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SYNTACTIC COMPLEXITY AND ITS EFFECT ON WRITTEN

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CHAPTER ONE

THE PROBLEM

Mathematical computations are skills that people need to be able to advance in our complex society. It is not only necessary for people to be able to compute, they must also know when to use the correct mathematical operation. Additionally, it is generally accepted that even when people can compute mathematical problems, they often have trouble with word problems. However, little attention has been paid to why this is so. This study was conducted as an attempt to determine the effect syntactic complexity has on written mathematical problems. In other words, what effect did the way a mathematical word problem was written have on a person's ability to answer the problems correctly.

An overview of the problem of the study is presented in this chapter. To accomplish this the chapter is divided into four sections. In the first section (i.e., the background of the problem), readability, the effect syntax has on reading comprehension, and the effect syntax has on mathematical word problems are presented. The second and third sections include the statement of the problem and the significance of the study. Finally, the fourth section contains the definition of terms.

Background Of The Problem

Readability

For a reader to comprehend what is written, the material must be meaningful to them. In other words, a person's reading ability needs to be matched with the difficulty of the material being read. To determine the readability (i.e., the degree of difficulty of reading material) of written materials, a variety of readability formulas have been developed. The most widely used formulas for judging readability are based on only two factors: sentence length (e.g., the average number of words in each sentence contained in the reading material) and vocabulary difficulty (e.g., the number of unfamiliar words in the reading material) (Dale & Chall, 1948: Spache, 1953).

However, readability is probably a function of more variables than just sentence length and vocabulary difficulty. Included in these variables are content, coherence, vocabulary, and syntactic complexity (Botel & Granowsky, 1972). Content refers to the subject matter that is being read (e.g., science, social studies, mathematics, etc.). Comprehending what is read in these subject areas is related to a person's individual experience, interest, and learning (Fry, 1972). Coherence refers to the orderly relationship within the reading material that aids in comprehension. Vocabulary, in relation to readability, is measured by the percentage of unfamiliar words and how frequently they appear in the reading material. It is the percentage of these unfamiliar words that often determines the difficulty level of the reading material (Fry, 1972). Finally, syntactic complexity is measured by sentence length and structure.

Since content, coherence, and sentence structure are also functions of readability, they too should be measured when determining the difficulty of reading material. But, content and coherence are difficult to measure objectively. For example, a person's interest in a certain area could only be measured subjectively and not by quantifiable means (Botel & Granowsky, 1972). However, sentence structure can be measured objectively and should be included with sentence length when measuring syntactic complexity.

The Effect Syntax Has On Reading

Syntax (i.e., the order in which words are grouped) organizes the reading material so that it is meaningful to the reader. Without this organization, sequences of words are difficult to comprehend (Miller & Isard, 1963). This is because meaning in the English language is characterized by word order (Lundsteen, 1976).

Reading has been the curriculum area most intensely studied in relation to syntactic complexity. In fact, research indicates that the syntactic complexity of a written sentence or paragraph can affect comprehension (Loban, 1963; Miller & Hintzman, 1975). William Smith (1972) found that students generally have the ability to comprehend the material better if it is written nearest to their reading ability.

For example, fourth grade readers comprehend fourth grade reading material better than older students (i.e., eighth and twelfth graders). In other studies, Reid (1970) and Ruddle (1965) found that students have the ability to comprehend material better when the material utilizes linguistic structures that are commonly employed in their speech. In other words, a student's ability to comprehend written material is likely to be better if it is closely related to the student's natural speech. Therefore, a discrepancy in syntax between the speech patterns of the students and the written materials they are given to read can influence reading comprehension.

The Effect Syntax Has On Mathematical Word Problems

While the effect of syntax on reading comprehension has received attention, little work has been done to determine what effect syntax has on a student's ability to succeed in other academic areas. If syntactic complexity can affect reading comprehension, then it seems possible that this phenomenon may be evidenced in the curricular area of mathematics. Specifically, it seems possible that syntactic complexity can affect a student's ability to comprehend written mathematical problems. Furthermore, if the student does have difficulty comprehending the written mathematical problems, it would seem that the student might also experience difficulty in solving the problems correctly. That is, if the student does not understand how to organize the problem and which mathematical operation to use from reading the problem, then the student will not be able to solve the problem correctly.

Much of the prior research related to mathematical problems has concentrated on how the subjects solved the problems (Groen & Parkman, 1972; Parkman & Groen, 1971; Restle, 1970; Suppes & Groen, 1967). These researchers were interested in the processes involved in performing the mathematical operations. For example, Suppes and Groen (1967) found that, in general, the subjects select the larger number and then use the smaller number to complete the counting processes. Parkman and Groen (1971) found that simple addition problems presented horizontally with the larger digit in the left position were easier for subjects to process than problems in the reverse order. While these studies attempted to determine the processes involved in performing mathematical operations, no attention was paid to the role of verbal or situational context on mathematical problems.

There has been some research that has tried to determine what effect complexity of the language has on students' ability to solve written mathematical problems. This research has shown that many students have difficulty solving word problems. This is especially true of low-achieving students. Loftus and Suppes (1972) found that students were more likely to solve a word problem correctly if it is similar to the problem that preceded it in the structural complexity of the language. Trenholme, Larsen, and Parker (1977) found that the syntactic complexity of written mathematical problems did have an effect on the mathematical performance of low-achieving eighth grade students.

Statement Of The Problem

The purpose of this study was twofold: (a) to determine if the syntactic complexity of written mathematical problems had an influence on low-achieving eighth and tenth grade students' ability to solve the problems and (b) to determine if there was a difference between the eighth and tenth grade students' ability to solve the written mathematical problems. Aspects of this study are a replication of the Trenholme et al. (1977) study. As in the Trenholme et al. study, syntactic complexity was measured by sentence structure, while mathematical ability was measured by the score of incorrect responses on three syntax tests containing written mathematical problems. The mathematical computation skills and vocabulary level on these tests were held constant at a fourth grade level or below. However, this study differs from the Trenholme et al. study in that the computations (i.e., addition and subtraction with and without regrouping) on the testing instruments were changed so that they would be equally distributed throughout the tests. Also the investigator controlled for reading vocabulary and mathematical computations by determining that the subjects had a minimum fourth grade achievement level in these skills. Furthermore, this study differs from the Trenholme et al. study in that it not only attempts to determine the influence of syntactic complexity on written mathematical problems, but it also attempts to determine if there is a difference on syntactic complexity between two grade levels (i.e., eighth and tenth grade).

Significance Of The Study

People need to be able to apply mathematical computations in everyday life. However, having only the knowledge of how to add or subtract will not solve the problem of determining which operation is appropriate and how to implement it. The purpose of mathematical word problems is to instruct the student in deciding which operation is needed and how to implement it so that when a student faces a similar problem in a real life situation, he or she will be capable of solving the problem.

To evaluate a student's ability to apply mathematical computations, educators use a variety of mathematical achievement tests. These tests evaluate a pupil's ability to compute both numerical operations and written mathematical problems. Students are placed in mathematics classes and receive instructions according to these achievement tests. Therefore, educators need to insure that these achievement tests are indeed measuring mathematical ability and not syntactic complexity.

Finally, educators need to take into account the syntactic complexity that is commonly employed in mathematics texts and workbooks since they may contain mathematical word problems that are too syntactically complex for their students to solve. If this is the case, then educators will need to either instruct their students in syntactic structure so thev are able to solve these problems, or be alert to the syntactic structure of the word problems when ordering textbooks.

Definition of Terms

Mathematical Operations -- The process of assigning a new element, or number, to given elements of one or more sets in order to form a union (e.g., addition) or to separate the elements (e.g., subtraction). Addition, subtraction, multiplication, and division are mathematical operations. However, for this study only the operations of addition and subtraction are included.

Mathematical Computations -- The skills needed to successfully complete a mathematical operation (for example: $3 + 2 = 5$; $3 + 2$ is the operation conducted to successfully find the number 5).

Low-Achieving Students -- Students who are performing at two or more grade levels below the expected performance of an eighth or tenth grader in mathematics.

Remedial Mathematics Program -- A basic mathematics program that is included in the secondary school curriculum which is not considered a college preparatory mathematics program. Students in the remedial mathematics programs receive instruction in applying general mathematical concepts.

Grammar -- An abstract concept that explains how a language works (Lundsteen, 1976) by describing the ways a language is used (Greene & Petty, 1975). In other words, grammar is a description of the way people speak and write.

Syntax -- The way "words are put together to form phrases and sentences" (Morris, 1969, p. 1305). That is the order in which the words are grouped in a sentence that will affect the meaning of that sentence.

<u>Syntactic Complexity</u> -- The degree of difficulty, with regard to syntax, that a sentence or paragraph is written. For example, sentences may be written in a simple, compound, or complex syntactic structure. For this study it was assumed that as the syntactic structure of the sentences became more complex it would be harder for the subjects to read the sentences with full comprehension. This study will measure syntactic complexity of written mathematical problems through the administration of three tests: (a) Easy Syntax Text, (b) Moderate Syntax Test, and (c) Hard Syntax Test. The Easy Syntax Test was composed of simple sentences, with sentence structure becoming more complex in the Moderate Syntax Test and the Hard Syntax Test.

CHAPTER TWO

REVIEW OF THE LITERATURE

A review of the literature focusing on the effect syntax has on mathematical word problems is presented in this chapter. To accomplish this the chapter is divided into four sections. In the first section, mathematical word problems are presented. Included in this section are the skills needed to (a) compute mathematical operations (i.e., mathematical computations and operations) and (b) solving mathematical word problems (i.e., the ability to read and understand the problem). A brief review of grammar is described in the second section which includes: (a) the three types of grammar (i.e., traditional grammar, structural grammar, and transformational-generative grammar) and (b) syntax and syntactic complexity. The third section contains the effect syntactic complexity has on mathematical word problems. Finally, the literature findings are summarized in the fourth section.

Mathematical Word Problems

Mathematical word problems are believed to be a very important part of a mathematics program. It is through word problems that students apply their knowledge of mathematical computations and operations in order to solve the problems correctly. By instructing students in how to solve word problems, educators assume that a transfer will occur so that students will be able to solve problems they may face in a variety of real-life situations (Trueblood, 1969). For example, instruction in word problems should assist an individual in the computational skills needed when buying an article where he or she would be receiving change.

Even though mathematical word problems are believed to be a very important part of a mathematics program, educators know that many students have difficulty in solving these problems (Loftus & Suppes, 1972). In order to solve word problems, students must first be able to compute mathematical operations.

Ability to Compute Mathematical Operations

Mathematical computations. Mathematical computations are skills a person needs to be able to complete a mathematical operation. For example, in the problem $3 + 2 = 5$, $3 + 2$ is the operation conducted to successfully find the number 5. As long as the numbers in the operation are small, as in the above example, the person trying to solve the problem can find the solution easily by putting the elements in a one-to-one correspondence with the numerals (i.e., by counting). However, when the numbers in the operation are large (e.g., $235 + 512$) counting becomes inefficient. It is when the numbers in the operation are large that mathematical computations assist people in finding the solution.

Mathematical operations. A mathematical operation is the process of assigning a new element (i.e., a number) to given elements of one or more sets (i.e., group or group of elements). For example, in the operation of addition, a new element (or number) is assigned to the union of two given disjoint sets (i.e., two groups of elements with no elements in common). In other words, the number 5 is assigned to the union of disjoint sets with 3 elements and 2 elements. The operation of subtraction is similar to addition in that it also assigns a new element to given elements. However, in subtraction the new element separates the given elements (e.g., the number 2 is assigned to the given elements 5 and 3 so as to separate the set).

Research has been conducted in relation to the processes that are involved in performing mathematical operations. Suppes and Groen (1967) found that, in general, their subjects selected the larger number and then used the smaller number to complete the counting process. In 1971, Parkman and Groen studied the processes involved in addition of single digit integers. They found that simple addition problems presented horizontally with the larger digit in the left position were easier for subjects to process than problems presented in the reverse order.

Solving Mathematical Word Problems

In order to complete a word problem, students must be able to read and understand what the problem is asking them to do (Reys, 1975; Schoenherr, 1968). In other words, after reading the word problem the students must be able to plan for a solution by identifying the known and unknown elements of the problem (e.g., two apples and three apples equals how many apples). After the students have identified the known and unknown elements, they need to determine which operation will be performed to correctly solve the problem. It is only after the students identify the elements of the problem and decide which operation to use, that they perform the operation and examine their solution to determine if it is correct.

Ability to read and understand the problem. The first and most important ability the students must possess in order to solve word problems is the ability to read and understand what the problem is asking them to do. In solving word problems, the students must be able to understand the full meaning of the sentences in order to be able to complete the problem correctly.

One aspect of the written problem that the students must understand in order to derive the full meaning of the problem is the vocabulary that is used. If the students do not understand the mathematical terms used in the problem, they will have difficulty in solving the problems correctly. Lyda and Duncan (1967) conducted research on mathematical vocabulary in an attempt to find if direct study of mathematical terms had an impact on students' problem solving ability. They selected mathematical terms from second grade mathematics textbooks and spent part of the mathematics period, for eight weeks, studying the vocabulary. They found that by direct study of the vocabulary, the students' ability to solve the problems correctly increased significantly. This study implies that mathematical terms, or vocabulary, has a significant effect in a person's ability to solve word problems.

Another aspect of the written problem that the students must understand in order to obtain the full meaning of the problem is the ability to comprehend the wording of the problem. In other words, the students must realize what the sentences are asking them to do. In order to comprehend the meaning of the sentences in the problems, the students must understand the relationships of the words in the sentences. This is why syntax plays an important part in the ability to solve mathematical word problems. Syntax organizes the words in the sentences so that it is meaningful to the reader (Meyers & Hammill, 1976; Wisher, 1976). If the syntactic structures of the sentences are too complex for the students to understand, they will experience difficulty in solving the problem.

Before dealing with the effect syntax, especially syntactic complexity, has on mathematical word problems, an understanding of what syntax is and the effect it can have on reading comprehension is necessary. Since syntax is a branch of grammar, an understanding of grammar as it relates to this study is also needed.

Grammar

Because of the vast amount of material on grammar that is available in the literature, this section only includes that which relates to this study. Therefore, this section includes a general understanding of grammar as it relates to this study.

Grammar is an abstract construct that explains how a language works (Lundsteen, 1976). It is a description of the way people use a language (Greene & Petty, 1975). In other words, grammar is a description of the manner in which people speak and write. This includes their choice of words and their construction of sentences. There are generally three types of grammar: (a) traditional grammar, (b) structural grammar, and (c) transformational-generative grammar or simply transformational grammar.

Types Of Grammar

Traditional grammar. Traditional grammar is also referred to as old school or formal grammar (Lundsteen, 1976). This is because it describes the manner in which the English language is based on the rules of Latin grammar. Traditional grammar prescribes rules for using language rather than describing how language is used. It classifies words into parts of speech (i.e., noun, verb, etc.) and emphasizes the subject-predicate relationship.

Traditional grammar has been of little use in helping English speaking children to use language effectively (Briggs, 1913; Hoyt, 1906; Kraus, 1957; Rapeer, 1913). Educators, in the past, have assumed that by teaching traditional grammar in the elementary schools, the students would have a better understanding of the English language. However, research has shown this is not always correct. As early as 1906, Hoyt stated that there was no difference between students who were instructed in traditional grammar and those who were not and their ability to use English correctly. Hoyt administered three examinations, one in grammar, one in composition, and one in interpretation to 200 beginning high school pupils. The correlations found were as follows: (a) grammar and composition .30, (b) grammar and interpretation .35, and (c) interpretation and composition .41. Hoyt concluded that these correlations were not great enough to lead one to believe that instruction in traditional grammar improves the student's ability to use correct English.

In an attempt to replicate Hoyt's study, Rapeer (1913) administered Hoyt's three examinations (i.e., grammar, composition, and interpretation) to beginning high school pupils from two high schools. Rapeer's correlations were as follows: (a) grammar and composition .23, (b) grammar and interpretation .10, and (c) composition and interpretation .24. Rapeer's findings were too low to be practical and he concluded that instruction in formal grammar "is of little value to elementary pupils" (p. 131).

Rapeer's conclusion that instruction in formal grammar is of little value was confirmed by Kraus (1957). Kraus instructed three groups of eleventh graders in sentence structure to find which procedure was most efficient. Kraus selected six eleventh grade classes and placed them in one of three experimental groups. Students in Group I were instructed in sentence structure alone using a traditional grammar approach. Students in Group II received identical instruction in sentence structure, but also wrote weekly themes. The students in Group III were only instructed in sentence structure in connection with errors made in writing weekly themes. The results showed that all three groups made significant gains. However, the gains made by Group III appeared to be the most effective. This study indicates that students can learn sentence structure from either grammatical rules or in connection with needs demonstrated in their own writing. However, the latter seems to be more effective.

Structural grammar. Structural grammar describes the way the language is used (Greene & Petty, 1975). It differs from traditional grammar in that it recognizes that the English language is not a fixed language as in Latin. Because the English language is not a fixed language, structural grammar emphasizes word order, word forms, the meaning conveyed, and a few basic sentence patterns (Lundsteen, 1976). In other words, structural grammar views the English language as a function of word order and word forms, and the meaning they convey in sentences (Kean & Personke, 1976).

Word order (i.e., the branch of grammar referred to as syntax) is not included at this time because it is presented later in this section under the heading of syntax. However, word forms are presented in this section because structural grammar views the foundation of the English language as being composed of a few basic sentences that can be modified by word forms.

There are basically two groups of word forms or classes (Lundsteen, 1976). The first form or class is referred to as open class words which consists of nouns, verbs, adjectives, and adverbs. This class is referred to as open class because they can change and affect the meaning of the sentence. The second form or class is referred to as closed class words. Closed class words connect the open class words in a variety of ways (e.g., a preposition) to give the sentence structure and show relationships. According to structural grammar, it is the ordering of these forms or classes in sentence patterns that conveys the meaning of what is said or written.

Transformational-generative grammar. Transformational-generative grammar, or simply transformational grammar, emphasizes the process of the way the language works instead of dissecting already formed sentences and labeling their parts and surface features (Lundsteen, 1976). Transformational grammar begins with a basic sentence pattern and a number of rules so as to generate variations of this pattern by substituting, reordering, and combining parts (Greene & Petty, 1975). It is through this transformation process that all sentences in the English language are generated.

In transformational grammar, sentences have both a deep and a surface structure (Palmer, 1973). Frank Smith (1975) defines surface structure as the "physical characteristics of language" (p. 84). In speech, for example, the physical characteristics are the sounds that are spoken. In reading or writing, the physical characteristics are the marks on the paper. Deep structure is defined as "meaning . . . or the underlying thought processes of the language user" (F. Smith, 1975, p. 84). For example, consider the sentence "Dr. White's bills are high". This sentence can have two different meanings, or deep structures. One interpretation of the sentence can mean that is expensive for a patient to use Dr. White's services. A second interpretation of the same sentence can mean that the bills Dr. White has to pay are high. Therefore, two meanings, or deep structures, can be contained in the surface structure of the same sentence.

Whichever grammar one chooses as the best approach to the English language (i.e., traditional, structural, or transformational), grammar is the study of language that deals with both the forms and structures of words (morphology) as well as their customary arrangement in phrases and sentences (Greene & Petty, 1975; Lundsteen, 1976). In other words, morphology and syntax are both branches of grammar.

Morphology is the study of how one can change the meaning of a word by changing its word form (Lundsteen, 1976). A morpheme is the smallest unit of meaningful language that cannot be broken down into smaller units. By adding affixes, either prefixes or suffixes, to a word one can change its meaning.

Syntax is the study of word order. It is through word order that phrases and sentences obtain their meanings. Since syntax was of central importance in this study, the following section presents a general understanding of syntax as it relates to this study.

Syntax and Syntactic Complexity

Syntax is defined as "the study of the meaningful combination of words" (Green & Petty, 1975, p. 17). In other words, syntax is the order in which words are grouped or arranged to form meaningful phrases and sentences. Since syntax groups words in order to form meaningful phrases and sentences, it has the capacity to organize the reading material so that it is meaningful to the reader (Meyers & Hammill, 1976; Wisher, 1976). One has only to compare two simple sentences to see that syntax plays an important part in reading. The two sentences "The boy can play" and "Can the boy play?" contain the same words. However, because of the word order the two sentences have completely different meanings. Also, if the word order in the sentence "The boy can play" was changed to "The play can boy", then the sentence would be meaningless to the reader. It is quite apparent that without the organization that syntax provides the reader, sequences of words would be difficult to comprehend. This is because meaning in the English language is characterized by word order (Lundsteen, 1976).

Research has been conducted to determine the effect syntax has on a reader's ability to comprehend and to learn. In 1963, Miller and Isard conducted a study to see if there were any differences in students' ability to understand ungrammatical strings of words and grammatical sentences. They recorded 150 sentences that they played for eight subjects. The sentences they recorded consisted of three types:

1. The first set consisted of ungrammatical strings which violated both semantic and syntactic rules. An example of an ungrammatical string is "A political annual the slew document jeweler" (p. 227).

2. The next set was anomalous sentences that violated semantic rules but did not violate syntactic rules. For example, "Romantic ink follows wasted games" (p. 226).

3. The final set of sentences they recorded were grammatical sentences that obeyed both semantic and syntactic rules. An example of a grammatical sentence is "A witness signed the legal official document" (p. 226).

The investigators played the sentences from a tape recorder and the subjects had to immediately repeat the sentence after they heard it. The subjects listened to the sentences in two types of learning environments: (a) in a room with no background noise and (b) in a room with background noise. The results showed that the differences between the three types of sentences were statistically significant.

Miller and Isard found that their subjects performed the best when repeating the grammatically correct sentences, and exhibited the least performance with ungrammatical strings. This implies that their subjects were able to comprehend material best if the material was meaningful to them. Therefore, the results of Miller and Isards' study indicate that syntax does have an effect on a reader's ability to comprehend.

In 1961, Epstein compared structured and unstructured material to see if syntactic structure plays a role in verbal learning. He had six categories of materials:

1. Category one was a series of nonsense-syllables that were structured grammatically by inserting two functional words (i.e., a and the) and grammatical tags (e.g., ed on past tense verbs or s on plural nouns.

2. Category two consisted of two functional words without the grammatical tags.

3. Category three contained the same items as category one except the items were arranged in random order.

4. Category four contained the same items as category one except that the grammatical tags were restructured.

5. Category five consisted of meaningful words that met the demands of syntactic structure.

6. Category six contained the same words that were in category five, however, they were placed in a random unstructured manner.

The subjects, 192 students in an introductory psychology course, viewed the six categories of materials and were required to write down all the syllables after seeing them for seven seconds. If their responses were incorrect in any way they would repeat the process until it was completed perfectly. In his results, Epstein found that among the categories consisting of nonsense-syllables, category one required the fewest number of trials to complete the process. Also, among the categories that contained meaningful words, category five required fewer trials. These results indicate that the subjects performed better when the sentences met the demands of syntactic structure. Therefore, Epstein's results imply that the syntactical structure of materials aids a person's verbal learning.

Since syntax has been shown to have an effect on a person's reading ability (Epstein, 1961; Miller & Isard, 1963), educators need to be aware of sentence structure. For example:

> At age six, the average spoken sentence is about six or seven words long. In the period from kindergarten to the twelfth grade there is a gradual and progressive increase in the skill of the typical child according to the following criteria: (1) length of communication unit (or sentence); (2) grammatical maturity (or complexity); and (3) semantic (meaning), rhetorical (aim), and stylistic differences. (Lundsteen, 1976, p. 40).

Therefore, as children's language matures, they move away from a simple sentence structure and move on to more complex sentence structures.

As stated earlier, syntax organizes the reading material so that it is meaningful to the reader. Therefore, the way a sentence is structured can have an effect on a student's ability to comprehend reading material. That is, if the syntactic structure of a sentence is presented in a complex manner, then it may have an effect on a student's reading ability.

Sentences in the English language are structured so that they contain a subject and a predicate and usually consist of a noun or noun phrase followed by a verb (Lundsteen, 1976). This basic sentence pattern can be modified by either elaborating the basic pattern or compressing it. In other words, this basic sentence pattern can be modified by adding words to give more information or breaking the information in complex sentences down to form several shorter sentences. It is through this modification process of either elaborating or compressing that the syntactic structure of the sentence becomes either complex or very simple. For example, to make a sentence more readable, one can shorten a complex sentence by dividing compound and complex sentences into several shorter ones (Coleman, 1962).

In 1974, William Smith reported a study he conducted to determine if eighth and tenth graders altered passages when they rewrote those passages. The passages Smith administered to his subjects were written at three levels of syntactic complexity: (a) passages written at a syntactic level below the subjects' own level; (b) passages written at the subjects' own level of complexity; and (c) passages written at a level higher than the subjects' syntactic level. Smith found that the subjects altered the sentences that were written at a syntactic level below their own level as well as those passages that were too complex. The passages that were written at a syntactic level below the subject's own level were increased in complexity. The passages that were written at higher levels were decreased in complexity. The passages that were written at their own level of complexity were not appreciably changed. In general, Smith found that the ninth graders rewrote the passages in a more complex manner than the eighth graders. From this research Smith concluded that syntactic complexity of the language increases as a person matures. Smith also concluded that a person will reduce or attempt to reduce the complexity of the language to a level that is meaningful to that person.

This research indicates that sentence structure plays an important part in comprehension. This is because comprehension depends on the student's ability to recognize the surface syntactic structures and be able to understand the kinds of relations they represent (Neuwirth, 1976). If a student does not recognize or understand the surface syntactic structures of the reading material, then the reading material will not be meaningful to that student. In other words, if the student cannot comprehend the surface structure then the student will not be able to understand the meaning (or deep structure) of the reading material. Without an understanding of the surface structure, deep structure becomes impossible.

Other research in syntactic complexity has been conducted to determine what effect it has on primary reading materials (Kaiser, Neils, & Floriani, 1975). Since shortened sentence length has primarily been the only syntactic control in textbooks, Kaiser et al. conducted a study to see if these passages varied in terms of syntactic complexity. They also wanted to determine if these passages increased in syntactic complexity progressively throughout the text. To accomplish this, the investigators applied a syntactic complexity formula to the sentence structures. A basic sentence pattern (i.e., a sentence containing only a subject-predicate pattern) received a complexity count of zero. Any additions to this basic sentence pattern were given a count of one, two, or three, depending on the complexity of the additions. Therefore, the syntactic complexity of any sentence was the sum of the numbers assigned to it because of additions to the basic pattern. Kaiser et al. found that there was a great deal of variability between passages in terms of syntactic complexity. They also found that this complexity did not follow a systematic progression from less to more complex. From the results, they concluded that the authors and editors of children's textbooks need to be aware of the effect syntactic complexity has on reading material. They also stated that these authors and editors should use a syntactic complexity formula when preparing textbooks.

Syntactic Complexity in Mathematical Word Problems

While the effect of syntax on reading comprehension has received attention, little work has been done to determine what effect syntax has on a student's ability to complete written mathematical problems. In other words, if a student has difficulty comprehending the written problem, that student will also have difficulty in organizing the problem and deciding which mathematical operation to use. It seems reasonable to assume that difficult vocabulary and syntax will interfere with effective problem solving (Trueblood, 1969). This hypothesis was confirmed in a study by Linville (1976), when he conducted research to determine if syntax and vocabulary contributed to the difficulty of mathematical word problems. He also wanted to determine if sex, intelligence, and reading achievement has an effect on the subjects' ability to complete the problems. In order to ascertain whether these variables contributed to the difficulty of mathematical word problems, Linville administered four instruments (i.e., Test I--Easy Syntax, Easy Vocabulary; Test II--Easy Syntax, Difficult Vocabulary; Test III--Difficult Syntax, Easy Vocabulary; and Test IV--Difficult Syntax, Difficult Vocabulary) to 408 fourth grade pupils from 18 classes. One-hundred-four subjects each took Tests I, II, or III. The remaining 96 subjects took Test IV. The results showed significant differences for both syntax and vocabulary. Easy syntax scores were significantly higher than difficult vocabulary scores. Linville also found significant differences with regard to both intelligence and reading achievement. The subjects with higher intelligence had greater success in solving the word problems than students with lower intelligence. Likewise, students who scored high on reading achievement had greater success than did students who had lower scores on reading achievement. Finally, Linville found there were no significant differences between males and females. Both sexes were found to respond equally on the written mathematical problems. The results indicate that both syntax and vocabulary level can be contributors to difficulty in solving mathematical word problems. This study also implies that students with normal or above intelligence who are reading at grade level or above will experience greater success in solving written mathematical problems than students with lower intelligence who are reading below grade level.

In other research, Trenholme, Larsen, and Parker (1977) found that the syntactic complexity of written mathematical problems did have an effect on the mathematical performance of low-achieving eighth graders. Trenholme et al. administered three instruments (i.e., Test I--

Easy Syntax Test; Test II--Moderate Syntax Test; and Test III--Hard Syntax Test) to 45 eighth grade students enrolled in two remedial mathematics classes. The results showed that the subjects' scores on Test I were significantly higher than their scores on Test II or III, with Test III having the lowest scores. This implies that syntactic complexity of written mathematical problems does have an effect on a student's ability to complete the problems, particularly a low-achieving student.

Summary

Students receive instruction in mathematical computations so that they will be able to function effectively in our complex society. However, they need to possess other skills besides the ability to just compute mathematical operations. They must also be able to apply these computations to their every day life. This is why mathematical word problems are also considered to be a very important part of the mathematics program. It is by instructing students in mathematical word problems that educators assume the ability to compute mathematical operations will be transferred to the ability to compute in real life situations outside the educational setting.

Even though mathematical word problems are considered to be an important part of a mathematics program, there are many students who have difficulty with word problems. One possible explanation for this occurrence may be that the syntactic structure of the sentences in the problems are too complex for the students to understand.

Research has shown that syntax has an effect on reading comprehension. This implies that syntax may also have an effect on written mathematical problems. In other words, if the students do not understand the meaning of the sentences in the written mathematical problems, they may experience difficulty in organizing the problem and selecting the correct mathematical operation needed to solve the problem correctly. Therefore, syntactic complexity may have an effect on a student's performance with mathematical word problems.

CHAPTER THREE

RESEARCH DESIGN

A description of the research design is presented in this chapter. The sections included in this chapter are: (a) the statement of the problem, (b) the hypotheses, (c) a description of the sample, (d) a description of the instruments, (e) the data collection procedures, (f) the statistical analysis, and (g) the limitations of the study.

Statement of the Problem

The purposes of this study were: (a) to determine if the syntactic complexity of written mathematical problems had an effect on low-achieving eighth and tenth grade students' ability to solve the problems and (b) to determine if there was a difference between the eighth and tenth grade students' ability to solve the written mathematical problems.

Aspects of this study are a replication of a study by Trenholme, Larsen, and Parker (1977). As in the Trenholme et al. study, syntactic complexity was measured by sentence structure, while mathematical ability was measured by the number of incorrect responses on the three syntax tests containing written mathematical problems. The mathematical computation skills and vocabulary level on these tests were held constant at a fourth grade level or below. Therefore, it would appear that any variations in the scores should be attributed to the syntactic complexity (i.e., easy syntax, moderate syntax, or hard syntax) of the written mathematical problems.

This study differs from the Trenholme et al. (1977) study in that the computations (i.e., addition and subtraction, with and without regrouping) on the testing instruments were changed so that they would be equally distributed throughout the tests. Also, the investigator controlled for the subjects' reading vocabulary and mathematical computations by determining that the subjects had a minimum fourth grade achievement level in these skills. Furthermore, this study differs from the Trenholme et al. study in that it not only attempts to determine the influence of syntactic complexity on written mathematical problems, but it also attempts to determine if there is a difference between two grade levels (i.e., eighth and tenth grade) relating to the influence of syntactic complexity on mathematical word problems.

Hypotheses

Hypothesis 1: There will be a significant difference between the mean discrepancy scores (i.e., the total number of problems minus the number correct) of the Easy Syntax Test, the Moderate Syntax Test, and the Hard Syntax Test administered to low-achieving eighth grade students. The direction the differences are expected to progress are from Easy Syntax Test to Hard Syntax Test, with the subjects obtaining larger discrepancy scores on the Hard Syntax Test.

<u>Hypothesis 2</u>: There will be a significant difference between the mean discrepancy scores of the Easy Syntax Test, the Moderate Syntax Test, and the Hard Syntax Test administered to low-achieving tenth grade students. The direction the differences are expected to progress are from Easy Syntax Test to Hard Syntax Test, with the subjects obtaining larger discrepancy scores on the Hard Syntax Test.

<u>Hypothesis 3</u>: There will be a significant difference between the total mean discrepancy scores of low-achieving eighth and tenth grade students on the Easy Syntax Test, the Moderate Syntax Test, and the Hard Syntax Test. Differences are expected to occur between the two grade levels on each test, with the tenth grade obtaining lower discrepancy scores on each test.

Description of the Sample

The subjects in this study consisted of 60 low-achieving eighth and tenth grade students enrolled in remedial mathematics classes. The students were selected from three public schools located in two separate surburban areas in Oklahoma. Twenty of the eighth graders were selected from one Middle School and the remaining eighth graders were selected from one Junior High School. Both locations are adjacent to the same major city in a large metropolitan community. The 30 tenth grade students were selected from one Mid-High School. The Mid-High School was located in the same school district as the Middle School that was involved in this study.

The 20 eighth grade students selected from the Middle School were drawn from classes taught by four different teachers. The remaining

10 eighth grade students were drawn from one teacher's classroom. The 30 tenth grade subjects were drawn from four classes taught by the same teacher. The 60 subjects selected for this study were all enrolled in remedial mathematics classes where they received instruction in the application of general mathematical concepts. The subjects' performance in mathematics were at two or more grade levels below the expected performance of an eighth and tenth grader. However, the subjects were performing at least at a fourth grade level of achievement in mathematics.

Of the 60 subjects, there were 39 males and 21 females. The ages of the subjects ranged from 13 years 6 months to 17 years 3 months, with a mean age of 15 years 2 months. The full-scale intelligence of the subjects ranged from 70 to 119, with a mean intelligence of 94. However, only 16 of the 30 intelligence scores for the eighth grade subjects were obtainable. Finally, of the 60 subjects, 59 were Caucasian and one eighth grader was of Arabian ethnicity. Information pertaining to both the eighth and tenth grade sample for sex, age, and full-scale intelligence is presented in Table 1.

Description of the Instruments

The three tests that were administered in this study are described in this section. Four other topics related to the instruments are also included: (a) the vocabulary level used on the instruments, (b) the number of operations required to complete the problems, (c) the difficulty of the operations that are included on the tests, and (d) the process of logical reasoning needed to complete the problems on

Table 1

Data Pertaining to the Subjects with Regard to Sex, Age, and Full-Scale Intelligence

		Eighth Graders (N=30)	Tenth Graders (N=30)
Sex	M	19	20
	F	11	10
Age (Years-Months)	Range	13-6 to 15-1	15-5 to 17-3
	Mean	14-2	16-1
Full-Scale Intelligence	Range	70 to 119	78 to 110
	Mean	91.69 (N=16)	94.53

the instruments (i.e., deductive reasoning).

Three instruments (see Appendix A) were used to measure syntactic complexity of written mathematical problems: (a) Easy Syntax Test (EST), (b) Moderate Syntax Test (MST), and (c) Hard Syntax Test (HST). The three instruments used in this study were designed by Trenholme (1976) and used in a study that was concerned with the effects of syntactic complexity upon the ability to solve written mathematical problems with low-achieving eighth grade students (Trenholme, Larsen, & Parker, 1977). For the present investigation, the number of problems, the basic wording of the problems, and the sentence structures in each test remained the same as in the Trenholme et al. study. However, the computations (i.e., addition and subtraction, with and without regrouping) on the testing instruments were changed so that they would be equally distributed throughout each test. Also, the problems were reorganized according to degree of difficulty (i.e., the easier problems were introduced first with the harder problems at the end of each test) by Dr. Marcia Funnell, Assistant Professor of Elementary Mathematics Education at the University of Oklahoma.

As in the Trenholme et al. (1977) study the items on the EST consisted of two or three simple sentences and one interrogative sentence. An example of a problem from the EST is shown below.

> Jim likes to bake cookies for his family. Last night he baked 56 cookies. He gave 24 of them to his friend. How many cookies will his family have to eat?

Trenholme, Larsen, and Parker (1977) found that the Kuder-Richardson 21 reliability for the EST was .84.

The items on the MST also follow Trenholme et al. example in that they consisted of either (a) one simple sentence, one complex sentence, and one interrogative sentence or (b) one simple sentence and one complex interrogative sentence. A complex sentence contains a dependent clause and an independent clause.

Examples of both types of problems from the MST are shown below.

(a) Rusty had 92 boxes to take to the basement. (simple sentence) After the first trip he made, there were 38 boxes to take to the basement. (complex sentence) How many boxes did he take on the first trip? (simple interrogative sentence)

(b) During the summer Paul's team played 68 games. (simple sentence) If they won 26 of the games they played, how many games did Paul's team lose? (complex interrogative sentence)

Trenholme et al. found that the Kuder-Richardson 21 reliability for the MST was .81.

Finally, as in Trenholme et al., the items on the HST consisted of either (a) a compound sentence and a complex interrogative sentence (i.e., two dependent clauses joined by a conjunction) or (b) a compound/complex interrogative sentence (i.e., either two dependent clauses and an independent clause or one dependent clause and two independent clauses). Examples of both types of problems from the HST are shown below.

(a) Mary walked 33 blocks from school to the library and then she walked home. (compound sentence) If she walked a total of 47 blocks, how many blocks is it from the library to her home? (complex interrogative sentence)

(b) If it is 23 miles on a bicycle from Jim's house to Bob's house by staying on the streets and it is 15 miles shorter by cutting through the park, how long is the trip the shorter way? (compound/complex interrogative sentence)

Trenholme et al. found the Kuder-Richardson 21 reliability for the HST to be .85.

The average number of words used in each problem, the average number of words per sentence, and the average number of sentences per problem for each test were computed and are provided in Table 2. The average number of words per problem was computed by determining the number of words in each problem and dividing by the number of problems on a test. The average number of words per sentence was computed by determining the number of words in each sentence and dividing by the number of sentences on a test. The average number of sentences per problem was computed by determining the number of sentences in each problem and dividing by the number of problems on a test.

Vocabulary Level

In constructing the items for the three tests, the Dale-Chall List of 3000 Familiar Words (1948) was consulted. Only words or derivatives of those words considered to be at or below a fourth grade reading level were used. This was done to keep the readability of the three tests well within the expected reading vocabulary of eighth and tenth graders.

Number of Operations

Only one operation or step is required to complete the problems on all three tests. The operation required for each problem was either addition or subtraction. Multiplication and division were not included in this study because they may have a confounding influence on the outcome. In other words, the mathematical operation may be measured instead of syntactic complexity if a subject is not able to complete the problem correctly because it requires multiplication or division.

Table 2

Mean Number of Words Per Problem and Sentence, Mean Number of Sentences Per Problem, and Number of Problems Per Test

	Test 1	Test 2	Test 3
Mean number of words per problem	27.00	28.89	27.82
Mean number of words per sentence	7.35	10.60	21.82
Mean number of sentences per problem	3.68	2.74	1.38
Number of problems per test	22	19	24

Difficulty of Operations

The problems on all three tests were selected from a fourth grade textbook (Duncan, Quast, Allen, Capps, Ebos, & Haubner, 1978) so as to be within the expected range of competency for eighth and tenth grade students enrolled in remedial mathematics classes. The mathematical computations required to complete the problems were distributed equally among the three tests and are listed below.

Addition:

1. Two digit numerals with no regrouping (i.e., carrying) required.
2. Two digit numerals with regrouping required in the one's column.
3. Three digit numerals with no regrouping required.
4. Three digit numerals with regrouping required in the one's column.
5. Three digit numerals with regrouping required in the one's and ten's column.
6. Four digit numerals with no regrouping required.
7. Four digit numerals with regrouping required in the one's column.

Subtraction:

1. Two digit number from a two digit number with no regrouping (i.e., borrowing) required.
2. Two digit number from a two digit number with regrouping required in the one's column.

3. Three digit number from a three digit number with no regrouping required.
4. Three digit number from a three digit number with regrouping required in the one's column.
5. Three digit number from a three digit number with regrouping required in the one's and ten's column.

Deductive Reasoning

In order to be certain that these measurements are measuring syntactic complexity, all of the questions require deductive logic. In other words, all of the problems in the three tests proceed from a generalized statement to a specific question.

Data Collection Procedures

Administration of the Instruments

All of the subjects were administered the three group tests of syntactic complexity (i.e., EST, MST, and HST) during their regular mathematics class period. The tests administered at the Middle School and the Mid-High School were given to the subjects by the investigator, without the teachers' attendance. The tests administered at the Junior High School were given to the subjects by a qualified examiner who was instructed in the procedures of administering the instruments. Each class was administered only one test per class period. In other words, one class period for three days was needed to administer the three instruments so as not to place a time limit on the subjects.

In order to control for a possible practice effect, the tests were administered to the subjects in a different order. One group of eighth and tenth graders were administered the EST on the first day; the second day the MST was administered; and finally, on the third day the HST was administered. A second group of eighth and tenth graders was administered the MST on the first day; the second day the HST was administered; and finally, on the third day the EST was administered. Finally, a third group of eighth and tenth graders was administered the HST on the first day; the second day the EST was administered; and finally, on the third day the MST was administered.

The subjects were instructed to read the problems and complete the required computations. They were told that space was available on the tests for any necessary calculations. They were also told to put their answers on the line provided at the right of each problem. Furthermore, the subjects were told that they would not be able to receive help during the testing session. Finally, to avoid anxiety, the subjects were told that these instruments would not affect their mathematics grade.

Collection of Other Data

In September 1977, the Comprehensive Tests of Basic Skills (1973) was administered to the 30 tenth grade subjects and 16 of the eighth grade subjects. The tenth graders were administered the fourth level, from S of the Comprehensive Tests of Basic Skills (CTBS), and the eighth graders were administered the third level, form S. The investigator collected and recorded the Reading Vocabulary and Mathematics Computation subtest scores of those 46 subjects in order to ascertain that they were performing at a minimum fourth grade achievement level in those areas. A minimum fourth grade achievement level in reading vocabulary was considered necessary because the three tests of syntactic complexity in mathematical word problems were written at a fourth grade reading level. Also, a minimum fourth grade achievement level in mathematical computations was necessary because the three tests contained computations taken from a fourth grade mathematics textbook (Duncan, Quast, Allen, Capps, Ebos, & Haubner, 1978). Therefore, the Reading Vocabulary subtest scores were recorded to insure that the vocabulary or reading levels that were employed in the three tests were within the performance level of the subjects. Also, the Mathematics Computation subtest scores were recorded to insure that the subjects were capable of performing the necessary computations.

To ascertain a minimum fourth grade reading vocabulary for the 14 eighth grade subjects who were not administered the CTBS in September 1977, the investigator located other scores from achievement tests that were administered at different times. Three of the subjects had received reading vocabulary scores from achievement tests that had been administered during the 1977-78 school year. Two of the subjects had been administered the Wide Range Achievement Test (1965) and one subject had been administered the Gates-MacGinitie Reading Tests (1965). The remaining 11 subjects had received reading vocabulary scores from achievement tests that were administered in April 1977. One subject had been administered the CTBS and the other ten subjects had been administered the Gates-MacGinitie Reading Tests.

In order to maintain a minimum fourth grade level in mathematical computations for 10 of the 14 eighth grade subjects that were not administered the CTBS, the investigator relied upon an informal teacher-made instrument that was administered in September 1977. To gain a minimum fourth grade achievement level on that teacher-made test, the subjects had to be able to add and subtract with regrouping. Since these were the mathematical computations that were contained on the three tests in this study, the investigator considered the teacher-made test to be an effective measurement for this study. To insure that the remaining four eighth grade subjects were capable of performing the necessary computations, the investigator relied upon teachers' judgment. Research has shown that teachers' judgment is just as effective as standardized testing (Ausubel, Schiff, & Zeleny, 1974; Dixon, Fukuda, & Berens, 1969; English & Kiddler, 1969). One advantage of teachers' judgment is that it is conducted over a prolonged period of time and the behavior can be observed under a variety of situations (Ausubel, Schiff, & Zeleny, 1974).

Intelligence scores were also collected and recorded for 46 of the 60 subjects. In September 1976 the Short-Form Test of Academic Aptitude, Level 4 (1970) was administered to the 30 tenth grade subjects. The same instrument was administered to 16 of the 30 eighth grade subjects in September 1977. The investigator collected these data in an attempt to control for the subjects' ability to complete the three tests of syntactic complexity in written mathematical problems. Since this study dealt with low-achieving students and not mentally retarded students, a minimum full-scale intelligence score of 70 was the lowest intellectual level included in the study. Once again the investigator had to rely upon teachers' judgment that the remaining 14 eighth grade subjects also had the intellectual level needed to complete the tests in this study.

Statistical Analysis

This study consisted of three sets of measurements (i.e., easy syntax, moderate syntax, and hard syntax) on the same experimental variable (i.e., syntactic complexity). Since the hypotheses in this study consisted of several samples of the same general character and the investigator wanted to determine whether there were any significant differences between the means of the discrepancy scores (i.e., the total number of problems minus the number correct), a split-plot factorial design with repeated measures was utilized (Kirk, 1968). A graphic design is provided in Table 3.

The dependent variables in this study were the discrepant mathematics scores that were obtained on the three tests of syntactic complexity. The major independent variables were grade level (i.e., eighth or tenth grade) and syntactic complexity (i.e., easy syntax, moderate syntax, and hard syntax).

Where the statistical analysis indicated significant differences between the means, a multiple comparison (vis., the multiple t test) of the means was utilized. This was done to determine where the significant differences actually existed.

Limitations

Even though the investigator attempted to control for confounding effects in this study, there are several limitations. The first limitation of this study involved age. The investigator attempted

Table 3

Research Design

Group	Easy Syntax	Moderate Syntax	Hard Syntax
8th grade	$\bar{X}_{1a}$	$\bar{X}_{1b}$	$\bar{X}_{1c}$
10th grade	$\bar{X}_{2a}$	$\bar{X}_{2b}$	$\bar{X}_{2c}$

Note: $\bar{X}$ = mean score on math test.

to control for age by utilizing grade levels. However, a wide range of ages was found to be contained within each grade level. There was a 1 year 7 months age-range (i.e., 13 years 6 months to 15 years 1 month) for the eighth grade subjects and 1 year 10 months age-range (i.e., 15 years 5 months to 17 years 3 months) for the tenth grade subjects. This wide age-range within grade levels, particularly with the tenth grade, was considered to be a limitation because there are many processes, including learning, that vary with the passage of time (Campbell & Stanley, 1963).

A second limitation of this study involved the different achievement tests that were administered to the eighth grade subjects. In order to ascertain a minimum fourth grade reading level, Reading Vocabulary subtest scores were collected from three achievement tests (i.e., Comprehensive Tests of Basic Skills, Wide Range Achievement Test, and Gates-MacGinitie Reading Tests). Although every subject had at least a minimum fourth grade level on the Reading Vocabulary subtests, there may be variations in the effectiveness of the three achievement tests regarding the measurement of this ability.

A third limitation of this study involved the number of different teachers' classrooms from which the sample was selected. The eighth grade sample was selected from five different teachers' classroom, while the tenth grade sample was selected from the same teacher's classroom. The investigator views the differing number of teachers as a limitation because every teacher is different and one teacher may be more effective than another. Therefore, while the 30 tenth graders received the effect of only one teacher for the school year 1977-78, the effect of five different teachers was distributed among the eighth graders (i.e., ten eighth graders were selected from one teacher's classroom, eight eighth graders were selected from a second teacher's classroom, another eight eighth graders were selected from a third teacher's classroom, and finally, one eighth grader was selected from a fifth teacher's classroom).

A fourth and final limitation of this study involved the teachers' judgment with regard to (a) the mathematical computational level of 12 eighth grade subjects and (b) the intellectual level of 14 eighth grade subjects. Even though research indicates that teachers' judgments are just as effective as standardized testing (Ausubel, Schiff, & Zeleny, 1974; Dixon, Fukuda, & Berens, 1969; English & Kiddler, 1969), the investigator views as a limitation the fact that three teachers were involved in judging the mathematics computation level for the 12 eighth grade students and three teachers were also responsible for judging the intellectual levels of the 14 eighth graders. Therefore, because several teachers were responsible for these judgments, there may be variations in the accuracy of their judgments.

CHAPTER FOUR

RESULTS

In order to present a brief background of the study and the results of the statistical analyses, this chapter is divided into four sections. The first section is a brief description of the purpose of the study. The second section contains the results of the statistical analyses of the three hypotheses. Other variables (i.e., age, sex, full-scale intelligence, reading vocabulary, and mathematical computation level) are analyzed in the third section. Finally, the results are summarized in the fourth section.

Background of the Problem

This study was conducted as an attempt to determine the effect syntactic complexity has on written mathematical problems. In other words, what effect did the manner in which a mathematical word problem was written have on a subjects' ability to answer the questions correctly? The subjects consisted of 60 low-achieving eighth and tenth grade students who were enrolled in remedial mathematics classes. Each of the 60 subjects had a minimum fourth grade achievement level in reading vocabulary and mathematical computations.

In order to determine the effect syntactic complexity has on written mathematical problems, the subjects were administered the revised form of the Trenholme (1976) instruments. After administering the instruments to the 60 subjects, the investigator utilized the split-half method (Downie & Heath, 1974) to measure the internal consistency of the instruments. The reliabilities for the tests administered to the eighth grade, tenth grade, and the combined eighth and tenth grade group are presented in Table 4.

Table 4

Reliabilities for the Eighth Grade, Tenth Grade
and Combined Group on the EST, MST, and HST

	8th Grade	10th Grade	Combined Group
Easy Syntax Text	.80	.02	.72
Moderate Syntax Test	.51	.11	.41
Hard Syntax Test	.75	.40	.80

The reliabilities of the instruments were found to present a limitation to the present study. Even though the reliabilities of the EST and HST for the eighth grade and combined group were found to be adequate (Guilford & Fruchter, 1973), the other reliabilities were very low. However, the investigator credits the low reliabilities to the small sample size and the homogeniety of the sample. Anastasi (1968) states that "any correlation coefficient is affected by the range of individual differences in the group" (p. 92). Since the sample size for this present investigation was small and included only low-achieving students with a minimum fourth grade reading vocabulary level and mathematical computation level, there was a lack of variability within the subjects. Therefore, the small range of talent lowered the reliability scores (Minium, 1970).

Evaluation of the Hypotheses

Hypothesis 1: There will be a significant difference between the mean discrepancy scores (i.e., the total number of problems minus the number correct) of the Easy Syntax Test, Moderate Syntax Test, and Hard Syntax Test administered to low-achieving eighth grade students. The direction the differences are expected to progress are from Easy Syntax Test to Hard Syntax Test, with the subjects obtaining larger discrepancy scores on the Hard Syntax Test.

In order to determine whether a difference existed between the discrepancy scores of the Easy Syntax Test (EST), Moderate Syntax Test (MST), and Hard Syntax Test (HST) for the eighth grade students, a split-plot analysis of variance (ANOVA) with repeated measures was utilized (Kirk, 1968). The results of the ANOVA are presented in Table 5.

Table 5

ANOVA for the Eighth Grade on the Discrepancy Scores of the EST, MST, and HST

Source	df	SS	MS	Calculated F-Value	Significance Level
Between Tests	2	134.15	67.08	12.40	$p < .001$
Error	58	313.84	5.41		

The results of the ANOVA revealed that a difference did exist between the discrepancy scores of these tests for the eighth grade students. Therefore, the investigator utilized a multiple *t* comparison of the means (Bartz, 1976) to determine where the differences actually existed. This information is presented in Table 6.

Table 6

Multiple *t* Comparison of the Means of the EST, MST, and HST for the Eighth Grade

Test	EST	MST	HST
EST	---	.67	3.95*
MST		---	4.62*
HST			---

*$p < .001$

The results of the multiple *t* comparison revealed that there was no difference between the discrepancy scores of the EST and MST. However, there were significant differences between the discrepancy scores of the EST and HST and the discrepancy scores of the MST and HST.

Hypothesis 2: There will be a significant difference between the mean discrepancy scores of the Easy Syntax Test, Moderate Syntax Test, and Hard Syntax Test administered to low-achieving tenth grade students. The direction the differences are expected to progress are from Easy Syntax Test to Hard Syntax Test, with the subjects obtaining larger discrepancy scores on the Hard Syntax Test.

As was done with the eighth grade sample, a split-plot ANOVA with repeated measures was utilized to determine if a difference existed. The results of the ANOVA are presented in Table 7. Since the results revealed that a difference did not exist between the discrepancy scores on the EST, MST, and HST, no further analysis was conducted on the data.

Table 7

ANOVA for the Tenth Grade on the Discrepancy Scores on the EST, MST, and HST

Source	df	SS	MS	Calculated F-Value	Significance Level
Between tests	2	.87	.43		
				.24	$p > .05$
Error	58	103.80	1.79		

Hypothesis 3: There will be a significant difference between the total mean discrepancy scores of low-achieving eighth and tenth grade students on the Easy Syntax Test, Moderate Syntax Test, and Hard Syntax Test. Differences are expected to occur between the grade levels on each test, with the tenth grade obtaining lower discrepancy scores on each test.

A split-plot ANOVA with repeated measures was utilized in order to determine whether a difference existed between the eighth and tenth grade students on the discrepancy scores of the testing instruments. These results are presented in Table 8 and they showed that a difference did exist between the eighth and tenth grade students on the discrepancy scores of the EST, MST and HST. Therefore, the investigator compared the discrepancy scores of the testing instruments by grade and the results are presented in Tables 9, 10, and 11. The comparison revealed that there were differences between grade levels on all three tests (i.e., EST, MST, and HST), with the tenth grade having a lower discrepancy score on each of the three tests.

Analysis of Other Variables

An analysis of the discrepancy scores on the EST, MST, and HST on other independent variables was conducted to ascertain that they were not confounding the results. These variables included age, sex, full-scale intelligence quotient (FSIQ), reading vocabulary level, and mathematical computation level.

Age

In order to determine if age was a confounding variable on the eighth grade subjects ability to complete the tests, a split-plot ANOVA

Table 8

ANOVA for Grade on the Discrepancy Scores of the EST, MST, and HST for the Eighth and Tenth Grade Sample

Source	df	SS	MS	Calculated F-Value	Significance Level
Grade	1	271.34	271.34		
				25.27	$p < .001$
Error	58	622.72	10.74		

Table 9

Discrepancy Scores on the EST by Grade

Grade	Mean	Standard Deviation	Calculated F-Value	Significance Level
8th	3.83	3.05		
			9.43	$p < .01$
10th	2.00	1.17		

Table 10

Discrepancy Scores on the MST by Grade

Grade	Mean	Standard Deviation	Calculated F-Value	Significance Level
8th	3.43	2.22		
			9.26	$p < .01$
10th	1.93	1.53		

Table 11

Discrepancy Scores on the HST by Grade

Grade	Mean	Standard Deviation	Calculated F-Value	Significance Level
8th	6.20	3.90		
			27.27	$p < .001$
10th	2.17	1.64		

with repeated measures (Kirk, 1968) was utilized with the discrepancy scores of the EST, MST, and HST. The results of this ANOVA for the eighth grade are presented in Table 12. They revealed that a difference did not exist between age and the discrepancy scores for the eighth grade subjects.

A split-plot ANOVA with repeated measures was also utilized on the discrepancy scores of the testing instruments for the tenth grade subjects in order to determine if age influenced their ability to complete the tests. The results of the ANOVA for the tenth grade are presented in Table 13. These results showed that a difference did exist between age and the discrepancy scores on the EST, MST, and HST for the tenth grade subjects. Therefore, the discrepancy scores of each test were compared by age levels for the tenth grade. This information is presented in Tables 14, 15, and 16.

The outcome of the comparisons revealed that age did not influence the discrepancy scores on the EST and MST. However, the analysis indicated that age did influence the discrepancy scores of the HST. Therefore, in order to determine where the difference existed a multiple <u>t</u> comparison (Bartz, 1976) was utilized to compare the means of the HST by age. This information is presented in Table 17.

The multiple <u>t</u> comparison revealed that the difference on the HST was between the fifteen year-olds and the seventeen year-olds, with the fifteen year-olds making fewer incorrect responses. However, because there were only two seventeen year-olds, this result should be viewed with caution.

Table 12

ANOVA for Age on the Discrepancy Scores of the EST, MST, and HST for the Eighth Grade

Source	df	SS	MS	Calculated F-Value	Significance Level
Age	2	16.88	8.34		
				.43	$p > .05$
Error	27	523.80	19.40		

Table 13

ANOVA for Age on the Discrepancy Scores of the EST, MST, and HST for the Tenth Grade

Source	df	SS	MS	Calculated F-Value	Significance Level
Age	2	15.59	7.80		
				3.16	$p < .05$
Error	27	66.64	2.47		

Table 14

Discrepancy Scores on the EST by Age for the Tenth Grade

Age	Mean	Standard Deviation	Calculated F-Value	Significance Level
15 yrs. (N = 12)	1.25	.87		
16 yrs. (N = 16)	2.31	.95	2.19	$p > .05$
17 yrs. (N = 2)	4.00	1.41		

Table 15

Discrepancy Scores on the MST by Age for the Tenth Grade

Age	Mean	Standard Deviation	Calculated F-Value	Significance Level
15 yrs.	1.67	1.56		
16 yrs.	2.12	.59	1.78	$p > .05$
17 yrs.	2.00	1.41		

Table 16

Discrepancy Scores on the HST by Age for the Tenth Grade

Age	Mean	Standard Deviation	Calculated F-Value	Significance Level
15 yrs.	1.92	1.08		
16 yrs.	2.19	1.80	6.53	$p < .001$
17 yrs.	3.50	3.50		

Table 17

Multiple t Comparison of the Means of the HST by Age for the Tenth Grade

Age	15 yrs.	16 yrs.	17 yrs.
15 yrs.	---	.78	2.29*
16 yrs.		---	1.93
17 yrs.			---

*$p < .05$

Sex

In order to determine if sex had any influence on the subjects' ability to complete the tests, a split-plot ANOVA with repeated measures was utilized on the discrepancy scores of the EST, MST, and HST for both the eighth and tenth grade subjects. These results are presented in Tables 18 and 19. Since the ANOVAs indicated that a difference did not exist between the discrepancy scores on the three testing instruments for both the eighth and tenth grade subjects according to sex, no further analysis was conducted on the data.

Full Scale Intelligence Quotient (FSIQ)

In order to determine what effect FSIQ had on the subjects ability to complete the tests, a split-plot ANOVA with repeated measures was utilized with the discrepancy scores of the EST, MST, and HST for both the eighth and tenth grade subjects. These results are presented in Tables 20 and 21.

Table 18

ANOVA for Sex on the Discrepancy Scores of the EST, MST, and HST for the Eighth Grade

Source	df	SS	MS	Calculated F-Value	Significance Level
Sex	1	14.04	14.04		
				.75	$p > .05$
Error	28	526.44	18.80		

Table 19

ANOVA for Sex on the Discrepancy Scores of the EST, MST, and HST for the Tenth Grade

Source	df	SS	MS	Calculated F-Value	Significance Level
Sex	1	.05	.05		
				.02	$p > .05$
Error	28	82.18	2.94		

Table 20

ANOVA for FSIQ on the Discrepancy Scores of the EST, MST, and HST for the Eighth Grade

Source	df	SS	MS	Calculated F-Value	Significance Level
FSIQ	4	86.78	21.69		
				1.31	$p > .05$
Error	11	182.22	16.56		

Table 21

ANOVA for FSIQ on the Discrepancy Scores of the EST, MST, and HST for the Tenth Grade

Source	df	SS	MS	Calculated F-Value	Significance Level
FSIQ	4	22.03	5.51		
				2.28	$p > .05$
Error	25	60.20	2.41		

These results revealed that FSIQ did not influence either the eighth or tenth grade students ability to solve the problems on the testing instruments. Therefore, no further analysis was conducted on the data.

Reading Vocabulary Level

Even though the testing instruments were written at a fourth grade reading level, and all the subjects had a minimum fourth grade reading vocabulary level, the investigator was interested in the reading vocabulary levels for both the eighth and tenth grade. This is because reading vocabulary level may have influenced the subjects' ability to complete the problems on the testing instruments. Subjects with higher reading vocabulary achievement levels may have had a better understanding of the syntactic structures contained in the three tests. Therefore, a student $\underline{t}$ distribution (Minium, 1970) was utilized on the eighth and tenth grade reading vocabulary level means to determine if there was a significant difference between the means. This information is presented in Table 22. The statistical analysis revealed that a significant difference did exist between the eighth and tenth grade subjects with the tenth grade subjects having a higher mean reading vocabulary level.

The investigator also wanted to determine if reading vocabulary level had a confounding effect on either the eighth or tenth grade subjects ability to complete the tests. Therefore, a split-plot ANOVA with repeated measures was utilized with the discrepancy scores of the EST, MST, and HST by reading vocabulary level for both eighth and tenth grade subjects and these results are presented in Tables 23 and 24.

Table 22

Difference in Reading Vocabulary Level Between the Eighth and Tenth Grade

Grade	Mean Vocabulary Level	Standard Deviation	Calculated t-Value	Significance Level
8th	6.13	2.34		
			5.69	$p < .01$
10th	9.83	2.67		

The results of the ANOVAs presented in Tables 23 and 24 indicated that a difference did not exist between reading vocabulary level and the discrepancy scores for either the eighth or tenth grade. Consequently, no further analysis was conducted on the data.

Mathematical Computation Level

As with reading vocabulary level, the investigator was interested in the mathematical computation levels for both the eighth and tenth grade subjects because the computations required on the testing instruments were taken from a fourth grade textbook. Even though all the subjects had a minimum fourth grade mathematical achievement level, those subjects with higher computation achievement levels may have had a better understanding of the computations required on the three tests. Therefore, a student t distribution was utilized to compare the mean mathematical computation levels in order to determine if there was a significant difference between the computation levels for the eighth

Table 23

ANOVA for Reading Vocabulary Level on the Discrepancy Scores of the EST, MST, and HST for the Eighth Grade

Source	df	SS	MS	Calculated F-Value	Significance Level
Reading	7	206.76	29.54		
				1.95	$p > .05$
Error	22	333.73	15.17		

Table 24

ANOVA for Reading Vocabulary Level on the Discrepancy Scores of the EST, MST, and HST for the Tenth Grade

Source	df	SS	MS	Calculated F-Value	Significance Level
Reading	8	21.79	2.72		
				.95	$p > .05$
Error	21	60.44	2.88		

and tenth grade subjects. This information is presented in Table 25. As with reading vocabulary, a significant difference was found to exist between the mean mathematical computation levels, with the tenth grade subjects achieving at a higher mean mathematical computation level.

Also, a split-plot ANOVA with repeated measures was utilized with the discrepancy scores of the EST, MST, and HST according to mathematical computation level for both the eighth and tenth grade subjects. These analyses were conducted to determine whether mathematical computation levels had an effect on either the eighth or tenth grade subjects' ability to complete the tests and are presented in Tables 26 and 27.

The results of the statistical analyses for the effect of mathematical computation levels on the discrepancy scores revealed that a difference did exist for the eighth grade, but did not exist for the tenth grade. Therefore, no further analysis was conducted for the tenth grade. Since there was a difference with the eighth grade, the discrepancy scores on the EST, MST, and HST were compared according to mathematical computation levels. This information is presented in Tables 28, 29, and 30.

These statistical analyses showed that mathematical computation level did not influence the discrepancy scores on the EST and MST with the eighth grade subjects. However, the analysis indicated that mathematical computation levels did have a significant effect on the discrepancy scores of the HST. In order to determine where the differences existed, a multiple $\underline{t}$ comparison was utilized to compare the means of the HST by mathematical computation level (Bartz, 1976). This information is presented in Table 31.

Table 25

Difference in Mathematical Computation Level Between the Eighth and Tenth Grade

Grade	Mean	Standard Deviation	Calculated t-Value	Significance Level
8th	4.35	.56		
			7.59	$p < .01$
10th	6.27	1.25		

Table 26

ANOVA for Mathematical Computation Level on the Discrepancy Scores of the EST, MST, and HST for the Eighth Grade

Source	df	SS	MS	Calculated F-Value	Significance Level
Mathematics	2	119.00	59.50		
				5.78	$p < .01$
Error	15	154.50	10.30		

Table 27

ANOVA for Mathematical Computation Level on the Discrepancy Scores of the EST, MST, and HST for the Tenth Grade

Source	df	SS	MS	Calculated F-Value	Significance Level
Mathematics	4	2.61	.65		
				.20	$p > .05$
Error	25	79.62	3.18		

Table 28

Discrepancy Scores on the EST by Mathematical Computation Level for the Eighth Grade

Mathematical Computation Level	Mean	Standard Deviation	Calculated F-Value	Significance Level
4th grade (N = 11)	4.27	2.61		
5th grade (N = 6)	2.83	2.48	.83	$p > .05$
6th grade (N = 1)	2.00	0.00		

Table 29

Discrepancy Scores on the MST by Mathematical Computation Level for the Eighth Grade

Mathematical Computation Level	Mean	Standard Deviation	Calculated F-Value	Significance Level
4th grade	4.36	2.54		
5th grade	2.17	1.60	2.05	$p > .05$
6th grade	2.00	0.00		

Table 30

Discrepancy Scores on the HST by Mathematical Computation Level for the Eighth Grade

Mathematical Computation Level	Mean	Standard Deviation	Calculated F-Value	Significance Level
4th grade	9.36	3.67		
5th grade	3.50	1.38	6.98	$p < .01$
6th grade	8.00	0.00		

Table 31

Multiple *t* Comparison of the Means of the HST by Mathematical Computation Level for the Eighth Grade

Mathematical Computation Level	4th Grade	5th Grade	6th Grade
4th Grade	---	3.73*	.42
5th Grade		---	1.34
6th Grade			---

$^*p < .05$

The multiple t comparison of the mean discrepancy scores on the HST according to mathematical level indicated differences between the fourth and fifth grades. However, these results should be viewed with caution since there was only one student achieving at a sixth grade mathematical computation level.

Summary

The statistical analyses of the hypotheses revealed that (a) there was a significant difference between the discrepancy scores of the EST, MST, and HST for the eighth grade, (b) there was not a significant difference between the discrepancy scores of the three tests for the tenth grade, and (c) there was a significant difference between the eighth and tenth grade on the discrepancy scores of the testing instruments. Since a difference on the discrepancy scores was revealed for the eighth grade, further analyses were performed to locate the origin of the difference. The investigator found there was no difference between the discrepancy scores of the EST and MST. However, there were significant differences between the discrepancy scores of the EST and HST and the discrepancy scores of the MST and HST. Further analyses were also performed on the difference revealed between the eighth and tenth grade on the discrepancy scores of the EST, MST, and HST. Significant differences were found between the eighth and tenth grade on the discrepancy scores of all three tests, with the largest difference between the two grade levels appearing on the HST. A further explanation of these results and the influence other variables may have had on this study are discussed in Chapter Five.

CHAPTER FIVE

DISCUSSION

In this chapter a discussion of the effect syntactic complexity had on written mathematical problems with low-achieving eighth and tenth grade subjects is presented. First, a summary of the findings of the study which includes the statistical analyses related to the three hypotheses as well as analyses focusing on other variables is presented. The limitations, as they relate to this study are discussed next. The third section contains an interpretation of the results. Educational and future research recommendations are included in the fourth section. Finally, the conclusions of the study are summarized.

Findings

Statistical Analyses Related to the Hypotheses

In Chapter Four, statistical analyses were conducted on the discrepancy scores (i.e., the total number of problems minus the number correct) on the Easy Syntax Test (EST), Moderate Syntax Test (MST), and Hard Syntax Test (HST) in order to determine the effect syntactic complexity had on low-achieving eighth and tenth grade subjects' ability to solve written mathematical problems. The following is a brief summary of those findings.

1. There was a significant difference between the discrepancy scores on the three tests that measured the effect syntactic complexity had on mathematical word problems (i.e., EST, MST, and HST) with low-achieving eighth grade subjects. Further analysis disclosed significant differences between the discrepancy scores of the EST and HST and the discrepancy scores of the MST and HST, with larger discrepancy scores on the HST.

2. There was not a significant difference between the discrepancy scores on the EST, MST, and HST for low-achieving tenth grade subjects.

3. There was a significant difference discovered between low-achieving eighth and tenth grade subjects relating to their achievement on the testing instruments. Further analysis found significant differences between the eighth and tenth grade subjects on all three tests, with the greatest difference between the two grade levels exhibited on the HST. The analysis also revealed that the tenth grade subjects received lower discrepancy scores than the eighth grade subjects on all three tests.

Statistical Analyses Related to Other Variables

To ascertain that other variables were not confounding the results of the study, statistical analyses were conducted on age, sex, full-scale intelligence quotient (FSIQ), reading vocabulary level, and mathematical computation level. These analyses indicated that:

1. Age did not influence the eighth grade subjects' ability to solve the problems on the three tests, but age did have an effect on

the tenth grade subjects. Further analysis demonstrated the difference was between fifteen year-olds and seventeen year-olds' achievement on the HST, with the fifteen year-olds making fewer incorrect responses. It is possible that this difference may be the product of the seventeen year-olds functioning at a lower achievement level. In other words, the fact that the seventeen year-olds were still in the tenth grade may be an indication that they were functioning at a lower achievement level. Analyses on the reading vocabulary and mathematical computation means determined that the seventeen year-olds were functioning at a lower mean reading vocabulary and mathematical computation achievement level than the fifteen year-olds. The seventeen year-olds had a 7.3 mean reading vocabulary while the fifteen year-olds had a 8.2 mean reading vocabulary level. Also, the seventeen year-olds had a 4.7 mean mathematics computation level while the fifteen year-olds had a 6.8 mean mathematics computation level. Whether this difference had an effect on the outcome of the study is difficult to determine because there were only two seventeen year-old subjects in the study. Therefore, this result should be viewed with caution.

2. Sex did not influence either the eighth or tenth grade subjects' ability to solve the problems on the three tests.

3. FSIQ did not have an influence on either the eighth or tenth grade subjects' ability to solve the problems on the testing instruments.

4. As with sex and FSIQ, reading vocabulary level did not influence either the eighth or tenth grade subjects' ability to solve the problems on the tests.

5. Mathematical computation level did not influence the tenth grade subjects' ability to solve the problems on the three tests, but mathematical computation level did have an effect on the eighth grade subjects. Further analysis showed that this difference was between the fourth and fifth grade mathematical computation achievement levels on the discrepancy scores of the HST, with the fifth grade achievement level making fewer incorrect responses. A possible explanation for the difference may be that the achievement tests administered to the subjects did not measure the skills needed to solve the required computations on the testing instruments for this study. In other words, the achievement tests may have indicated that the subjects were functioning at a fourth grade mathematics computation level when in fact those subjects may not be able to regroup (i.e., carry in addition and borrow in subtraction). Another explanation for this difference may be that the 12 eighth grade subjects whose minimum fourth grade achievement level in mathematics computation were derived from teachers' judgments did not possess the ability to solve the problems on the tests (i.e., addition and subtraction with and without regrouping). However, further analyses suggest this difference was brought about by the syntactic structure of the sentences in the HST. This is evidenced by the fact that there was no difference on the EST or MST according to mathematical computation level. Also, the subjects functioning at the fifth grade mathematics computation level had a higher mean reading vocabulary than the subjects functioning at the fourth grade computation level (i.e., the subjects functioning at the fifth grade computation level had a 6.9 mean reading vocabulary level while the subjects functioning

at the fourth grade computation level had a 5.8 mean computation level). Finally, 23 of the 30 eighth grade subjects demonstrated on the HST that they could add and subtract using regrouping procedures. Their errors on the HST were the result of utilizing the wrong computation to solve the problem correctly (i.e., they added when they should have subtracted). Therefore, these findings indicate that for those eighth grade subjects who were functioning at a fourth grade mathematics computation level, the syntactic structure of the sentences in the HST had an influencing effect on their ability to solve the problems.

Limitations

Before the results are interpreted, a discussion of possible limitations as they relate to this study is needed. These possible limitations include (a) the reliabilities of the testing instruments, (b) the different achievement tests that were utilized to determine a minimum fourth grade reading vocabulary level for the subjects, (c) the teachers' judgments that were responsible for determining the mathematical computation level of the subjects, and (d) the achievement level of the testing instruments.

The first limitation that may have had an influence on the findings in this study involved the low reliabilities of the testing instruments. Even though the reliabilities of the EST and HST for the eighth grade and total group (i.e., both the eighth and tenth grade subjects) were found to be adequate according to criteria set by Guilford and Fruchter (1973), the other reliabilities were very low. However, before the revisions were made on the instruments for this study, the tests were administered to eighth grade students and the reliabilities were found to be (a) .84 for the EST, (b) .81 for the MST, and (c) .85 for the HST (Trenholme, Larsen, & Parker, 1977). Since the sample size for this investigation was small and included only low-achieving subjects who were functioning at minimum fourth grade achievement levels for reading vocabulary and mathematical computations, there was a lack of variability within the subjects. Therefore, the low reliabilities found in this study were credited to the lack of variability within the subjects (Anastasi, 1968; Minium, 1970).

A second limitation that might have had an influence on the results found in this study involved the different achievement tests that were utilized to determine a minimum fourth grade reading vocabulary level for the subjects. Even though all the subjects had a minimum fourth grade reading vocabulary level, this information was taken from three different achievement tests for the eighth grade subjects and there may be variations in the effectiveness of the achievement tests regarding the measurement of this ability. In other words, the subjects' reading vocabulary level may have been higher or lower than their actual achievement level depending on the achievement test they were administered. However, the statistical analysis disclosed that there were no differences between the discrepancy scores on the EST, MST, and HST according to reading vocabulary level for either the eighth or tenth grade subjects. Therefore, these results imply that reading vocabulary level did not influence the subjects' ability to solve the problems on the testing instruments.

A third limitation that may have influenced the outcome of this study involved the procedure utilized to determine the minimum fourth grade mathematics computation level for 12 eighth grade students. That is: (a) one teacher's judgment was responsible for determining the computation level for seven subjects, (b) a second teacher was involved in judging the computation level for two subjects, and (c) a third teacher's judgment was responsible for three subjects. Even though research suggests that teacher's judgment is just as effective as standardized testing (Ausubel, Schiff, & Zeleny, 1975; Dixon, Fukuda, & Berens, 1969; English & Kiddler, 1969), there may be variations in the accuracy of three teachers' judgments. In other words, the subjects' mathematics computation level may have been higher or lower than their actual achievement level depending on which teacher's judgment was responsible. However, mathematical computation level should not have an influence on the subjects' ability to solve the problems on the three tests since all the subjects had a minimum fourth grade computation level.

A fourth and final limitation related to this study involved the testing instruments. Since the testing instruments were written at a fourth grade or easier reading level which contained only fourth grade or easier computations, the tests may have been too easy for those subjects functioning at higher achievement levels. This is viewed as a possible limitation because the eighth grade subjects were functioning at significantly lower achievement levels than the tenth grade subjects in both reading vocabulary and mathematical computations. Therefore, the instruments may have been measuring the effect syntactic complexity had on mathematical word problems for only the eighth grade subjects and not the tenth grade subjects.

Interpretations

The results of this study convey that for the sample utilized in this investigation, syntactic complexity can affect a person's ability to solve mathematical word problems when the problems are written at the person's achievement level. This finding is illustrated by the fact that even though all the subjects had the minimum reading vocabulary and mathematics computation levels needed to complete the testing instruments, only the eighth grade subjects sustained significant differences between the three tests. Also, the eighth grade subjects were functioning at significantly lower achievement levels than the tenth grade subjects in reading vocabulary (i.e., eighth graders were functioning at a mean vocabulary level of 6.13, whereas the tenth graders were functioning at a 9.83 vocabulary level) and mathematical computations (i.e., a 4.35 mean computation level for eighth graders and a 6.27 mean computation level for tenth graders). Therefore, since the testing instruments administered in this study were written at the achievement level where the majority of the eighth grade subjects were functioning, these eighth grade subjects experienced greater difficulty on these testing instruments because the syntactic structures of the sentences were too complex for them to understand.

To state that syntactic complexity does not affect older students (i.e., tenth graders) cannot be determined from the outcome of this study since the testing instruments were written at an achievement level that was much lower than their functioning level. Therefore, research needs to be conducted on older subjects with testing instruments that are more compatible with their achievement level, in order to determine if syntax has an influence on their performance.

Recommendations

The results of this study suggest that syntactic complexity does effect students' ability to solve written mathematical problems when the problems are written at their achievement level. Therefore, educational and future research recommendations regarding the results of this study are presented in this section.

Educational Recommendations

1. Educators use a variety of mathematical achievement tests in order to evaluate students' mathematical ability. Included in these achievement tests are mathematical word problems. Since this study has demonstrated that syntactic structures of sentences may effect students' ability to solve word problems when the problems are written at the students' achievement level, educators need to be aware that these achievement tests may be measuring syntactic complexity and not mathematical ability. If this is the case, then educators need to measure the students' ability to apply mathematical concepts in another manner.

2. Research indicates there is a great deal of variability between passages in primary reading materials in terms of syntactic complexity and this complexity does not follow a systematic progression from less to more complex (Kaiser, Neils, & Floriani, 1975). Also, research, in addition to this investigation, has shown that syntax interferes with effective problem solving (Linville, 1976; Trenholme, Larsen, & Parker, 1977). Therefore, educators need to take into account the syntactic complexity that is commonly employed in mathematics textbooks and workbooks

when they are ordering these materials. If these textbooks or workbooks contain mathematical word problems where the syntactic structures are too complex for the students to understand what the problem is asking them to do, then those textbooks and workbooks will be of little value to the students. This implies that teachers will need to either (a) be alert to the syntactic structures of the word problems when ordering textbooks or (b) instruct their students in syntactic structure so they are able to solve these problems.

Future Research Recommendations

1. Since this study has shown that syntactic complexity did affect the low-achieving eighth grade subjects' ability to solve mathematical word problems, and the testing instruments were written at their achievement level, research needs to be conducted with testing instruments that are written at higher achievement levels to determine the effect syntactic complexity has on higher achieving subjects. In other words, research needs to be conducted with low-achieving tenth grade students utilizing testing instruments that are written at their achievement level in order to determine if syntax has an effect on their ability to solve the problems.

2. In a pilot study, Trenholme, Larsen, and Parker (1977) found that syntactic complexity did not influence normal-achieving eighth graders. They stated that "for normal-achieving eighth grade math students, syntactic complexity does not appear to be of educational importance" (p. 7). However, they indicate that the testing instruments administered to the normal-achieving eighth graders were the same instruments

that were administered to the low-achieving subjects. Since these instruments were written at a fourth grade achievement level, and this study indicates that the testing instruments need to be written at the subjects' achievement level to be able to measure the effect syntax has on mathematical word problems, these instruments may not have been effective measurements for normal-achieving eighth grade subjects. Therefore, research also needs to be conducted with normal-achieving subjects utilizing testing instruments that are compatible with their achievement levels in order to determine the effect syntactic complexity has on their ability to solve written mathematical problems.

3. Although the reliabilities of the testing instruments utilized in this study found that the reliabilities of the EST and HST for both the eighth grade subjects and the combined group (i.e., both the eighth and tenth grade subjects) were adequate according to criteria set by Guilford and Fruchter (1973), the other reliabilities were very low. These low reliabilities were credited to the small sample size and the homogeniety of the sample that caused a lack of variability within the subjects (Anastasi, 1968; Minium, 1970). However, since Trenholme, Larsen, and Parker (1977) found adequate reliabilities on these instruments before they were revised, these revised instruments need to be administered to a larger, more heterogeneous sample in order to ascertain that these instruments were reliable.

4. In this study syntactic complexity was measures by controlling the type of sentence structures in each of the testing instruments. For example, the word problems on the MST contained only moderately

difficult syntactic sentence structures, etc. These tests were constructed in this manner because research suggests that students are more likely to solve a word problem correctly when the complexity of the language in the word problem is similar to the problem that preceded it (Loftus & Suppes, 1972). If the difficulty of the syntax had been randomized, it is possible that students would appear to have difficulty with syntax at a particular level of syntactic complexity when in fact it would be due to the change of syntactic complexity. Nevertheless, even though the investigator believes the three separate testing instruments are the most effective procedure, future research may need to be conducted where the syntactic structures are randomized throughout the testing instruments.

Conclusions

The outcome of this study replicated the results of the Trenholme, Larsen, and Parker (1977) study in that syntactic complexity had an effect on low-achieving eighth grade students' ability to solve mathematical word problems. In addition, this study also disclosed that (a) syntax did not have an influence on tenth grade subjects' ability to solve the problems on the testing instruments and (b) the differences between the eighth and tenth grade subjects' ability to solve the problems on all three tests were large enough to be significant. Finally, the majority of the eighth grade subjects were functioning at achievement levels compatible to the testing instruments, while the tenth grade subjects were functioning at higher achievement levels.

These findings imply that syntactic complexity may have an effect on written mathematical problems with low-achieving eighth grade students if the word problems are written on the students' reading vocabulary and mathematics computation achievement levels. However, the influence syntactic complexity has on older students' (i.e., tenth graders) ability to solve mathematical word problems cannot be determined from the results of this study. This is because the testing instruments were written at an achievement level that was lower than their functioning level. Therefore, research needs to be conducted with testing instruments written at higher achievement levels that are compatible to the achievement levels of low-achieving tenth graders and normal-achieving subjects in order to determine if syntax has an effect on their ability to solve mathematical word problems.

TESTING INSTRUMENTS ADMINISTERED

APPENDIX A

EASY SYNTAX TEST

Here are some problems for you to solve. Place your answer for each problem in the space at the right of each problem. You may do your work on this paper.

ANSWERS

1. Jim likes to bake cookies for his family. Last night he baked 56 cookies. He gave 24 of them to his friend. How many cookies will his family have to eat? ________

2. The third grade class went to the beach. Pat found 15 shells at one end of the beach. Roy found 23 shells at another end of the beach. How many shells did Pat and Roy find? ________

3. Mr. Clark works in a garage. He greased 40 cars before lunch. He greased 37 cars after lunch. How many cars did he grease that day? ________

4. Ben has 646 points in the ringtoss. Ned has 312 points. Ned is how many points behind? ________

5. My dog likes to bury bones. He buried 27 bones in our yard yesterday. Today he buried 13 bones in the neighbor's yard. How many bones did he bury in the two yards? ________

6. Mary saves stamps for her hobby. She has 538 stamps in her stamp book. Her aunt sends her 421 stamps in the mail. How many stamps does she have now? ________

7. Chris bought a book about cars. He gave the clerk $3.25 for the book. The book cost $3.19. How much change will he receive? ________

8. There were 316 hens in the hen house. Pretty soon 138 of the hens ran out. Then how many hens were in the hen house? ________

9. Mr. Smith's class had a science center in their room. Karen brought 328 leaves for the center. Mark brought 452 leaves for the center. How many leaves did the children bring? ________

10. Sally's girl scout troup sold 356 boxes of cookies. Karen's troop sold 279 boxes of cookies. How many boxes of cookies have been sold so far? ________

11. Jane's family is building a house. Her dad worked 2674 hours on the house. Her brother worked 5313 hours on the house. How many hours did they both work? ________

12. Donna's father works in a bookstore. He sold 3582 books in one week. That next week he sold 4209 books. How many books did he sell in those two weeks? ________

13. Mr. Benson travels for his company. This week he traveled 4039 miles in an airplane. Last week he traveled 5028 miles in a train. How many miles did he travel? ________

14. Tim likes to read books at night. He checked 32 books out of the library. Later he returned 21 of the books. How many books did he keep? ________

15. Mother had 22 candles. She put 19 of them on Mary's birthday cake. How many candles did she not use? ________

16. Mother and Molly are washing and drying dishes. Mother washed 775 glasses. Molly must still dry 232 of them. How many glasses have been dried? ________

17. Mother has 42 roses. She has put 18 in a bowl. How many roses will be put in another bowl? ________

18. Tim has to finish his book for homework. He has read 67 pages of the book. He has 23 pages yet to read. How many pages are in the book? ________

19. John Smith hit 388 base hits in his lifetime. He made 212 home runs. How many of his hits were not home runs? ________

20. Jack wants to buy a ball. The ball costs 77¢ at the store. He has only 24¢ in his pocket. How much money does he still need? ________

21. The school library has 616 books on its shelves. The librarian ordered some new books. Now the library has 894 books on its shelves. How many new books were ordered? ________

22. Mrs. Street has a flower garden in her backyard. She has 368 roses in her garden and she has 942 flowers in all of her garden. How many flowers are not roses? ________

MODERATE SYNTAX TEST

Here are some problems for you to solve. Place your answer for each problem in the space at the right of each problem. You may do your work on this paper.

ANSWERS

1. There were 67 cookies in the cooky jar at John's house. After all the family had eaten lunch, there were 41 cookies in the cooky jar. How many cookies had been taken from the jar? ________

2. Eddie and Jim bought 67 nails to use in building their clubhouse. When they had finished, they had 20 nails in the box for nails. How many nails did they use? ________

3. Bill rode his bicycle 38 blocks to the library. After he had checked out some books, he then rode 21 blocks to his aunt's house. How many blocks did Bill ride? ________

4. Rusty had 92 boxes to take to the basement. After the first trip he made, there were 38 boxes to take to the basement. How many boxes did he take on the first trip? ________

5. Mary and her brother were making a stamp collection. During the year Mary collected 25 stamps, while her brother had collected 28 stamps. How many stamps did they have in their collection? ________

6. Jane's school had a play. If they sold 430 children's tickets and 250 adult's tickets, how many tickets were sold? ________

7. A truck holds 432 gallons of gas. After unloading some gas at a gas station, the truck holds 121 gallons. How many gallons of gas were unloaded at the station? ________

8. An airplane was flying at 2647 feet. Because it was beginning to rain, the pilot decided to go up another 3132 feet. How high would the airplane be then? ________

9. Yesterday the circus opened in our town. There were 5004 children's tickets sold and 3007 adult's tickets sold. How many tickets were sold that day? ________

10. During the summer Paul's team played 68 games. If they won 26 of the games they played, how many games did Paul's team lose? ________

11. Mrs. Smith bought a cooked ham that weighed 22 pounds. When she weighed what was left of it today, she found it weighed 19 pounds. How much of the ham had been used? ________

12. There are 646 pupils going to White School. If 310 of these pupils are boys, how many girls go to White School? ________

13. The city baseball park had enough seats for 748 people. Because the final game of the season was being played, only 316 of the seats were empty. How many people were at the game? ________

14. The gas tank on Mr. Brown's boat has 424 gallons of gas in it. When 256 gallons were put in, the tank was full. How many gallons will the gas tank hold? ________

15. The Brown family planned to drive to a hotel 350 miles from their house. When they stopped for lunch, they had gone 239 miles. How many miles farther did they still have to drive? __________

16. Gwen let Betty borrow her 635 trading cards. When Betty returned the cards, she gave Gwen only 216 back. How many cards were not returned? __________

17. The weight of several bags of potatoes and onions is 526 pounds. If the weight of the potatoes is 189 pounds, what is the weight of the onions? __________

18. Monday 389 pupils were absent from White School. If 274 pupils were present, how many pupils go to White School? __________

19. Jack has 265 pictures in his book. When he pastes in some new ones, he will have 752 pictures in his book. How many pictures did he paste in? __________

HARD SYNTAX TEST

Here are some problems for you to solve. Place your answer for each problem in the space at the right of each problem. You may do your work on this paper.

ANSWERS

1. Because the deer were not getting enough to eat, Air Force planes dropped 24 bales of hay in East Texas and later they dropped 53 bales of hay in West Texas. How many bales of hay were dropped for the deer? ________

2. Ricky and his father used 64 pieces of wood for a bird house they were building and 25 pieces for another bird house. For both bird houses they used how many pieces of wood? ________

3. When Jim went to the park he had 48 cents and when he came home he had 23 cents in his pocket. How much money did he spend at the park? ________

4. When 24 girl scouts went on an overnight camping trip with 56 girl scouts from another city, how many girl scouts went on the trip? ________

5. Mary and her sister went to the circus. As they watched the ponies perform, Mary counted 164 ponies in the left ring and her sister counted 425 in the right ring. How many ponies were there? ________

6. If it is 23 miles on a bicycle from Jim's house to Bob's house by staying on the streets and it is 15 miles shorter by cutting through the park, how long is the trip the shorter way? ________

7. During the time that the circus was traveling, the ponies ate 270 pounds of hay and the elephants ate 610 pounds of peanuts. How many pounds of food did the animals eat? __________

8. If in the first hour of the circus Jane's group sold 528 bags of peanuts and Joe's group sold 162 bags of peanuts, how many bags had both groups sold? __________

9. If Rusty had 976 tickets before he stopped at Mrs. Brown's and 634 afterward, how many did he sell? __________

10. Since Mark and John have already worked 4136 hours building a boat and Mark thinks it will take another 3402 hours to finish it, how many total hours will it have taken to build the boat? __________

11. In building a new pen for his dog, Mr. Smith used some lumber which cost $16.25 and some lumber which cost $11.06. How much has he spent building the pen so far? __________

12. If our schoolhouse is 36 feet high and the flagpole is 27 feet higher, then how tall is the flagpole? __________

13. When Joan's kite was at a height of 476 feet, Joan let out more string and the kite rose another 438 feet. At what height was Joan's kite then? __________

14. After 34 hot dogs were eaten at the picnic, out of the 76 that had been bought, how many had not been eaten? __________

15. If a total of 498 tickets were sold at the Fair for Friday and Saturday nights and 312 people went to the Fair on Friday night, how many people went on Saturday night? ____________

16. When we went to the circus, we found out that the fat lady weighed 195 pounds and one of the bareback riders weighed 108 pounds. How much heavier is the fat lady? ____________

17. If Dick spent $81.43 on a bicycle and received $14.07 in change, how much did he give the clerk? ____________

18. If there were 952 persons who visited the Fair one morning and 656 were adults, how many were children? ____________

19. An airplane has 54 seats so if 26 people are seated, how many empty seats are there? ____________

20. Mary walked 33 blocks from school to the library and then she walked home. If she walked a total of 47 blocks, how many blocks is it from the library to her home? ____________

21. If 38 of the 60 boys in camp went fishing, how many boys did something else besides fishing? ____________

22. If 354 of the 589 people who went on the trip left the park before the others, how many people stayed longer in the park? ____________

23. If Mr. Smith pays $178 of his monthly salary of $543 for his room and meals, how much does he have to spend for other things? ________

24. If at a sale there were 621 cherry trees and all but 384 were sold, how many cherry trees were sold? ________

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