect concrete quantity to abstract concepts. Toll and Van Luit (2013) had similar findings in their study of 933 kindergarteners in the Netherlands. While the focus of their study was on children with low working memory, all of the participants improved early numeracy through the use of a structured remediation program.

Recent research has clearly demonstrated the abilities of 4- and 5- year-old children to learn, retain and later apply mathematical concepts. During this time, children's vocabularies

grow rapidly and affect their educational outcomes for years to come. In *The Early Catastrophe, The 30 Million Word Gap by Age 3*, Hart and Risley (2003) traced the learning trajectories of children in 42 families over a period of two and a half years and made several stunning discoveries. By three years of age, 86% to 98% of a child's vocabulary was derived directly from their parent's vocabulary. Further, they found that children from low socio-economic status families had on average 30 million fewer words in their vocabulary than their higher socio-economic status peers. Perhaps the most interesting aspect of the study were the differences in learning trajectories. Achievement test scores of participants' language skills at third grade revealed significant achievement gaps between low-, mid-, and high-socio economic backgrounds with actual scores nearly matching the projected trajectories (Hart & Risley, 2003). These results underscore the social imperative for children from lower socio-economic status to receive exposure to a greater quantity and quality of vocabulary. The effects of appropriate vocabulary not only persist, but greatly increase academic achievement.

Number sense. Number sense includes such skills as rote counting, one-to-one principal, stable count order, cardinality, part-whole, and canonical base-10 concepts. *Rote counting* refers to ability to recite the names of numbers while counting involves labeling quantities or numerals. *One-to-one correspondence* is the connection of one name to a specific quantity and numeral. Number names specifically label a unique quantity and are not used to label more than one quantity. *Stable count order* involves understanding numerals follow a specific order such as 1, 2, 3, and so on, and that this order is stable. *Cardinality* is the understanding that the last number counted represents to total quantity of concrete objects or magnitude of a numeral. *Part-whole concept* is the knowledge that numbers can be decomposed and decomposed. For example, 15 can be decomposed into one tens unit plus five ones units. *Canonical base-ten* refers to the

number of tens units and the number of ones units in a two-digit number. In the context of this study, it also implies a child's ability to correctly decompose a two-digit number into the correct number of bundles of tens units and single ones units (Browning, 2008).

Informal and formal learning. Informal number learning involves children's experiences with number. It includes counting objects, automatically recognizing quantities or subitizing number (von Aster & Shalev, 2007), and developing a sense of comparison of number magnitude. Formal learning involves direct instruction, the use of numerals or other symbols, formal modeling and representations of number, and quantity-numeral relationships and operations (Lee, 2006). The process of mapping concrete quantity to semi-concrete symbols or pictures, and ultimately to abstract numerals and operation symbols, bridges informal and formal mathematics operations (Dehaene et. al., 2004).

Place Value Acquisition

Place value understanding has been widely accepted as the threshold to formal mathematics learning. Mix, Prather, Smith, and Stockton (2014) found in a study of approximately two hundred 3- to 7-year-olds, that children begin comparing magnitudes between digits in two-digit numbers between ages 3 and 4 years. In the United States, children learn to memorize all combinations of addition and subtraction of numerals 1 through 20. This knowledge is procedural and while children may achieve fluency and accuracy within these two decades of numbers, it does not clearly connect to the physical quantity, nor does memorization necessarily translate to manipulation or understanding of greater magnitudes of numbers (Miura, 1987).

Knowledge of the values represented by digits is necessary in order to understand decomposition of numbers into tens and ones units for trading in addition and borrowing in

subtraction of two-digit numbers. Verguts and Fias (2004) found strong neuro-cognitive evidence of a combination of the use of learned rules and connecting necessary for mapping and processing of multi-digit numbers. Further, language was found to be a mediating factor in this process. Arguing for connectionist theory, Miura (1987) found when place value is understood, numbers are conceived as the sum of tens and ones units to give the full amount.

Stages of acquisition. Artuso (1993) describes the process by which children successfully map quantities to numerals as they develop place value understanding in five stages:

- Stage 1: The child understands numerals represent quantities.
- Stage 2: The child understands the positions of digits in numerals have meanings as part-whole.
- Stage 3: The child understands the digits at their nominal values as the number of ones.
- Stage 4: The child understands the meaning of the tens and ones units positions of the digits as canonical representations.
- Stage 5: The child also understands that tens units can also represent 10 ones units in combination with numbers of tens units as non-canonical representations.

In Stage 1, children have begun the process of connecting quantity to numeral. In Stage 2, children have an emergent understanding of base-10 and that the positions of digits in numerals have specific meanings. Stage 3 marks the beginning of place value understanding as children conceptualize individual digits as separate quantities. In Stage 4, children develop canonical base-10 place value understanding, successfully mapping quantities of ten as a tens unit in the tens place and quantities of single units as ones units in the ones place. When children have achieved understanding of composition and decomposition of tens units in Stage 5, they are now able to perform formal math operations requiring trading in addition and borrowing in

subtraction. The rate of progression through these stages of mapping and development of place value understanding vary across languages (Artuso, 1993).

Multilingual Classrooms

A significant body of research has shown that children who are exposed to multilingual environments fare better in their development of mathematics concepts. In research involving monolingual Chinese, monolingual English, and bilingual Chinese and English, children demonstrated mastery of mathematics concepts in the following order: monolingual Chinese, bilingual Chinese-English, and then monolingual English. While the clear take away from the research was the advanced mastery of place value and numeracy concepts of children of Mandarin language heritage, the fact that the bilingual children understood and were able to use *both* number name systems in *two* different languages was noted.

Yazejian, Bryant, Freel, Burchinal, and the Educare Learning Network Investigative Team (2015), found pronounced and lasting advantages to dual language learning in early childhood when the children entered the program prior to 3 years old in contrast to prior studies of early childhood programs indicating that any advantages of multilingual classrooms diminish by second grade. Between 2003 and 2013, in a study including over 5,000 children ranging from infant through 5 years old, children in 12 schools in the program were studied for receptive language and socio-emotional skills development. The study further revealed the period of time between 20 months and 4 years of age proved to be a most advantageous time for vocabulary acquisition.

Macizo, Herrera, Roman, and Martin (2011) provide a compelling argument for multilingual mathematics instruction. They examined both monolingual German and bilingual German/English speakers and found that bilinguals have superior working memory when

compared to monolingual speakers. They also observed that bilinguals decomposed numbers into tens and ones units as well as the word order in the number name playing a role in number recognition. Participants tended to focus on the *first* word in the number name, hence a non-inverted number name stating the tens units first often led to accurate decomposition of the number.

Linguistic Relativity

Baroody (2001) describes Whorf's linguistic relativity hypothesis as a process through which our language shapes our thoughts. He suggested that this could readily apply to the labels children attach to quantity and numerals. If children learn simple patterns that can be used repeatedly to label quantity and identify numerals, they will transfer to place value understanding with numerals. In his later studies of addition and subtraction with first grade children, children who understood place value through explicit non-inverted number names outperformed non-explicit number names by as much as three times the accuracy (Baroody, 2001). Figure 3 proposes learning trajectories comparing the efficiency of explicit non-inverted number naming systems to non-explicit and inverted number naming systems.

Explicit non-inverted number names. Cultural differences such as curriculum and pedagogy, parental involvement, and social education dynamic all contribute to successful acquisition of numeracy and place value (Miller et al., 2000; Miura, 1987). In their pivotal report to the United States Department of Education, *What the United States Can Learn From Singapore's World-Class Mathematics System (and What Singapore Can Learn from the United States): An Exploratory Study*, Ginsburg, Leinwand, Anstrom, and Pollock (2005) present a comparative analysis of mathematics education in both countries. First grade children in

Singapore not only master two-digit addition and subtraction, they begin mastery of two-digit multiplication and division. The latter is mastered during third grade in the United States.

While English speaking children in the United States clearly do acquire place value knowledge and are able to map quantity to numerals via language, linguistic relativity posits that some languages *are more efficient* than others in facilitating this connection and understanding (Figure 3). Students in the United States who, in addition to English, also spoke Chinese, Japanese or Korean, demonstrated superior levels mathematics achievement for third grade through college-age when compared to English only students (Miura, 1987).

A sizable body of evidence exists to support the notion that children who learn to name numbers as groups tend to group quantities. They are able to conceptualize units of 10 that are composed of 10 individual ones units. They are better able to decompose and represent quantity and represent quantity in symbolic form. Sousa (2008) discussed the role of the using 10 words to name numerals 1 through 99 as compared to 99 unique words on children's ability to name numbers. Far less working memory is required to recall 10 words when identifying numbers. In addition to this, the pattern of tens units followed by ones units compared was also easier to remember.

Non-explicit and semi-inverted or inverted number names. Curtis, Okamoto, and Weckbacher (2009) found a strong connection between the qualities of counting knowledge and the ability to compare quantity at the earliest ages. English speaking children in their study did not spontaneously count quantities. Children were successful in comparing number magnitudes only when physical quantities were counted, stated, and modeled for them. The question then becomes one of language efficiency. In 2011, Macizo et al. compared Spanish/English and German/English bilinguals. They found that when using their primary language of Spanish or

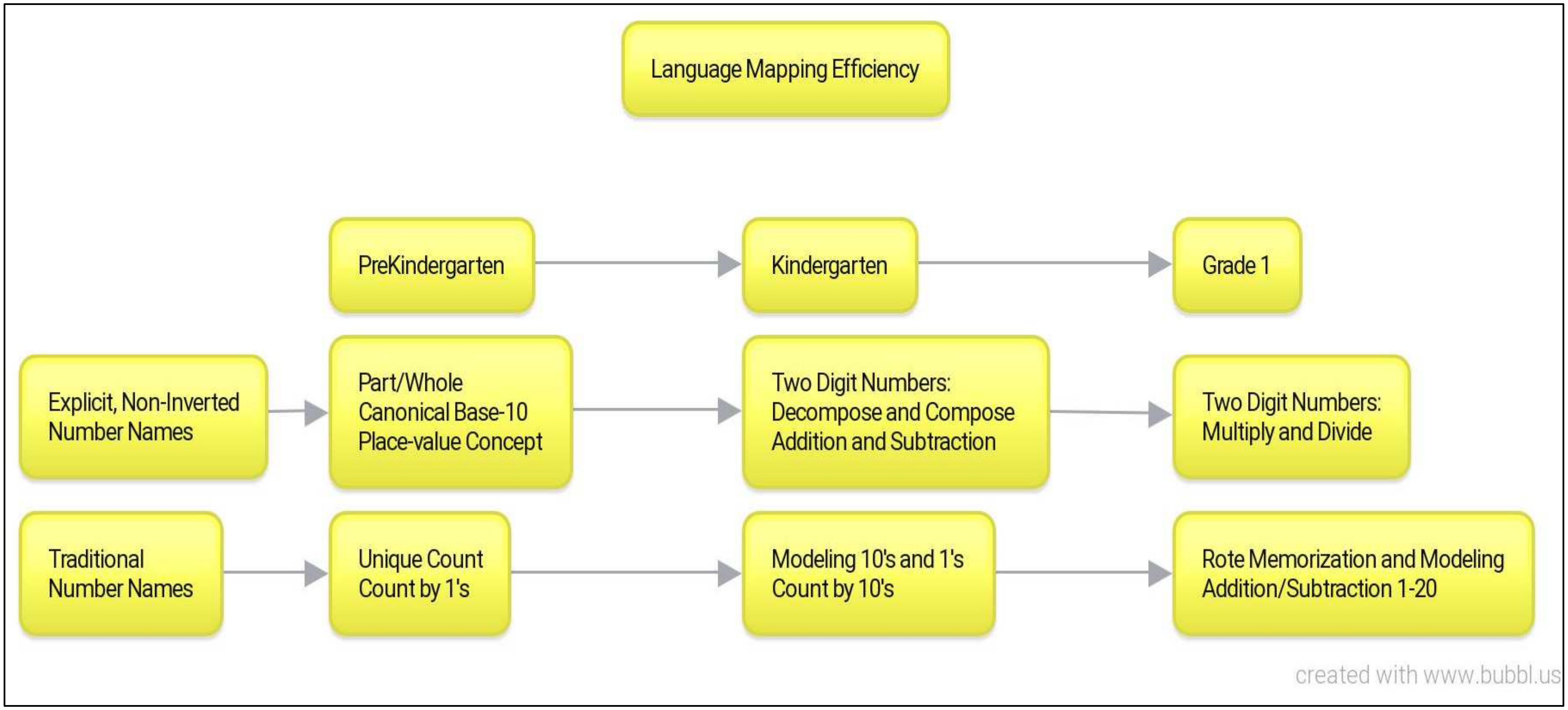

Figure 3. Language mapping efficiency. Explicit, non-inverted number names facilitate number sense development.

German, participants were able to accurately and fluently identify tens and ones units when the digits were reversed. They struggled with identification when using English number names.

English non-explicit number names are unique labels for each quantity or numeral. The number names for single digit numbers follow uniquely label the Arabic numerals 1through 9 as one, two, three, four, five, six, seven, eight, and nine. Two-digit numbers then follow a general rule of "decade name + "ty" + unit" (Miller et al., 2000, p. 130) in a non-inverted order – that is, the number of tens units is first followed by the number of ones units. The 'teens' decade is the exception to the rule. The names eleven and twelve do not state the number of tens units and in fact, have no clear connection to quantity. The remainder of the names thirteen, fourteen, fifteen, sixteen, seventeen, eighteen, and nineteen are all inverted with the number of ones units stated first. In addition, these number names contain confounding syllables such as "thir" and "fif" that have no clear connection to unit names. Non-explicit number names do not readily provide amounts in place value order when mapping quantity to numeral thus proving more difficult for English speaking children to learn (Miller et al., 2000).

Children learn to count one-by-one as each label is connected to unique quantities (Davidson, Eng, & Barner, 2012). Children who learned unique names for each quantity tended to count each individual piece and conceptualized each as individual ones units. They struggled with the concept of a tens unit that was composed of ten individual units and instead took quantities as collections comprised solely of individual ones units. In a study conducted at the University of California San Diego, Davidson et al. (2012), 84 English speaking children were examined for their understanding between quantity and the number label (number name or numeral). The participants were selected specifically because of their knowledge of cardinality. Children were presented amounts in single digits, teens and twenties. Their results revealed that

the English speaking children did not consistently demonstrate an understanding of the label for the quantity. These children had demonstrated an ability to rote count as a recitation of number names with proficiency yet did not demonstrate mastery of mapping quantity to number name and symbol.

Working memory plays a key role in numeracy acquisition (Locuniak & Jordan, 2008). Because each numeral from 1 to 99 is uniquely labeled, a child must memorize 99 unique words. These words may physically take longer to retrieve as they are longer than more explicit non-inverted number names. In extensive reviews of the literature, Ng and Rao (2010), and Sousa (2008) present clear evidence that learning 10 words and arranging them in simple patterns congruent with symbolic representations of Arabic numerals provides for rapid retrieval, requires far less working memory, and allows children to focus on operations.

Children develop a sense of “one-ness”, “two-ness” and “three-ness” by the age of 3 (Baroody, 2004). Four- and 5-year-olds experience a period of rapid vocabulary expansion. Evidence from research shows that while children who learn non-explicit number names may learn to rote count successfully to 100, this does not necessarily translate into place value understanding. Using non-explicit and perhaps semi-inverted or inverted number names to map place value in numerals is a longer process that must be broken into sequential steps over early elementary education (Ginsburg et al., 2005).

Mathematics Learning Standards

Neither prekindergarten nor kindergarten are compulsory in the United States; however, decades of research indicates the benefits of both. While more recent research reveals that children who were enrolled in high quality prekindergarten may initially hold an advantage over peers who did not, achievement test scores indicate the advantage fades by the end of first grade.

Research revealed a farther reaching learning trajectory. Children enrolled in high quality prekindergarten with targeted mathematics instruction did tend to demonstrate greater mastery in later grades. While this mastery was still not comparable to Asian peers, it did indicate a more lasting benefit could be derived from mathematics instruction in prekindergarten and kindergarten.

Prekindergarten. The National Association for the Education of Young Children (NAEYC) and the National Council of Teachers of Mathematics (NCTM) present learning guidelines rather than specific standards for prekindergarten curriculum. The NCTM principles of equity, curriculum, teaching, learning, assessment, and technology provide the foundation for early childhood mathematics education (NAEYC, 2010). These guidelines include building a foundation of numeracy through an emphasis on rote counting. By the end of prekindergarten, children should be able to count physical quantities up to 10 and rote count up to 20. In addition, they should have a foundational understanding of one-to-one correspondence, stable count order and cardinality principals.

Kindergarten. The CCSSM Kindergarten standards require children in kindergarten to rote count 1 through 100 by tens and ones, and be able to count, model, and decompose quantities of 11 through 19 with manipulatives, symbolically, and verbally. They are expected to have mastery of one-to-one correspondence, stable count order, and cardinality concepts. They should understand foundations of place value, that a tens unit is composed of 10 ones units and that two-digit numbers are composed of tens units and ones units. Kindergarteners are also expected to have successfully mapped quantities to numerals from 0 to 20 and be capable of comparing relative magnitudes of numerals 1 to 10. They should also be capable of decomposing

and composing numbers 1 through 10 in order to create tens units, and 11 through 20 into tens and ones units.

Grade 1. The focus of curriculum and instruction in first grade is building a foundation for base-10 place value. During this school year, children are introduced to tens and ones units, in multiple representations. Children work with concrete quantities of manipulatives, semi-concrete pictures, and abstract Arabic numerals. A primary outcome is mapping of quantity to numeral as tens and ones units. First graders should to be able to rote count up to 120, model numerals concretely and using symbols such as sticks to represent tens units and dots to represent ones units. Children should understand place value and that 10 ones units can be bundled into a single tens unit. Children are expected to understand that numerals in the "teens" are composed of a tens unit combined with one to nine ones units. They must master addition and subtraction by tens and ones units through 20 using multiple representations, and mentally by tens units through 100.

Grade 2. Mapping of place value is extended to hundreds units, conceived as 10 tens units and 100 ones units. CCSSM standards require children to rote count up to 1,000 as well as skip count by fives, tens, and hundreds units. Children must mentally add or subtract all numerals through 20; understand a hundreds unit is composed of 10 tens units; have successfully mapped hundreds, tens, and ones units to their respective place values in numerals; and be capable of decomposing and composing three-digit numerals. They must also be capable of applying place value in addition and subtraction of three-digit numerals and to add and subtract tens and hundreds units mentally.

Grade 3. Students must understand place value through the thousands, fluently add and subtract through 1,000, and round numbers to tens and hundreds place values. They must also fluently multiply and divide numerals up through 100.

Grade 4. Students must be able to add and subtract four-digit numbers, and multiply and divide three-digit numbers. They must fluently decompose and compose numbers through 100 by factoring and multiplying. They must be capable of generalizing place value to multi-digit numerals through 1,000,000 and applying place value in addition and subtraction operations. They must be capable of dividing single digit divisors with quotients through thousands units.

Grade 5. Students must understand the relationship between place values in multi-digit numerals as multiples of 10, including decimal place values through thousandths. They must add, subtract, multiply and divide multi-digit numbers to the thousandths place value with fluency. Students must also express place value of multi-digit numerals through multiple representations, including expanded notation.

Students are expected to meet the minimum benchmark goals and objectives at the end of each academic year. This study seeks to compare student rates of achievement in first through fifth grades, of children with experience using explicit non-inverted number names in prekindergarten and kindergarten to those with no experience. Based upon current research, children with experience may demonstrate higher performance.

Methodology

Research Design

The hypothesis of this quasi-experimental, longitudinal study is children who learn explicit non-inverted number names in early childhood, master grade level mathematics learning objectives in prekindergarten through fifth grade, and have higher learning trajectories than peers who did not learn number names using the intervention. This study seeks to answer the following research questions through extant data collected from cohort groups of children in two schools over a period of time spanning 2003 through 2014. The cohorts consisted of prekindergarten and kindergarten students who learned an explicit non-inverted number names intervention. In subsequent grade levels, comparison groups consisted of classmates who entered the schools after kindergarten and did not learn the explicit non-inverted number names intervention in prekindergarten and kindergarten.

The study was conducted at two private elementary schools (School A and School B) located in a large city in Central Texas. Research was conducted at School A from fall 2003 through spring 2009 and at School B from fall 2011through spring 2014 with a total of 13 class cohorts. Data were obtained in two forms: formative brief interview task assessments in prekindergarten and kindergarten, and summative standardized test data from kindergarten through fifth grades. Both formative and summative assessment data were gathered to track cohort growth, compare with peers, and determine lasting effects. Summative assessment data will be analyzed to answer a single research question.

Research question. *Do children who learn explicit non-inverted number names in prekindergarten and kindergarten demonstrate different levels of mathematics achievement in*

first through fifth grades than children without experience with explicit non-inverted number names?

Methodology

Institutional Review Board (IRB) permissions were obtained by for both sites and maintained for the duration (Beauford, 2009, 2010; Magargee & Beauford, 2014). Children at School A were taught the intervention between 2003 and 2009, with formative assessments of prekindergarten and kindergarten participants conducted in the fall and spring semesters and standardized test scores collected first through fifth grades in the spring semesters between 2004 and 2009. Children attending School B were taught the same intervention in prekindergarten and kindergarten between 2011 and 2014. Formative assessments of prekindergarten and kindergarten participants were conducted at the end of both the fall and spring semesters each school year. Standardized test scores were collected from the spring semesters of 2013 and 2014 for kindergarten, first and second grade students.

Intervention

The intervention consisted of teaching and using explicit non-inverted number names. At School A, prekindergarten and kindergarten children learned explicit non-inverted number names at school and were encouraged to use them at home. Children in prekindergarten classes used the intervention for the entire school year while children in kindergarten transitioned to traditional English number names during the spring semesters. School B children in both prekindergarten and kindergarten classes were taught the intervention for the entire school year. Children learned explicit non-inverted number names exclusively in the classroom with exposure to traditional English number names outside of the classroom (Beauford, 2009; Magargee & Beauford, 2014).

Prior to the school year and throughout the study, teachers were trained to count using explicit non-inverted number names in English and Spanish. Study protocols requiring the exclusive use of the intervention in the classroom were explained to teachers. Explicit non-inverted number names were used daily in all classroom activities such as counting, reading, singing, telling dates and days of school, telling time, naming quantities, and mathematics activities. Monthly site visits were conducted to observe teacher maintenance of study protocols and to provide support (Beauford, 2009; Magargee & Beauford, 2014).

In the beginning of each school year, parents new to the program were provided with information fully describing the intervention. Parent were given informed consent and permission to participate in the study was obtained. During each school's open house night, which occurred in the beginning of each school year, parents learned how their children would be taught explicit non-inverted number names and the assessment schedule for the school year. For the duration of the study, parents were provided the opportunity for communication with researchers and teachers (Beauford, 2009; Magargee & Beauford, 2014).

School District

The study was conducted on two private elementary campuses in a large city in central Texas. All schools within the district are accredited by the Texas Catholic Conference Education Department (TCCED). The TCCED is recognized by the Texas Education Agency (TEA) and charged with ensuring compliance with applicable state and national learning standards. The historically Hispanic, private school district encompassed 43 schools, 33 of them elementary with a total enrollment of over 13,000 students. Of the 33 elementary schools, 24 were located within the city. Ninety-one percent of the elementary campuses have prekindergarten programs and 98 have kindergarten classrooms ranging from 45 to 75 students in enrollment. Separate

classrooms were provided for 3-, 4-, and 5-year-old children (Prekindergarten-3, Prekindergarten-4, and Kindergarten). Overall, the district offers small class sizes with an average student to teacher ratio of 15:1. The elementary school had an attendance rate of 97% and a total high school graduation rate of 99% (Catholic schools fact sheet, 2015). Approximately 75% of the students within the school district were minority heritage, (64.3% Hispanic, 25.2% non-Hispanic white, 5.8% identified as multi-racial, 2.7% African American, 1.8% Asian/Pacific Islander, and 0.2% Native American (Catholic schools fact sheet, 2015).

School A. Prekindergarten and kindergarten children were taught explicit non-inverted number names in every instance quantities were identified or numerals were used in the classroom. The kindergarten teachers began to use traditional English and Spanish number names during the spring of each year in order to prepare the children for transition to first grade. Prekindergarten and kindergarten children were formatively assessed in the fall and spring from 2006 through 2009. Children in grades 1 through 5 were assessed using the Stanford Achievement Test, with data collected for each cohort in the first grade from 2004 through 2009, and respective grades in the spring of 2009. Aggregated and disaggregated results were obtained for mathematics problem solving and computation domains (Beauford, 2009, 2010; Browning & Beauford, 2011; Magargee & Beauford, 2014).

Six cohorts were formed in School A, with a total of 271 participants in prekindergarten through fifth grade. The number of intervention group and comparison group participants varied each year as children withdrew or enrolled in the school.

Table 1

School A Cohorts by Grade

2003-2004	2004-2005	2005-2006	2006-2007	2007-2008	2008-2009
K (n = 14, 14)	1 (n = 20, 14)	2 (n = 13, 8)	3(n = 17, 8)	4 (n = 18, 8)	5 (n = 14, 6)
Pk (n = 17, 17)	K (n = 17, 17)	1 (n = 18, 17)	2 (n = 22, 13)	3 (n = 22, 13)	4 (n = 33, 19)
	Pk (n = 10, 10)	K (n = 19, 19)	1 (n = 25, 19)	2 (n = 24, 14)	3 (n = 21, 11)
		Pk (n = 13, 13)	K (n = 16, 16)	1 (n = 24, 16)	2 (n = 20, 10)
			Pk (n = 17, 17)	K (n = 18, 18)	1 (n = 21, 18)
					K (n = 13, 13)

Note: Pk = Prekindergarten, K = Kindergarten; (n = total students, total students who received intervention)

School B. Prekindergarten and kindergarten children were taught explicit non-inverted number names for every instance number was used in the classroom. Children were formatively assessed in December and May of each school year from 2011 through 2014. The Iowa Test of Basic Skills (ITBS) standardized tests were used as summative assessments in the spring semesters of 2013 and 2014. Results were obtained for mathematics concepts, problem solving, and mathematics computation (Magargee & Beauford, 2014).

Five cohorts were formed with a total of 106 participants in prekindergarten through second grade. The number of intervention group and comparison group participants varied each year as children withdrew or enrolled in the school (Magargee & Beauford, 2014).

Table 2

School B Cohorts by Grade

2011-2012	2012-2013	2013-2014
K (n = 24, 24)	1 (n = 17, 14)	2 (n = 16, 12)
Pk-4 (n = 16, 16)	K (n = 16, 16)	1 (n = 15, 15)
	Pk-4 (n = 10, 10)	K (n = 10, 10)
	Pk-3 (n = 10, 10)	Pk-4 (n = 13, 13)
		Pk-3 (n = 13, 13)

Pk-3 = 3-year-old Prekindergarten, Pk-4 = 4-year-old Prekindergarten, K = Kindergarten; (n = total students, student who received intervention)

Operational Definitions

Rote counting. Children were asked to count to the highest possible number without assistance. Children were observed for use of explicit or non-explicit number names, highest number counted, skipped numbers, patterns in counting, and self-correcting strategies.

Identifying place value. Children were presented cards containing the numerals 14 and 23 and asked to state the quantity of tens and ones units represented by the numerals.

Reading numerals. Children were asked to read aloud the numerals: 12, 26, 15, 43, and 30. Responses were recorded and children were observed for correctness, whether they use an explicit or non-explicit number name, self-correcting or problem solving strategies, as well as an analysis of incorrect responses.

Modeling numerals. Children were given manipulatives consisting of bundles of 10 straws or craft sticks representing tens units, single straws or craft sticks representing ones units, and two buckets labeled “tens” and “ones”, in place value order. After demonstrating how to model using the numerals 14 and 23, the children were asked to model the numbers: 11, 28, 13,

42, and 30. They were observed for verbalization, self-correcting and problem solving skills, and possible responses: canonically correct, canonically incorrect – inverted, canonically incorrect by one unit, correct with unit straws, and incorrect. A numeral was modeled "canonically correct" with the correct amount of tens and ones units placed in the correct containers (place value). A number modeled "canonically correct – inverted" had the correct number of tens and ones units, with the containers reversed. "Canonically incorrect by one unit" indicated one less or one more ones unit than the correct amount. "Correct with unit straws" indicated correctly modeled numerals using only ones units placed in the correct containers and without tens units.

To track both individual and cohort progress during the school year, formative assessments as brief interviews were conducted. At both School A and School B, prekindergarten and kindergarten classes were assessed at the end of the fall and spring semesters each year. Children were assessed for mastery of grade level objectives of rote counting and numeral identification as well as subsequent grade level objectives of place value identification in a two-digit numeral and understanding of tens and ones place value through modeling.

Summative Assessments

Standardized summative assessments were used to measure and track place value learning objectives. School A used the Stanford Achievement Test Tenth Edition (Stanford 10) Form A, Primary and Intermediate Levels and School B used the Iowa Test of Basic Skills (ITBS) Form C, Levels 6, 7, and 8 for all summative assessments. Both are untimed, nationally normed assessments of academic achievement. The ITBS and Stanford 10 align with NCTM and Common Core standards addressing conceptual understanding and reasoning as well as

knowledge of core math facts as shown in Table 3 (Beauford, 2010; Hoover, Dunbar, & Frisbie, 2001; Magargee & Beauford, 2014; Pearson, 2011, 2015).

The Stanford 10 provides Local Percentile (LPRS), National Percentile (NPRS), National Normal Curve Equivalent (NCE) scores. The SAT results provide a comprehensive breakdown of concepts measured: number sense and operations; patterns, relationships, and algebra; data, statistics, and probability; geometry and measurement; communication and representation; estimation; mathematical connections; reasoning and problem solving; and thinking skills (Beauford, 2009, 2010; Pearson Education, 2011, 2015).

The ITBS Form C, Level 6, administered to kindergarteners provides overall mathematics achievement data for individual students expressed as: Standard Score (SS), National Stanine (NS), Local Percentile Rank (LPR), Local Stanine (LS), Normal Curve Equivalent (NCE), Private School Percentile (PRIV), and National Percentile Rank (NPR). The ITBS Form C, Levels 7 and 8, administered in Grades 1 and 2, respectively, provided the same measures as concepts, problems, computation, and overall mathematics scores. Paired with the ITBS in Grade 2, the Cognitive Abilities Test (CogAT) Form 6, provides verbal, quantitative, nonverbal and composite age and grade scores expressed as: Standard Age Score (SAS), Percentile Rank (PR) and Stanine (S) (Hoover et al., 2001; Magargee & Beauford, 2014).

Table 3

Grade Levels in Which CCSSM Were Measured by Standardized Assessments

Common Core Concepts	ITBS	SAT
Counting and Cardinality	K	
Operations and Algebraic Thinking	K, 1, 2, 3, 4, 5	1, 2, 3, 4, 5
Number and Operations in Base 10	K, 1, 2, 3, 4, 5	1, 2, 3, 4, 5
Number and Operations – Fractions	3, 4, 5	4, 5
Measurement and Data	K, 1, 2, 3, 4, 5	1, 2, 3, 4, 5
Geometry	K, 1, 2, 3, 4, 5	1, 2, 3, 4, 5

IBM SPSS 22 software program was used to perform an analysis of the summative assessments using both descriptive and inferential statistics exploring differences between group and group combination means and medians. The groups were defined according to the grade in which they began learning explicit non-inverted number names, with these groups further divided into the grade in which summative assessments were conducted. Intervention groups were those children who began in prekindergarten as 3- and 4- year-olds, and children who began in kindergarten as 5-year-olds. The comparison group was considered to be those children who enrolled in the schools as new students in first through fifth grades. The null hypothesis H_0 represented no statistically significant difference existing among or between the mathematics achievement measures means of the intervention and comparison groups. The alternate hypothesis H_a represented a statistically significant difference existing among or between the means of the intervention and comparison groups or group combinations.

Both the *Stanford 10* and the *ITBS* assessments aligned with nationally recognized mathematics learning standards. The *Stanford 10* Mathematics Problem Solving set of subtests

correlated to the *ITBS* Number Concepts and Mathematics Problems sets of subtests, while the *Stanford 10* Mathematics Procedures subtests correlated with *ITBS* Mathematics Computation. The total mathematics achievement scores for both tests were closely matched domains. In first and second grades, scores for School A and School B were analyzed as a combined data set and as individual schools. The combined data set paired *Stanford 10* and *ITBS* problem solving scores, procedures scores, and total achievement scores. In addition, a core academic achievement score measuring reading and mathematics achievement was combined. In grades 3 through 5, all data were obtained from the *Stanford 10*. Scores for mathematics problem solving, mathematics procedures, total mathematics achievement, and core reading and mathematics were expressed as national and local percentile ranks as well as normal cure equivalents.

Normal Curve Equivalent (NCE) scores were reported on the Stanford 10 assessments 2004 – 2009 and the ITBS 2012 – 2014. NCE scores are z-scores derived from the standard scores, providing an interval scale from approximately 0 to 100 with a mean of 50. Developed for the U.S. Department of Education as a means of comparing student growth, providing certain constraints are observed, these scores provide a means of comparing interventions across varying testing groups and assessment instruments. A primary consideration is the consistency of the timing of the assessment. Assessment data should be obtained from roughly the same point in the school year so as not to introduce individual student growth into the scores (Lipsey et al., 2012). Standardized test assessments were conducted in the spring of each school year at both schools.

The NCE scores of total mathematics achievement, mathematics problem solving, and mathematics procedures knowledge were extracted as dependent variables. NCE scores of core academic achievement in mathematics, reading, and English language arts were used as a covariate measure of overall academic ability. Because mathematics achievement is a part of the

core academic measure, an analysis of variance within NCE core academic among independent variable groups must be performed to test for significant interaction (Field, 2013).

Validity Issues and Limitations of the Study

A number of factors may have affected the validity of the study to varying degrees. Because the intervention was cross-cultural, it was not possible to administer in isolation. Teachers or parents could have held negative perceptions regarding the intervention, thus introducing bias, particularly if the children were aware and wanted to please adults. The formative interview assessments were repeated each semester, providing children opportunity to learn the test. Children were formatively assessed at varying time of the day; hunger, fatigue, illness, and attention span could have affected performance. Also, it was assumed that teachers maintained fidelity to standardized testing protocols. Two different standardized tests were used, with multiple national norms leading to different test items across grade levels, compared against different references. Efforts were made to continually monitor and adjust study administration in order to lessen the impact of these factors. Relatively small convenience samples of individual cohort were limitations of both segments of the study. Because the intervention was cross cultural, it was not possible to teach explicit non-inverted number names in isolation and eliminate exposure to traditional English and Spanish number names.

Data Analysis

Descriptive and analytical statistics of quantitative data were performed using SPSS. Descriptive statistics will be used to present and compare longitudinal data collected from formative and summative assessments. Analyses of NCE scores will compare means, explore relationships, and compare summative data. Outcomes will be compared with expected learning outcomes as defined by TEKS and CCSSM learning standards. Standardized assessment scores

will be compared among cohorts and comparison groups, between cohorts and comparison groups, and with local, state and/or national percentiles of individual cohorts and comparison groups.

Analysis and Results

A longitudinal study was conducted from 2003 through 2014, in two small, private elementary schools (School A and School B) within a private school district in Central Texas. A total of 377 children in 13 classes participated in the study (Appendix A). As shown in Table 4, standardized test scores were obtained from 341 participants with nearly equal numbers of female and male participants in each grade, with the exception of third grade. Children in prekindergarten classes in both schools and kindergarten classes in School A did not participate in standardized testing, accounting for the difference between the total number of children participating in the study and those who had standardized test scores.

A mathematics intervention was taught to children in prekindergarten and kindergarten with formative assessments conducted during the instruction process and summative assessments through standardized tests conducted in first through fifth grades at School A and kindergarten through second grade in School B. Results of the summative assessments in first through fifth grade have been analyzed using descriptive and inferential analysis to address the research question: *Do children who learn explicit non-inverted number names in prekindergarten and kindergarten demonstrate different levels of mathematics achievement in first through fifth grades than children without experience with explicit non-inverted number names?*

Three dependent variables were identified as measures of mathematics academic achievement. Sub-questions ask whether children in the intervention groups score differently in normal curve equivalent (NCE) scores of total mathematics achievement, problem solving, and mathematics procedures in each grade. The data were obtained from standardized tests of academic achievement, the *Stanford 10* for School A and the *ITBS* for School B. Three groups were identified indicating the number of years of experience cohort participants had with the

intervention. Participants who began in prekindergarten (Group 2) had two academic years of experience with explicit number names, kindergarten (Group 1) had three months to one academic year of experience, and children who entered the school after kindergarten (Group 0) were assumed to have had no experience with the intervention. Within each grade level, group sizes varied as shown in Table 4.

Table 4

Group Sizes of Participants in Grades 1 through 5, Schools A and B

Grade	Group 0	Group 1	Group 2	Female	Male	Total
Grade 1						
School A	20	26	55	48	53	101
School B	5	21	6	18	14	32
Total	25	47	61	66	67	133
Grade 2						
School A	30	17	32	33	46	79
School B	3	13	0	8	8	16
Total	33	30	32	41	54	95
Grade 3	26	12	22	22	38	60
Grade 4	14	8	11	15	18	33
Grade 5	14	6	0	9	11	20

A covariate, NCE core academic achievement (NCE Core), was paired with the dependent variables. Covariates and dependent variables were treated as interval scale variables in SPSS. Test assumptions of continuous and homogeneous distributions, independent groups, and approximately equal group sizes were first met (Tabachnick & Fidell, 2013). Data were analyzed for normality for all groups within each dependent variable as shown in Appendix A.

Dependent variables with normally distributed data were analyzed for differences in the means through one-way ANOVA among the three independent groups and independent samples *t*-tests between groups. Homogeneity of variance of distributions was tested using the Levene test with a significance greater than $p = .05$ in a 95% confidence interval. When significant differences were found in the ANOVA, a Scheffe post hoc analysis was conducted comparing each pair of variables in order to determine differences between specific groups. An ANCOVA was conducted using NCE Core Academic Achievement as covariate to control for student ability.

Results from the ANOVA's and independent samples *t*-tests were further analyzed for significance to corroborate and determine the specific areas of significance. If heterogeneity of variances was observed through the Levene test statistic, the Welch test statistic within the ANOVA was examined to support the finding of significance. The Kruskal-Wallis test of ranked means did not assume a normal distribution of data and was conducted when normal distributions could not be assumed or when group sizes were very small, and was also used as corroborating evidence of significance.

Effect sizes were calculated as partial eta squared using SPSS and compared to the rule of thumb: small effect of .01, medium effect of .09, and large effect of .25 (Tabachnick & Fidell, 2013). When comparing differences between mean groups, Cohen's *d* effect sizes were calculated using the pooled standard deviation and judged as small of 0.2, moderate of 0.5, or large of 0.8 (Tabachnick & Fidell, 2013).

Grade 1 Data Analysis and Inference

Children in Group 0 demonstrated higher achievement in mean NCE scores of total mathematics achievement, problem solving, and mathematics procedures than children in either

Groups 1 or 2, as illustrated in Figure 4. Children in Group 1 demonstrated the lowest achievement in all three measures.

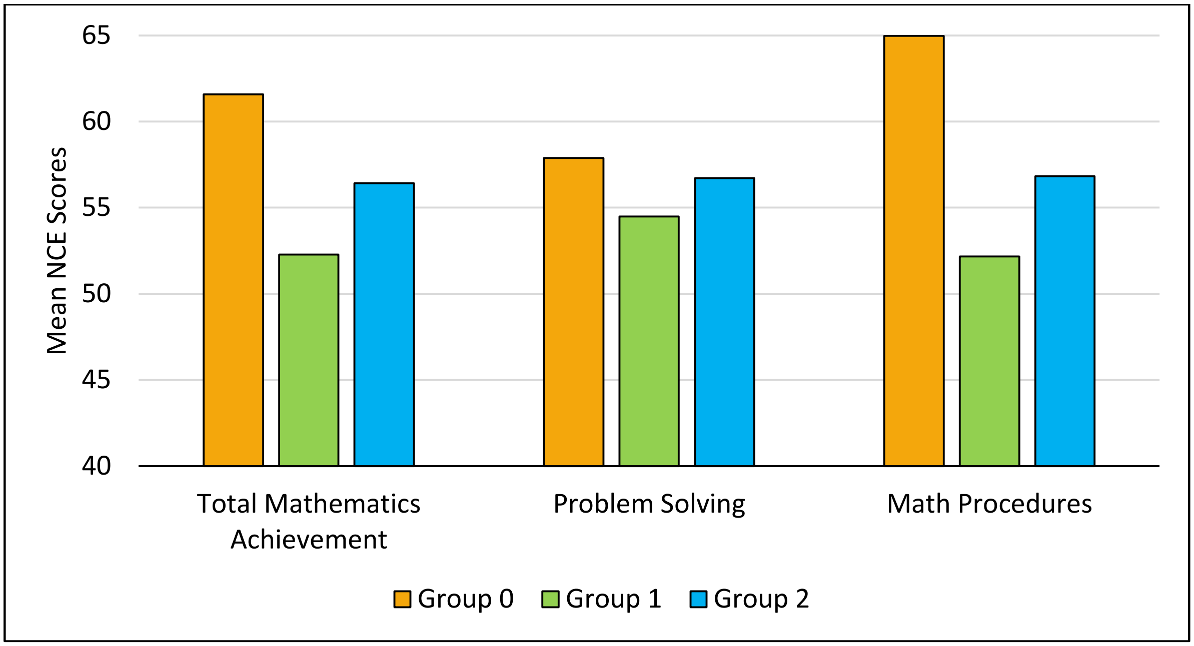

Figure 4. Grade 1 graph of mean NCE scores among experience groups.

Grade 1 mathematics achievement was analyzed to answer the question: Do children in the intervention groups score differently in NCE scores of total mathematics achievement, problem solving, and mathematics procedures in the first grade than children in the non-intervention group?

Descriptive analysis and data distributions of the three independent groups within the NCE scores of total mathematics achievement, problem solving, and mathematics procedures were examined and determined to meet assumptions of normality (see Appendix A, Tables 24 - 26 and Figures 23 - 38). No significant differences were found among the three groups in NCE scores of total mathematics achievement and problem solving. Significant differences were found within NCE scores of mathematics procedures among the years of experience groups as shown in Table 5, with children having zero years of experience demonstrating the highest mean scores. The strength of the relationship, as calculated by SPSS as eta squared was $\eta^2 = .081$.

Therefore, the null hypothesis was rejected with 8.1% of the variance accounted for by group membership.

Table 5

Grade 1 ANOVA Results for NCE Scores Among Experience Groups

	Years of Experience With Intervention								
	0 (n = 25)		1 (n = 47)		2 (n = 61)				
Variable	*M*	*SD*	*M*	*SD*	*M*	*SD*	$F(2, 130)$	p	η^2
Total Mathematics	61.58	19.52	52.28	17.30	56.42	15.60	2.50	.086	.037
Problem Solving	57.88	19.59	54.48	16.84	56.71	18.67	0.34	.741	.005
Mathematics Procedures	**64.97**	**18.09**	**52.16**	**17.35**	**56.82**	**12.03**	**5.73**	**.004**	**.081**

Post hoc comparisons using the Scheffe test were conducted to understand differences among the group means within NCE scores of mathematics procedures. The mean score for Group 1 was significantly lower than Group 0 at p = .004. An independent samples *t*-test between experience Groups 0 and 1 within NCE total mathematics achievement scores, indicated significance of $t(70) = 2.08$, p = .041, and within NCE mathematics procedures indicated significance $t(70) = 2.94$, p = .004, with children in Group 0 demonstrating higher mean scores.

Analysis of effect sizes further clarified the results. Children in Group 2 demonstrated approximately one third standard deviation higher achievement in mathematics procedures than Group 1 (Cohen's d = 0.312). Approximately one half a standard deviation lower than Group 0 (Cohen's d = 0.531) as shown in Table 6 and Figure 4. Children in Group 0 were one half standard deviation above Group 1 mean scores in NCE total mathematics and mathematics problem solving and seven tenths higher standard deviation in mathematics procedures. They were one half standard deviation higher than Group 2 in mathematics procedures.

Table 6

Grade 1 Cohen's d Effect Size in NCE Scores Among Experience Groups

Mean Difference Between Groups	NCE Total	NCE Problems	NCE Procedures	NCE Core
0 and 1	**0.505**	0.186	**0.723**	0.206
1 and 2	0.251	0.125	**0.312**	0.036
0 and 2	0.293	0.061	**0.531**	0.270

Children in Group 0 had the highest median NCE core academic achievement scores as shown in Figure 5. Low outliers were observed in Group 1 within problem solving. No outliers were observed in Groups 0 or 2. Group 0 had the largest interquartile range spread of the three groups.

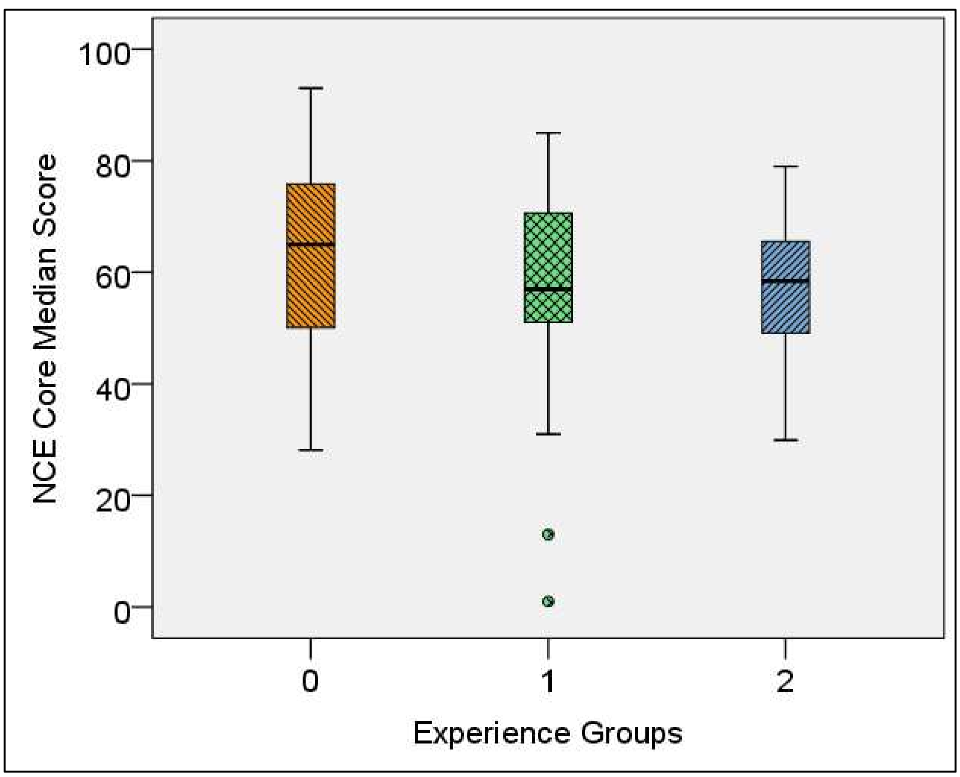

Figure 5. Grade 1 boxplot of median NCE scores of Core Academic Achievement among experience groups.

Mean NCE scores of core academic achievement were used to control for ability. Children in Group 2 demonstrated a higher standard deviation achievement in core academic achievement than Group 1 (Cohen's *d* = 0.036) but lower than Group 0 (Cohen's *d* = 0.270). Children in Group 1 demonstrated lower achievement than the comparison group (Cohen's *d* = 0.206) as shown in Table 6 and Figure 5.

An ANCOVA was performed within NCE procedures among groups with the covariate NCE of core academic achievement. Descriptive analysis and data distributions within the NCE scores of total mathematics achievement, problem solving, and mathematics procedures were examined and determined to meet assumptions of normality (see Appendix A). Significant differences were found within NCE scores of total mathematics achievement among the years of experience groups controlling for ability as shown in Table 7. The strength of the relationship, as calculated by SPSS as eta squared, was $\eta^2 = .062$. Therefore, the null hypothesis was rejected with 6.2% of the variance accounted for by group membership. Observed power was .729.

Table 7

Grade 1 ANCOVA Results for NCE Total Mathematics Achievement Among Experience Groups, Controlling for NCE Core Academic Achievement

Source	*df*	*SS*	*MS*	*F*	*p*	η^2
Covariate NCE Core	1	21668.00	21668.00	187.05	< .001	.596
Total Mathematics Achievement	2	972.35	486.18	4.20	**.017**	**.062**
Error	127	14712.20	115.84			
Total	131	452455.97				

Note. *N* = 133, *n* (0) = 25, *n* (1) = 47, *n* (2) = 61.

Significant differences were found within NCE scores of mathematics procedures among the years of experience groups controlling for ability as shown in Table 8. The strength of the

relationship, as calculated by SPSS as eta squared, was $\eta^2 = .104$. Therefore, the null hypothesis was rejected with 10.4% of the variance accounted for by group membership. Observed power was .935.

Table 8

Grade 1 ANCOVA Results for NCE Mathematics Procedures Among Experience Groups, Controlling for NCE Core Academic Achievement

Source	*df*	*SS*	*MS*	*F*	*p*	η^2
Covariate NCE Core	1	13924.83	13924.83	109.74	< .001	.464
Mathematics Procedures	2	1872.79	936.39	7.38	**.001**	**.104**
Error	127	16114.31	126.88			
Total	131	456709.78				

Note. *N* = 133, *n* (0) = 25, *n* (1) = 47, *n* (2) = 61.

Figure 6 shows the medians and distributions of the NCE scores for mathematics procedures, problem solving, and total achievement grouped by years of experience. Children in Group 0 demonstrated the highest NCE medians in total mathematics achievement, problem solving, and mathematics procedures; and the highest third quartile interquartile range spread among experience groups within total mathematics achievement and mathematics procedures. Group 0 had low outliers within total mathematics achievement and problem solving, and no outliers observed within mathematics procedures. Group 1 had the lowest first quartile interquartile range spread within total mathematics achievement and mathematics procedures. Group 2 had the lowest first quartile interquartile range spread within problem solving, and higher median scores in all three measures when compared to Group 1. No outliers were observed in Group 2.

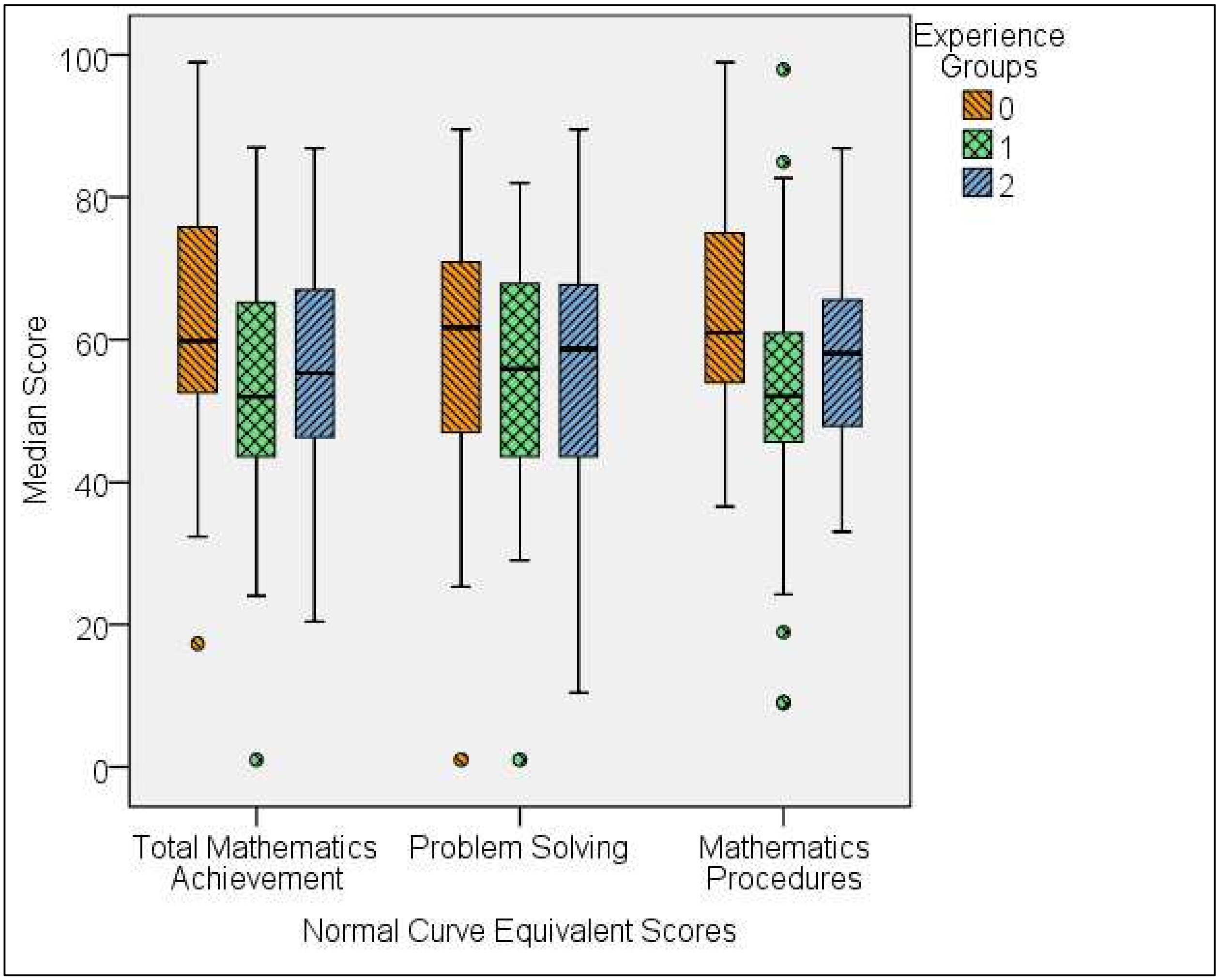

Figure 6. Grade 1 boxplot of median NCE scores among experience groups.

Grade 2 Data Analysis and Inference

No significant differences were found in Schools A and B combined. Within the three NCE measures, children in Group 1 demonstrated the highest mean scores, as illustrated in Figure 7. Children in Group 2 demonstrated higher achievement than children in Group 0 in NCE scores in total mathematics achievement and problems solving.

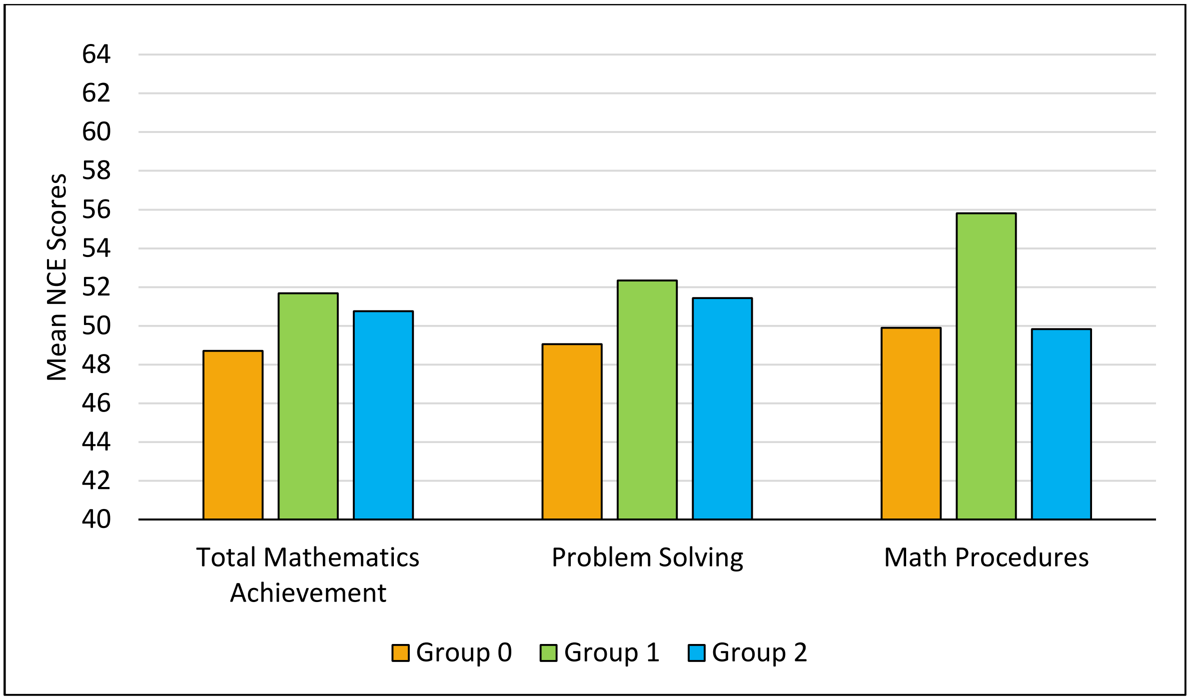

Figure 7. Grade 2 graph of mean NCE scores among experience groups.

Grade 2 mathematics achievement was analyzed to answer the question: Do children in the intervention groups score differently in NCE scores of total mathematics achievement, problem solving, and mathematics procedures in the second grade than children in the non-intervention group?

Descriptive analysis and data distributions of the three independent groups within the NCE scores of total mathematics achievement, problem solving, and mathematics procedures were examined and determined to meet assumptions of normality (see Appendix A, Tables 27 - 29 and Figures 39 - 54). No significant differences were found within NCE scores of total mathematics achievement, problem solving, or procedures among the years of experience groups as shown in Table 9.

Table 9

Grade 2 ANOVA Results for NCE Scores Among Experience Groups

	Years of Experience With Intervention								
	0 (n = 33)		1 (n = 30)		2 (n = 32)				
Variable	*M*	*SD*	*M*	*SD*	*M*	*SD*	$F(2, 92)$	p	η^2
Total Mathematics	48.71	18.61	51.68	15.37	50.75	15.25	0.27	.764	.006
Problem Solving	49.05	21.04	52.35	15.25	51.43	16.17	0.29	.746	.006
Mathematics Procedures	**49.90**	**16.86**	**55.81**	**16.66**	**49.84**	**15.50**	**1.35**	**.263**	.029

Analysis of effect sizes further clarified the results. Children in Group 2 demonstrated lower achievement in mathematics procedures than Group 1 (Cohen's d = 0.371) but approximately the same as Group 0 (Cohen's d = 0.003) as shown in Table 10 and Figure 7. Children in Group 0 also demonstrated the lowest achievement in total mathematics and mathematics problem solving with much larger differences between Groups 0 and 1.

Table 10

Grade 2 Cohen's d Effect Size in NCE Scores Among Experience Groups

Years of Experience	NCE Total	NCE Problems	NCE Procedures	NCE Core
0 and 1	**0.174**	0.180	**0.353**	0.305
1 and 2	0.060	0.058	**0.371**	0.299
0 and 2	**0.120**	0.127	**0.003**	0.035

Children in Group 2 had highest median NCE core academic achievement scores as shown in Figure 8. No outliers were observed in any group. Group 2 had the least interquartile range spread.

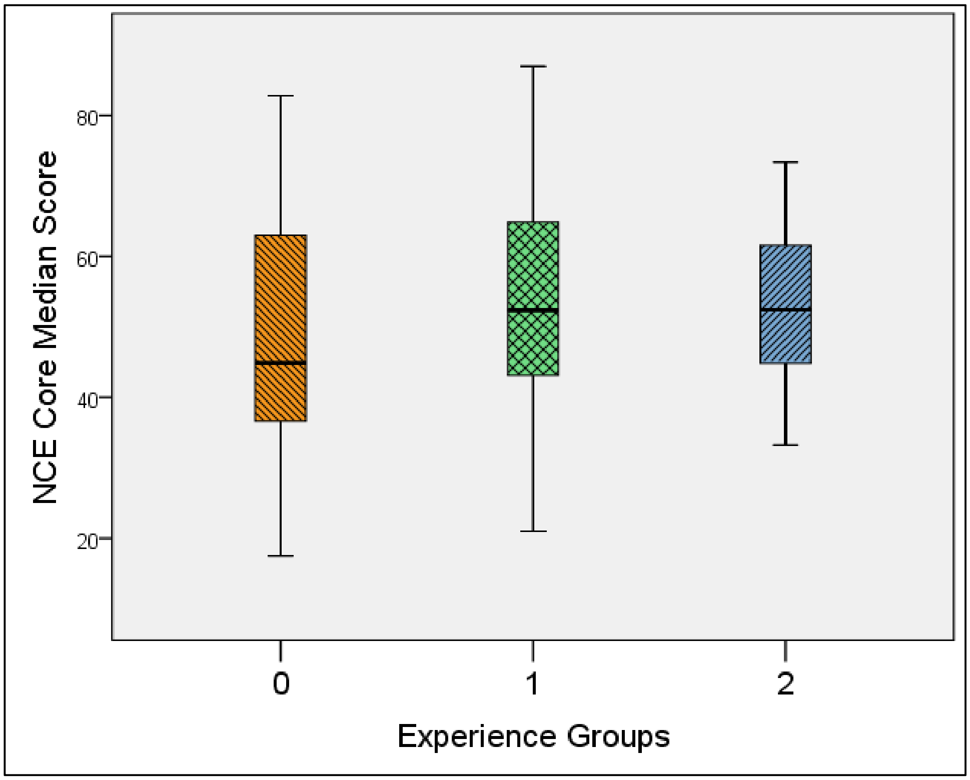

Figure 8. Grade 2 boxplot of median NCE scores of Core Academic Achievement among experience groups.

Mean NCE scores of core academic achievement were used to control for ability and account for possible advantages of children who participated in prekindergarten programs. Children in Group 2 demonstrated about the same achievement in core academic achievement as Group 0 (Cohen's $d = 0.035$), but higher than Group 1 (Cohen's $d = 0.299$). Children in Group 1 demonstrated higher achievement than Group 0 (Cohen's $d = 0.305$) as shown in Table 10 and Figure 8.

An ANCOVA was performed within NCE procedures among groups with the covariate NCE of core academic achievement to control for ability. Descriptive analysis and data distributions of the three independent groups and combinations within the NCE scores of total mathematics achievement, problem solving, and mathematics procedures were examined and determined to meet assumptions of normality (see Appendix A). Significant differences were

found within NCE scores of total mathematics achievement among the years of experience groups controlling for ability as shown in Table 11 and Table 12.

Table 11

Grade 2 ANCOVA Results for NCE Total Mathematics Achievement Among Experience Groups, Controlling for NCE Core Academic Achievement

Source	*df*	*SS*	*MS*	*F*	*p*	η^2
Covariate NCE Core	1	18433.08	18433.08	250.36	< .001	.733
Total Mathematics Achievement	2	85.46	42.73	0.58	.562	.013
Error	91	6699.92	73.63			
Total	95	265960.73				

Note. N = 95, *n* (0) = 33, *n* (1) = 30, *n* (2) = 32.

Table 12

Grade 2 ANCOVA Results for NCE Mathematics Procedures Among Experience Groups, Controlling for NCE Core Academic Achievement

Source	*df*	*SS*	*MS*	*F*	*p*	η^2
Covariate NCE Core	1	11965.00	11965.00	86.17	< .001	.486
Mathematics Procedures	2	499.74	249.87	1.80	.171	.038
Error	91	12635.93	138.86			
Total	95	279714.72				

Note. N = 95, *n* (0) = 33, *n* (1) = 30, *n* (2) = 32.

Figure 9 shows the medians and distributions of the NCE scores for mathematics procedures, problem solving, and total achievement grouped by years of experience. Children in Group 2 scored the highest medians in total mathematics achievement and problem solving, with one high outlier within mathematics procedures. Group 1 had about equal medians in total

mathematics achievement, higher medians than Group 0 in problem solving, and lower medians than Group 0 in mathematics procedures. Group 0 had the highest median scores in mathematics procedures and the highest interquartile range spread within all three measures among the three groups. No outliers were observed in Groups 1 or 0.

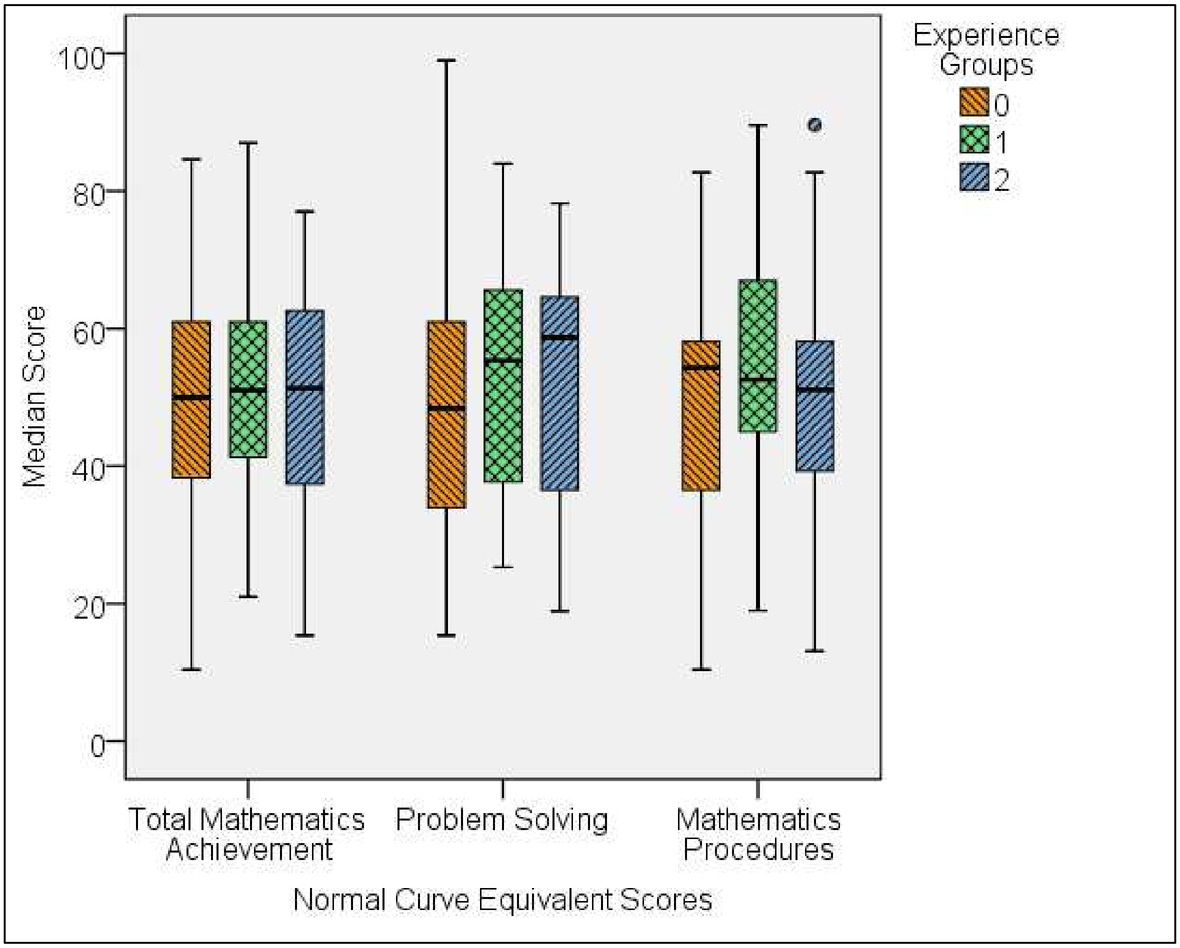

Figure 9. Grade 2 boxplot of median NCE scores among experience groups.

Grade 3 Data Analysis and Inference

Significant differences were found within NCE scores of mathematics procedures among experience groups. Children in Group 2 had higher mean NCE scores in all three measures, as shown in Figure 10. Children in Group 1 outperformed those in Group 0 in measures of NCE total mathematics achievement and mathematics procedures.

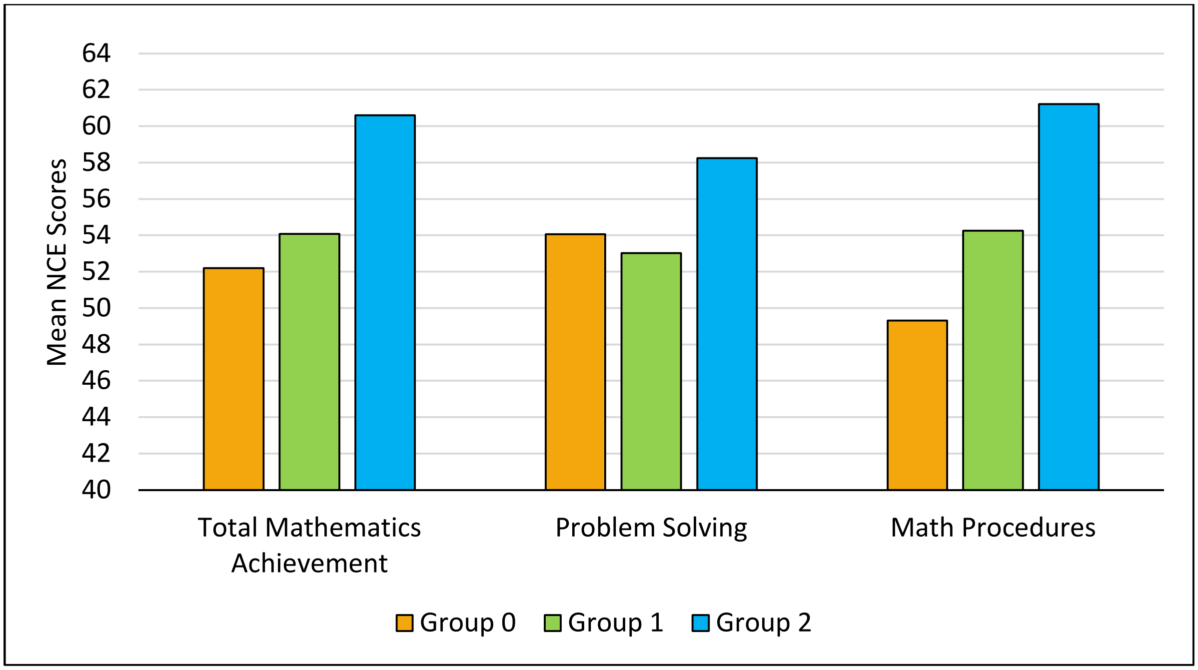

Figure 10. Grade 3 graph of mean NCE scores among experience groups.

Grade 3 mathematics achievement was analyzed to answer the question: Do children in the intervention groups score differently in NCE scores of total mathematics achievement, problem solving, and mathematics procedures in the third grade than children in the non-intervention group?

Descriptive analysis and data distributions of the three independent groups within the NCE scores of total mathematics achievement, problem solving, and mathematics procedures were examined and determined to meet assumptions of normality (see Appendix A, Tables 30 - 35 and Figures 55 - 86). No differences were found among the three groups in NCE scores of total mathematics achievement and mathematics problem solving. Significant differences were found within NCE scores of mathematics procedures (outliers removed) among the years of experience groups as shown in Table 13, with children in Group 2 demonstrating the highest mean scores. The strength of the relationship, as calculated by SPSS as eta squared was $\eta^2 = .12$.

Therefore, the null hypothesis was rejected with 12.0% of the variance accounted for by group membership.

Table 13

Grade 3 (Outliers Removed) ANOVA Results for NCE Scores Among Experience Groups

	Years of Experience With Intervention									
	0 (n = 26)		1 **(n = 10)**		2 (n = 22)					
Variable	*M*	*SD*	*M*	*SD*	*M*	*SD*	*df*	*F*	*p*	η^2
Total Mathematics	52.20	18.21	54.07	15.45	60.60	16.78	(2, 57)	1.49	.235	.05
Problem Solving	54.05	17.97	53.03	12.69	58.24	15.57	(2, 56)	0.56	.576	.02
Mathematics Procedures	**49.32**	**18.72**	**46.82**	**9.64**	**61.21**	**17.75**	(2, 55)	**3.75**	**.030**	**.12**

Post hoc comparisons using the Scheffe test were conducted to understand differences among the group means within NCE scores of mathematics procedures. The mean score for children in Group 2 was higher than Group 0 at p = .066. In an independent samples *t*-test between experience Groups 2 and 0, revealed Group 2 was higher than Group 0 within NCE mathematics procedures scores, with an indicated significance of $t(46) = 2.25$, $p = .030$, as shown in Table 14.

Table 14

Grade 3 (Outliers Included) Independent Samples t-test Results for NCE Scores Between Zero and Two Years of Experience Groups

	Years of Experience With Intervention						
	0 (n = 26)		2 (n = 22)				
Variable	*M*	*SD*	*M*	*SD*	*t*(46)	*p*	Cohen's d
Total Mathematics	52.20	18.21	60.60	16.78	1.65	.106	0.48
Problem Solving	54.05	17.97	58.24	15.57	0.85	.397	0.25
Mathematics Procedures	**49.32**	**18.72**	**61.21**	**17.75**	**2.25**	**.030**	**0.65**

Analysis of effect sizes further clarified the results. Children in Group 2 demonstrated the highest achievement in all three NCE measures as shown in Table 15 and Figure 10. Group 2 scored higher in total mathematics achievement than Group 1 (Cohen's d = 0.405) and Group 0 (Cohen's d = 0.475). Children in Group 2 also scored higher achievement in problem solving procedures than Group 1 (Cohen's d = 0.367) and Group 0 (Cohen's d = 0.249). Group 2 had higher scores in mathematics procedures than Group 1 (Cohen's d = 0.374) and Group 0 (Cohen's d = 0.652).

Table 15

Grade 3 (Outliers Included) Cohen's d Effect Size in NCE Scores Among Experience Groups

Year Experience	NCE Total	NCE Problems	NCE Procedures	NCE Core
0 and 1	0.109	0.066	**0.259**	0.259
1 and 2	**0.405**	0.367	**0.374**	0.374
0 and 2	**0.475**	0.249	**0.652**	0.652

Children in Group 2 had higher median NCE core academic achievement scores than those in Groups 0 and 1 as shown in Figure 11. No outliers were observed in any group. Group 0 had a largest, and Group 1 the least interquartile range spread.

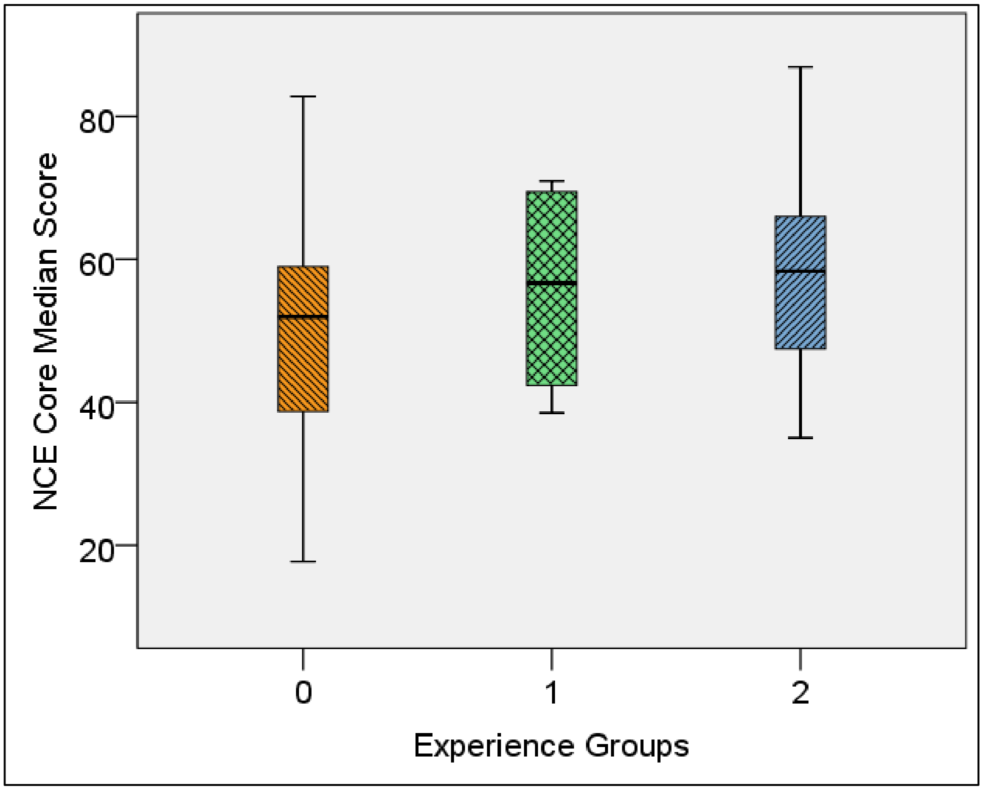

Figure 11. Grade 3 boxplot of median NCE scores of Core Academic Achievement among experience groups.

Mean NCE scores of core academic achievement were used in order to control for ability and account for possible advantages of children who participated in prekindergarten programs. Children in Group 2 demonstrated higher core academic achievement than Group 1 (Cohen's d = 0.374 and Group 0 (Cohen's d = 0.652). Children in Group 1 demonstrated higher achievement than Group 0 (Cohen's d = 0.259) as shown in Table 15 and Figure 11.

An ANCOVA was performed within NCE procedures among groups with the covariate NCE of core academic achievement to control for ability. Descriptive analysis and data distributions of the three independent groups and combinations within the NCE scores of total

mathematics achievement, problem solving, and mathematics procedures were examined and determined to meet assumptions of normality (see Appendix A). No significant differences were found within the three NCE scores among the years of experience groups when controlling for ability as shown in Table 16.

Table 16

Grade 3 ANCOVA Results for NCE Mathematics Procedures Among Experience Groups, Controlling for NCE Core Academic Achievement

Source	*df*	*SS*	*MS*	*F*	*p*	η^2
Covariate NCE Core	1	10252.70	10252.70	61.83	< .001	.525
Mathematics Procedures	2	**346.77**	**173.39**	**1.05**	**.358**	**.036**
Error	56	9285.35	165.81			
Total	60	200544.11				

Note. *N* = 60, *n* (0) = 26, *n* (1) = 12, *n* (2) = 22.

However, in pairwise comparisons, significant differences were observed within the NCE of mathematics problem solving between experience Groups 0 and 1, when controlling for ability (p = .043), with Group 1 demonstrating higher mean scores. Significant differences were also observed in pairwise comparisons within the NCE of mathematics procedures between experience Groups 1 and 2 when controlling for ability (p = .029).

Figure 12 shows the medians and distributions of the NCE scores for mathematics procedures, problem solving, and total achievement grouped by years of experience. Children in Group 2 scored the highest medians in total mathematics achievement, problem solving, and procedures. Group 1 had higher median scores than Group 0 in all three measures, with two high outliers within problem solving. Group 0 had the least spread in interquartile range among the three groups. No outliers were observed in Groups 0 and 2.

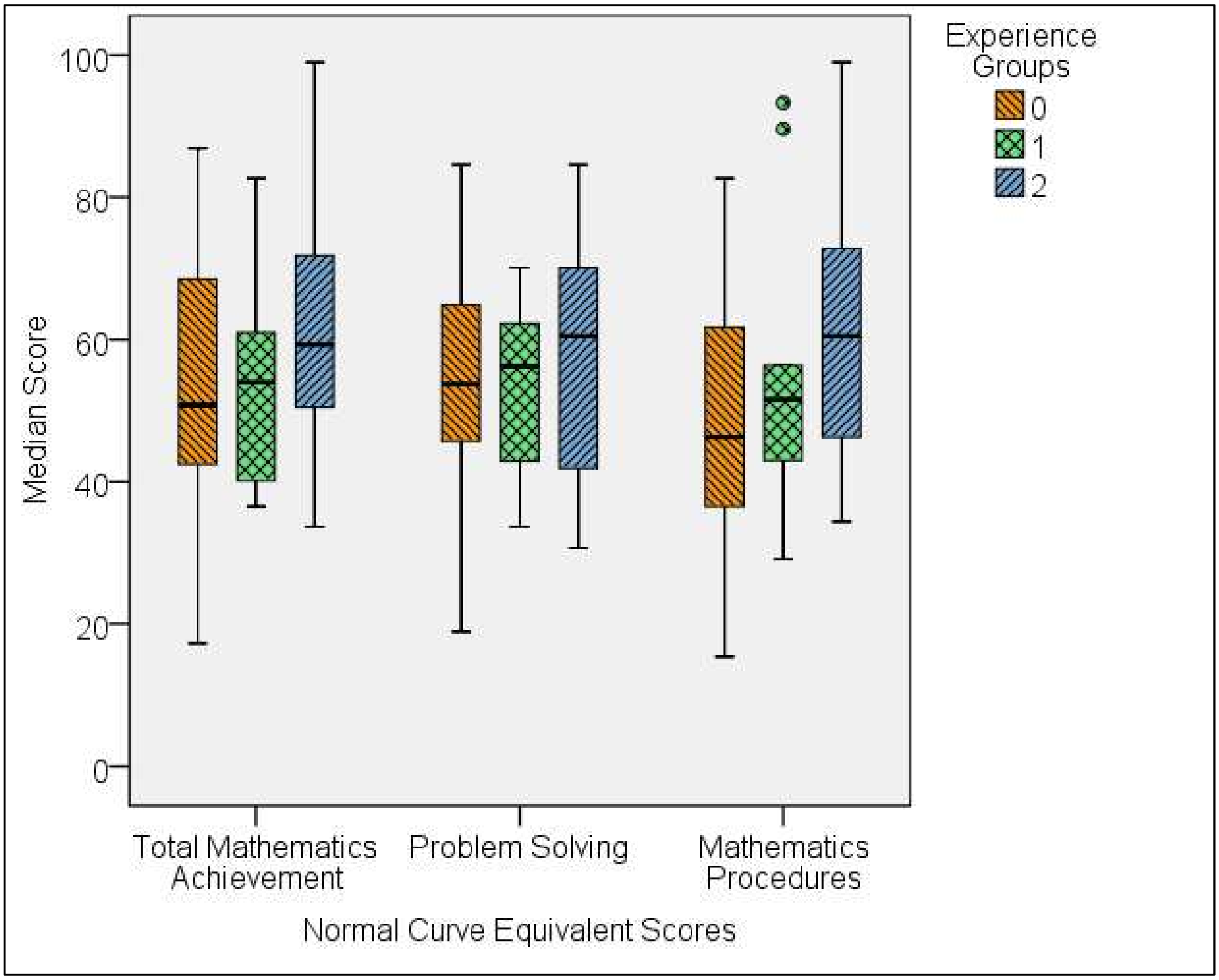

Figure 12. Grade 3 boxplot of median NCE scores among experience groups.

Grade 4 Data Analysis and Inference

No significant differences were found within NCE procedures among experience groups, as illustrated in Figure 13. Children in Group 2 demonstrated the highest levels of achievement in NCE scores of total mathematics achievement and procedures. Children in Group 1 outperformed children in Group 0 in all three measures.

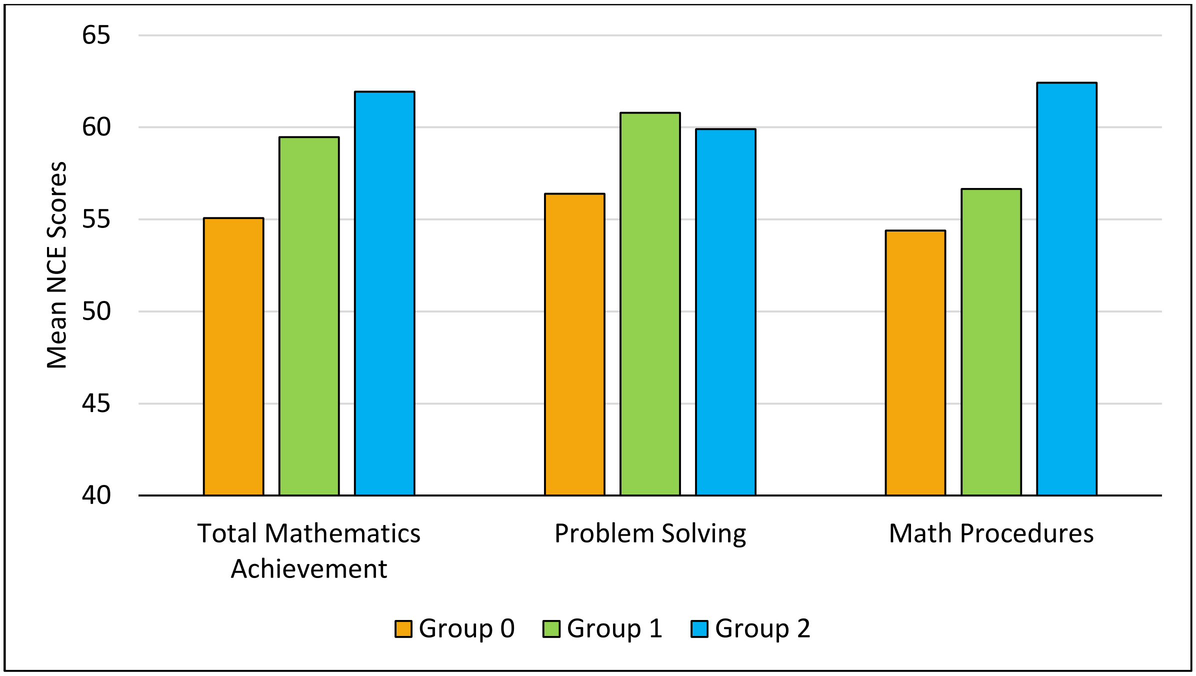

Figure 13. Grade 4 graph of mean NCE scores among experience groups.

Grade 4 mathematics achievement was analyzed to answer the question: Do children in the intervention groups score differently in NCE scores of total mathematics achievement, problem solving, and mathematics procedures in the fourth grade than children in the non-intervention group?

Descriptive analysis and data distributions of the three independent groups within the NCE scores of total mathematics achievement, problem solving, and mathematics procedures were examined and determined to meet assumptions of normality (see Appendix A, Tables 36 - 38 and Figures 87 - 102). No significant differences were found among the groups within NCE scores of total mathematics achievement, problem solving, or procedures among the years of experience groups as shown in Table 17.

Table 17

Grade 4 ANOVA Results for NCE Scores Among Experience Groups

	Years of Experience With Intervention								
	0 (n = 14)		1 (n = 8)		2 (n = 11)				
Variable	*M*	*SD*	*M*	*SD*	*M*	*SD*	$F(2, 30)$	*p*	η^2
Total Mathematics	55.07	14.46	59.46	10.63	61.94	13.15	0.751	.480	.048
Problem Solving	56.39	17.29	60.79	11.01	59.90	12.23	0.302	.741	.020
Mathematics Procedures	**54.39**	**14.61**	**56.66**	**11.56**	**62.42**	**12.63**	**1.151**	**.330**	**.071**

Note. N = 33, n (0) = 14, n (1) = 8, n (2) = 11.

Analysis of effect sizes further clarified the results. Children in Group 2 demonstrated higher achievement in mathematics procedures than Group 1 (Cohen's d = 0.476) and higher than Group 0 (Cohen's d = 0.588) as shown in Table 18 and Figure 13. Children in Group 0 also demonstrated the lowest achievement in total mathematics and mathematics problem solving.

Table 18

Grade 4 Cohen's d Effect Size in NCE Scores Among Experience Groups

Year Experience	NCE Total	NCE Problems	NCE Procedures	NCE Core
0 and 1	0.312	0.304	**0.097**	0.290
1 and 2	0.207	0.077	**0.476**	0.020
0 and 2	**0.465**	0.235	**0.588**	0.198

Children in Group 1 had higher median NCE core academic achievement scores than those in Groups 0 and 2 as shown in Figure 14. No outliers were observed in either group and Group 2 had a larger interquartile range spread than those in Groups 0 and 1.

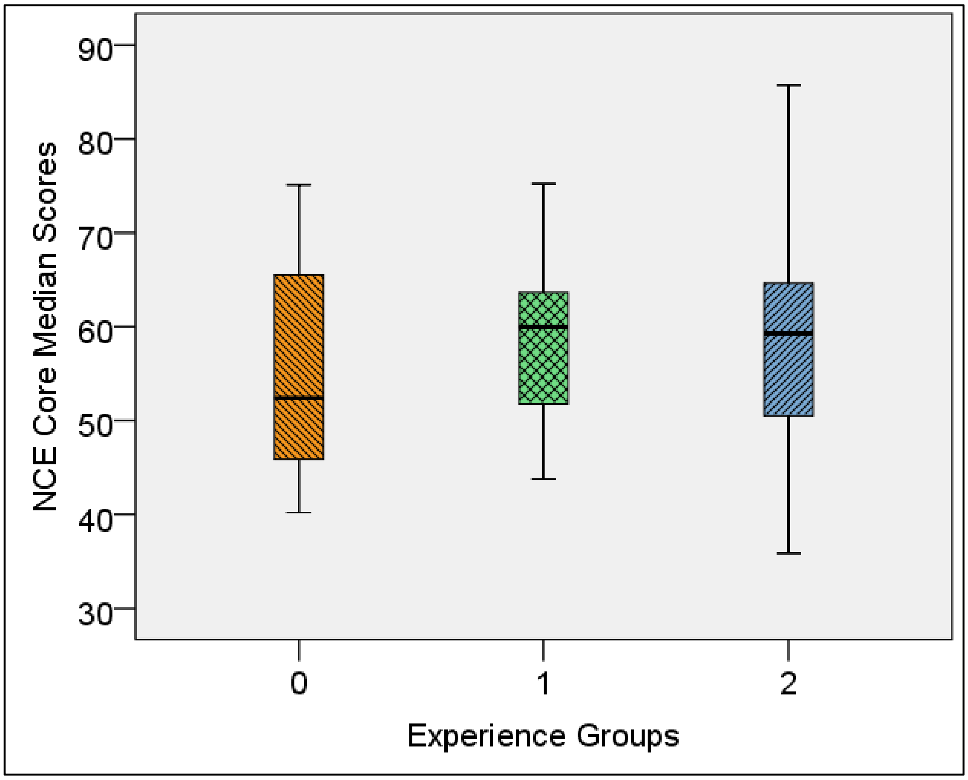

Figure 14. Grade 4 boxplot of median NCE scores of Core Academic Achievement among experience groups.

Mean NCE scores of core academic achievement were used in order to control for ability and account for possible advantages of children who participated in prekindergarten programs. Children in Group 2 demonstrated about equal core academic achievement as Group 1 (Cohen's d = 0.020) and higher than Group 0 (Cohen's d = 0.198). Children in Group 1 demonstrated higher achievement than Group 0 (Cohen's d = 0.290), as shown in Table 18 and Figure 14.

An ANCOVA was performed within NCE procedures among groups with the covariate NCE of core academic achievement to control for ability. Descriptive analysis and data distributions of the three independent groups and combinations within the NCE scores of total mathematics achievement, problem solving, and mathematics procedures were examined and determined to meet assumptions of normality (see Appendix A). As with the ANOVA, no

significant differences were found within NCE scores of mathematics procedures among the years of experience groups controlling for ability as shown in Table 19.

Table 19

Grade 4 ANCOVA Results for NCE Mathematics Procedures Among Experience Groups, Controlling for NCE Core Academic Achievement

Source	*df*	*SS*	*MS*	*F*	*p*	η^2
Covariate NCE Core	1	2444.75	2444.75	24.78	< .001	.461
Mathematics Procedures	2	**256.54**	**128.27**	**1.30**	**.288**	**.082**
Error	29	2860.87	98.65			
Total	33	115256.33				

Note. *N* = 33, *n* (0) = 14, *n* (1) = 8, *n* (2) = 11.

Figure 15 shows the medians and distributions of the NCE scores for mathematics procedures, problem solving and total achievement grouped by years of experience. Children in Group 2 scored the highest medians in total mathematics achievement, roughly the same as Groups 0 and 1 in problem solving and higher than Group 0 in mathematics procedures. Two high outliers were observed in Group 2 within NCE total mathematics achievement and problem solving. Group 1 had one high outlier within total mathematics achievement, while no outliers were observed in Group 0. Group 0 had the largest spread in interquartile range among the three groups.

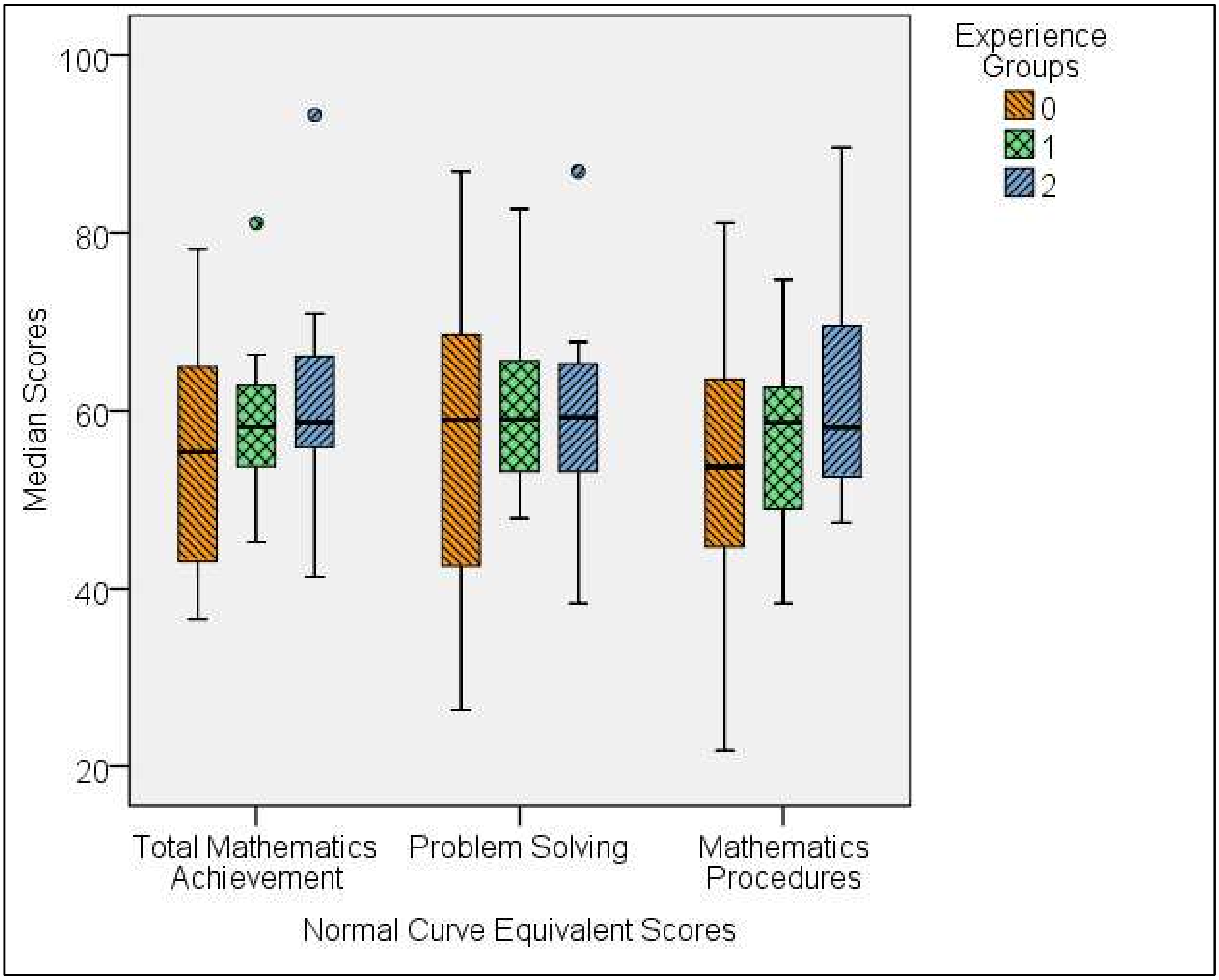

Figure 15. Grade 4 boxplot of median NCE scores among experience groups.

Grade 5 Data Analysis and Inference

No significant differences were found between children Group 0 and Group 1 in all three NCE measures. Children in Group 1 had higher mean NCE scores within the total mathematics achievement, problem solving, and mathematics procedures, as illustrated in Figure 16.

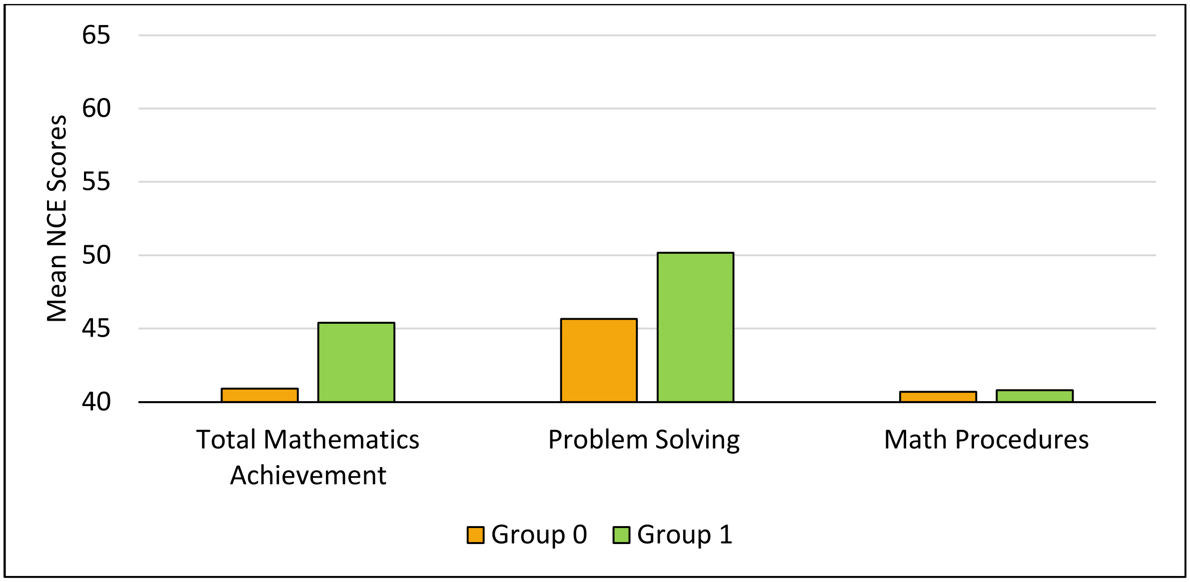

Figure 16. Grade 5 graph of mean NCE scores among experience groups.

Children in Grade 5 had experience in kindergarten only, and therefore included only Groups 0 and 1. Grade 5 mathematics achievement was analyzed to answer the question: Do children in the intervention groups score differently in NCE scores of total mathematics achievement, problem solving, and mathematics procedures in the fifth grade than children in the non-intervention group?

Descriptive analysis and data distributions of the two independent groups within the NCE scores of total mathematics achievement, problem solving, and mathematics procedures were examined and determined to meet assumptions of normality (see Appendix A, Tables 39 - 41 and Figures 103 - 114). No differences were found between the groups in NCE scores as shown in Table 20.

Table 20

Grade 5 Independent Samples t-test Results for NCE Scores Between Experience Groups

	Years of Experience With Intervention						
	0 (n = 14)		1 (n = 6)				
Variable	*M*	*SD*	*M*	*SD*	$t(1, 18)$	p	η^2
Total Mathematics	45.06	22.15	45.38	14.43	0.033	.974	< .000
Problem Solving	45.66	23.17	50.17	15.96	0.432	.671	.010
Mathematics Procedures	**44.86**	**20.27**	**40.08**	**10.24**	**0.542**	**.594**	**.016**

Analysis of effect sizes further clarified the results. Children in Group 1 demonstrated higher achievement in mathematics procedures than the Group 0 (Cohen's d = 0.377) as shown in Table 21 and Figure 16. Children in Group 0 also demonstrated lower achievement in problem solving and mathematics procedures.

Table 21

Grade 5 Cohen's d Effect Size in NCE Scores Between Experience Groups

Year Experience	NCE Total	NCE Problems	NCE Procedures	NCE Core
0 and 1	**0.377**	0.227	0.011	0.029

Children in Group 1 had higher median NCE core academic achievement scores than those in Group 0 as shown in Figure 17. No outliers were observed in either group and Group 0 had a larger interquartile range spread than those in Group 1.

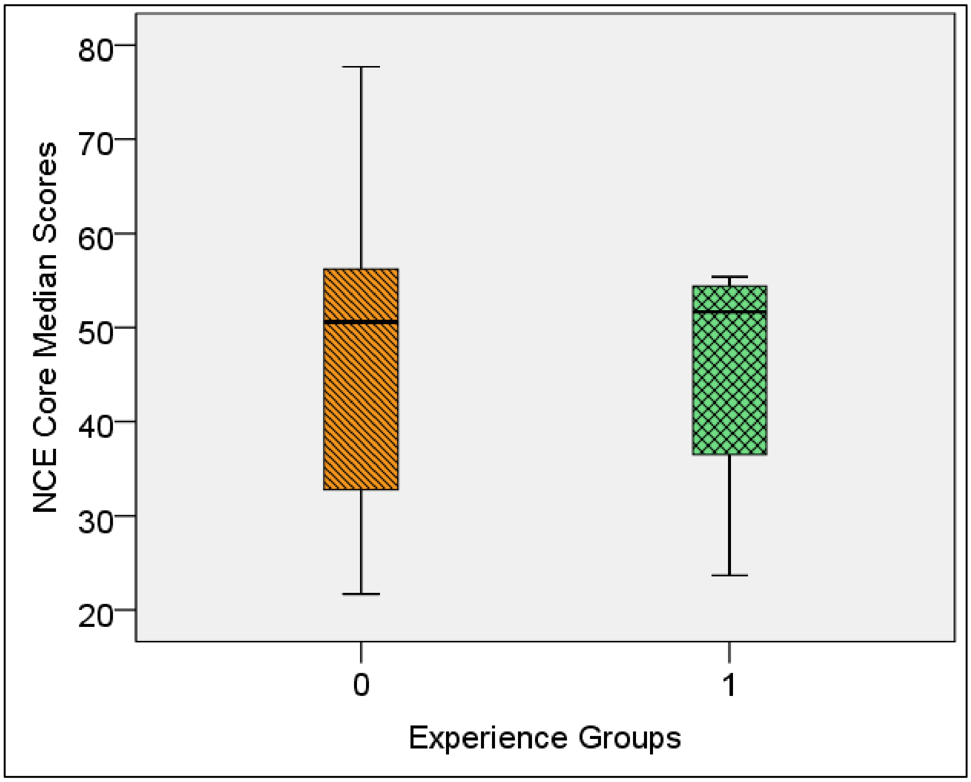

Figure 17. Grade 5 boxplot of median NCE scores of Core Academic Achievement among experience groups.

Mean NCE scores of core academic achievement were used in order to control for ability and account for possible advantages of children who participated in prekindergarten programs. Children in Group 1 demonstrated almost equal, despite the higher scores in the upper quartile in core academic achievement than Group 0 (Cohen's *d* = 0.029) as shown in Table 21.

An ANCOVA was performed within NCE procedures among groups with the covariate NCE of core academic achievement to control for ability. Descriptive analysis and data distributions of the three independent groups and combinations within the NCE scores of total mathematics achievement, problem solving, and mathematics procedures were examined and determined to meet assumptions of normality (see Appendix A). No significant differences were found within NCE scores of mathematics procedures among the years of experience groups controlling for ability as shown in Table 22.

Table 22

Grade 5 ANCOVA Results for NCE Mathematics Procedures Between Experience Groups, Controlling for NCE Core Academic Achievement

Source	*df*	*SS*	*MS*	*F*	*p*	η²
Covariate NCE Core	1	4472.48	4472.48	59.59	< .001	.778
Mathematics Procedures	1	**117.77**	**117.77**	**1.57**	**.228**	**.089**
Error	16	1200.96	75.06			
Total	19	42683.66				

Note. $N = 20$, $n\ (0) = 14$, $n\ (1) = 6$, $n\ (2) = 0$.

Figure 18 illustrates the median NCE scores as well as interquartile ranges within total mathematics achievement and problem solving of children in Group 1 were higher than those in Group 0 within NCE scores of total mathematics achievement and mathematics procedures. In addition, children in Group 0 had a much smaller spread in scores. Group 1 had both high and low outliers in total mathematics achievement and mathematics procedures, while Group 0 had only high outliers in the same NCE measures. No outliers were detected in either group within problem solving.

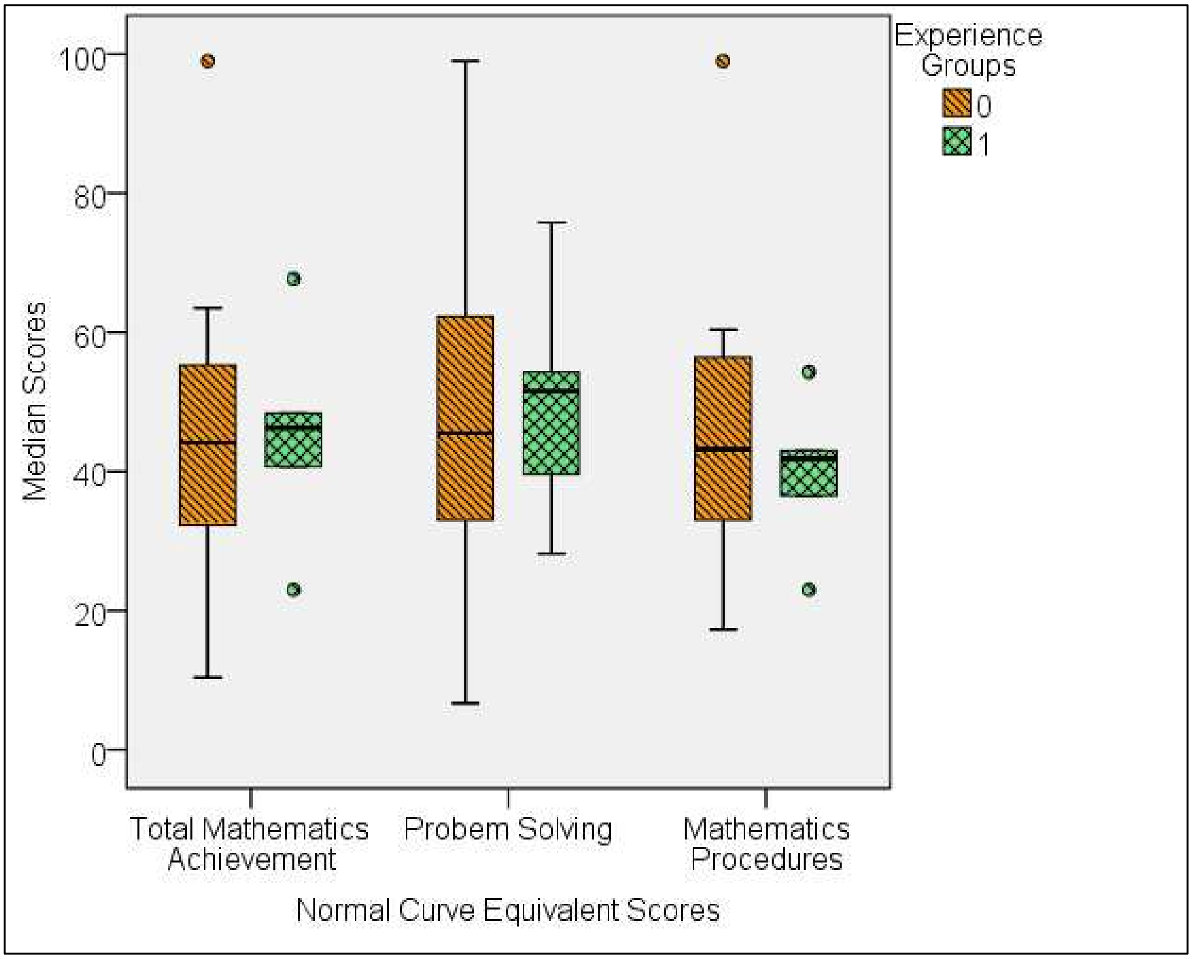

Figure 18. Grade 5 boxplot of median NCE scores among experience groups.

Summary of Results

One-way ANOVA, Welch, independent samples t-test, and Kruskal Wallis test analyses revealed significant differences within NCE performance among experience groups in first and third grades. ANCOVAs controlling for ability were performed at all grade levels to confirm results. In the first grade, students in Group 0 scored significantly higher than those with explicit non-inverted number names experience, even when controlling for ability. In the third grade, students in Group 2 scored significantly higher than those in Group 0, but this significance did not hold up when controlling for ability. These results answered the primary research question: *Do children who learn explicit non-inverted number names in prekindergarten and kindergarten*

demonstrate differently levels of mathematics achievement in first through fifth grades than children without experience with explicit non-inverted number names?

Figure 19 illustrates 5 year NCE score trends for total mathematics achievement for Groups 0, 1, and 2. No significance is noted in first grade among experience groups.

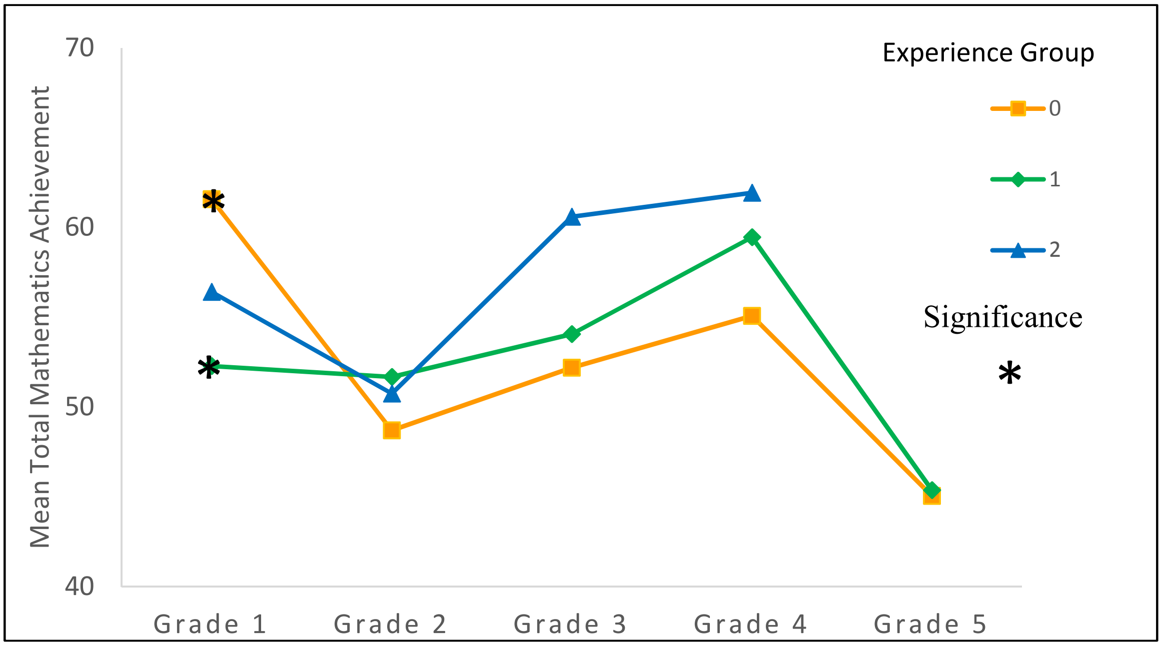

Figure 19. Mean NCE total mathematics achievement among experience groups and grade levels with significance observed in Grade 1 when controlling for ability.

Figure 20 illustrates 5 year NCE score trends for problem solving for Groups 0, 1, and 2. No significance is noted among experience groups.

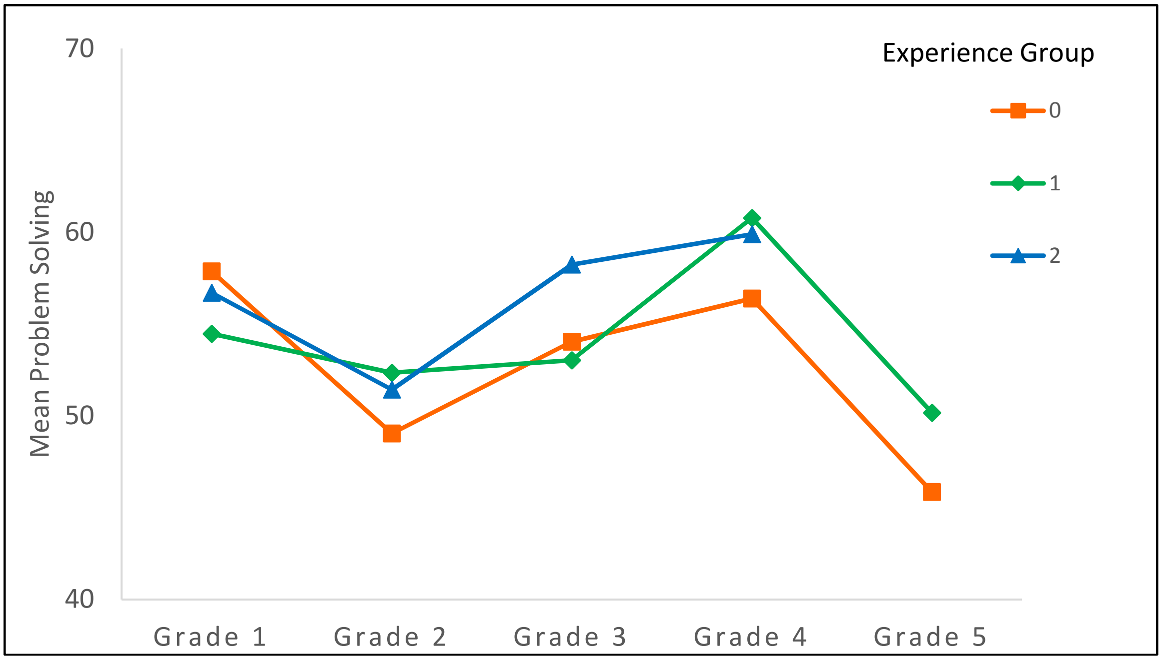

Figure 20. Mean NCE problem solving among experience groups and grade levels with no significance observed.

Figure 21 illustrates 5 year NCE score trends for mathematics procedures for Groups 0, 1, and 2. Significance is noted in first grade between Group 0 and Group 1. In third grade, significance is noted between Group 0 and Group 2.

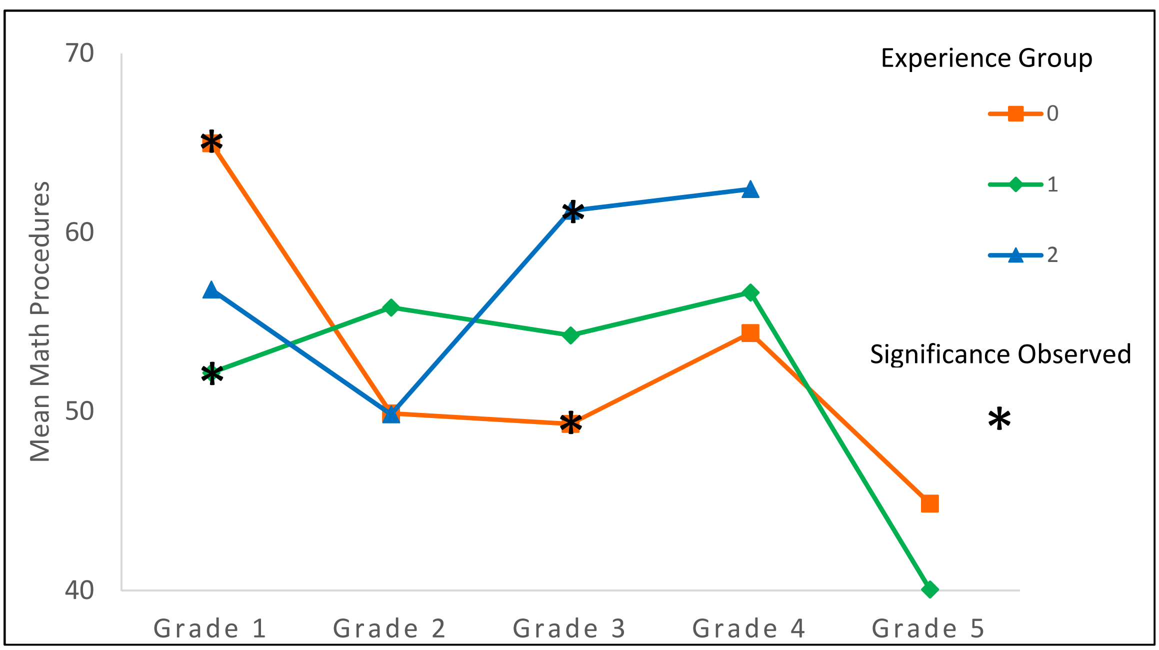

Figure 21. Mean NCE mathematics procedures among experience groups and grade levels with significance observed in Grades 1 and 3.

Figure 22 illustrates 5 year NCE score trends for core academic achievement for all 5 years of experience groups. Significance is noted in first grade between Group 0 and Group 1. In third grade, significance is noted between Group 0 and Group 2.

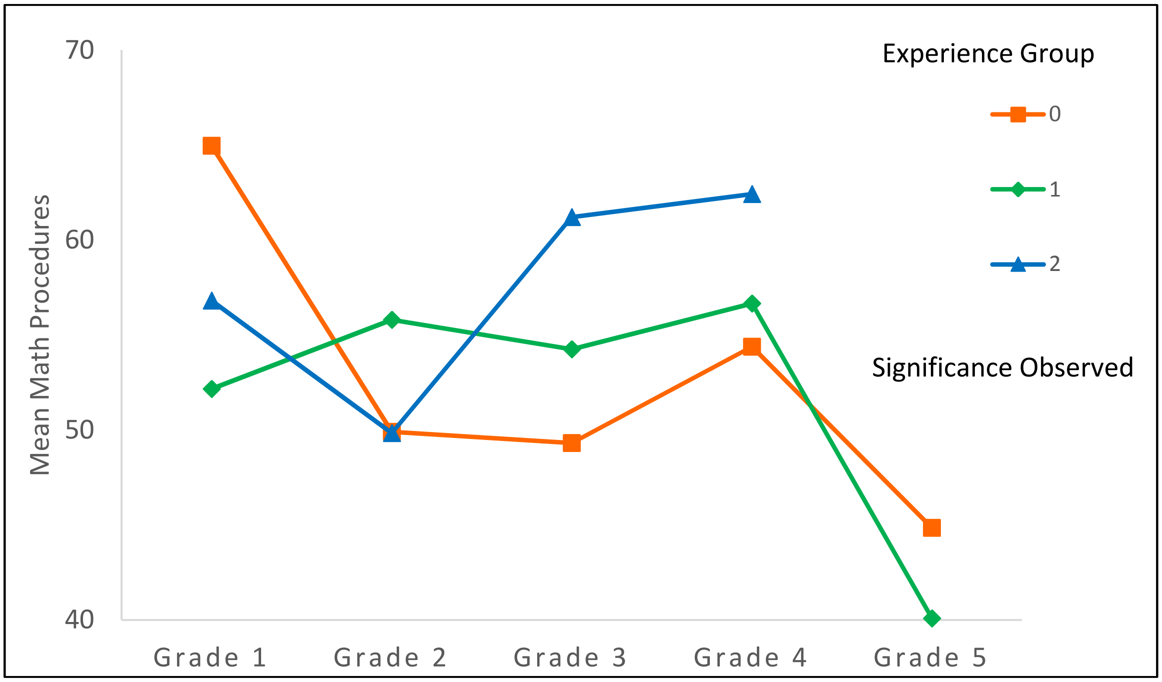

Figure 22. Mean NCE core academic achievement among experience groups and grade levels with no significance observed.

Overall, scores in first grade were highest for children in Group 0 with no experience with explicit non-inverted number names. During second grade, this trend began to reverse with no experience being the lowest, followed by two years of experience in Group 2, and children in Group 1 demonstrating the highest mean scores. By third grade, children in Group 2 demonstrated the highest mean scores in all three measures, with this trend continuing into fourth grade within total mathematics achievement and procedures. In fifth grade, only children in Groups 0 and 1 were assessed. Overall, scores were lower for both groups across all three measures with nearly equivalent scores in total mathematics achievement, and Group 1 scoring higher in problem solving and lower in procedures.

Table 23 shows significant differences found within NCE means among years of experience groups. In Grade 1, children in Group 0 scored significantly higher in mathematics procedures as indicated by all five test analyses. This held true when controlling for ability. In Grade 3, children in Group 2 demonstrated significantly higher scores within procedures as indicated by all five test analyses. However, this did not hold true when controlling for ability. In the second, fourth, and fifth grades, no significant differences were observed.

Table 23

Observed Statistical Significance of NCE Mean Scores by Test and Grade Level

	t-test	ANOVA	Welch	ANCOVA	Kruskal Wallis
Grade 1					
Total Math	--	--	--	--	--
Problem Solving	--	--	--	--	--
Procedures	*	*	*	*	*
Grade 2					
Total Math	--	--	--	--	--
Problem Solving	--	--	--	--	--
Procedures	--	--	--	--	--
Grade 3					
Total Math	--	--	--	--	--
Problem Solving	--	--	--	--	--
Procedures	*	*	*	*	*
Grade 4					
Total Math	--	--	--	--	--
Problem Solving	--	--	--	--	--
Procedures	--	--	--	--	--
Grade 5					
Total Math	--	--	--	--	--
Problem Solving	--	--	--	--	--
Procedures	--	--	--	--	--

* $p < .05$

Discussion and Conclusions

This study was conducted to explore the efficacy of explicit non-inverted number names learned in early childhood through mathematics achievement trajectories. Results answered the primary research question: *Do children who learn explicit non-inverted number names in prekindergarten and kindergarten demonstrate different levels of mathematics achievement in first through fifth grades than children without experience with explicit non-inverted number names?*

Normal curve equivalent scores of total mathematics achievement, problem solving, mathematics procedures, and core academic achievement were obtained from longitudinal standardized test results of first through fifth grades in two private elementary schools. The expectation was that explicit non-inverted number names would enable young children to more efficiently map concrete quantity to abstract numerals. This would then facilitate early place value acquisition, well established as a milestone in transitioning from informal to formal mathematics. In theory, children who accomplished this at earlier ages would experience lasting benefits and would demonstrate a positive learning trajectory above peers who did not have experience with explicit non-inverted number naming systems.

The quality and nature of mathematics learning in kindergarten impacts children's' learning trajectories in subsequent grades (LeFevre et al., 2010; Locuniak & Jordan, 2008). Counting concepts and place value understanding in early childhood positively influence and facilitate mathematics achievement in early elementary (Clements & Sarama, 2008; Dehaene et. al., 2004; LeFevre et al., 2010; Locuniak & Jordan, 2008). Brankaer et al. (2014), Yazejian et al. (2015), and von Aster and Shalev (2007), found early childhood to be the essential time for the

introduction of novel mathematics vocabulary and concepts, and mapping of concrete quantity to symbolic representations.

If mathematics is conceptualized as a global language, the elements of that language could be better understood, as well as its progressive growth, depth of expression, and associated learning trajectories. More specifically, research focused on transitioning from informal to formal mathematics during early childhood and elementary can be better understood through the underlying cognitive processes, the factors involved, and learning trajectories given specific elements. One school of thought indicates children mentally map symbolic representations of numbers from either concrete quantity or counting words.

Language could be used as the vehicle to map from concrete quantity to abstract symbolic representations (numerals), with explicit non-inverted number names posited as the more efficient means (Miura, 1987; Miller et al., 2000), thus accelerating the transition from informal to mathematics (Dehaene et. al., 2004). Butterworth (2005) and Dehaene (2009) defined the connection between language, numerals, and storage centers in the brain while Sousa (2008) accounts numeric representations are stored in the brain's language center. Herrera and Macizo (2010 and 2012) further described the connection between non-inverted number names and ease of recall of numeric representations. Curriculum and pedagogy, parental involvement, and social education dynamic have all been recognized as powerful contributors to successful acquisition of numeracy and place value (Miller et al., 2000; Miura, 1987).

Children from cultures using explicit non-inverted number names demonstrate an earlier ability to conceptualize units of ten, decompose and compose quantities as well as accurately identify numeric representations (Curtis et al., 2009; Ng & Rao, 2010; Sousa, 2008). Sousa

(2008) found this number naming system requires far less working memory as well, thus supporting the argument for its inherent efficiency.

Knowledge and skill acquisition begins with a foundation of number counting, cardinality, one-to-one correspondence, stable count order, and fundamental concept of ones and tens units in prekindergarten and kindergarten. The place value concept is then systematically taught and applied through each subsequent grade level, with particular attention to understanding of ones, tens, hundreds, and thousands as units composed of base-10 canonical units (NAEYC, 2010; CCSSM, 2016).

This research project posits concrete quantities are mapped to symbolic representation via counting words and that the nature of those words determined the speed and accuracy of the mapping process. In other words, language is the vehicle connecting the physical world to the mental world. Language in effect, connects informal mathematics to formal mathematics.

Words that are unique to each quantity and its related numeral, that do not clearly state the quantity, and do not state the quantity in place value order, would logically seem to be less efficient than those that do all of these things. Traditional English number names are unique to each quantity and numeral, may or may not state the actual quantity, may or may not be in place value order, and may or may not offer clues as to the quantity within each place value. Explicit non-inverted number names accomplish all of these tasks.

If explicit non–inverted number names are more efficient than their inverted (or semi-inverted) and non-explicit (or semi-explicit) counterparts, then an intervention introducing them during the transition phase from informal to formal mathematics might be advantageous to young children. Explicit non-inverted number names could aid young children by efficiently mapping quantities to numerals. And if young children had a firmer grasp on what numerals

actually represent, i.e. quantity and place value, then they could transition into formal mathematics understanding at an earlier age and with better understanding of place value.

Discussion of Results

Taken as a whole, evidence moderately favors the intervention's positive contribution to future mathematics performance. However, upon closer examination, this evidence was not strong enough to conclusively rule in favor of the intervention. In the first grade, the standardized tests showed children who had not participated in the study performed significantly higher on NCE scores of Mathematics Procedures, even when controlling for ability through NCE Core Academic Achievement. In third grade, children with two years of experience performed significantly higher on NCE scores of mathematics procedures but, when NCE core academic achievement was considered as a covariate, the significance disappeared.

Examining the means found an interesting pattern of development. In first grade, children in the comparison group had higher means on all three measures. In second grade, children who had one year of experience in kindergarten had the highest means, and by third grade, children with two years of experience had the highest means. This held true for the fourth and fifth grade as well. In the fourth and fifth grades, children with the most experience with the intervention continued to demonstrate the highest achievement.

Grade 1. *Do children in the intervention groups score differently in NCE scores of total mathematics achievement, problem solving, and mathematics procedures in the first grade than children in the non-intervention group?*

Evidence suggests that in first grade, children benefitted from having no experience with the intervention. Children with no experience demonstrated the highest achievement in all three measures, with significant differences found within mathematics procedures. Children who had

experience in prekindergarten and kindergarten followed with mean scores in NCE problem solving nearly equal to those children with no experience. Children with experience only in kindergarten scored the lowest in all three measures. When NCE scores of core academic achievement were introduced as a covariate, these significant differences persisted within mathematics procedures between children with no experience and those with experience in kindergarten only. Mean scores of core academic achievement among the three experience groups were roughly equal.

Grade 2. *Do children in the intervention groups score differently in NCE scores of total mathematics achievement, problem solving, and mathematics procedures in the second grade than children in the non-intervention group?*

Children who had some experience with the intervention during kindergarten demonstrated the highest mean scores in all three measures. They were followed closely by children with experience in prekindergarten and children with no experience scoring the lowest within total mathematics achievement and problem solving. When NCE scores of core academic achievement were introduced as a covariate, no significant differences were observed within the three measures among experience groups. In second grade, children with experience had slightly higher mean scores of academic achievement than those with no experience. While no significant differences were observed among experience groups, second grade marked the beginning of a mean score trend within all three measures and among groups that persisted throughout the remainder of the grades levels in the study.

Grade 3. *Do children in the intervention groups score differently in NCE scores of total mathematics achievement, problem solving, and mathematics procedures in the third grade than children in the non-intervention group?*

By this year, children with experience beginning in prekindergarten outperformed both the kindergarten and no experience groups within all three measures. When outliers were removed, significant differences were observed among experience groups. With outliers included, this significance was observed within mathematics procedures between children beginning in prekindergarten and no experience. Children with experience beginning in prekindergarten demonstrated both the highest mean and highest median scores, over one half standard deviation higher mathematics procedures compared to no experience, and only slightly higher core academic achievement.

When NCE scores of core academic achievement were introduced as a covariate, these significant differences persisted within mathematics procedures in pairwise comparisons between children with experience in kindergarten only and those with no experience. Pairwise comparisons also revealed significant differences within problem solving between children with experience beginning in prekindergarten and those with no experience. Evidence suggests the children who had any amount of experience with the intervention derived some lasting benefits when compared to children who had no experience.

Grade 4. *Do children in the intervention groups score differently in NCE scores of total mathematics achievement, problem solving, and mathematics procedures in the fourth grade than children in the non-intervention group?*

No significant differences were observed within the three measures among experience groups. The trends within the means continued with children who had experience beginning in prekindergarten demonstrating the highest achievement within mean scores of total mathematics achievement and mathematics procedures. Children with experience in kindergarten only demonstrated the highest mean scores in problem solving and second highest achievement in

total mathematics achievement and mathematics procedures. Children with no experience had the lowest mean scores within all three measures.

When NCE scores of core academic achievement were introduced as a covariate, no significant differences were observed within the three measures among experience groups. Children with experience had roughly equal mean scores within core academic achievement and those with no experience, slightly lower mean scores. While not significantly different, the means trend continued, suggesting children with any amount of experience with the intervention derived some level of lasting benefit when compared to children with no experience.

Grade 5. *Do children in the intervention groups score differently in NCE scores of total mathematics achievement, problem solving, and mathematics procedures in the fifth grade than children in the non-intervention group?*

In fifth grade, only children with no or one year of experience were in the study at this point. No significant differences were observed within any of the three measures. Children with some experience in kindergarten had higher mean scores within total mathematics achievement and problem solving. Within mathematics procedures, children in both experience groups demonstrated roughly equal performance. Mean scores of core academic achievement were roughly equal as well. When considering core academic achievement as a covariate, no significant differences were observed. Because the group sizes were very small, the results were considered inconclusive.

Limitations

Several limitations should be considered when examining the results of this study. While the overall number of children participating in the study was sufficient, the nature of the study divided participants into five smaller groups. These groups were then divided into three, even

smaller, groups. This reduced the power of the analyses. Also, this longitudinal study took place over a ten-year time span, impacting first through fifth grades. During this time, learning standards, curriculum, textbooks, and assessments were revised. While protocols were provided, teaching the intervention was left to the discretion of the classroom educator, thus uniformity of its implementation was not ensured. Finally, assessment outcomes are assumed accurate but consideration must be given to the age groups being assessed as well as test proctor training and adherence to testing protocols.

Implications

The study contributes to the body of literature defining both early childhood and mathematics education. In their recent discussion of developing a globally focused, collaborative, and structured framework for inquiry into the nature and process of mathematics cognition, Alcock et al. (2016) proposed an organized approach to standards and curriculum development. Findings of this study are significant to several of the proposed research domains. Results from this study fall within the domains of deeper understanding of mathematics cognition and the learning process during early childhood, targeting specific skill sets and designing curriculum and pedagogy to facilitate growth, as well as tracking learning trajectories.

Developers of learning standards may utilize connections found between early childhood use of explicit non-inverted number names and early childhood acquisition of place value. Early childhood classroom educators may draw from this research when designing curriculum and pedagogy that facilitates the connection between concrete and abstract numeracy concepts. Educators of students with special learning needs may examine the use of explicit non-inverted number names as an additional mode of input in differentiated curriculum.

Future Research

As mathematics learning standards evolve, diverse methods of meeting these goals will be needed to bridge the gaps. From this longitudinal study, data will be further examined for efficacy of the intervention on gender as well as individual learning trajectories. Prekindergarten and kindergarten performance on formative assessments will be connected to elementary performance on summative assessments.

This intervention should continue to be explored both quantitatively and qualitatively. Large scale studies in diverse, multilingual environments would provide a broader picture of the efficacy of the intervention. Future studies could connect languages spoken at home with the intervention and associated mathematics achievement. A larger study could also gather cognitive ability data as a covariate in order to more accurately describe the effects of the intervention. If available, benchmark data could provide valuable pre-test information as a means of studying within group growth. Cross-cultural collaboration would provide critical information to see if the intervention is better suited for certain educational environments.

Conclusions

Children in first grade with no experience demonstrated significantly higher means in mathematics procedures than children who had learned the intervention, then this reversed by third grade with children having the most experience demonstrating significantly highest means across all three measures of achievement. This could be due to interaction with other factors such as parental involvement, classroom educators, curriculum, and educational environment. While the results of this study do not offer conclusive evidence of the efficacy of using explicit non-inverted number in early childhood, there is enough evidence to argue for further research to determine the true potential of these number names on mathematics learning. If this research is a

component of a systematic approach to curriculum and pedagogy design, explicit non-inverted number names hold great promise.

The results of this study provide evidence to support further research of a cross-cultural intervention on a much larger scale. As global borders dissolve and researchers collaborate with classroom educators, solutions to persistent educational issues move closer to solutions. An intervention such as the one explored in this study, is but one example of the universe of possibilities as we blend cultures and build a global education paradigm. The potential to provide inclusive curriculum and pedagogy vastly improves through this exploration, sharing, and communication. Innovative studies exploring cross-cultural mathematics interventions promise to broaden the spectrum of education, making it truly inclusive.

The language we use to educate our children in prekindergarten and kindergarten has the power to determine their learning trajectories. As classroom educators, we lay a banquet out before our children in order to address an incredible range of abilities and learning styles with multimodal input. This is the very heart of inclusive, differentiated education. To some children, explicit non-inverted number names may minimally impact their learning. But for others, they will be the key that opens the door to the world of mathematics. For them, explicit non-inverted number names will be the Math Names for numbers.

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Appendices

Appendix A Descriptive Data and Tests of Normality

Data contained in the dependent variables and covariates were assessed for normality of distribution for the variables as a whole and individual groups within variables by assessing indicators of normal distribution. For each variable, the mean and median were examined for equality; .68, .95, .99 range rule = .16 < | standard deviation / range | < .25; skewness z-score = | skew / skew error | < 3; kurtosis z-score = | kurtosis / kurtosis error | < 3; Shapiro-Wilk $p > .05$ for n < 50 and Kolmogorov-Smirnov $p > .05$ for n = or > 50; and a relatively "bell" shaped histogram (Tabachnick & Fidell, 2013; Westfall and Henning, 2013). Satisfaction of the majority of parameters resulted in the variable data distribution assumed normal. Data were also assessed as nonparametric distributions with consideration given to the closeness to normality. Observed sample size power was calculated through the Kruskal Wallis test of ranked means.

Descriptive and inferential analyses for each grade level, school, and grouping variable were first conducted with all cases, including outliers. Boxplot graphs of each normal curve equivalent dependent variable paired with each grouping variable were used to identify outliers. Outliers were removed, descriptive statistics calculated, and analyses were then conducted removing only the outliers unique to each grouping variable. This method was selected in order to conserve as much data as possible for each analysis.

Because data met the parameters for normality for each grade level, normality was assumed and parametric tests were used as the primary form of analyses. The Kruskal Wallis nonparametric test was run for each grade level and within each dependent variable as a confirmation of parametric test results.

Grade 1 Descriptives and Tests of Normality

Table 24

Grade 1 Group Sizes

Experience Groups	Female	Male	Total
0	11	14	25
1	21	26	47
2	34	27	61
0, 1, and 2	66	67	133

Table 25

Grade 1 Mathematics Achievement Descriptives

Variables	*N*	*M*	Median	*SD*
NCE Total	133	55.93	55.30	17.16
Group 0	25	61.58	59.80	19.45
Group 1	47	52.28	52.00	17.30
Group 2	61	56.42	55.30	15.60
NCE Problems	133	56.14	55.90	18.13
Group 0	25	57.88	61.70	19.59
Group 1	47	54.48	55.90	16.84
Group 2	61	56.71	58.70	18.67
NCE Procedures	133	56.71	55.30	15.83
Group 0	25	64.97	61.00	18.09
Group 1	47	52.16	52.10	17.35
Group 2	61	56.82	58.10	12.03
NCE Core	131	58.60	59.00	14.88
Group 0	25	61.61	65.00	16.46
Group 1	47	58.19	57.00	16.74
Group 2	59	57.65	58.40	12.52

Table 26

Grade 1 Mathematics Achievement Normality and Homogeneity

Variables	*SD*/ Range	Skewness/ Error	Kurtosis/ Error	Levene	Kolmogorov-Smirnov / Shapiro-Wilk
NCE Total	.175	0.910	0.175		.200
Group 0	.238	0.526	0.024	.739	.840
Group 1	.201	0.954	0.768	.739	.733
Group 2	.235	0.556	0.743	.739	.200
NCE Problems	.205	1.962	0.518		.200
Group 0	.221	2.116	1.860	.649	.207
Group 1	.208	1.265	1.163	.649	.085
Group 2	.236	0.712	0.689	.649	.200
NCE Procedures	.176	0.500	2.823		.020
Group 0	.289	1.052	0.438	.131	.192
Group 1	.195	0.628	1.880	.131	.075
Group 2	.223	0.709	0.805	.131	.200
NCE Core	.162	3.132	2.836		.200
Group 0	.254	0.907	0.343	.244	.493
Group 1	.199	3.112	3.621	.244	.005
Group 2	.255	0.955	1.023	.244	.162

Notes: Kolmogorov-Smirnov used when n > or = 50 and Shapiro-Wilk used when n < 50.

Grade 1 histograms. Histograms with superimposed normality curves were produced for each group within the dependent variables and the covariate. The distributions for stanine scores closely resembled normal distributions. Most distributions for total mathematics achievement, problem solving and mathematics procedures were normally distributed overall. Distributions for NCE Procedures for all groups and combinations are shown in Figures 23 through 38.

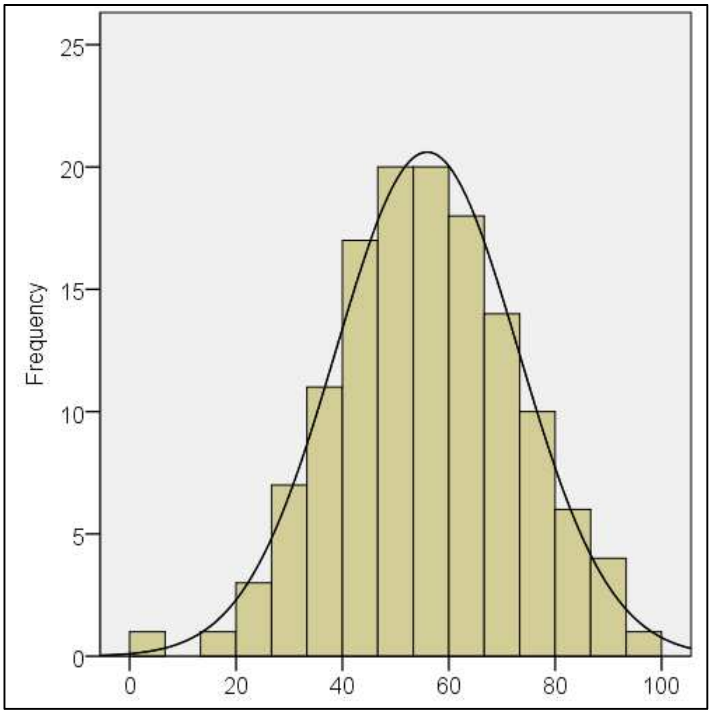


Figure 23. Grade 1 NCE total mathematics achievement histogram for Groups 0, 1, and 2.

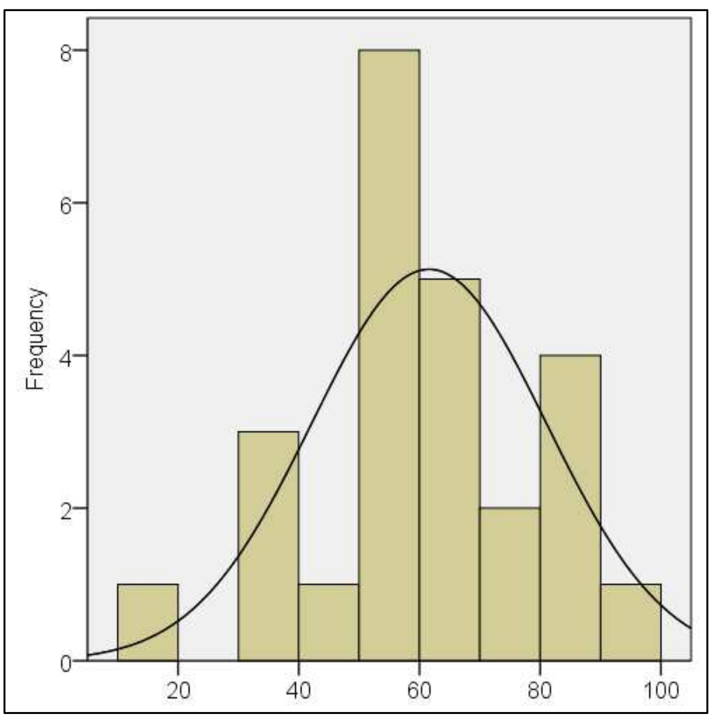


Figure 24. Grade 1 NCE total mathematics achievement histogram for Group 0.

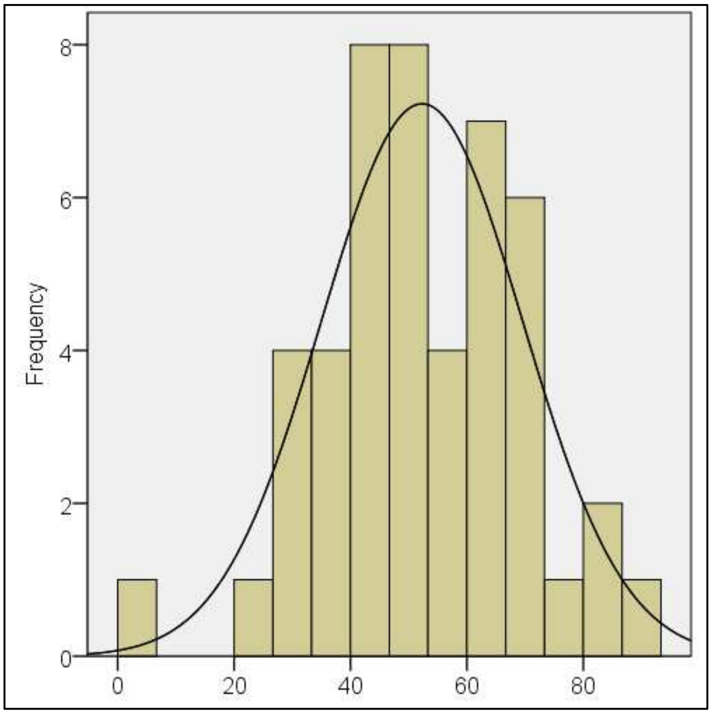


Figure 25. Grade 1 NCE total mathematics achievement histogram for Group 1.

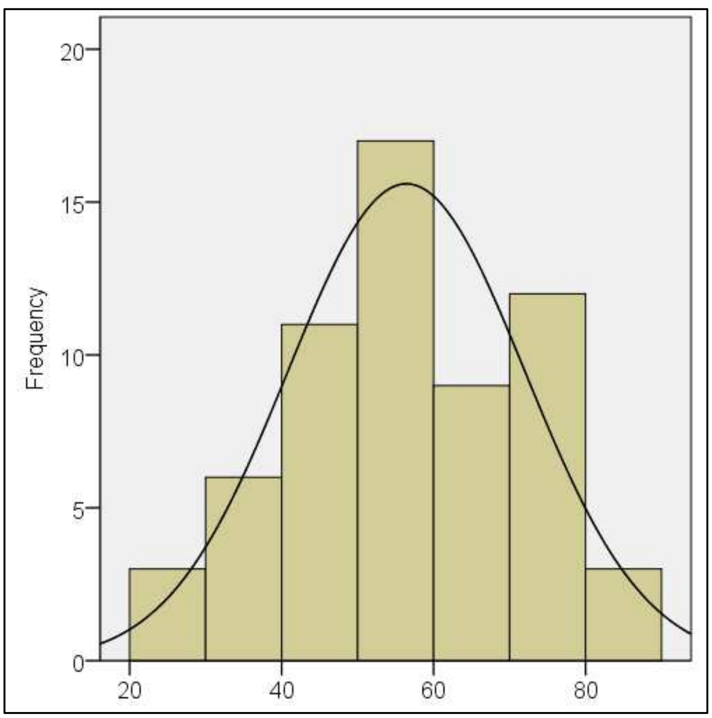


Figure 26. Grade 1 NCE total mathematics achievement histogram for Group 2.

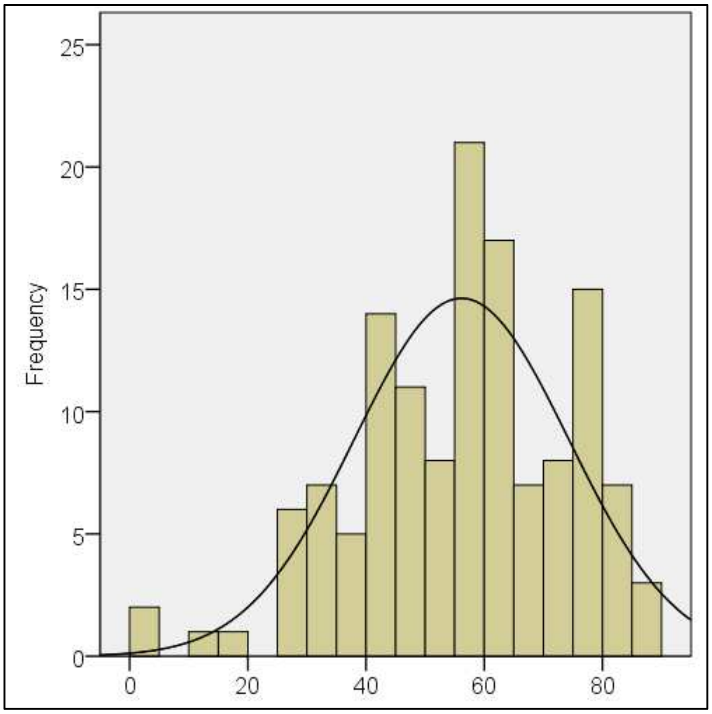


Figure 27. Grade 1 NCE problem solving histogram for Groups 0, 1, and 2.

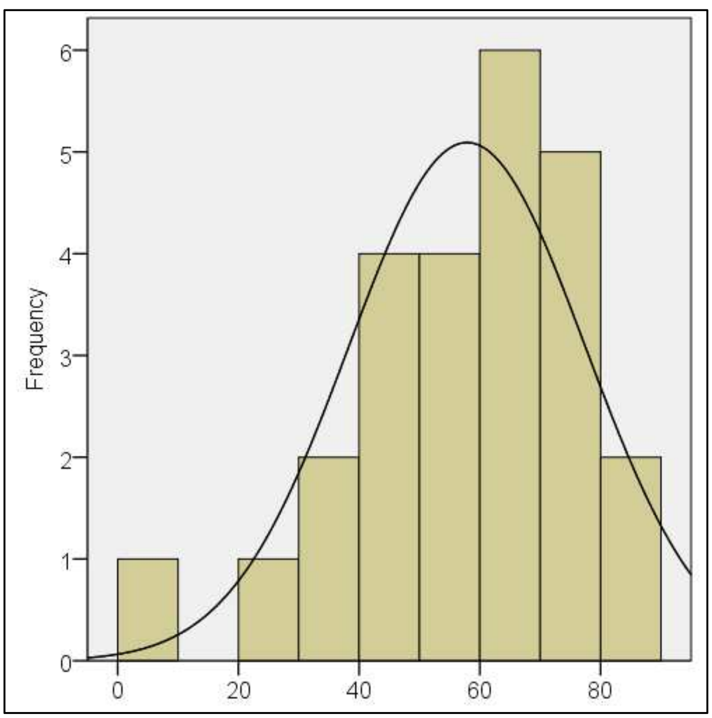


Figure 28. Grade 1 NCE problem solving histogram for Group 0.

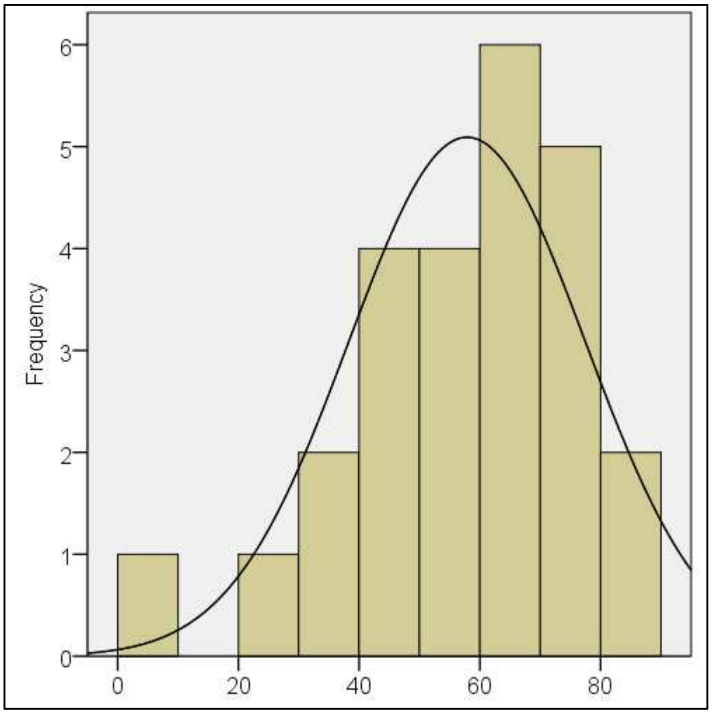


Figure 29. Grade 1 NCE problem solving histogram for Group 1.

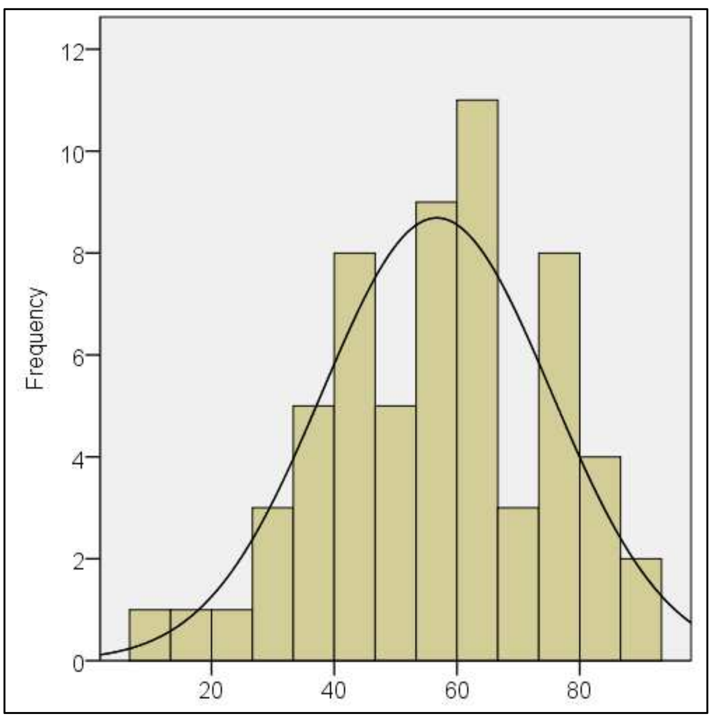


Figure 30. Grade 1 NCE problem solving histogram for Group 2.

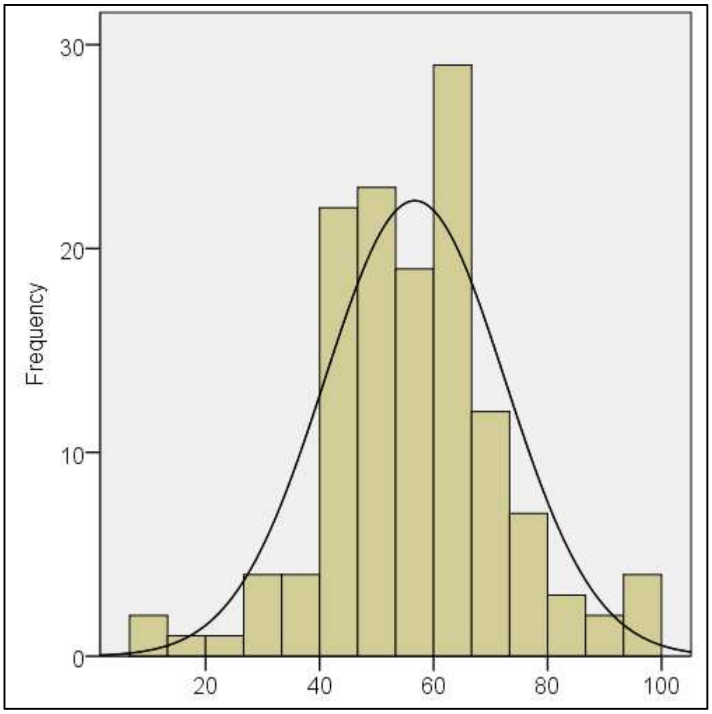


Figure 31. Grade 1 NCE mathematics procedures histogram for Groups 0, 1, and 2.

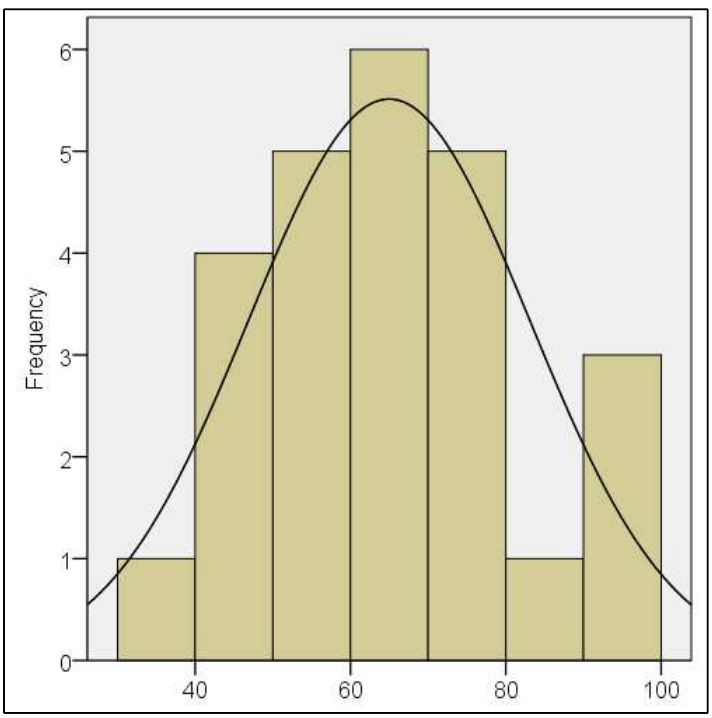


Figure 32. Grade 1 NCE mathematics procedures histogram for Group 0.

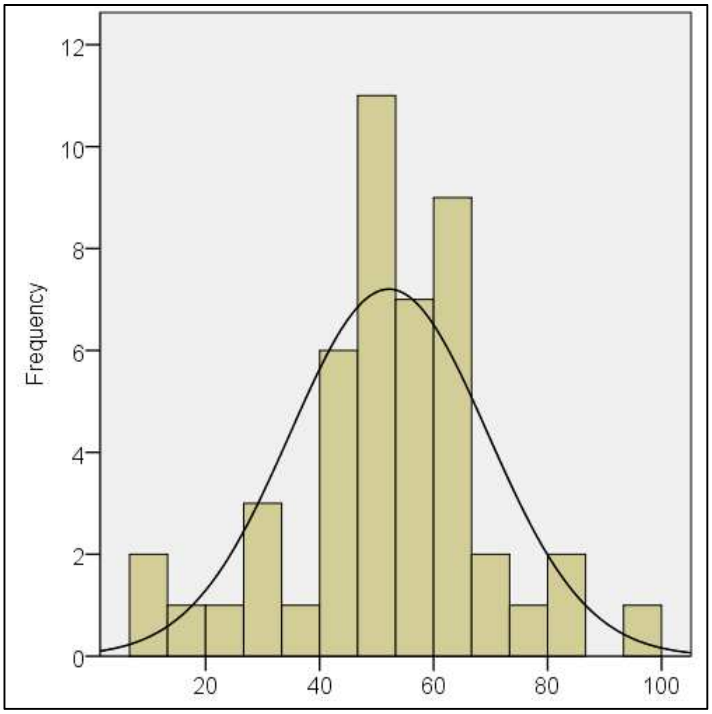


Figure 33. Grade 1 NCE mathematics procedures histogram for Group 1.

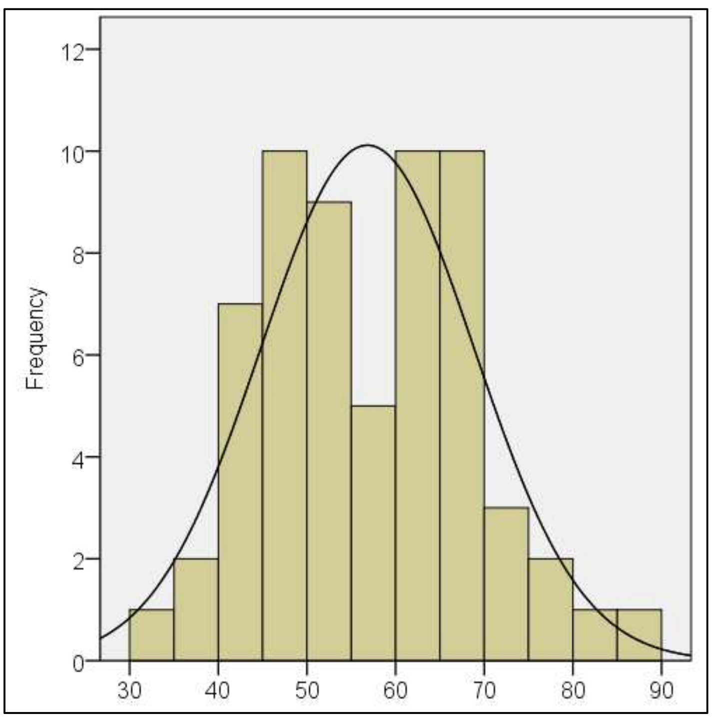


Figure 34. Grade 1 NCE mathematics procedures histogram for Group 2.

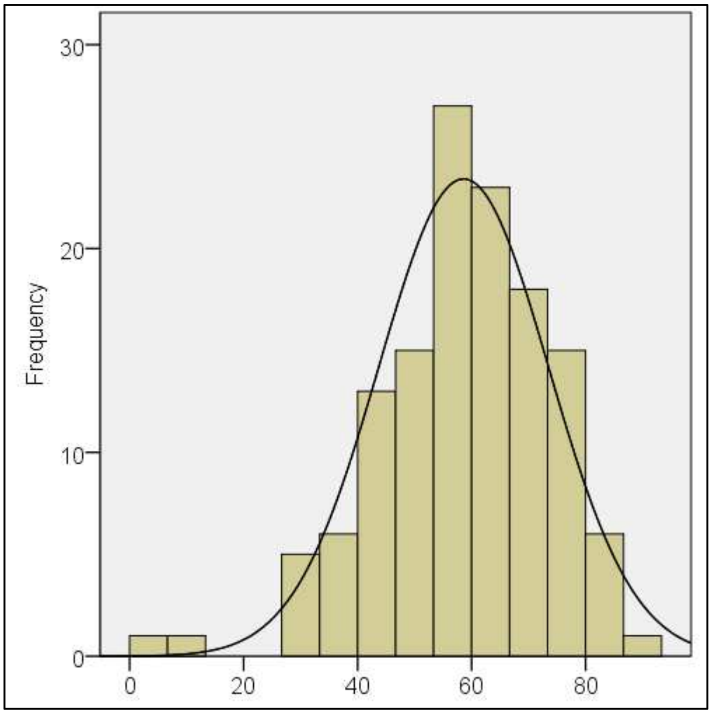


Figure 35. Grade 1 NCE core academic achievement histogram for Groups 0, 1, and 2.

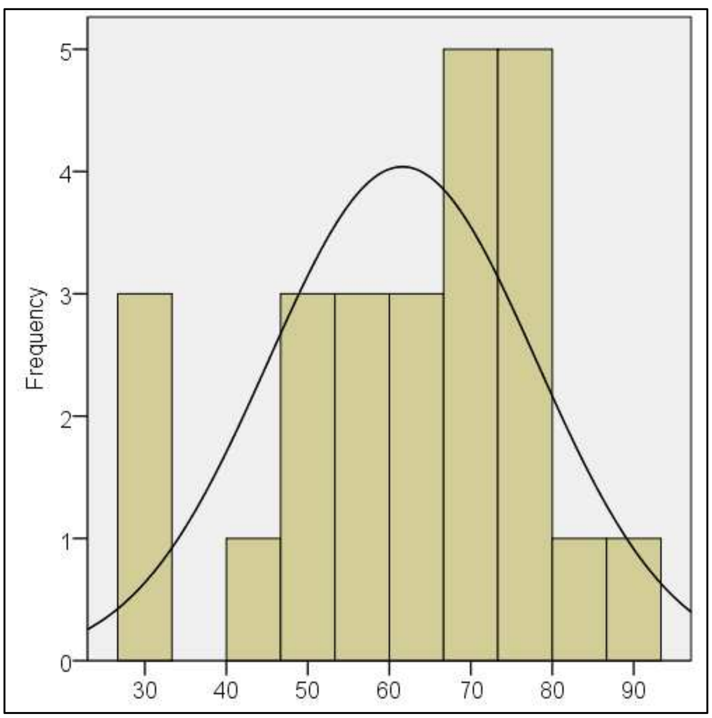


Figure 36. Grade 1 NCE core academic achievement histogram for Group 0.

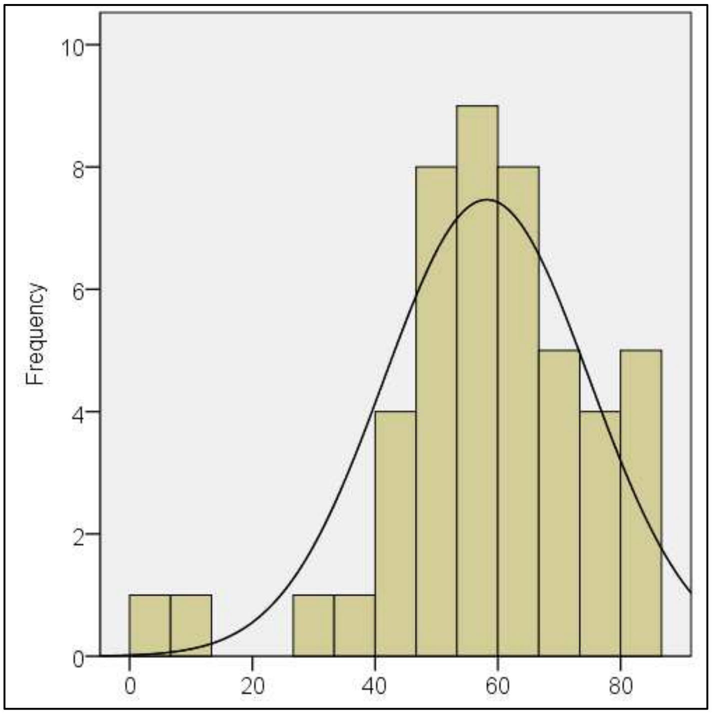


Figure 37. Grade 1 NCE core academic achievement histogram for Group 1.

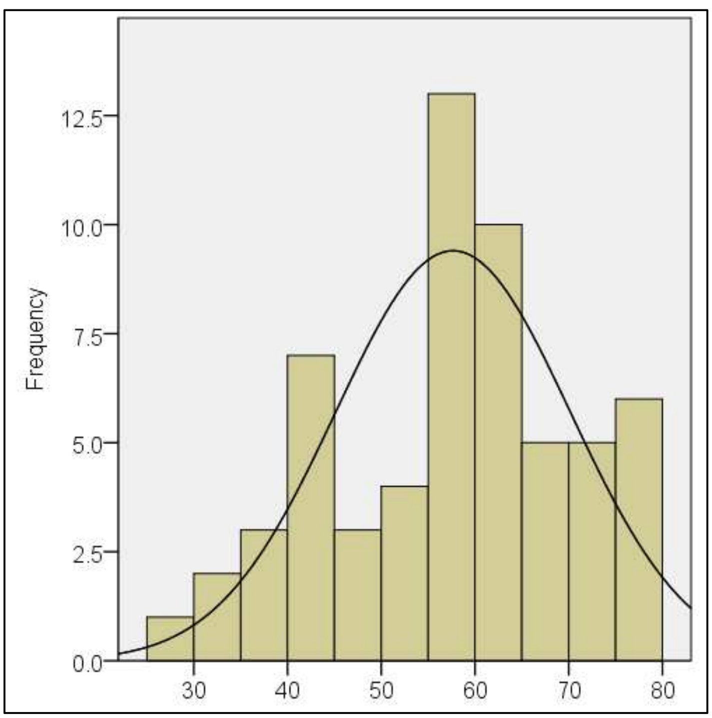


Figure 38. Grade 1 NCE core academic achievement histogram for Group 2.

Grade 2 Descriptives and Tests of Normality

Table 27

Grade 2 Group Sizes

Experience Groups	Female	Male	Total
0	15	18	33
1	13	17	30
2	13	19	32
0, 1, and 2	41	54	95

Table 28

Grade 2 Mathematics Achievement Descriptives

Variables	*N*	*M*	Median	*SD*
NCE Total	95	50.71	51.05	16.08
Group 0	33	48.71	50.00	18.61
Group 1	30	51.68	51.05	15.37
Group 2	32	50.75	51.30	15.25
NCE Problems	95	51.22	54.80	17.43
Group 0	33	49.05	48.40	21.04
Group 1	30	52.35	55.35	15.25
Group 2	32	51.43	58.70	16.17
NCE Procedures	95	52.16	51.10	16.00
Group 0	33	49.90	54.30	16.86
Group 1	30	55.81	52.55	16.66
Group 2	31	51.03	51.10	14.21
NCE Core	95	51.69	51.15	14.70
Group 0	33	48.49	44.90	17.38
Group 1	30	53.37	52.35	14.45
Group 2	32	52.91	52.45	11.59

Table 29

Grade 2 Mathematics Achievement Normality and Homogeneity

Variables	*SD*/ Range	Skewness/ Error	Kurtosis/ Error	Levene	Kolmogorov-Smirnov / Shapiro-Wilk
NCE Total	.210	0.084	0.643		.200
Group 0	.251	0.049	0.564	.406	.957
Group 1	.233	0.834	0.040	.406	.824
Group 2	.248	0.874	0.611	.406	.580
NCE Problems	.209	0.129	0.868		.005
Group 0	.252	0.822	0.372	.210	.557
Group 1	.260	0.131	1.164	.210	.426
Group 2	.273	0.957	1.158	.210	.049
NCE Procedures	.202	0.936	0.110		.001
Group 0	.233	0.511	0.286	.796	.812
Group 1	.236	0.665	0.140	.796	.425
Group 2	.244	2.192	0.998	.796	.040
NCE Core	.212	0.129	1.040		.200
Group 0	.266	0.782	1.033	.038	.245
Group 1	.219	0.047	0.058	.038	.962
Group 2	.288	0.213	1.104	.038	.303

Notes: Kolmogorov-Smirnov used when n > or = 50 and Shapiro-Wilk used when n < 50.

Grade 2 histograms. Histograms with superimposed normality curves were produced for each group within the dependent variables and the covariate. The distributions for stanine scores closely resembled normal distributions. Most distributions for total mathematics achievement, problem solving and mathematics procedures were normally distributed overall. Distributions for NCE Procedures for all groups and combinations are shown in Figures 39 through 54, with each distribution relatively normal overall.

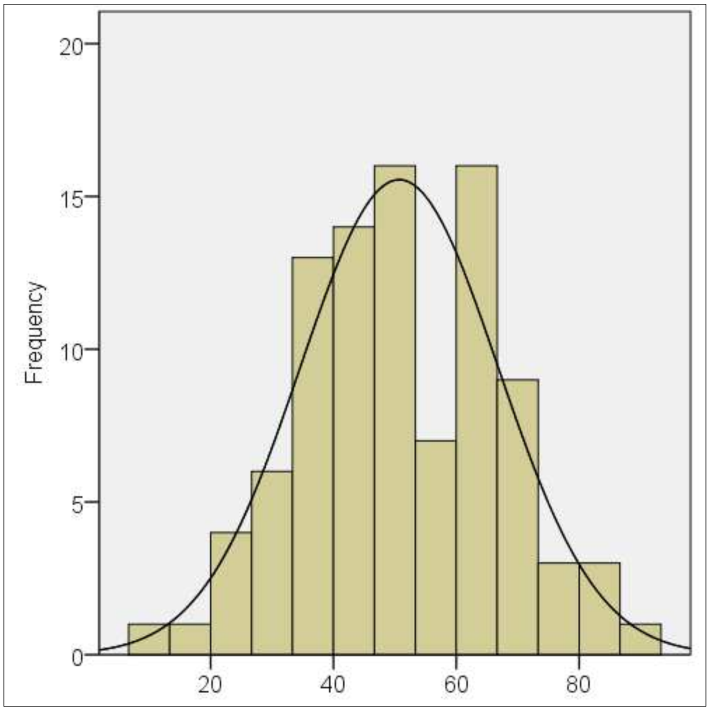


Figure 39. Grade 2 NCE total mathematics achievement histogram for Groups 0, 1, and 2.

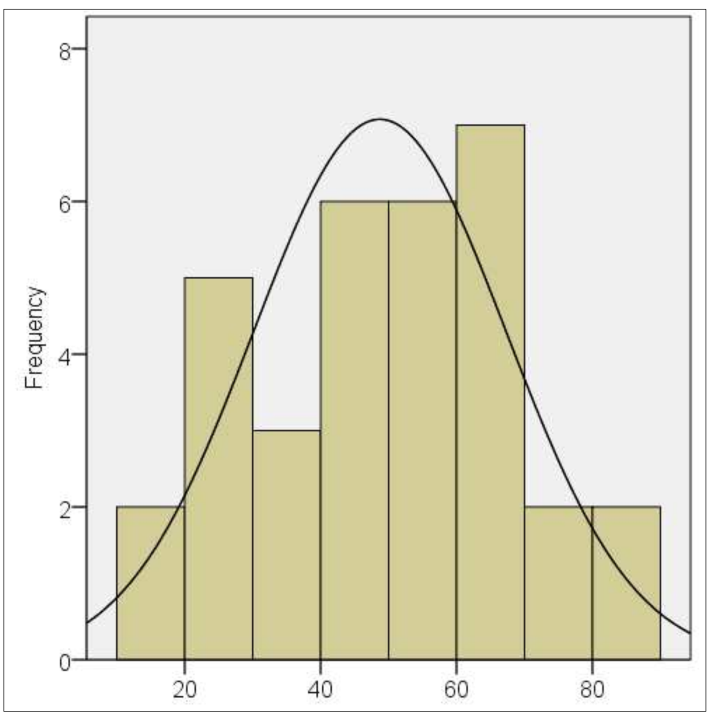


Figure 40. Grade 2 NCE total mathematics achievement histogram for Group 0.

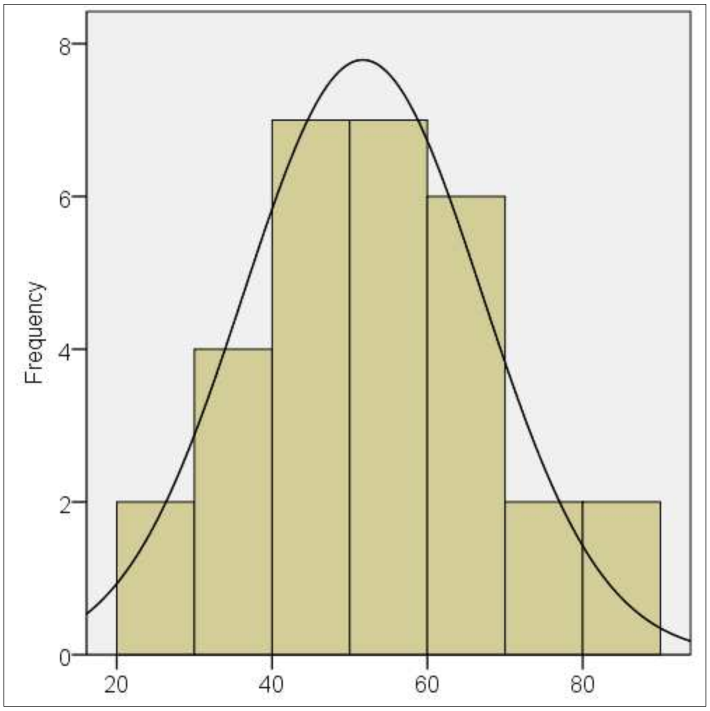


Figure 41. Grade 2 NCE total mathematics achievement histogram for Group 1.

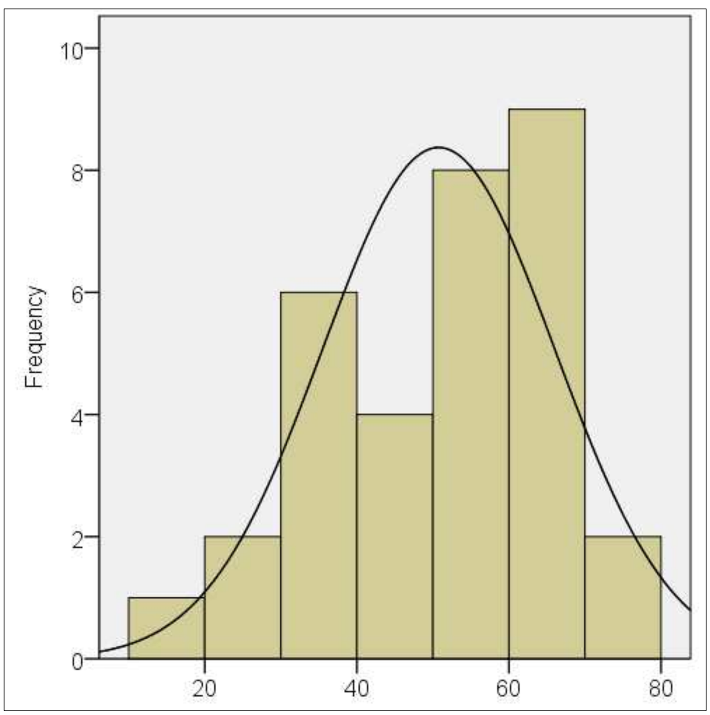


Figure 42. Grade 2 NCE total mathematics achievement histogram for Group 2.

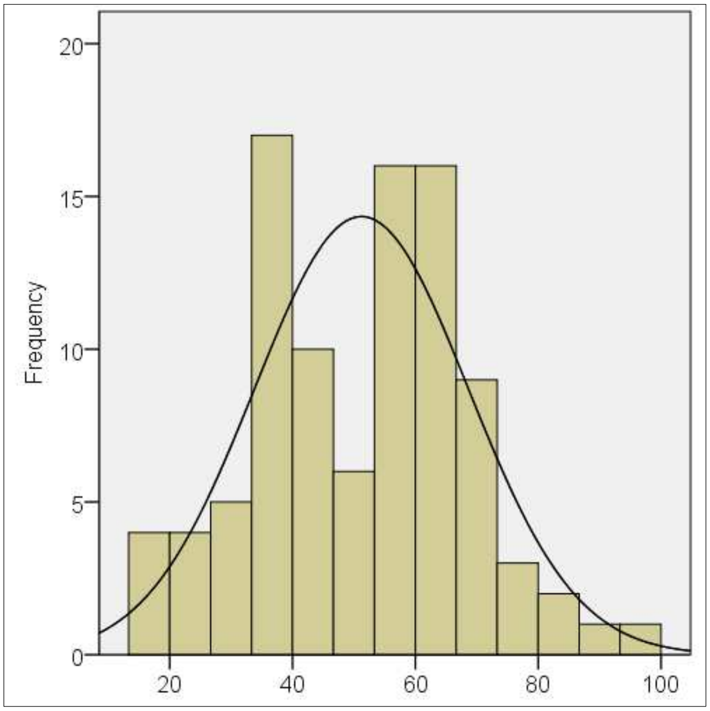


Figure 43. Grade 2 NCE problem solving histogram for Groups 0, 1, and 2.

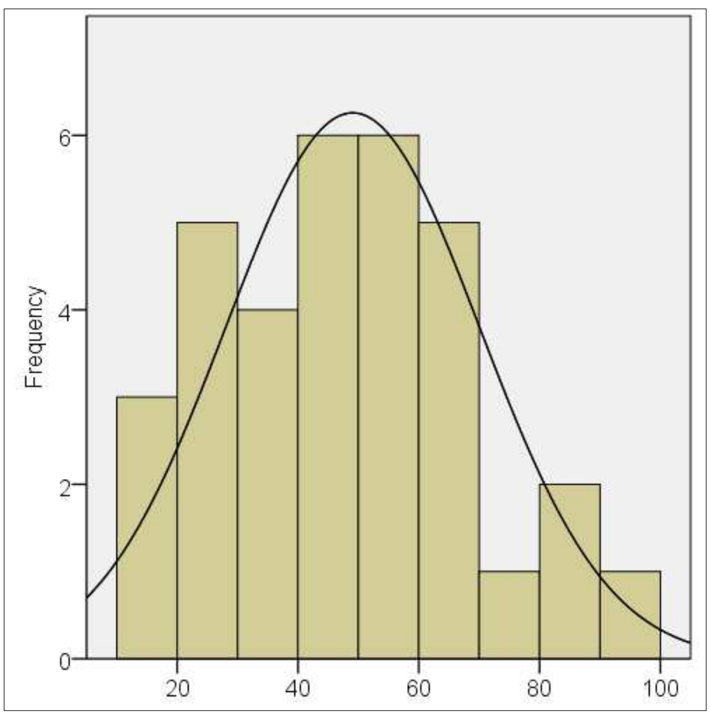


Figure 44. Grade 2 NCE problem solving histogram for Group 0.

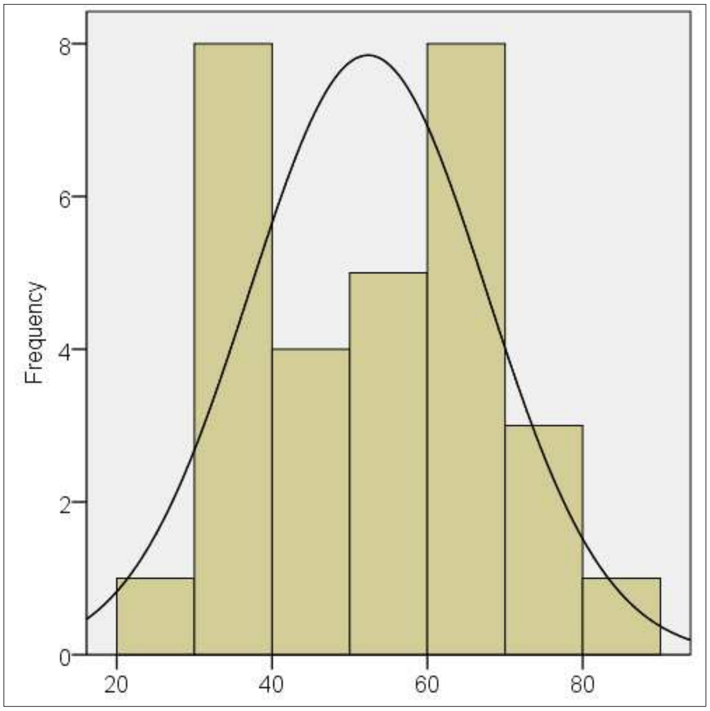


Figure 45. Grade 2 NCE problem solving histogram for Group 1.

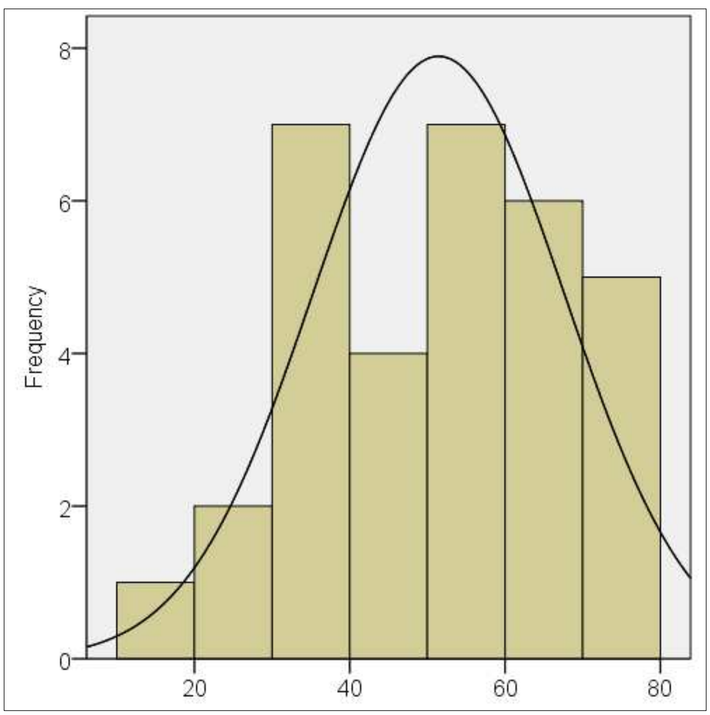


Figure 46. Grade 2 NCE problem solving histogram for Group 2.

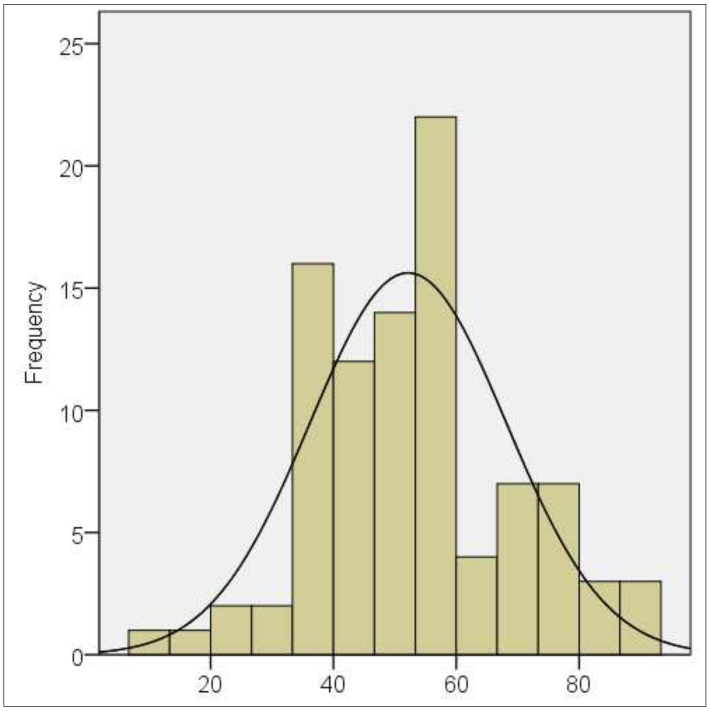


Figure 47. Grade 2 NCE mathematics procedures histogram for Groups 0, 1, and 2.

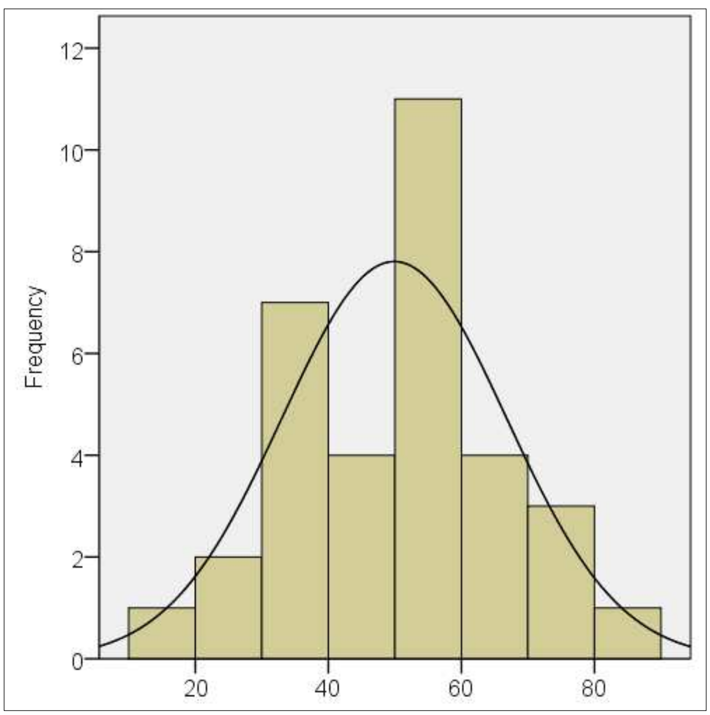


Figure 48. Grade 2 NCE mathematics procedures histogram for Group 0.

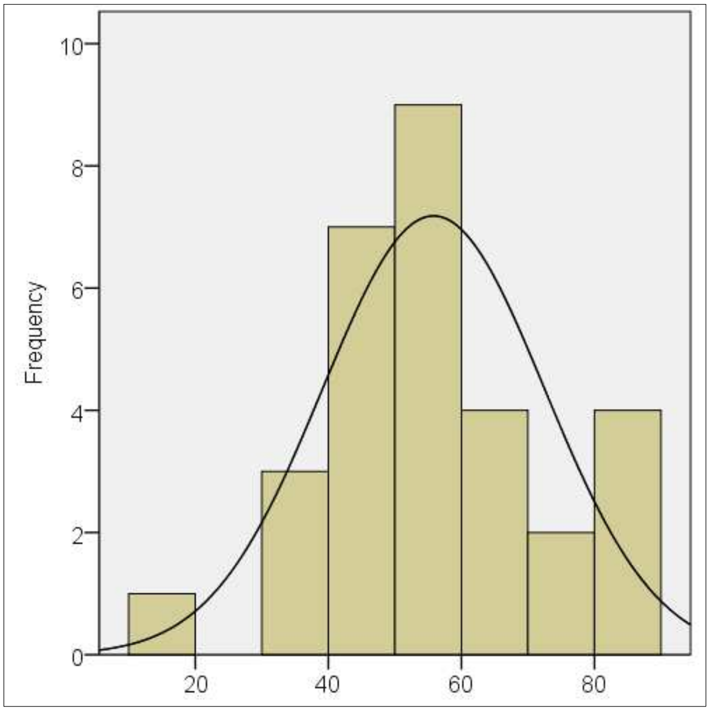


Figure 49. Grade 2 NCE mathematics procedures histogram for Group 1.

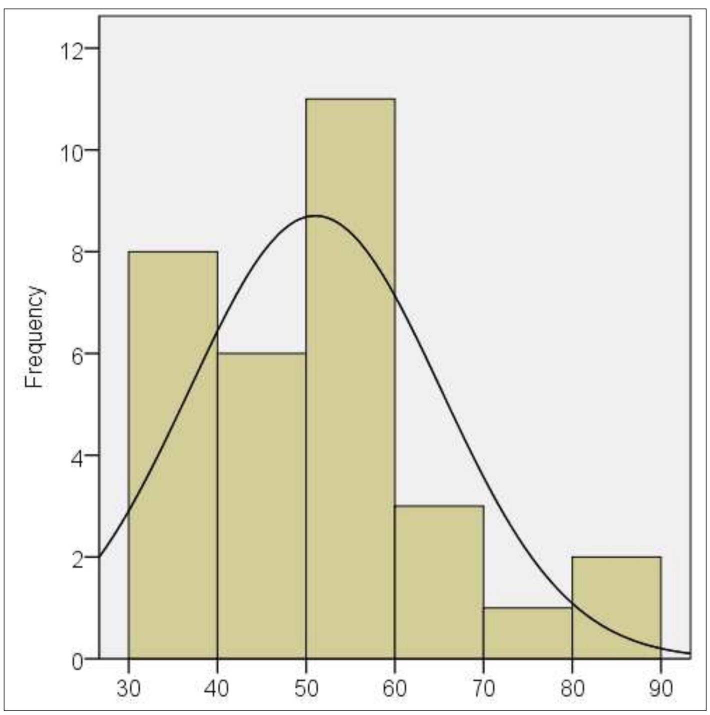


Figure 50. Grade 2 NCE mathematics procedures histogram for Group 2.

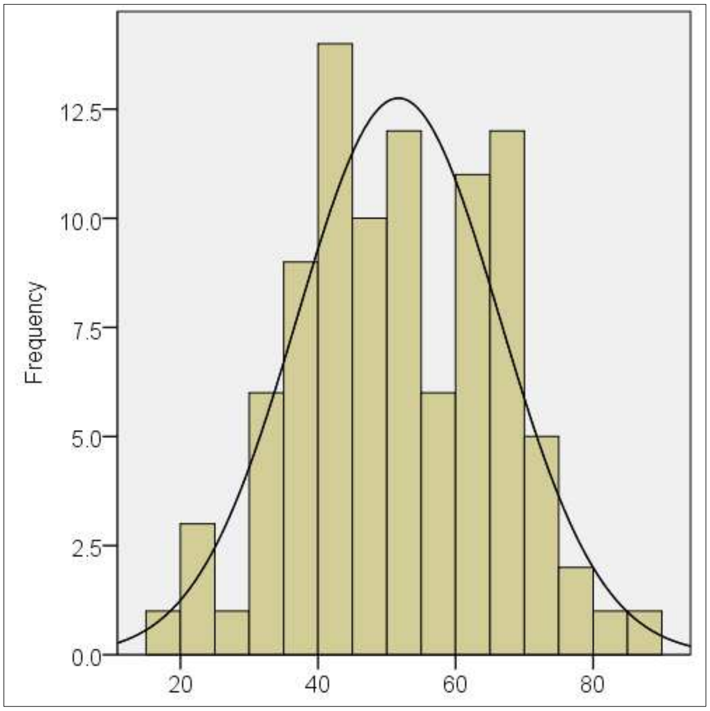


Figure 51. Grade 2 NCE core academic achievement histogram for Groups 0, 1, and 2.

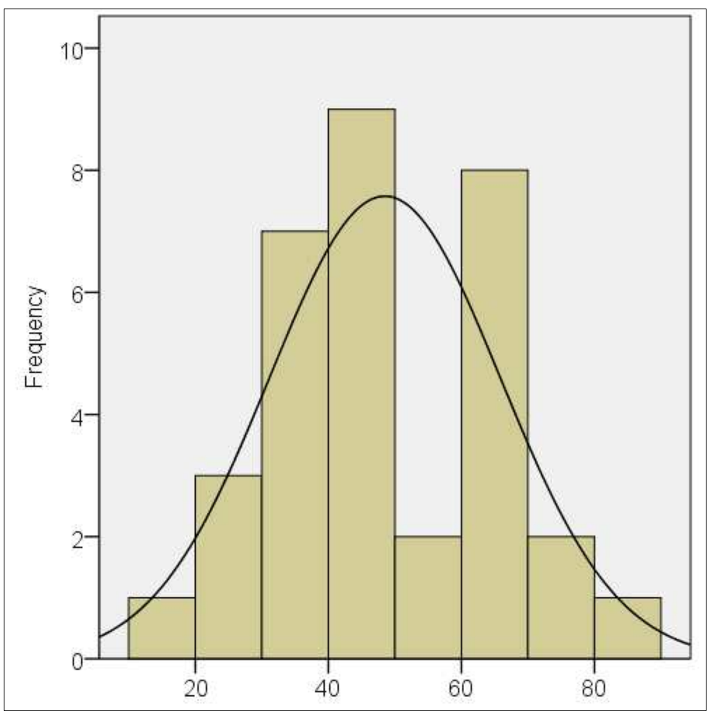


Figure 52. Grade 2 NCE core academic achievement histogram for Group 0.

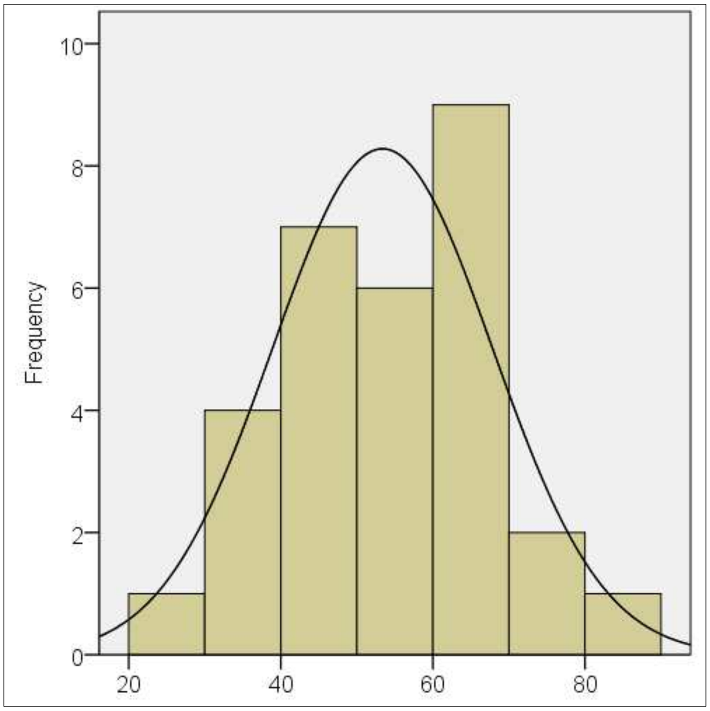


Figure 53. Grade 2 NCE core academic achievement histogram for Group 1.

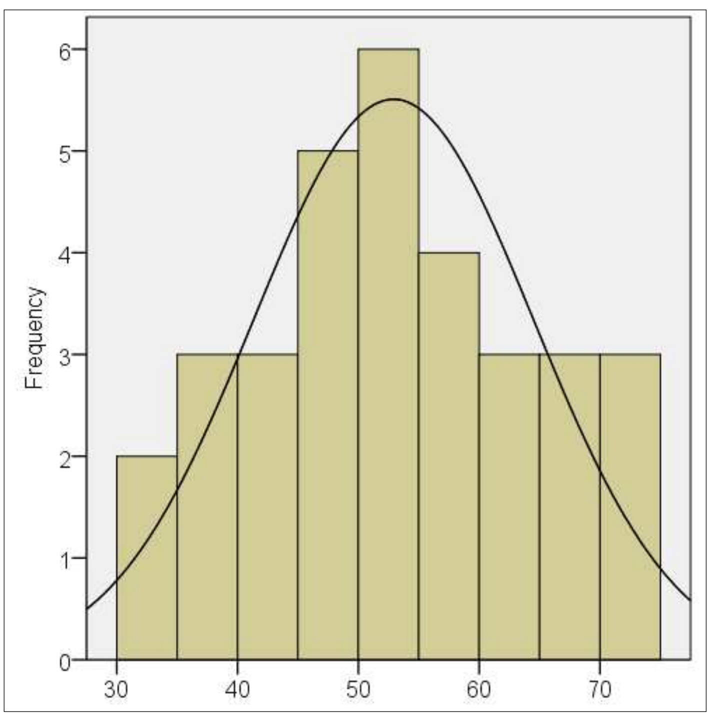


Figure 54. Grade 2 NCE core academic achievement histogram for Group 2.

Grade 3 Descriptives and Tests of Normality

Table 30

Grade 3 Group Sizes

Experience Groups	Female	Male	Total
0	13	13	26
1	3	9	12
2	6	16	22
0, 1, and 2	22	38	60

Table 31

Grade 3 Mathematics Achievement Descriptives

Variables	*N*	*M*	Median	*SD*
NCE Total	60	55.65	57.50	17.32
Group 0	26	52.20	50.80	18.21
Group 1	12	54.07	54.00	15.45
Group 2	22	60.60	59.30	16.78
NCE Problems	60	55.38	55.30	16.07
Group 0	26	54.05	53.75	17.97
Group 1	12	53.03	56.25	12.69
Group 2	22	58.24	60.50	15.57
NCE Procedures	60	55.38	55.30	16.07
Group 0	26	49.32	46.30	18.72
Group 1	12	54.26	51.60	19.45
Group 2	22	61.21	60.50	17.75
NCE Core	60	54.67	55.35	18.97
Group 0	26	50.18	51.95	15.75
Group 1	12	55.68	56.70	13.46
Group 2	22	57.66	58.35	13.89

Table 32

Grade 3 School A Mathematics Achievement Normality and Homogeneity

Variables	*SD*/ Range	Skewness/ Error	Kurtosis/ Error	Levene	Kolmogorov-Smirnov / Shapiro-Wilk
NCE Total	.212	0.003	0.306		.200
Group 0	.262	0.577	0.469	.814	.436
Group 1	.334	1.009	0.396	.814	.200
Group 2	.256	0.552	0.148	.814	.858
NCE Problems	.245	0.388	0.806		.200
Group 0	.274	0.129	0.328	.853	.335
Group 1	.349	0.630	0.986	.853	.273
Group 2	.289	0.346	1.080	.853	.314
NCE Procedures	.227	1.088	0.403		.026
Group 0	.278	0.261	0.594	.828	.290
Group 1	.303	1.776	0.726	.828	.054
Group 2	.275	0.955	0.554	.828	.382
NCE Core	.214	0.191	0.681		.200
Group 0	.242	0.004	0.180	.931	.970
Group 1	.414	0.141	1.667	.931	.024
Group 2	.268	0.344	0.613	.931	.784

Notes: 16 < SD/Range < .25, |Skewness/error| < 3, |Kurtosis/error| < 3, Levene p > .05, Shapiro-Wilk (n < 50) p > .05

Grade 3 histograms. Histograms with superimposed normality curves were produced for each group within the dependent variables and the covariate. The distributions for stanine scores closely resembled normal distributions. Most distributions for total mathematics achievement, problem solving and mathematics procedures were normally distributed overall. Distributions for NCE Procedures for all groups and combinations are shown in Figures 55 through 70, with each distribution relatively normal overall.

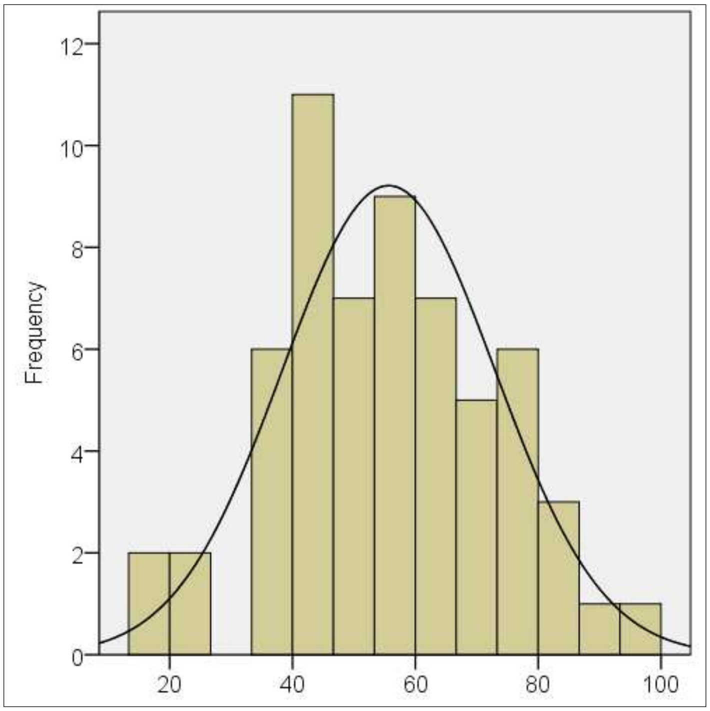


Figure 55. Grade 3 NCE total mathematics achievement histogram for Groups 0, 1, and 2.

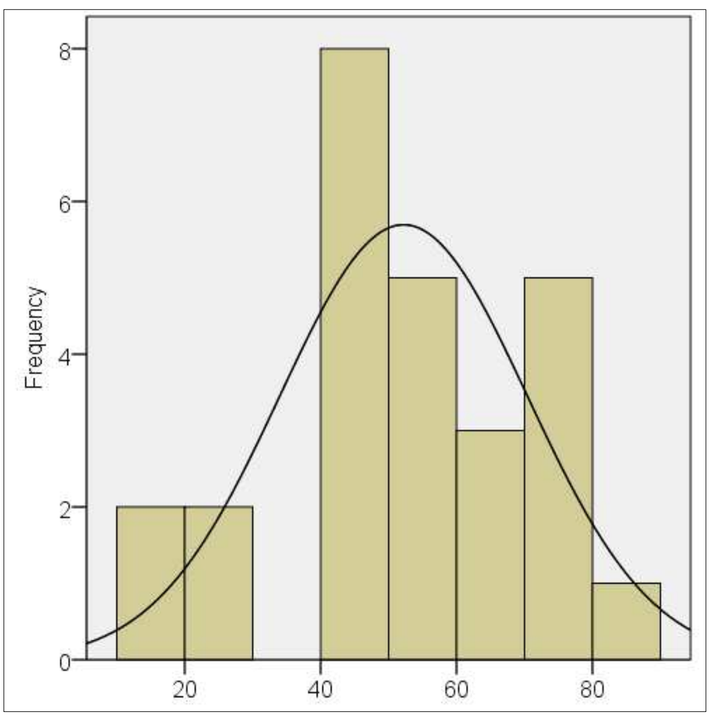


Figure 56. Grade 3 NCE total mathematics achievement histogram for Group 0.

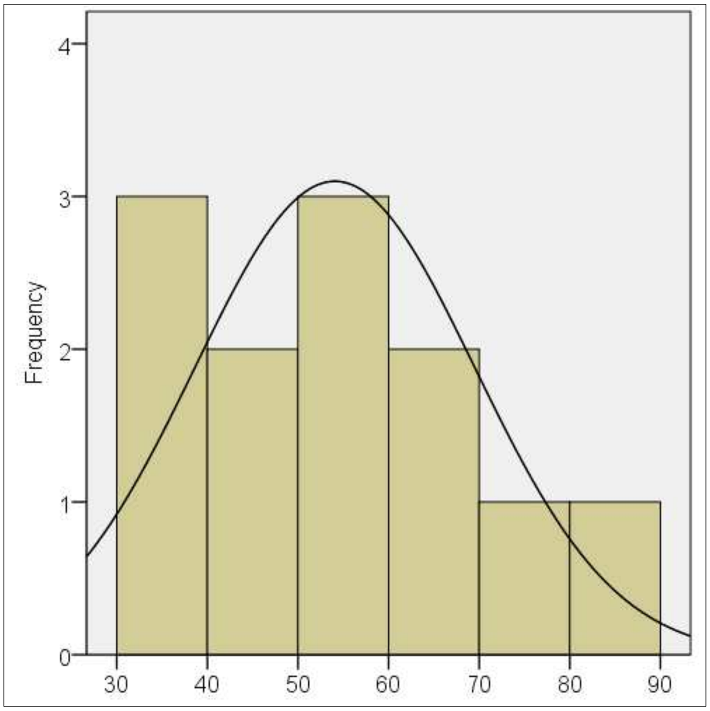


Figure 57. Grade 3 NCE total mathematics achievement histogram for Group 1.

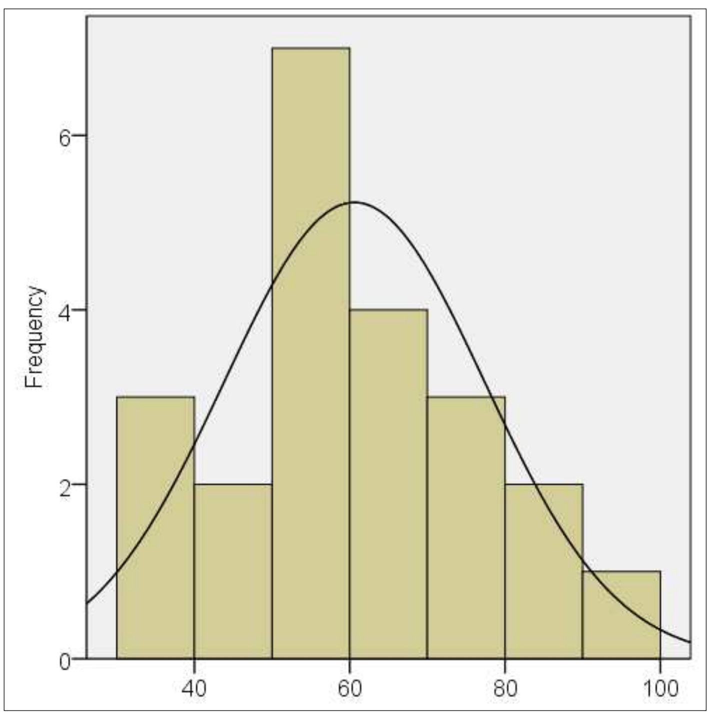


Figure 58. Grade 3 NCE total mathematics achievement histogram for Group 2.

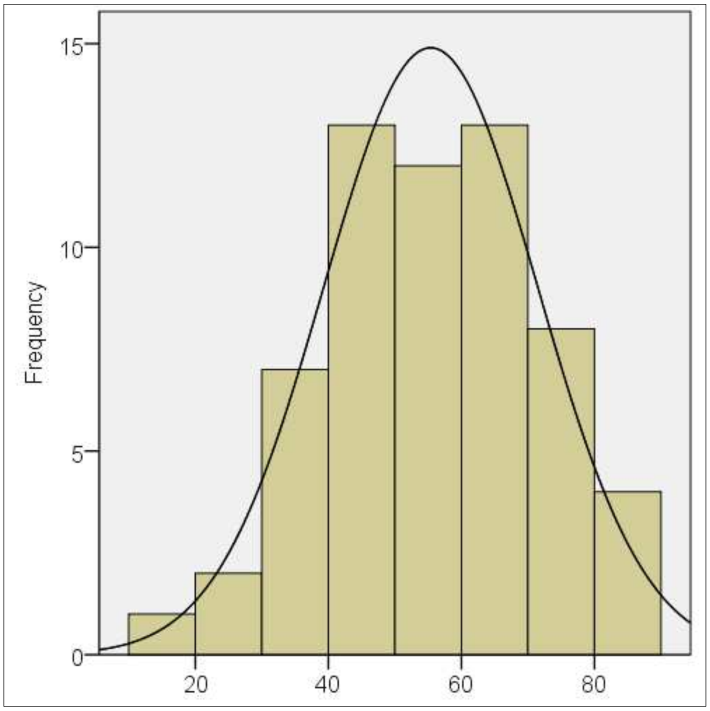


Figure 59. Grade 3 NCE problem solving histogram for Groups 0, 1, and 2.

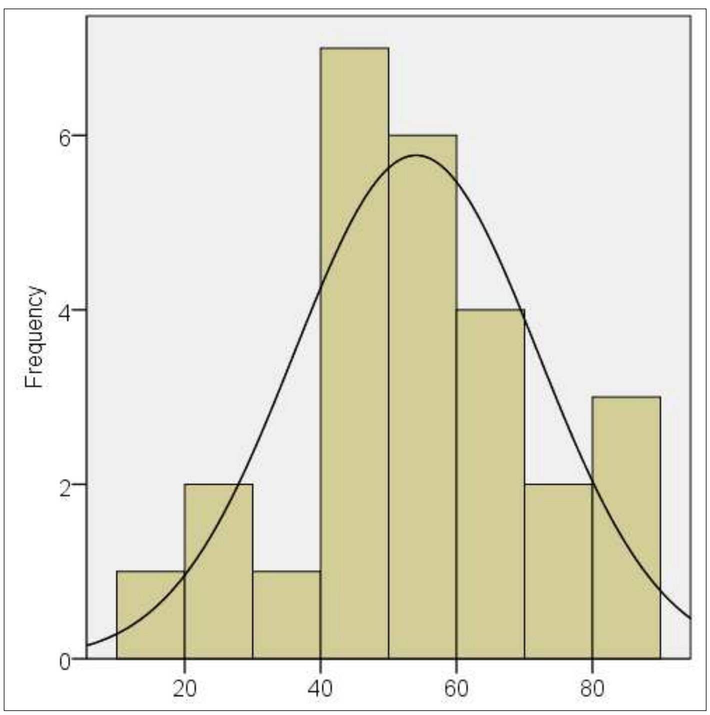


Figure 60. Grade 3 NCE problem solving histogram for Group 0.

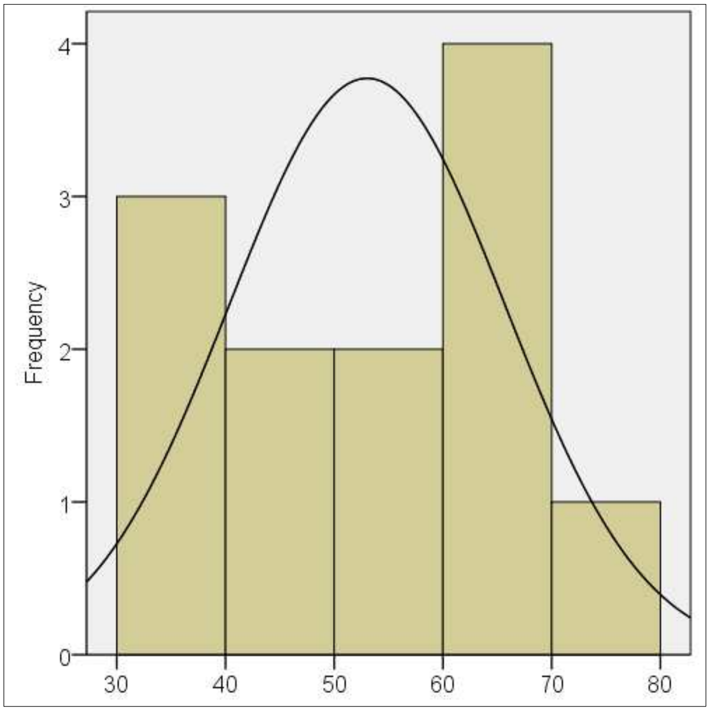


Figure 61. Grade 3 NCE problem solving histogram for Group 1.

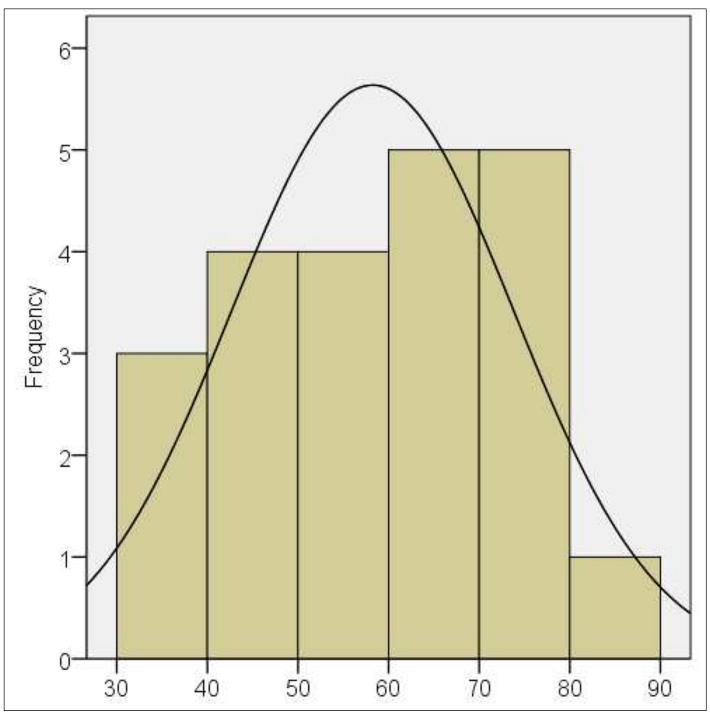


Figure 62. Grade 3 NCE problem solving histogram for Group 2.

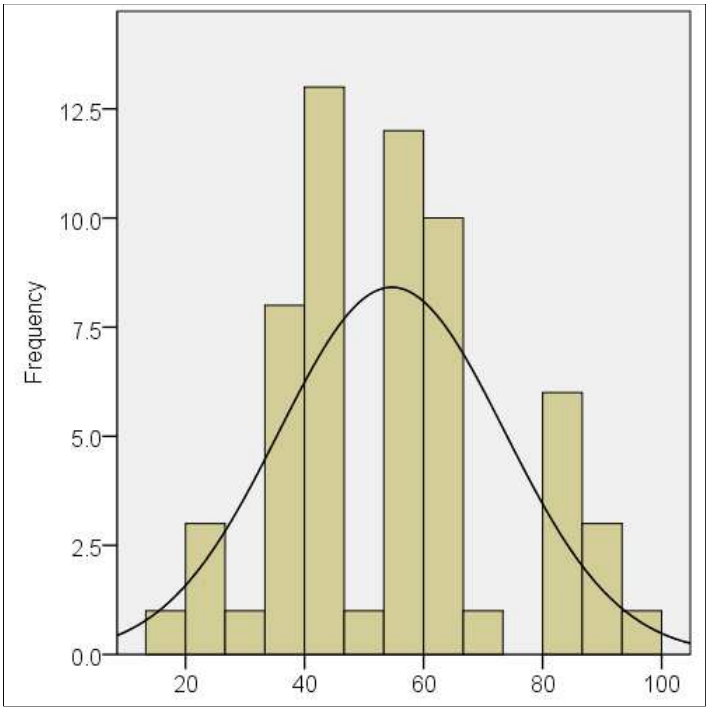


Figure 63. Grade 3 NCE mathematics procedures histogram for Groups 0, 1, and 2.

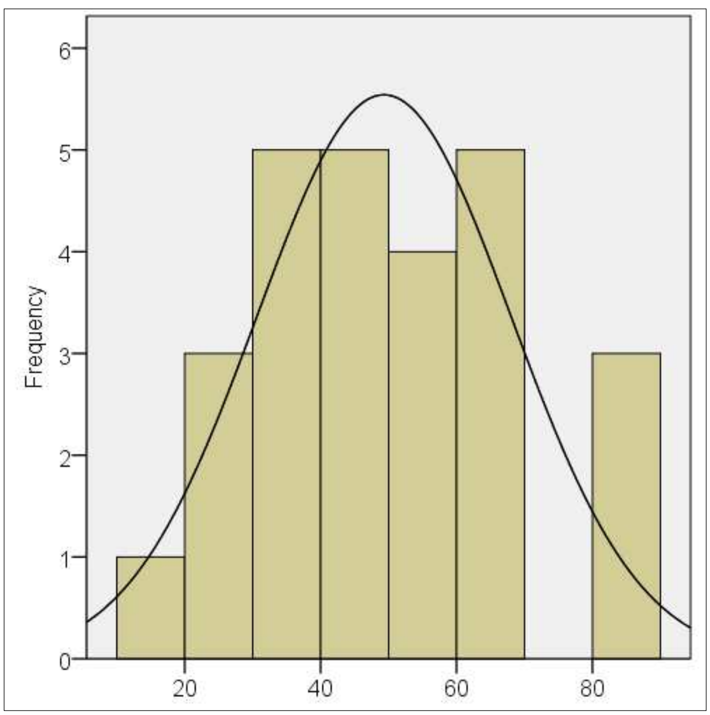


Figure 64. Grade 3 NCE mathematics procedures histogram for Group 0.

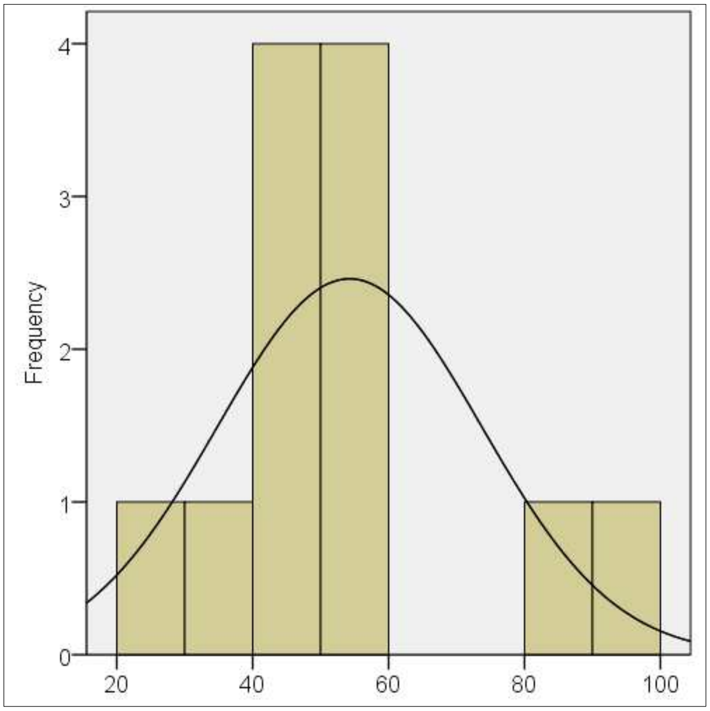


Figure 65. Grade 3 NCE mathematics procedures histogram for Group 1.

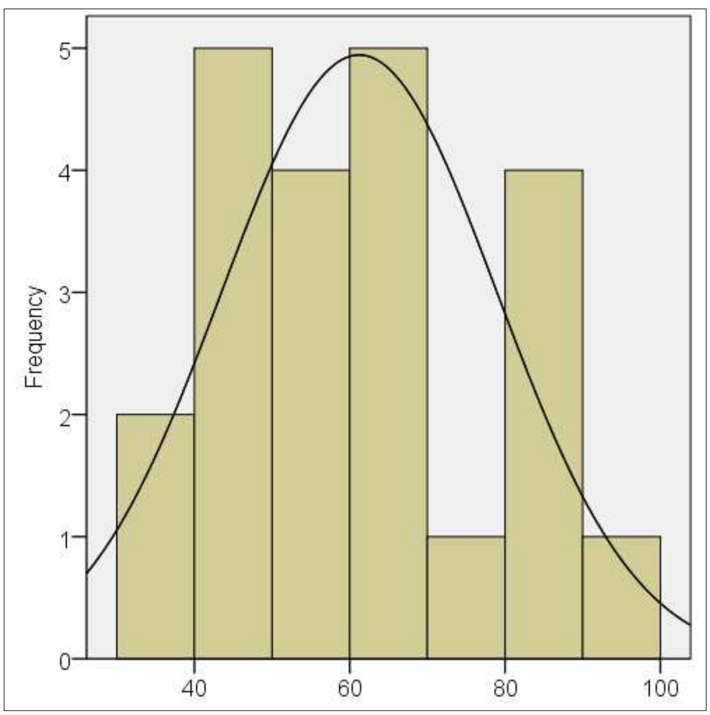


Figure 66. Grade 3 NCE mathematics procedures histogram for Group 2.

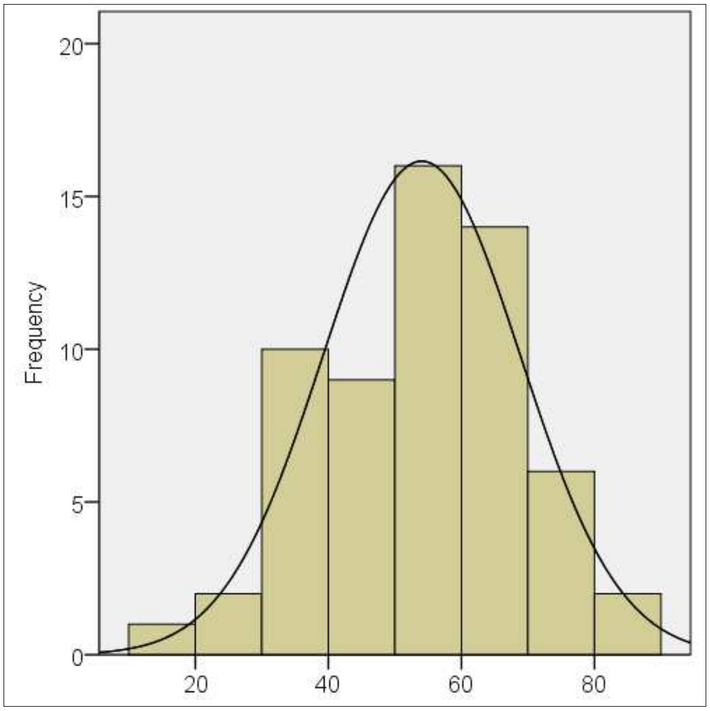


Figure 67. Grade 3 NCE core academic achievement histogram for Groups 0, 1, and 2.

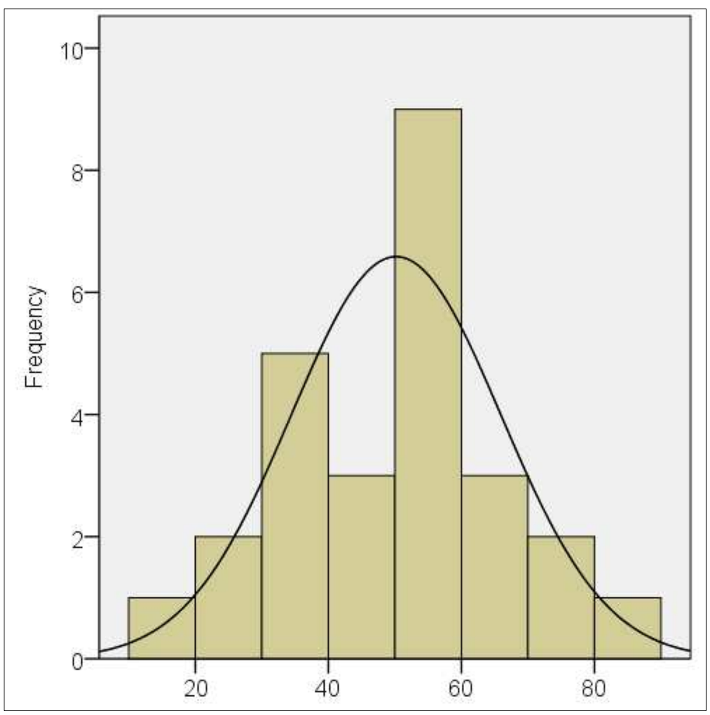


Figure 68. Grade 3 NCE core academic achievement histogram for Group 0.

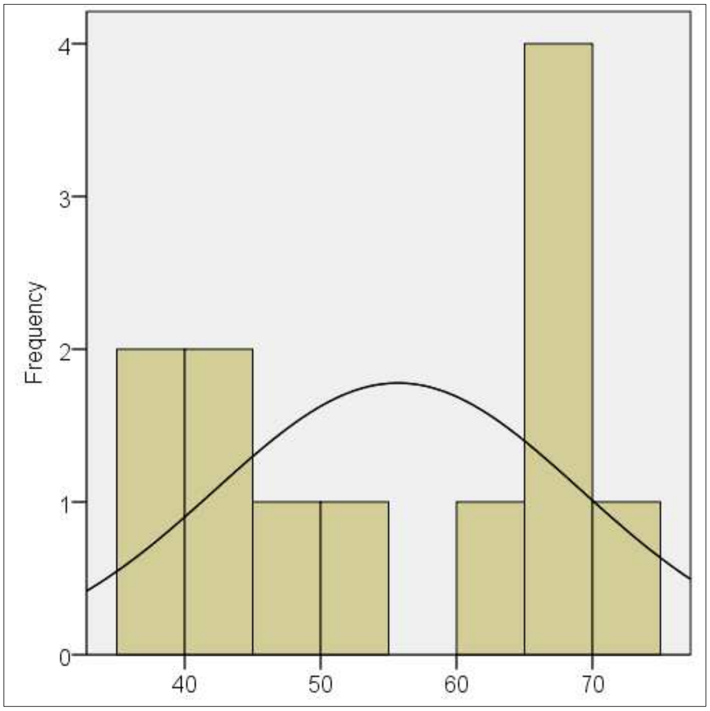


Figure 69. Grade 3 NCE core academic achievement histogram for Group 1.

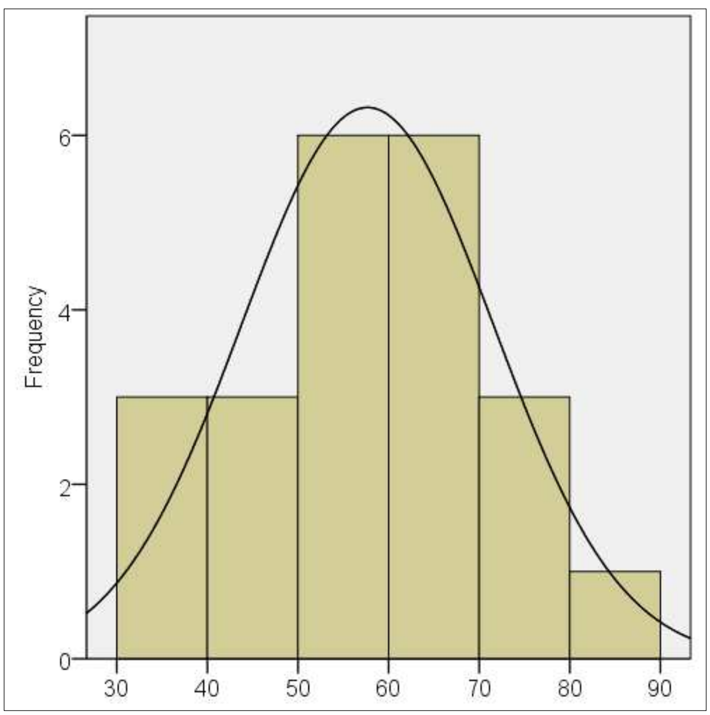


Figure 70. Grade 3 NCE core academic achievement histogram for Group 2.

Grade 3 Outliers Removed Descriptives and Tests of Normality

Table 33

Grade 3 Outliers Removed Group Sizes

Experience Groups	Female	Male	Total
0	13	13	26
1	3	9	12
2	6	16	22
0, 1, and 2	22	38	60

Table 34

Grade 3 Outliers Removed Mathematics Achievement Descriptives

Variables	*N*	*M*	Median	*SD*
NCE Total	60	55.65	57.50	17.32
Group 0	26	52.20	50.80	18.21
Group 1	12	54.07	54.00	15.45
Group 2	22	60.60	59.30	16.78
NCE Problems	60	55.38	55.30	16.07
Group 0	25	55.46	54.30	16.82
Group 1	12	53.03	56.25	12.69
Group 2	22	58.24	60.50	15.57
NCE Procedures	58	53.40	54.30	17.98
Group 0	26	49.32	46.30	18.72
Group 1	10	46.82	47.60	9.64
Group 2	22	61.21	60.50	17.75
NCE Core	60	54.03	53.10	14.82
Group 0	26	50.18	51.95	15.75
Group 1	12	55.69	56.70	13.46
Group 2	22	57.66	58.35	13.89

Table 35

Grade 3 Outliers Removed School A Mathematics Achievement Normality and Homogeneity

Variables	*SD*/ Range	Skewness/ Error	Kurtosis/ Error	Levene	Kolmogorov-Smirnov / Shapiro-Wilk
NCE Total	.212	0.003	0.306		.200
Group 0	.262	0.577	0.469	.814	.436
Group 1	.334	1.009	0.396	.814	.200
Group 2	.257	0.552	0.148	.814	.858
NCE Problems	.245	0.388	0.806		.200
Group 0	.278	0.140	0.284	.653	.335
Group 1	.349	0.630	0.986	.653	.273
Group 2	.289	0.346	1.080	.653	.314
NCE Procedures	.215	1.003	0.073		.053
Group 0	.278	0.261	0.594	.104	.290
Group 1	.353	1.029	0.379	.104	.198
Group 2	.275	0.955	0.554	.104	.382
NCE Core	.214	0.191	0.681		.200
Group 0	.242	0.004	0.180	.931	.970
Group 1	.414	0.141	1.667	.931	.024
Group 2	.268	0.344	0.613	.931	.784

Notes: 16 < SD/Range < .25, |Skewness/error| < 3, |Kurtosis/error| < 3, Levene p > .05, Shapiro-Wilk (n < 50) p > .05

Grade 3 outliers removed histograms. Histograms with superimposed normality curves were produced for each group within the dependent variables and the covariate. The distributions for stanine scores closely resembled normal distributions. Most distributions for total mathematics achievement, problem solving and mathematics procedures were normally distributed overall. Distributions for NCE Procedures for all groups and combinations are shown in Figures 71 through 86, with each distribution relatively normal overall.

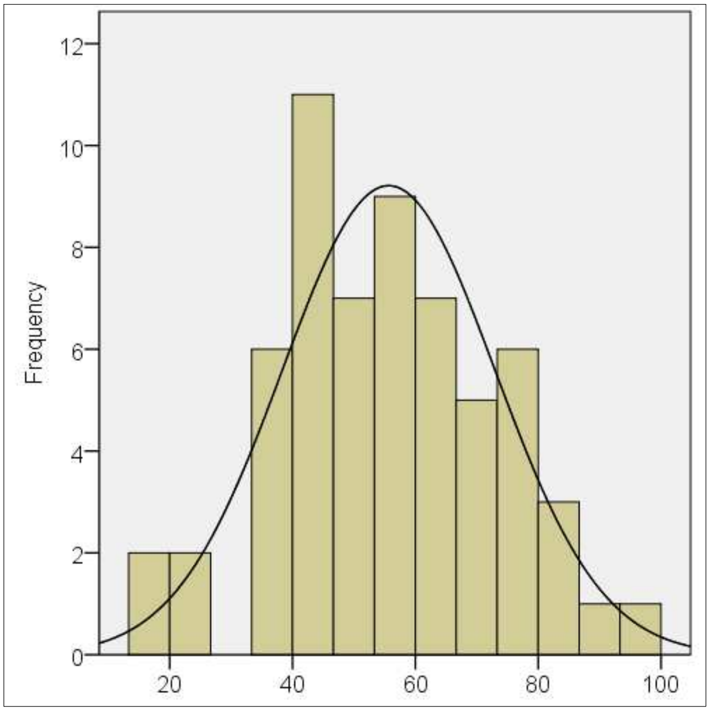


Figure 71. Grade 3 outliers removed NCE total mathematics achievement histogram for Groups 0, 1, and 2.

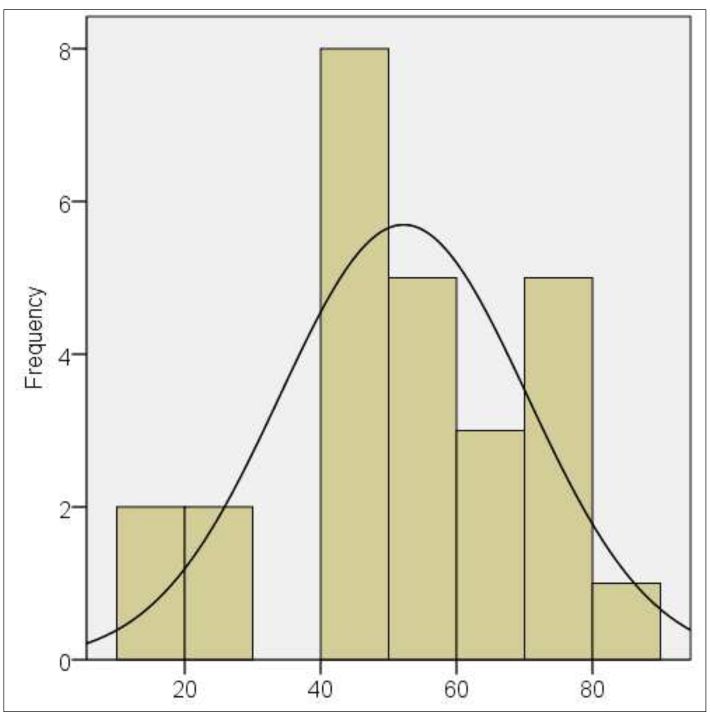


Figure 72. Grade 3 outliers removed NCE total mathematics achievement histogram for Group 0.

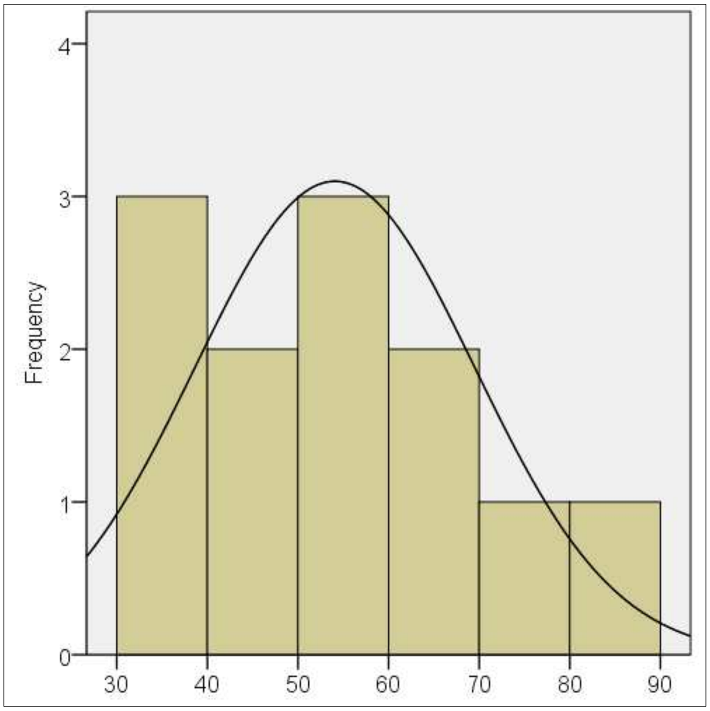


Figure 73. Grade 3 outliers removed NCE total mathematics achievement histogram for Group 1.

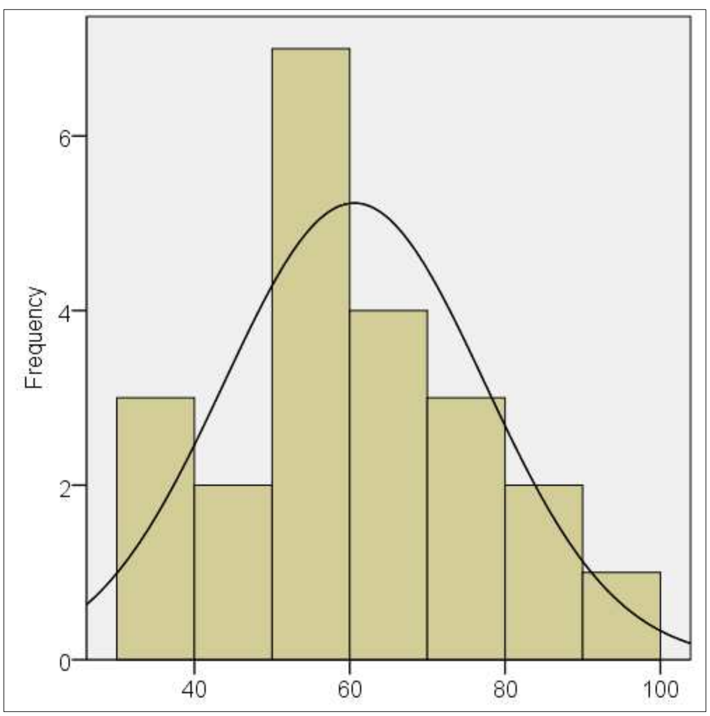


Figure 74. Grade 3 outliers removed NCE total mathematics achievement histogram for Group 2.

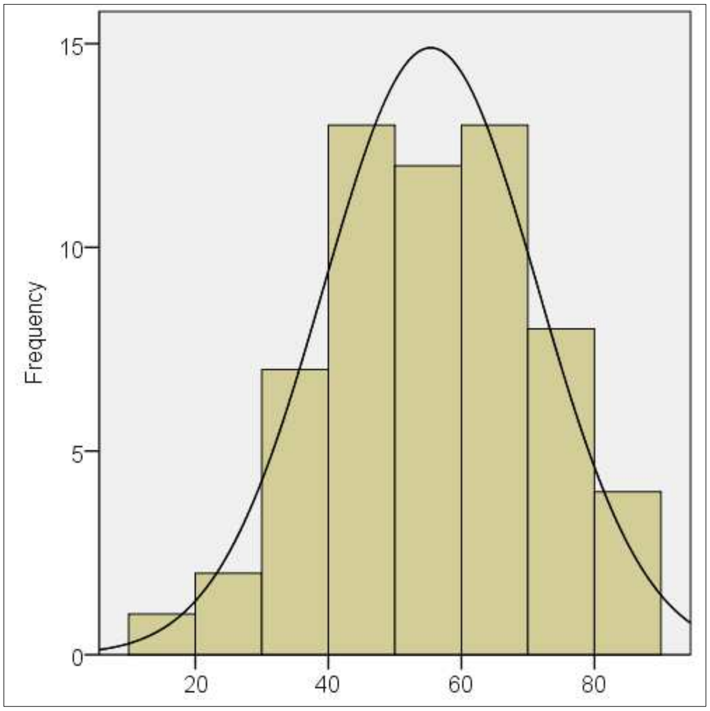


Figure 75. Grade 3 outliers removed NCE problem solving histogram for Groups 0, 1, and 2.

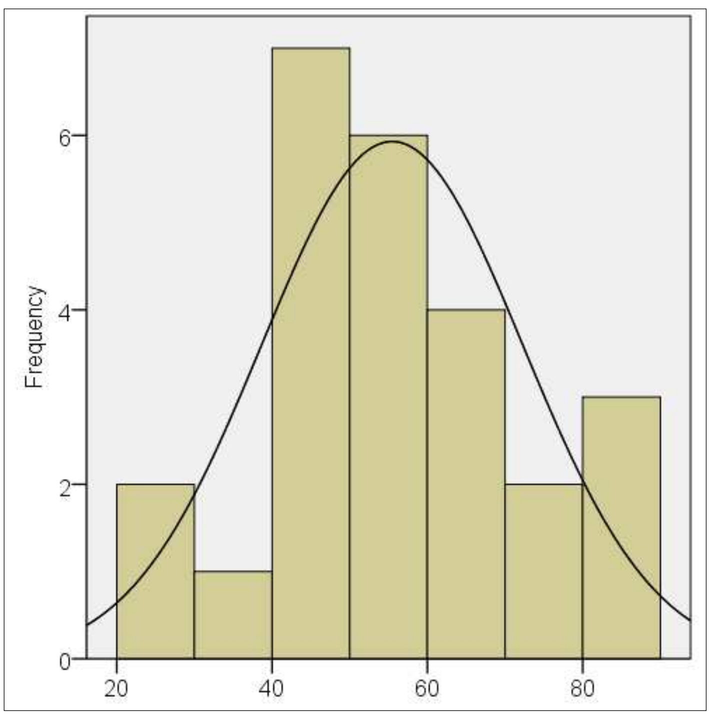


Figure 76. Grade 3 outliers removed NCE problem solving histogram for Group 0.

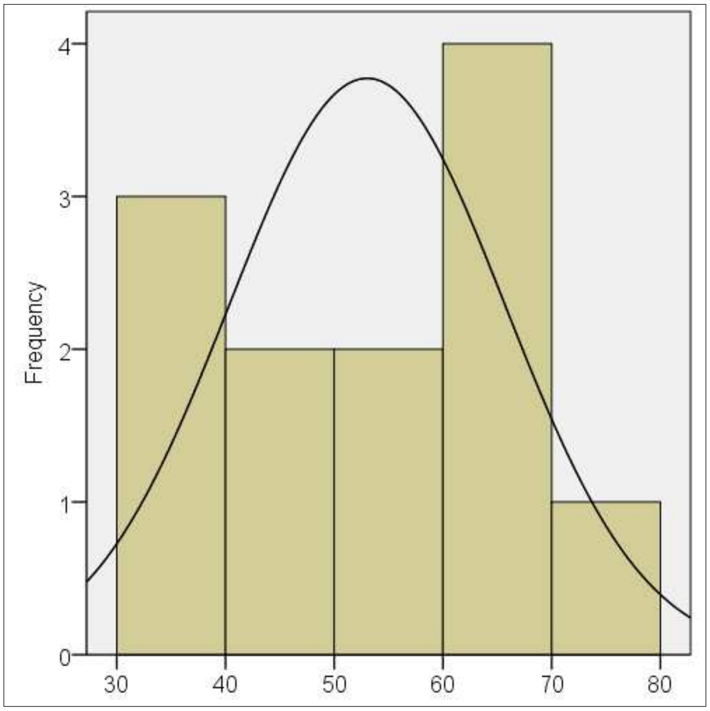


Figure 77. Grade 3 outliers removed NCE problem solving histogram for Group 1.

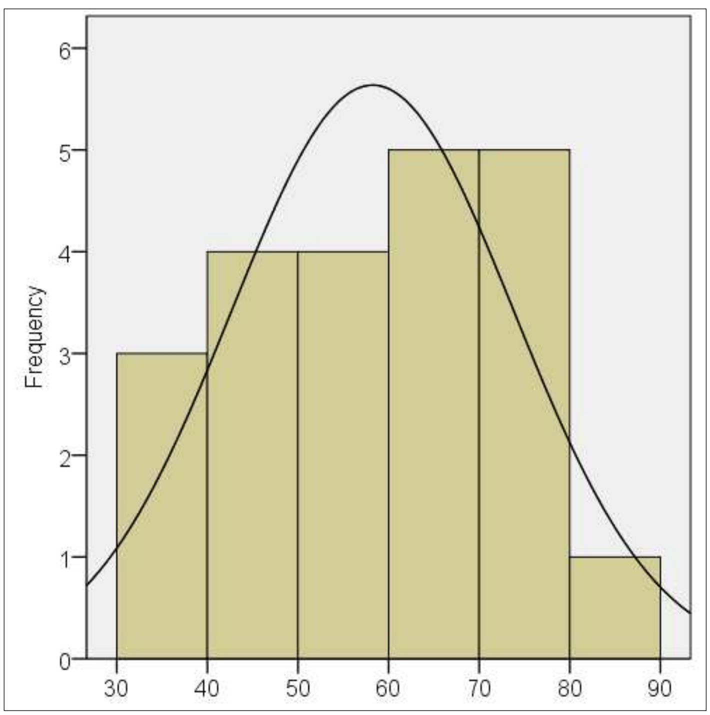


Figure 78. Grade 3 outliers removed NCE problem solving histogram for Group 2.

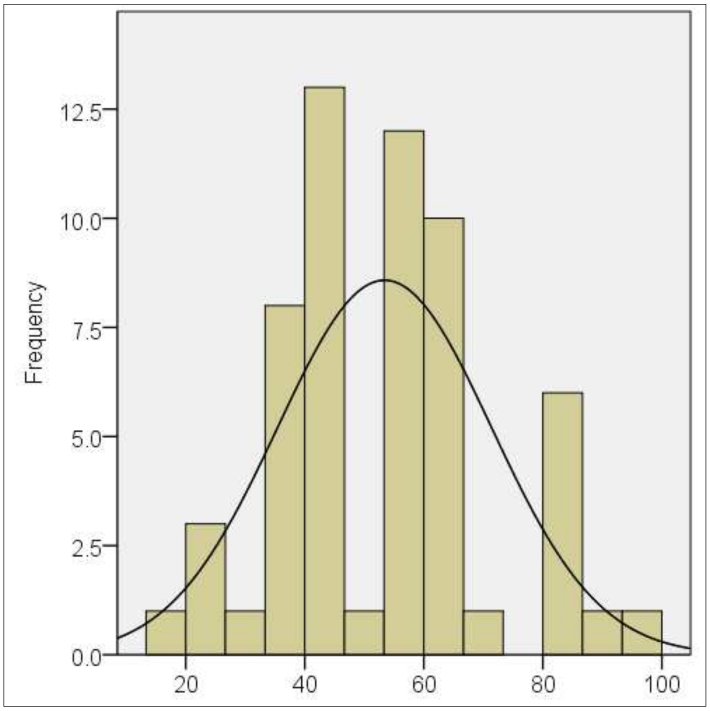


Figure 79. Grade 3 outliers removed NCE mathematics procedures histogram for Groups 0, 1, and 2.

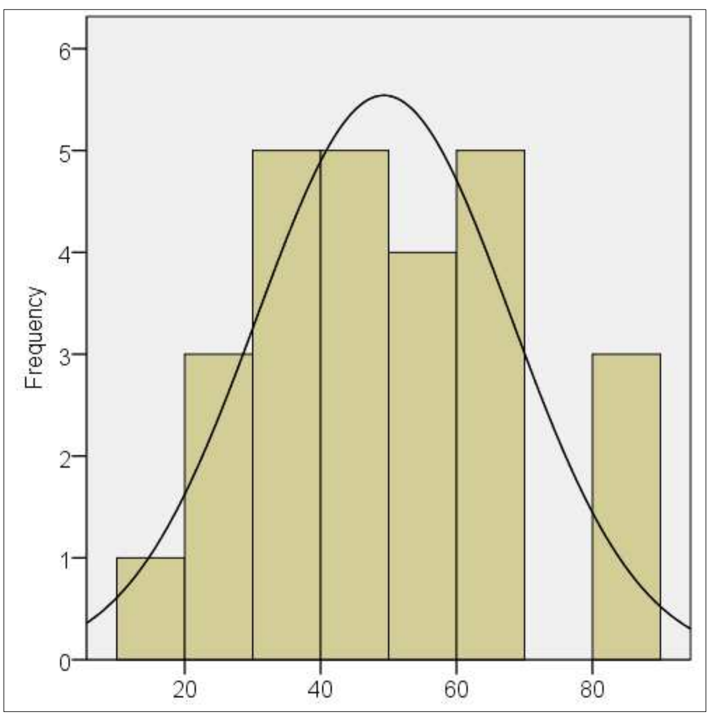


Figure 80. Grade 3 outliers removed NCE mathematics procedures histogram for Group 0.

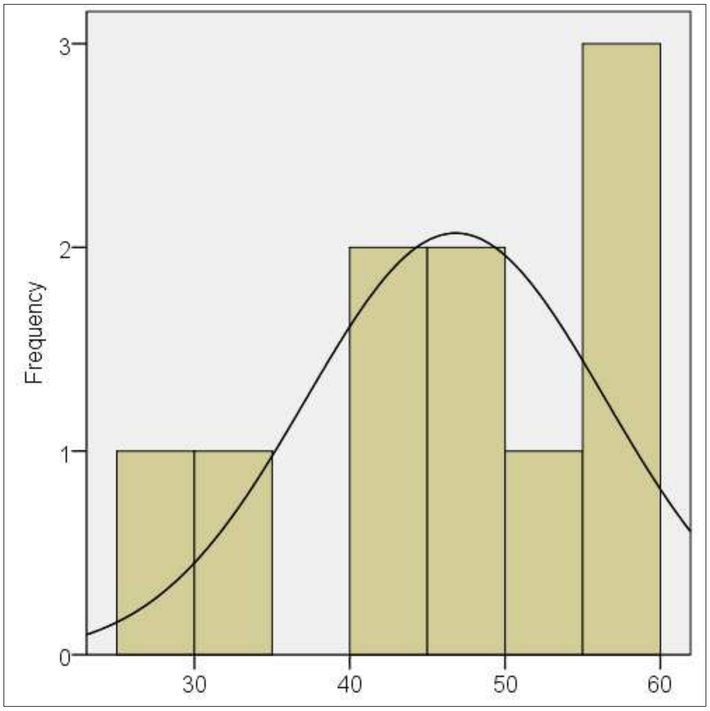


Figure 81. Grade 3 outliers removed NCE mathematics procedures histogram for Group 1.

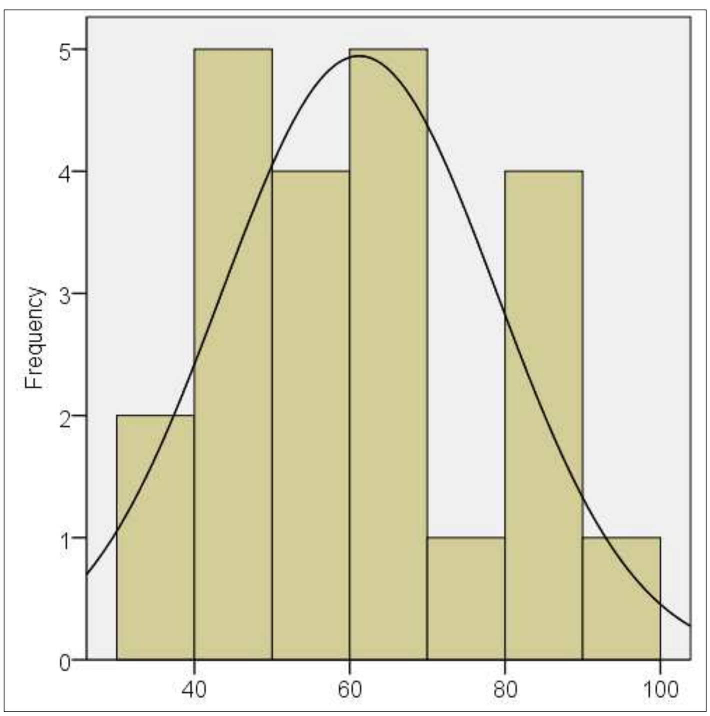


Figure 82. Grade 3 outliers removed NCE mathematics procedures histogram for Group 2.

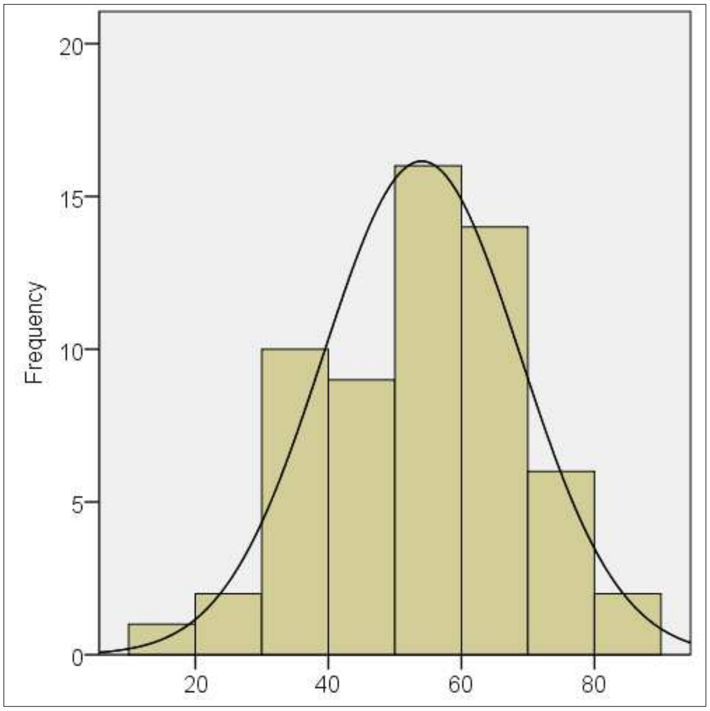


Figure 83. Grade 3 outliers removed NCE core academic achievement histogram for Groups 0, 1, and 2.

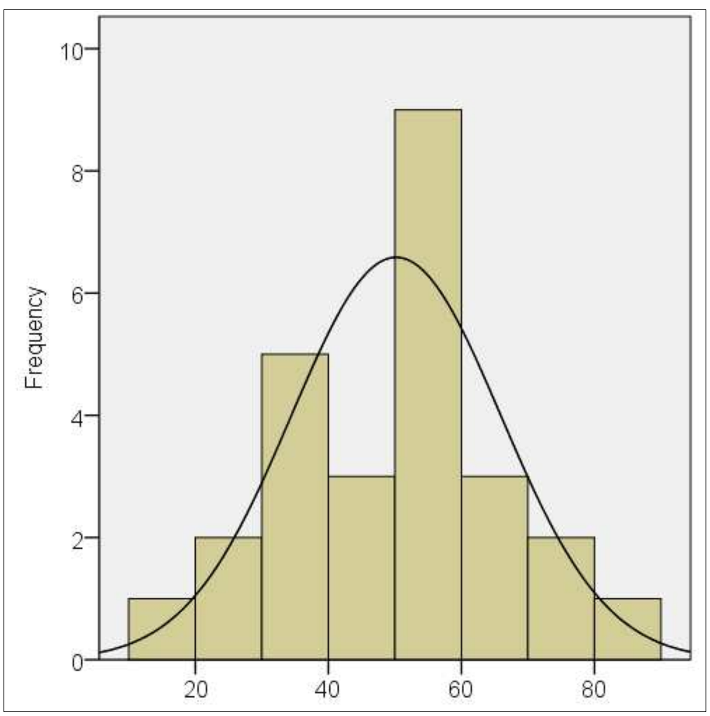


Figure 84. Grade 3 outliers removed NCE core academic achievement histogram for Group 0.

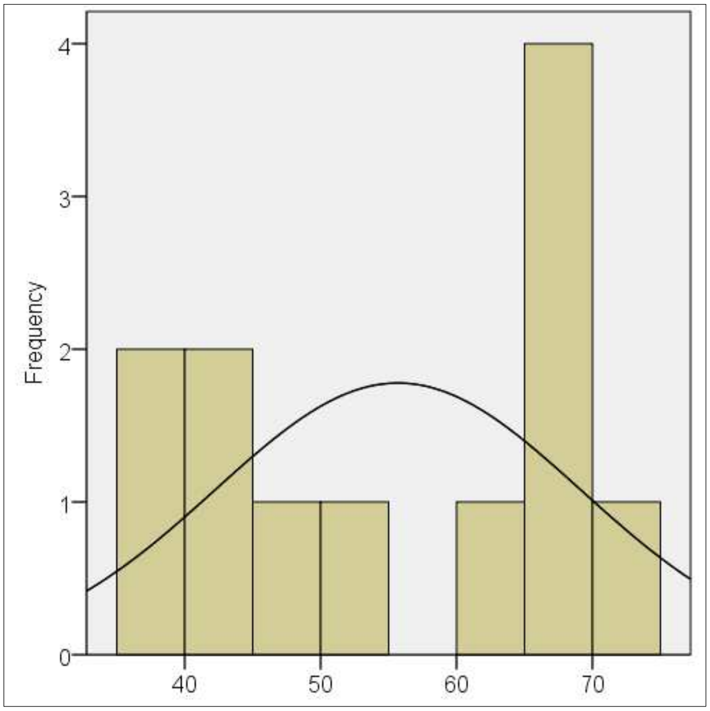


Figure 85. Grade 3 outliers removed NCE core academic achievement histogram for Group 1.

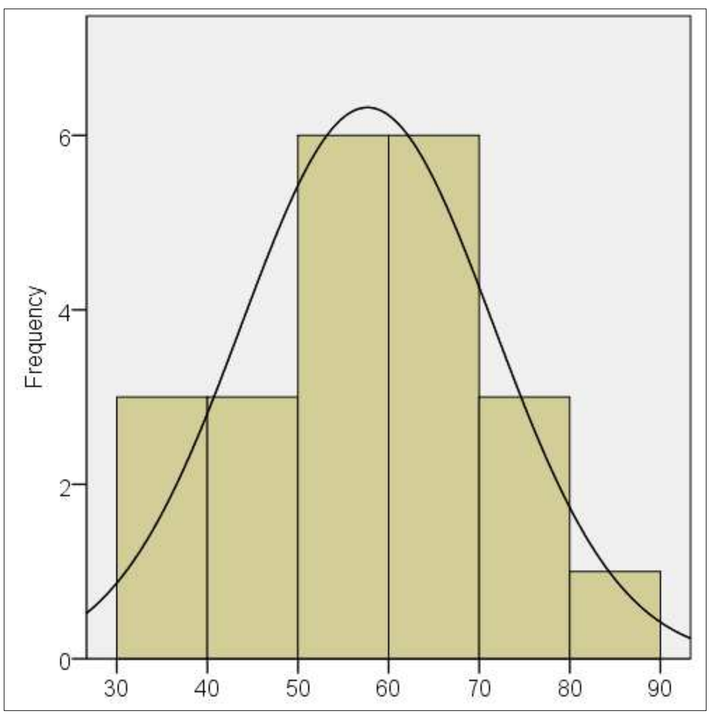


Figure 86. Grade 3 outliers removed NCE core academic achievement histogram for Group 2.

Grade 4 Descriptives and Tests of Normality

Table 36

Grade 4 Group Sizes

Experience Groups	Female	Male	Total
0	9	5	14
1	3	5	8
2	3	8	11
0, 1, and 2	15	18	33

Table 37

Grade 4 Mathematics Achievement Descriptives

Variables	*N*	*M*	Median	*SD*
NCE Total	33	58.61	57.50	13.11
Group 0	14	55.51	55.35	14.46
Group 1	8	59.46	58.15	10.63
Group 2	11	61.94	58.70	13.15
NCE Problems	33	58.62	59.30	14.10
Group 0	14	56.39	59.00	17.29
Group 1	8	60.79	59.05	11.01
Group 2	11	59.90	59.30	12.23
NCE Procedures	33	57.62	57.50	13.36
Group 0	14	54.39	53.70	14.61
Group 1	8	56.66	58.65	11.56
Group 2	11	62.42	58.10	12.63
NCEC	33	57.36	58.10	11.61
Group 0	14	55.70	52.40	11.19
Group 1	8	58.73	59.95	9.63
Group 2	11	58.48	59.30	14.05

Table 38

Grade 4 School A Mathematics Achievement Normality and Homogeneity

Variables	*SD*/ Range	Skewness/ Error	Kurtosis/ Error	Levene	Shapiro-Wilk
NCE Total	.231	1.269	0.461		.382
Group 0	.347	0.902	0.904	.426	.269
Group 1	.296	1.509	1.505	.426	.380
Group 2	.253	1.782	2.334	.426	.179
NCE Problems	.233	0.308	1.241		.426
Group 0	.285	0.355	0.350	.282	.888
Group 1	.316	1.363	1.002	.282	.411
Group 2	.252	0.941	1.662	.282	.467
NCE Procedures	.197	0.105	1.241		.834
Group 0	.246	0.477	1.031	.870	.767
Group 1	.318	0.394	0.028	.870	.735
Group 2	.299	1.386	0.484	.870	.316
NCEC	.233	0.518	0.341		.753
Group 0	.320	0.387	1.110	.591	.330
Group 1	.307	0.214	0.171	.591	.930
Group 2	.282	0.298	0.263	.591	.966

Notes: Kolmogorov-Smirnov used when n > or = 50 and Shapiro-Wilk used when n < 50.

Grade 4 histograms. Histograms with superimposed normality curves were produced for each group within the dependent variables and the covariate. The distributions for stanine scores closely resembled normal distributions. Most distributions for total mathematics achievement, problem solving and mathematics procedures were normally distributed overall. Distributions for NCE Procedures for all groups and combinations are shown in Figures 87 through 102, with each distribution relatively normal overall.

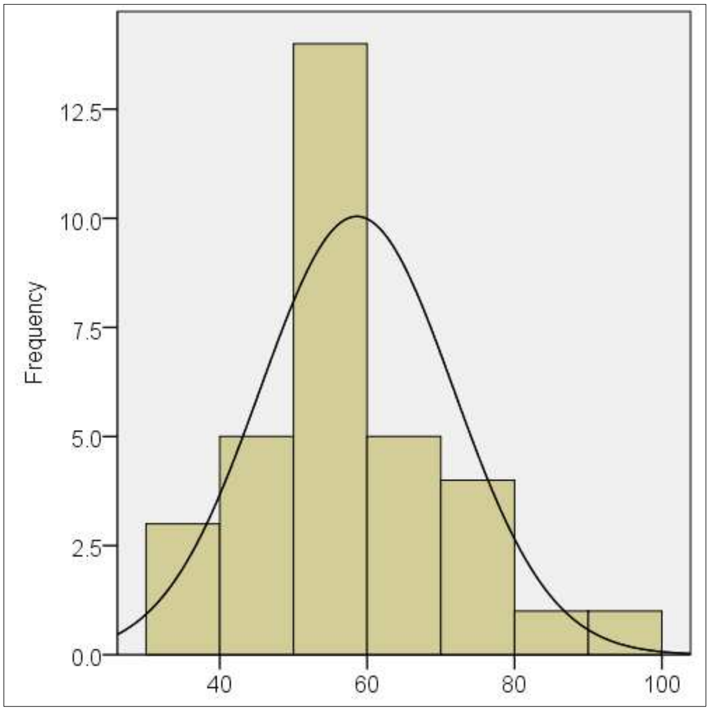


Figure 87. Grade 4 NCE total mathematics achievement histogram for Groups 0, 1, and 2.

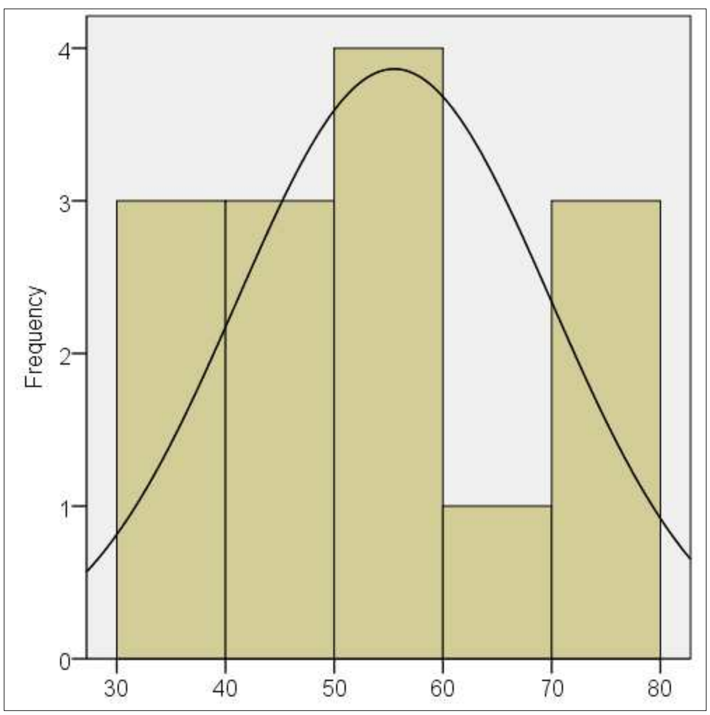


Figure 88. Grade 4 NCE total mathematics achievement histogram for Group 0.

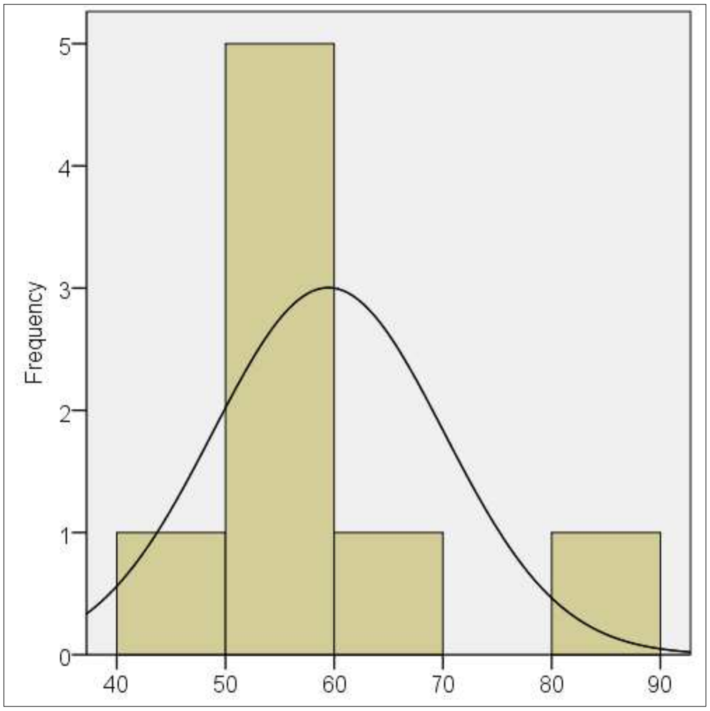


Figure 89. Grade 4 NCE total mathematics achievement histogram for Group 1.

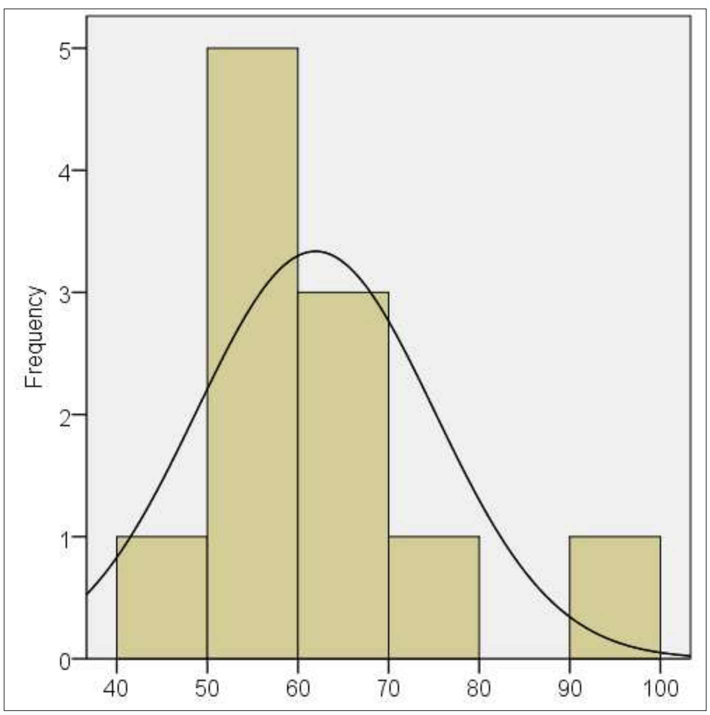


Figure 90. Grade 4 NCE total mathematics achievement histogram for Group 2.

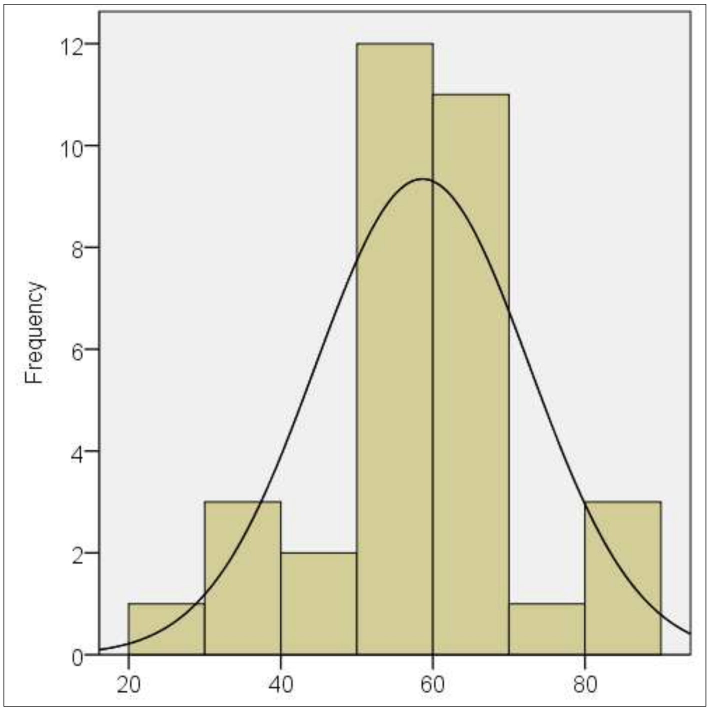


Figure 91. Grade 4 NCE problem solving histogram for Groups 0, 1, and 2.

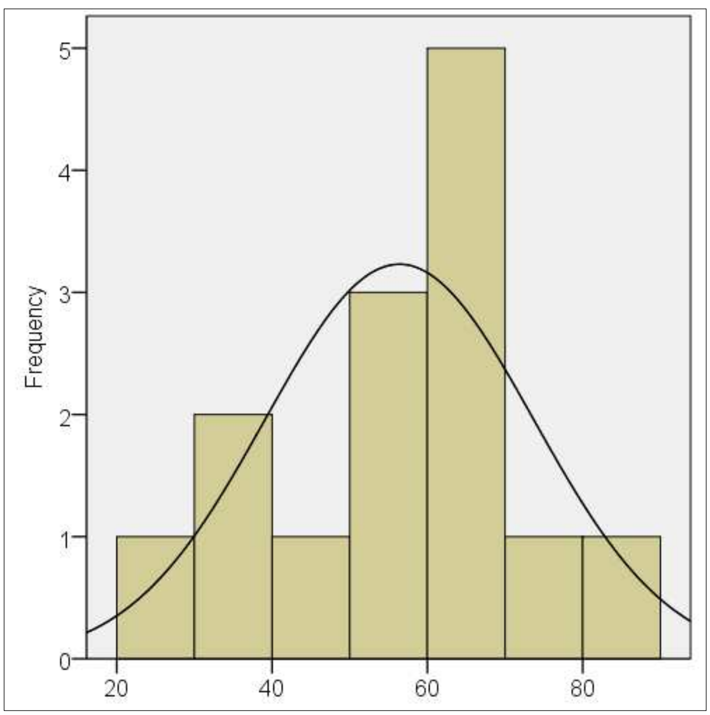


Figure 92. Grade 4 NCE problem solving histogram for Group 0.

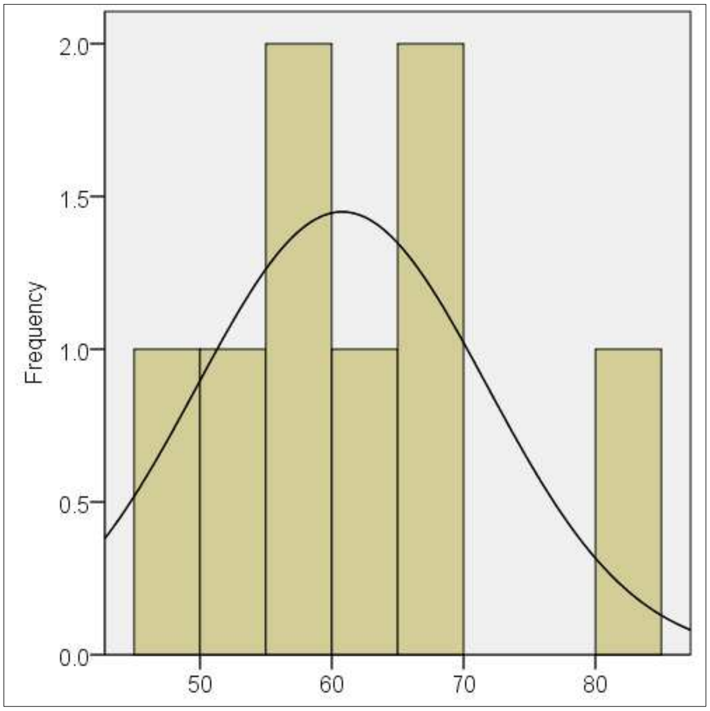


Figure 93. Grade 4 NCE problem solving histogram for Group 1.

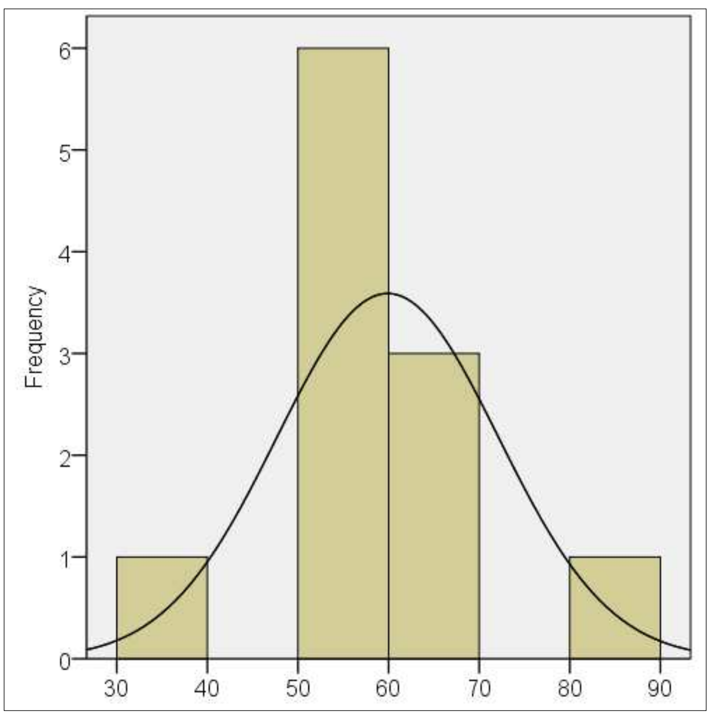


Figure 94. Grade 4 NCE problem solving histogram for Group 2.

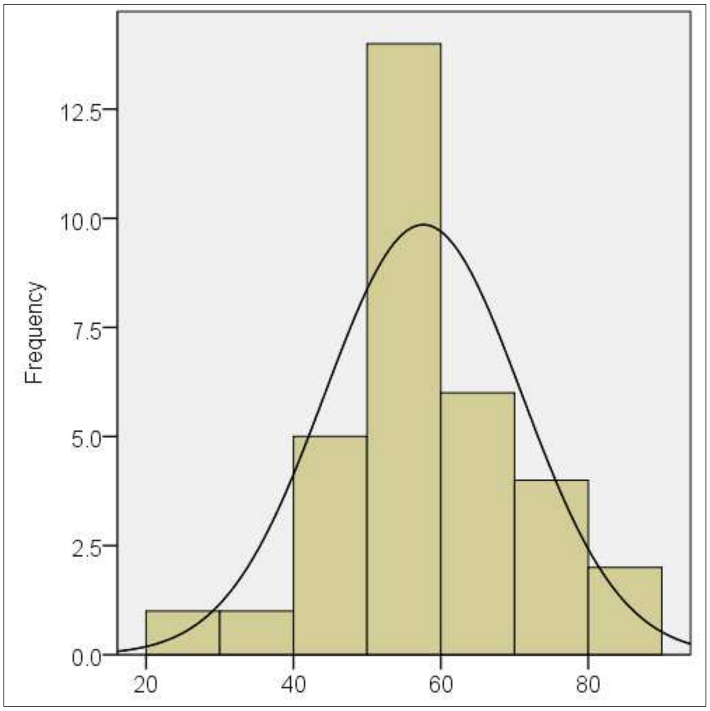


Figure 95. Grade 4 NCE mathematics procedures histogram for Groups 0, 1, and 2.

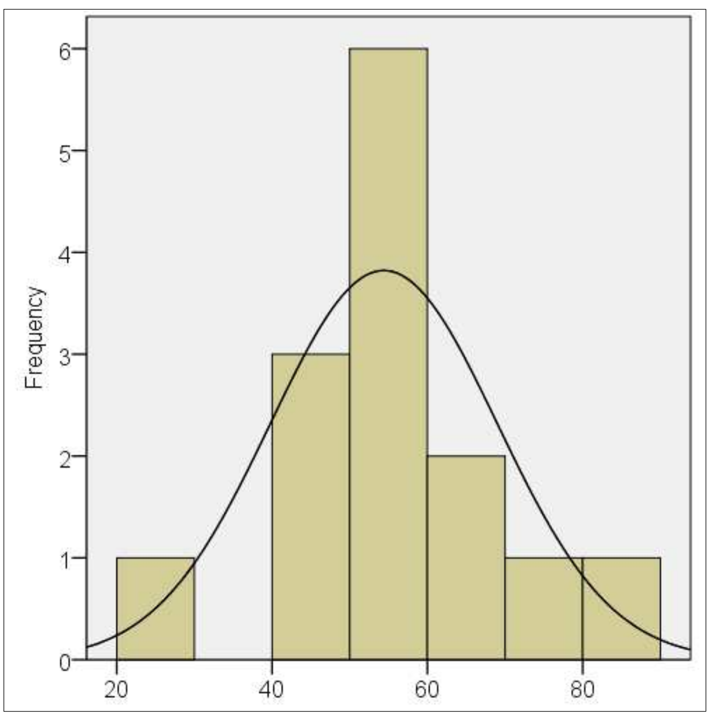


Figure 96. Grade 4 NCE mathematics procedures histogram for Group 0.

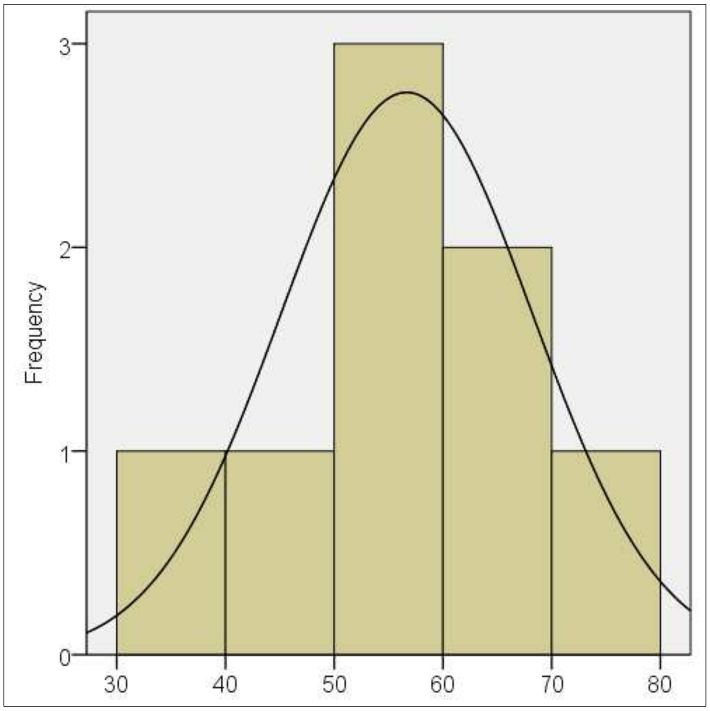


Figure 97. Grade 4 NCE mathematics procedures histogram for Group 1.

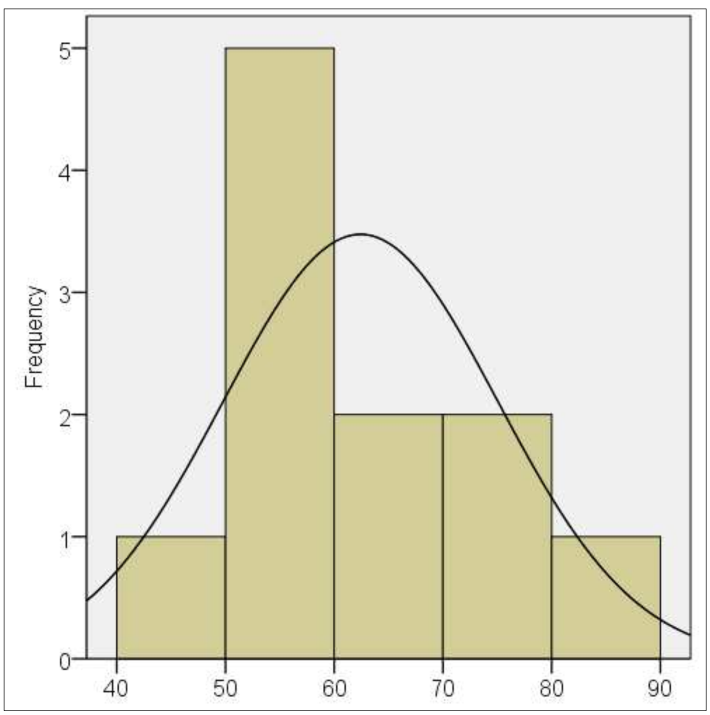


Figure 98. Grade 4 NCE mathematics procedures histogram for Group 2.

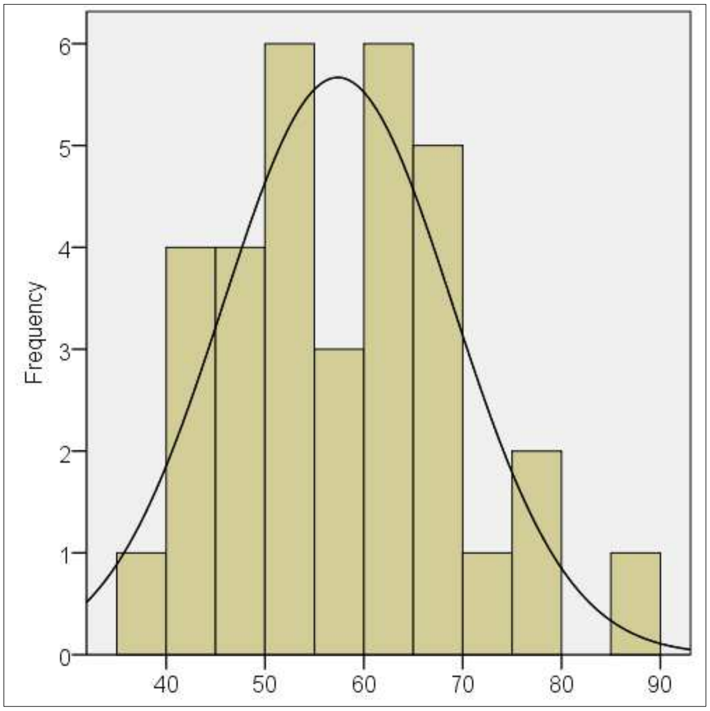


Figure 99. Grade 4 NCE core academic achievement histogram for Groups 0, 1, and 2.

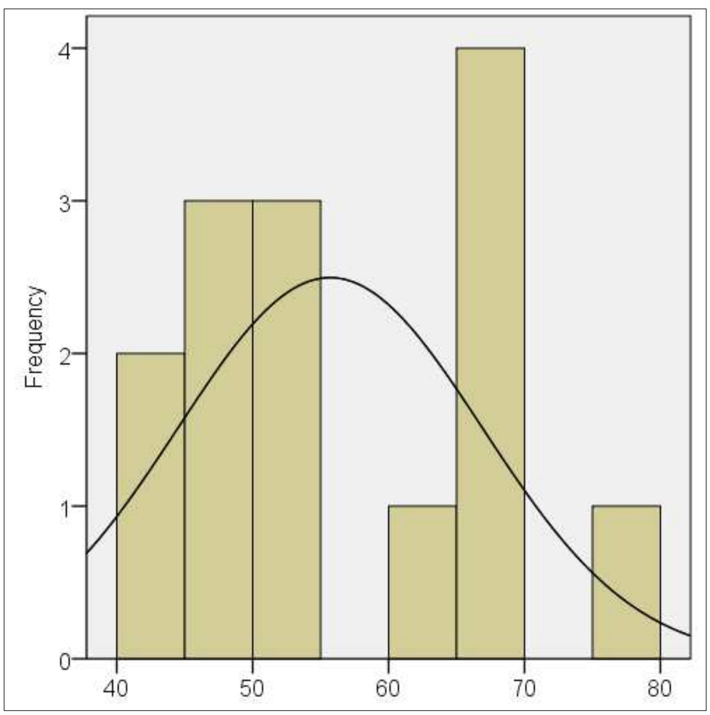


Figure 100. Grade 4 NCE core academic achievement histogram for Group 0.

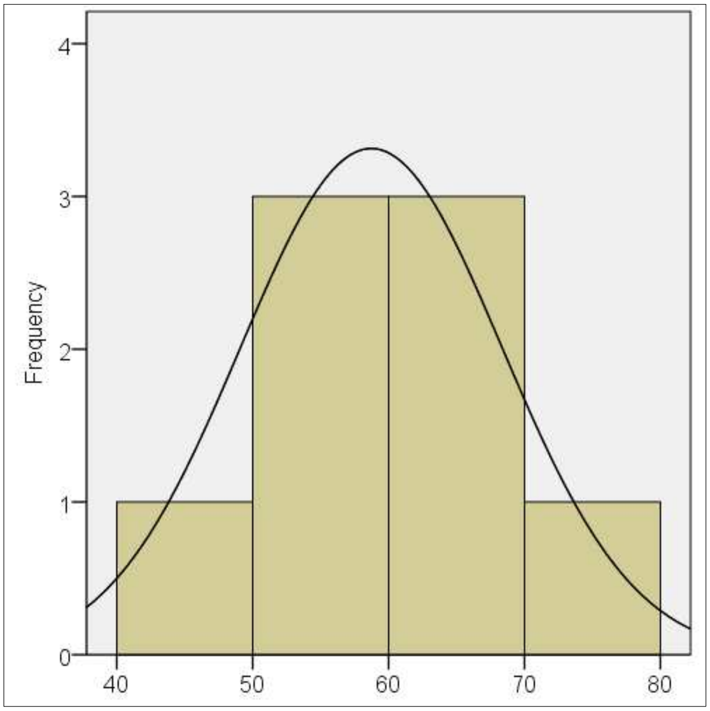


Figure 101. NCE core academic achievement histogram for Group 1.

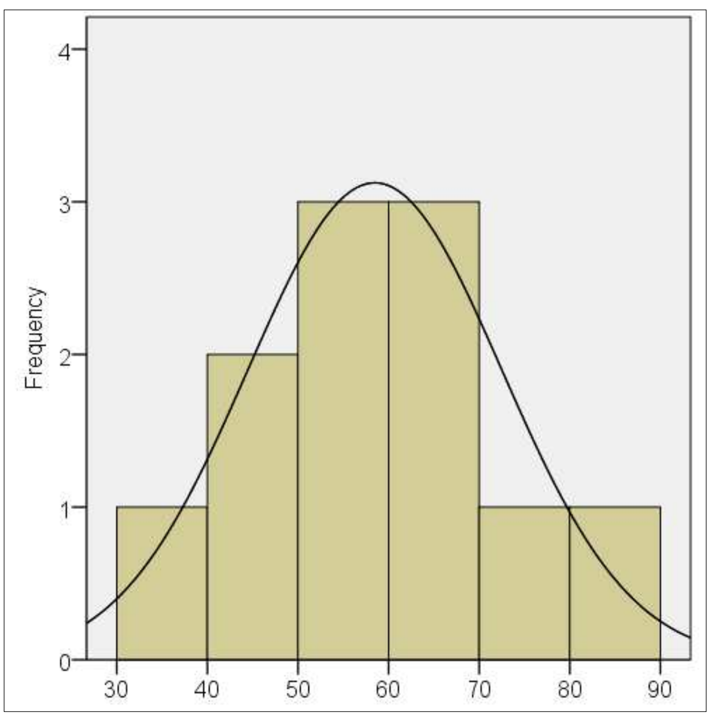


Figure 102. Grade 4 NCE core academic achievement histogram for Group 2.

Grade 5 Descriptives and Tests of Normality

Table 39

Grade 5 Group Sizes

Experience Groups	Female	Male	Total
0	7	7	14
1	2	4	6

Table 40

Grade 5 Mathematics Achievement Descriptives

Variables	*N*	*M*	Median	*SD*
NCE Total	20	45.16	44.40	19.76
Group 0	14	45.06	44.15	22.15
Group 1	6	45.38	46.25	14.43
NCE Problems	20	47.01	46.55	20.95
Group 0	14	45.66	45.50	23.17
Group 1	6	50.17	51.55	15.96
NCE Procedures	20	43.43	41.85	17.71
Group 0	14	44.86	43.20	20.27
Group 1	6	40.08	41.85	10.24
NCE Core	19	45.85	50.60	15.41
Group 0	13	45.99	50.60	16.95
Group 1	6	45.55	51.65	12.84

Table 41

Grade 5 School A Mathematics Achievement Normality and Homogeneity

Variables	*SD*/ Range	Skewness/ Error	Kurtosis/ Error	Levene	Shapiro-Wilk
NCE Total	.223	1.33	1.94	.301	.313
Group 0	.250	1.26	1.55	.385	.496
Group 1	.322	0.02	1.07	.385	.661
NCE Problems	.227	0.63	1.15	.249	.645
Group 0	.251	0.75	1.06	.499	.418
Group 1	.335	0.45	0.60	.499	.794
NCE Procedures	.217	2.88	4.33	.312	.023
Group 0	.248	2.25	2.76	.246	.106
Group 1	.327	0.70	1.03	.246	.629
NCE Core	.275	0.26	0.45	.189	.125
Group 0	.303	0.004	0.50	.393	.490
Group 1	.405	1.47	0.20	.393	.077

Notes: Kolmogorov-Smirnov used when n > or = 50 and Shapiro-Wilk used when n < 50.

Grade 5 histograms. Histograms with superimposed normality curves were produced for each group within the dependent variables and the covariate. The distributions for stanine scores closely resembled normal distributions. Most distributions for total mathematics achievement, problem solving and mathematics procedures were normally distributed overall. Distributions for NCE Procedures for all groups and combinations are shown in Figures 103 through 114, with each distribution relatively normal overall.

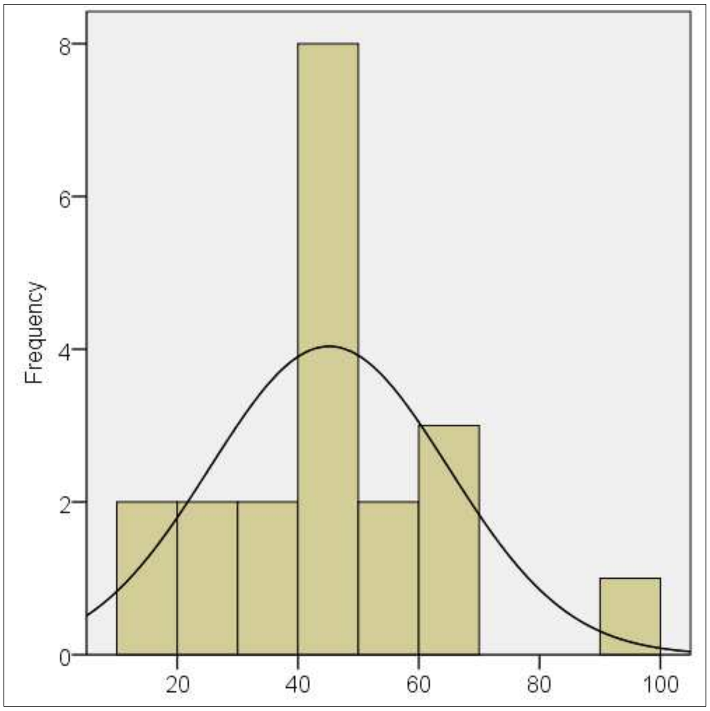


Figure 103. Grade 5 NCE total mathematics achievement histogram for Groups 0 and 1.

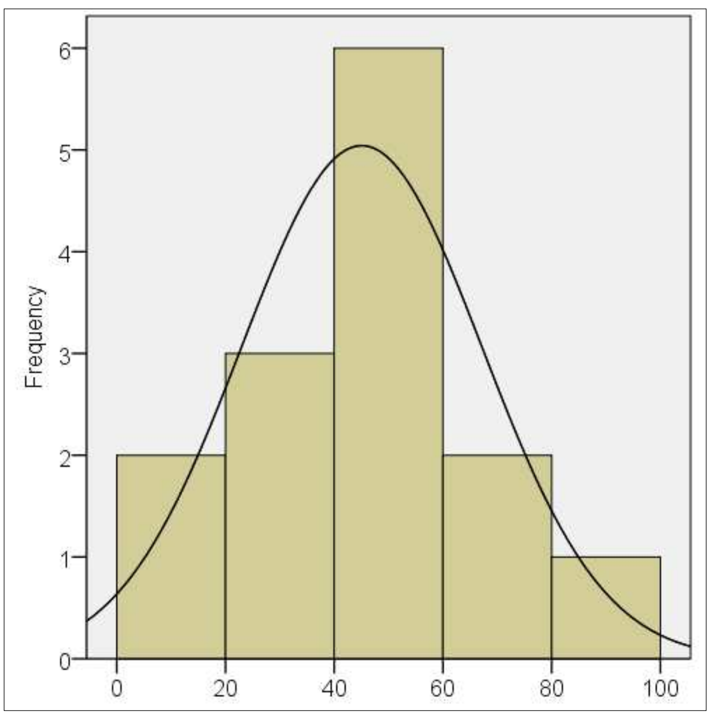


Figure 104. Grade 5 NCE total mathematics achievement histogram for Group 0.

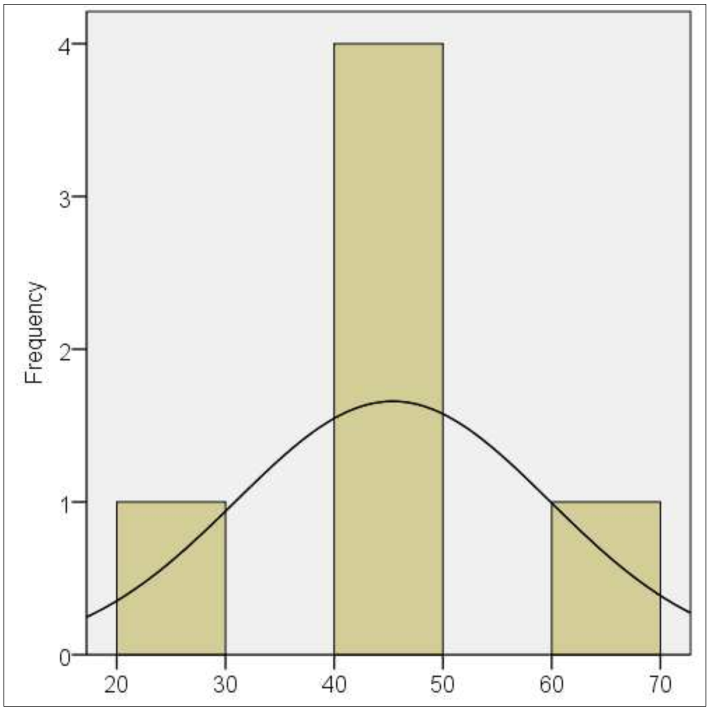


Figure 105. Grade 5 NCE total mathematics achievement histogram for Group 1.

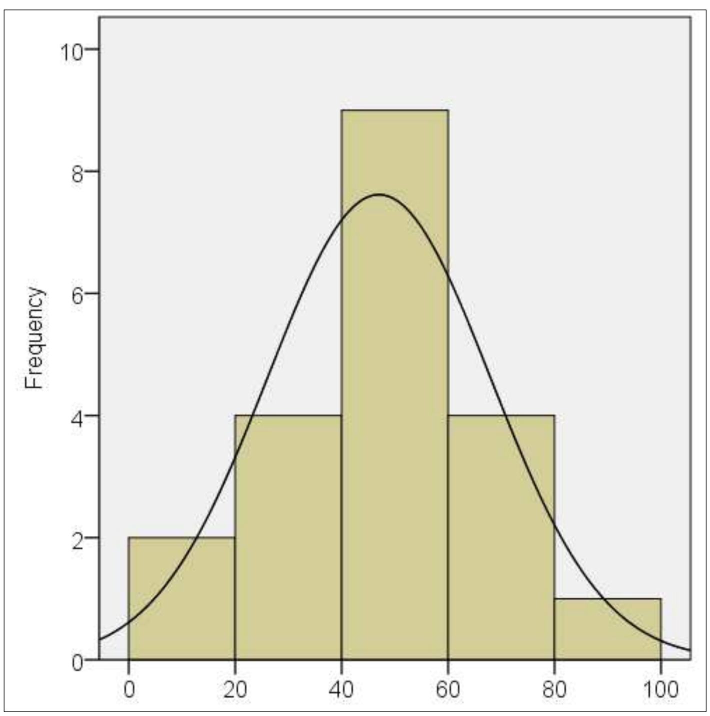


Figure 106. Grade 5 NCE problem solving histogram for Groups 0 and 1.

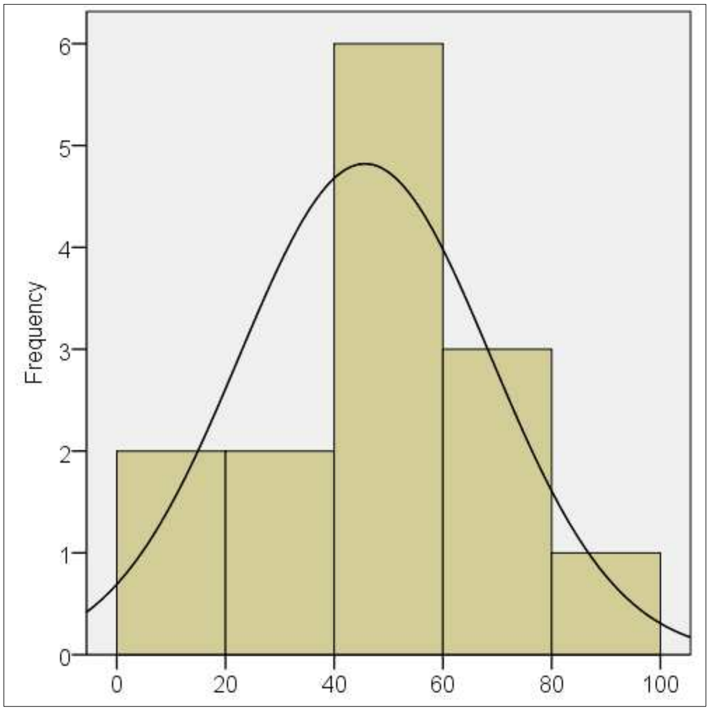


Figure 107. Grade 5 NCE problem solving histogram for Group 0.

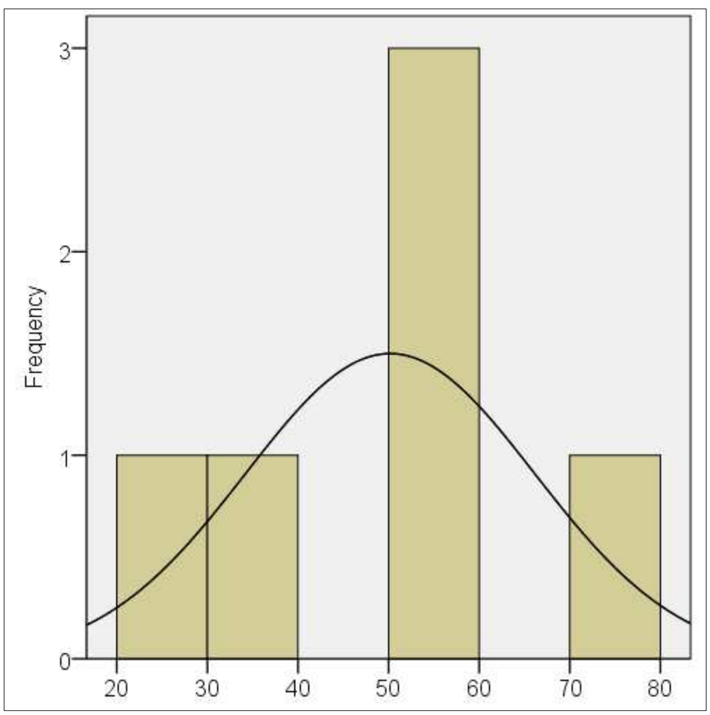


Figure 108. Grade 5 NCE problem solving histogram for Group 1.

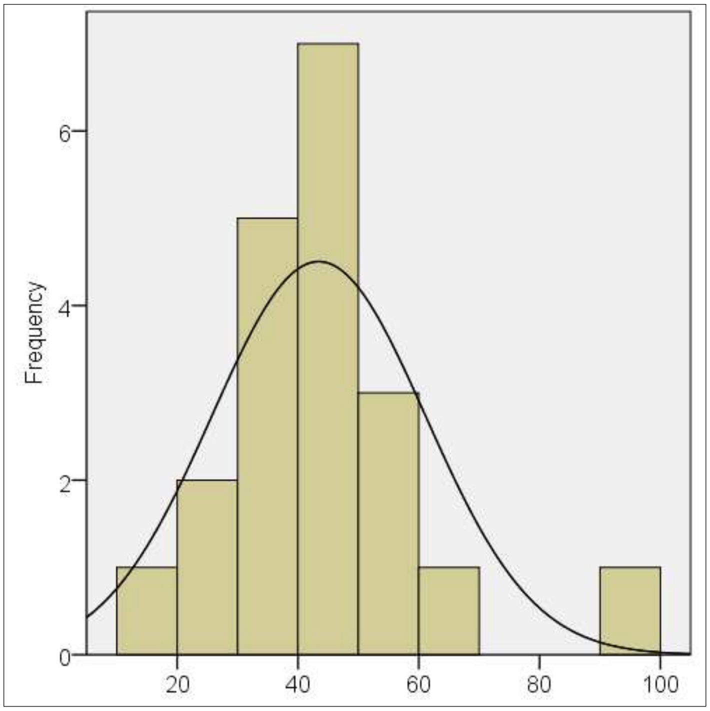


Figure 109. Grade 5 NCE mathematics procedures histogram for Groups 0 and 1.

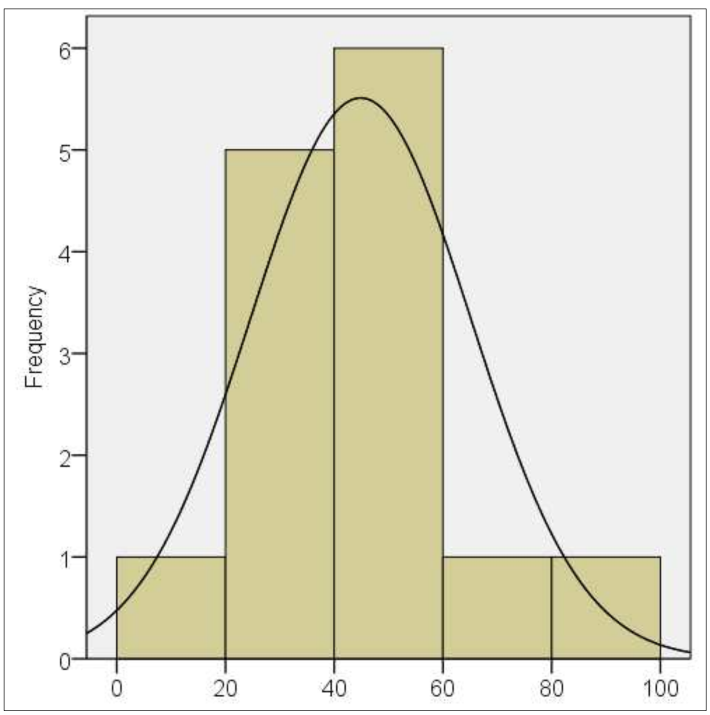


Figure 110. Grade 5 NCE mathematics procedures histogram for Group 0.

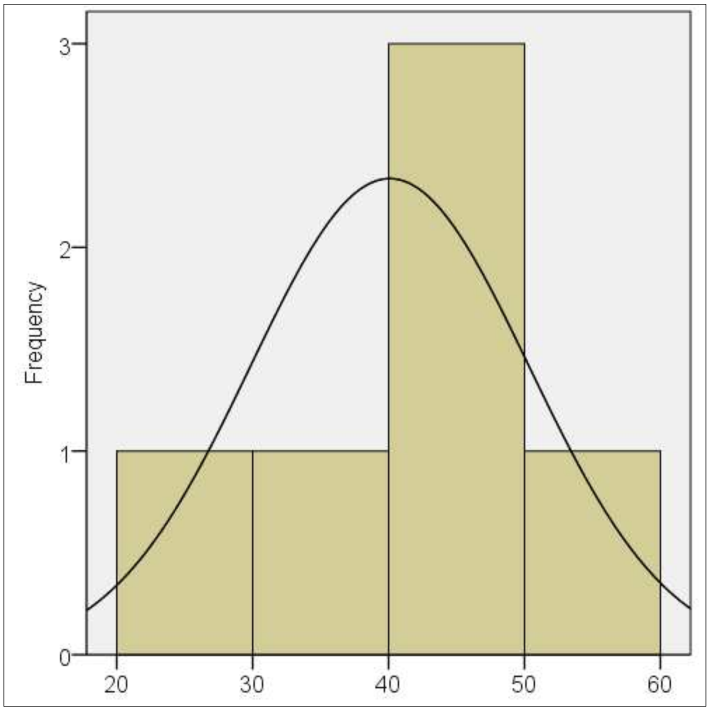


Figure 111. Grade 5 NCE mathematics procedures histogram for Group 1.

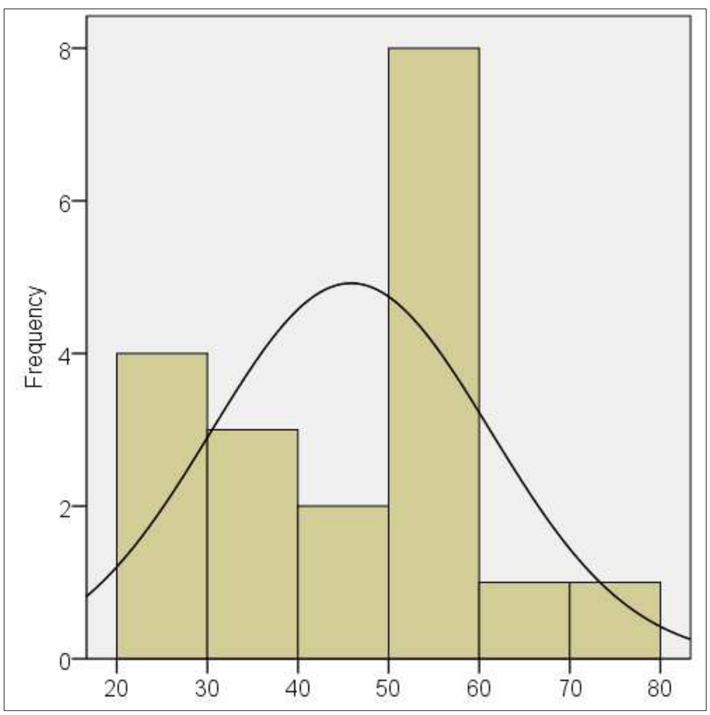


Figure 112. Grade 5 NCE core academic achievement histogram for Groups 0 and 1.

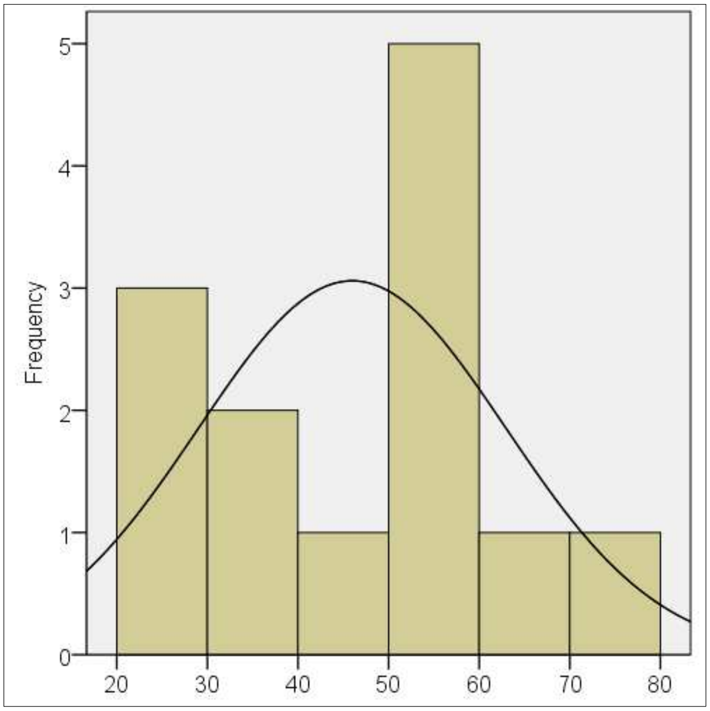


Figure 113. Grade 5 NCE core academic achievement histogram for Group 0.

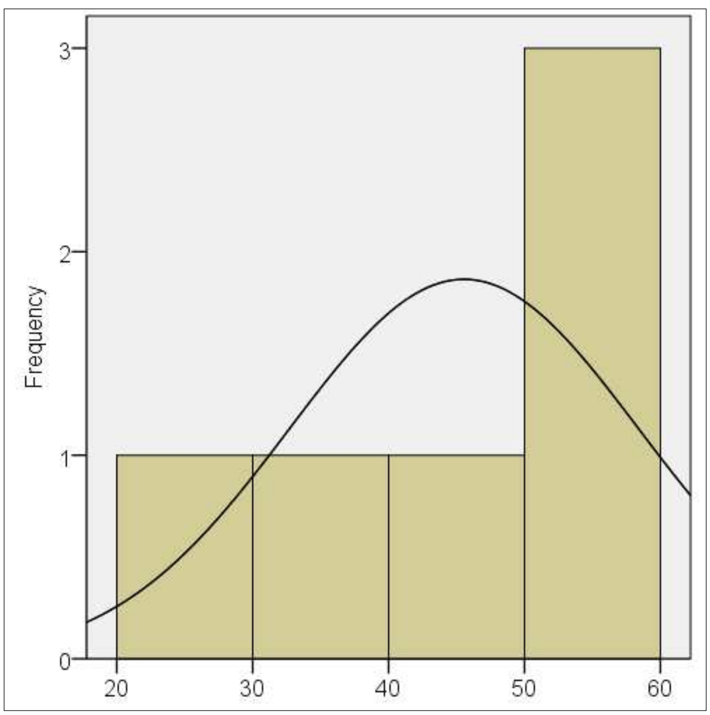


Figure 114. Grade 5 NCE core academic achievement histogram for Group 1.

Appendix B School A Formative Assessment Interview Tool

1.

1	2	3	4	5	6	7	8	9	10
11	12	13	14	~~15~~	16	17	18	19	~~20~~
21	22	23	24	25	26	27	28	29	30
31	32	33	34	35	36	37	38	39	40
41	42	43	44	45	46	47	48	49	50
51	52	53	54	55	56	57	58	59	60
61	62	63	64	65	66	67	68	69	70
71	72	73	74	75	76	77	78	79	80
81	82	83	84	85	86	87	88	89	90
91	92	93	94	95	96	97	98	99	100

Comments: ______________________

2.

1	2	3	4	5	6	7	8	9	10
11	12	13	14	15	16	17	18	19	20
21	22	23	24	25	26	27	28	29	30
31	32	33	34	35	36	37	38	39	40
41	42	43	44	45	46	47	48	49	50
51	52	53	54	55	56	57	58	59	60
61	62	63	64	65	66	67	68	69	70
71	72	73	74	75	76	77	78	79	80
81	82	83	84	85	86	87	88	89	90
91	92	93	94	95	96	97	98	99	100

Comments: ______________________

Date: ______________________

Child	**1**	**2**
Age		4 K G1
Gender		M F
1. Read **12**	NumberName/Traditional Said:	NumberName/Traditional Said:
2. Read **26**	NumberName/Traditional Said:	NumberName/Traditional Said:
3. Read **15**	NumberName/Traditional Said:	NumberName/Traditional Said:
4. Read **43**	NumberName/Traditional Said:	NumberName/Traditional Said:
5. Read **30**	NumberName/Traditional Said:	NumberName/Traditional Said:
Prompt		Y N
1. Model **11**	Tens / Ones Said:	Tens / Ones Said:
2. Model **28**	Tens / Ones Said:	Tens / Ones Said:
3. Model **13**	Tens / Ones Said:	Tens / Ones Said:
4. Model **42**	Tens / Ones Said:	Tens / Ones Said:
5. Model **30**	Tens / Ones Said:	Tens / Ones Said:

Appendix C School B Formative Assessment Interview Tool

Location: ____________________ Date: ____________________

1	2	3	4	5	6	7	8	9	10
11	12	13	14	15	16	17	18	19	20
21	22	23	24	25	26	27	28	29	30
31	32	33	34	35	36	37	38	39	40
41	42	43	44	45	46	47	48	49	50
51	52	53	54	55	56	57	58	59	60
61	62	63	64	65	66	67	68	69	70
71	72	73	74	75	76	77	78	79	80
81	82	83	84	85	86	87	88	89	90
91	92	93	94	95	96	97	98	99	100

2.

1	2	3	4	5	6	7	8	9	10
11	12	13	14	15	16	17	18	19	20
21	22	23	24	25	26	27	28	29	30
31	32	33	34	35	36	37	38	39	40
41	42	43	44	45	46	47	48	49	50
51	52	53	54	55	56	57	58	59	60
61	62	63	64	65	66	67	68	69	70
71	72	73	74	75	76	77	78	79	80
81	82	83	84	85	86	87	88	89	90
91	92	93	94	95	96	97	98	99	100

3.

1	2	3	4	5	6	7	8	9	10
11	12	13	14	15	16	17	18	19	20
21	22	23	24	25	26	27	28	29	30
31	32	33	34	35	36	37	38	39	40
41	42	43	44	45	46	47	48	49	50
51	52	53	54	55	56	57	58	59	60
61	62	63	64	65	66	67	68	69	70
71	72	73	74	75	76	77	78	79	80
81	82	83	84	85	86	87	88	89	90
91	92	93	94	95	96	97	98	99	100

Name:	1.	2.	3.
Grade:	PK K G	PK K G	PK K G
Gender:		M F	M F

Which says 14	Tens Units	Tens Units	Tens Units
Which says 23	Tens Units	Tens Units	Tens Units

Read 12	___ Explicit ___ Traditional	___ Explicit ___ Traditional	___ Explicit ___ Traditional
Read 26	___ Explicit ___ Traditional	___ Explicit ___ Traditional	___ Explicit ___ Traditional
Read 15	___ Explicit ___ Traditional	___ Explicit ___ Traditional	___ Explicit ___ Traditional
Read 43	___ Explicit ___ Traditional	___ Explicit ___ Traditional	___ Explicit ___ Traditional
Read 30	___ Explicit ___ Traditional	___ Explicit ___ Traditional	___ Explicit ___ Traditional

Model 11	Tens Units	Tens Units	Tens Units
Model 28	Tens Units	Tens Units	Tens Units
Model 13	Tens Units	Tens Units	Tens Units
Model 42	Tens Units	Tens Units	Tens Units
Model 30	Tens Units	Tens Units	Tens Units

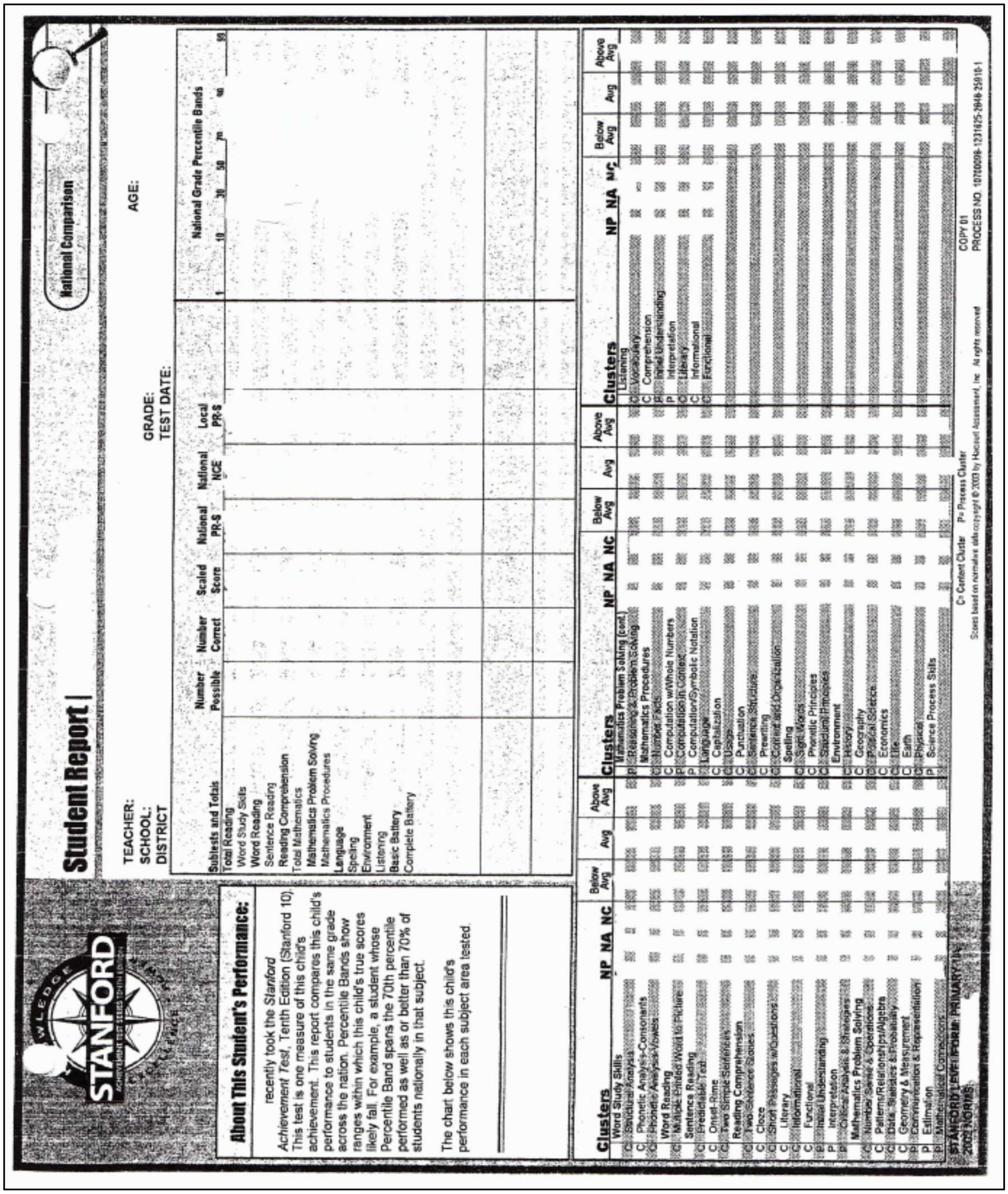
Comments:

1. ____________________

2. ____________________

3. ____________________

Appendix D School A Summative Assessment Stanford 10 Results Format



STANFORD

Student Report | National Comparison

TEACHER:
SCHOOL:
DISTRICT
GRADE:
TEST DATE:
AGE:

About This Student's Performance:

recently took the *Stanford Achievement Test*, Tenth Edition (Stanford 10). This test is one measure of this child's achievement. This report compares this child's performance to students in the same grade across the nation. Percentile Bands show ranges within which this child's true scores likely fall. For example, a student whose Percentile Band spans the 70th percentile performed as well as or better than 70% of students nationally in that subject.

The chart below shows this child's performance in each subject area tested.

Subtests and Totals	Number Possible	Number Correct	Scaled Score	National PR-S	National NCE	Local PR-S	National Grade Percentile Bands (1 10 30 50 70 90 99)
Total Reading							
Word Study Skills							
Word Reading							
Sentence Reading							
Reading Comprehension							
Total Mathematics							
Mathematics Problem Solving							
Mathematics Procedures							
Language							
Spelling							
Environment							
Listening							
Basic Battery							
Complete Battery							

Clusters	NP	NA	NC	Below Avg	Avg	Above Avg
Word Study Skills						
C Structural Analysis						
C Phonetic Analysis-Consonants						
C Phonetic Analysis-Vowels						
Word Reading						
C Multiple Printed Word to Picture						
Sentence Reading						
C Predictable Text						
C Onset-Rime						
C Two Simple Sentences						
Reading Comprehension						
C Two-Sentence Stories						
C Cloze						
C Short Passages w/Questions						
C Literary						
C Informational						
C Functional						
P Initial Understanding						
P Interpretation						
P Critical Analysis & Strategies						
Mathematics Problem Solving						
C Number Sense & Operations						
C Patterns/Relationships/Algebra						
C Data, Statistics & Probability						
C Geometry & Measurement						
P Communication & Representation						
P Estimation						
P Mathematical Connections						

Clusters	NP	NA	NC	Below Avg	Avg	Above Avg
Mathematics Problem Solving (cont.)						
P Reasoning & Problem Solving						
Mathematics Procedures						
C Number Facts						
C Computation w/Whole Numbers						
P Computation in Context						
P Computation/Symbolic Notation						
Language						
C Capitalization						
C Usage						
C Punctuation						
C Sentence Structure						
C Prewriting						
C Content and Organization						
Spelling						
C Sight Words						
C Phonetic Principles						
C Structural Principles						
Environment						
C History						
C Geography						
C Political Science						
C Economics						
C Life						
C Earth						
C Physical						
P Science Process Skills						

Clusters	NP	NA	NC	Below Avg	Avg	Above Avg
Listening						
C Vocabulary						
C Comprehension						
P Initial Understanding						
P Interpretation						
C Literary						
C Informational						
C Functional						

STANFORD LEVEL/FORM: PRIMARY 1/A
2002 NORMS

C= Content Cluster P= Process Cluster

Scores based on normative data copyright © 2003 by Harcourt Assessment, Inc. All rights reserved.

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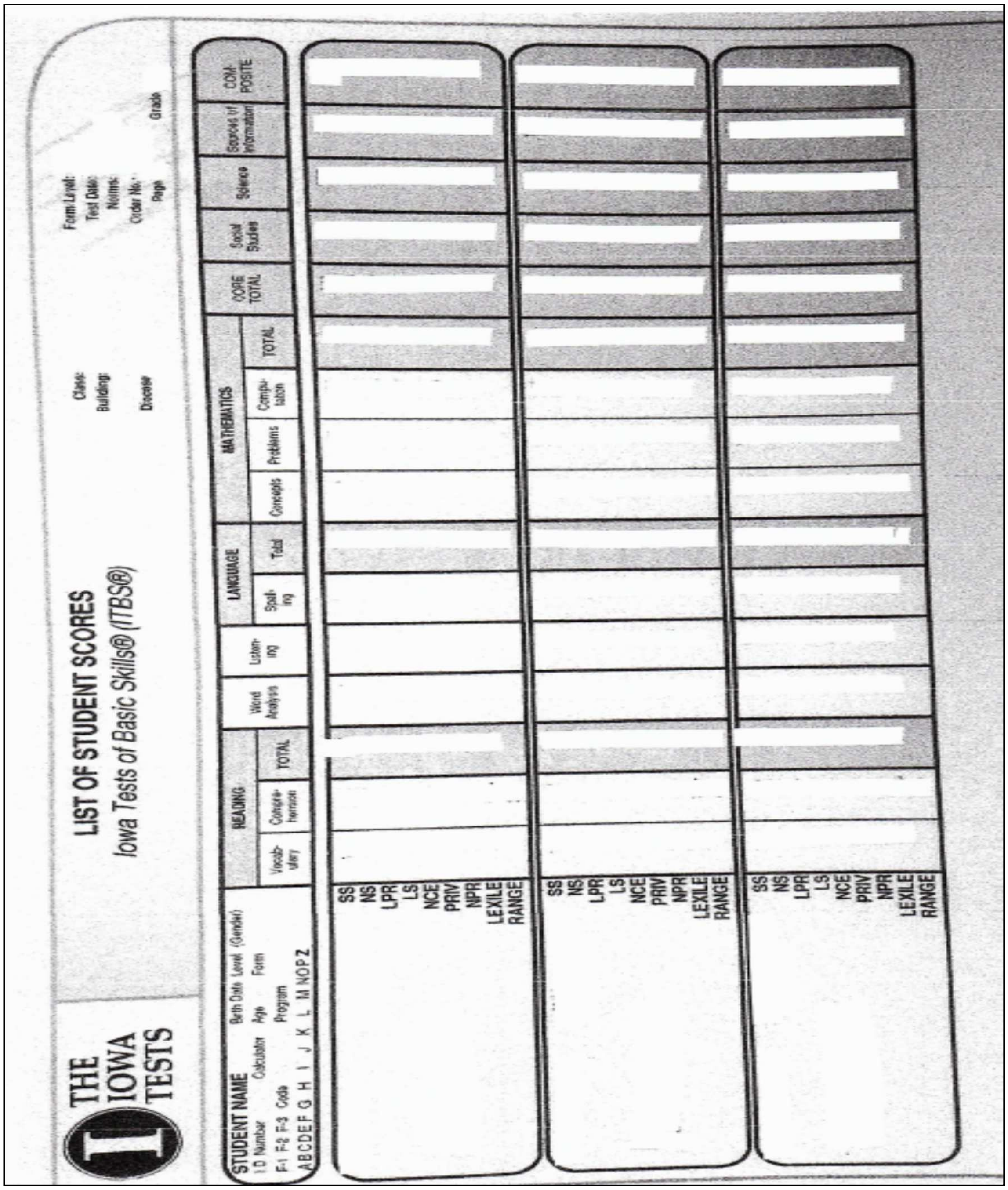
Appendix E School B Summative Assessment ITBS Results Format



THE IOWA TESTS

LIST OF STUDENT SCORES

Iowa Tests of Basic Skills® (ITBS®)

Class:
Building:
District:

Form/Level:
Test Date:
Norms:
Order No.:
Page
Grade

STUDENT NAME
I.D. Number Calculator Birth Date Level (Gender)
F-1 F-2 F-3 Code Age Form
Program
A B C D E F G H I J K L M N O P Z

	READING			Word Analysis	Listening	LANGUAGE		MATHEMATICS				CORE TOTAL	Social Studies	Science	Sources of Information	COMPOSITE
	Vocabulary	Comprehension	TOTAL			Spelling	Total	Concepts	Problems	Computation	TOTAL					
SS																
NS																
LPR																
LS																
NCE																
PRIV																
NPR																
LEXILE																
RANGE																

Appendix F Institutional Review Board

UNIVERSITY OF THE INCARNATE WORD

12/3/2015

Suzanne Dean Magargee

Dear Suzanne,

Your request to conduct the study *An Exploration of the Math Names for Numbers: An Early Childhood Mathematics Intervention* was approved by exempt review on 12/3/2015. Your IRB approval number is 15-12-003. Any written communication with potential or current subjects must be approved and include the IRB approval number. Electronic surveys or electronic consent forms, or other material delivered electronically to subjects must have the IRB approval number inserted into the survey or documents before they are used.

Please keep in mind these additional IRB requirements:

- This approval is for one year from the date of the IRB approval.
- Request for continuing review must be completed for projects extending past one year. Use the **IRB Continuation/Completion form.**
- Changes in protocol procedures must be approved by the IRB prior to implementation except when necessary to eliminate apparent immediate hazards to the subjects. Use the **Protocol Revision and Amendment form.**
- Any unanticipated problems involving risks to subjects or others must be reported immediately.

Approved protocols are filed by their number. Please refer to this number when communicating about this protocol.

Approval may be suspended or terminated if there is evidence of a) noncompliance with federal regulations or university policy or b) any aberration from the current, approved protocol.

Congratulations and best wishes for successful completion of your research. If you need any assistance, please contact the UIW IRB representative for your college/school or the Office of Research Development.

Sincerely,

Ana Wandless-Hagendorf

Ana Wandless-Hagendorf, PhD, CPRA
Research Officer
University of the Incarnate Word IRB