TEXTBOOK DIFFICULTY AND SYNTACTIC COMPLEXITY: AN ANALYSIS OF GRADES THREE AND FOUR SCIENCE TEXTBOOKS

by

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ABSTRACT

This study has two purposes. First, to investigate the syntax of grades three and four science textbooks in order to find out if there is a difference in the syntax used in grade four textbooks which may contribute to textbook difficulty and children's increased comprehension problems in the post-primary grades. The second purpose is to examine the readability of the texts in order to see if the standard reading level scores show a difference between grade three and four science textbooks.

Chapter I is a review of the main trends in reading comprehension, and the problems English as a Second Language students face when reading. The last section of this chapter explains the correlation that may exist between the comprehension of syntax and textbook difficulty.

Chapter II discusses the relevance of corpus linguistics to the analysis of textbook difficulty. The results of Biber's study, showing that different syntactic forms are used in different registers, are also discussed here.

Chapter III establishes the relation between children's understanding and use of the syntactic structures of the English language and their age.

Chapter IV describes the methodology of the study. The corpus of the study consists of six chapters selected from third and fourth grade science textbooks. Each selection was analyzed syntactically. The data are organized by means of charts so that the particular syntactic forms and their numbers can be displayed in a meaningful way. In addition, a reading level analyzer (computer program) was used to determine the standardized reading level of each text.

Finally, Chapter V presents the syntactic analysis of clauses in the texts and an interpretation of the results.

The results show that there are statistically significant syntactic differences between science textbooks used in grades three and four. The percentage of complex sentences in grade four textbooks is higher than in grade three textbooks. In contrast, the readability analyses done on the texts show little or no difference between grade three and grade four textbooks. The study suggests that syntactic analyses are necessary in order to have more accurate assessments of the reading levels of textbooks in accordance with the linguistic development of the child.

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CHAPTER I
Meaningful Reading

Reading is a very broad topic that has been researched for many years. However, there is always something new and interesting about it. Researchers have investigated the various key factors that affect reading comprehension such as vocabulary, reading strategies, text organization, background knowledge, and motivation. There is a fair amount of quantitative and qualitative work on this matter; however there are still areas that need more development and attention. The role of syntax in reading comprehension is one of them.

My main interests in this chapter are concentrated in these two major areas: comprehension and syntax. The first section will be devoted to reviewing some of the most controversial trends in reading. Special attention will be paid to the aspects of meaningful reading and reading instruction. In the second section attention will be paid to the process of English as a Second Language reading and the comprehension problems that may arise when a text is confronted by an ESL student. Finally, the correlation that may exist between syntactic comprehension and textbook difficulty will be explained.

Some General Considerations Concerning Meaningful Reading

Research on reading has characterized it as a constructive process (Tierney, 1990; Anderson, R., Hiebert, E., Scott, J. and Wilkinson, I., 1985) which is closely related to background knowledge, since readers use prior knowledge to fill gaps in the message. To the meaning conveyed by the text, the reader needs to add his/her personal experience then, he/she builds meaning. That is why individuals with different experiences may provide different interpretations of the same reading material. Consequently, the meaning constructed from the same text can vary greatly among people because of differences in the knowledge they possess.

Researchers have provided many definitions of reading over the years. The definition of reading as a process in which information from the text and the knowledge possessed by the reader act together to produce meaning is the one I use in this research (Anderson, R., Hiebert, E., Scott, J. and Wilkinson, I., 1985).

It is obvious that one of the main tasks facing children in their early school years is learning how to read. Reading has a central role in school curricula. Learning to read is the object of beginning instruction. It occupies most of the time in the school day of the first and second grade child and it is through reading that the child acquires skills and knowledge in other subject matters, such as social studies, science, foreign languages, mathematics, and art (Perfetty & Curtis, 1986 cited by Hashwell, 1992).

Reading is without doubt one of the most common tools used to learn about the world that surrounds us. It is used everyday for different purposes and in different contexts. When children come to school, reading occupies a central role in their everyday lives.

It has been pointed out by Biber (1988, p. 4) that children who fail at reading fail at school; children who fail at school do not learn how to read. It is difficult to establish a causal relationship here but schooling is inextricably bound to literacy in Western culture.

When children begin learning how to read they often experience reading in a different way than they do at home. They may have read isolated words and sounds, signs on the streets and short stories at home, but in school the time comes when they have to read and then summarize what they have read, read instructions in order to carry out an experiment or organize and recall what they have read for an exam. Many times that is when the trouble starts.

There are many strategies used to teach reading, many of which are used at the early grade levels and others when the child already has had some training in reading. The final aim of having students develop reading strategies is to provide them with their own mechanisms to face reading tasks. Anderson, Hiebert, Scott, and Wilkinson (1985) compare reading to the performance of a symphony orchestra. Both reading and the orchestra's performance require the coordination of a variety of interrelated forms of information. Reading is a holistic act like the performance of a symphony. It can be analyzed into subskills, but performing the subskills one at a time does not constitute reading. Reading only takes place when the parts are put together in an integrative performance like a symphony. Reading is also like the performance of a symphony orchestra in that success in reading comes from practice over long periods of time, like skill in playing musical instruments. As with a musical score, there may be more than one interpretation of a text. The interpretation depends on the background of the reader, the purpose for reading, and the context in which reading occurs.

Duffy & Roehler (1993) point out several stages of developmental reading growth. First, the **Readiness Level** which includes preschool, kindergarten, and first grade. Then, the **Initial Mastery Stage** that ordinarily begins in the first grade and continues into the second grade. The third one is called the **Expanded Fundamental Stage**. It begins in the second grade and continues into the fourth grade. Here emphasis on word identification diminishes and emphasis on comprehension increases. The **Application Stage** begins at about the fourth grade and continues into the eighth grade. Students are greatly involved not only with basals reading textbooks but also with textbooks for other curricular areas, such as social studies, science, and mathematics. The last one is the **Power Stage** which begins in the eighth grade and can continue long after formal schooling ends.

However, Duffy & Roehler (1993) make clear that we have to be careful when discussing stages of developmental reading growth because it may create the impression that all students develop "normally." An accurate expectation is that some of the students at each grade level will follow a typical developmental reading progression, but others will not.

These differences in reading development may be caused by diverse factors such as word recognition, vocabulary knowledge, overall reading ability or background knowledge. In numerous studies, the reader's background knowledge has proved a better predictor of recall than any other factor (Anderson and Pearson, 1984). But not only is background knowledge a good predictor of comprehension, it also guides the reader through the text and enables him/her to suggest scenarios, make predictions, identify and empathize with characters, and relate to events or settings and their interplay (Tierney, 1990).

Students' prior knowledge comes in many forms: a) specific knowledge about a topic; b) general world knowledge; c) knowledge about the organization of the text (Resnick, 1987). Many times the relationship between knowledge and the text is not a simple one. Knowledge can be inert and not brought to bear in the comprehension process (Bransford & Johnson, 1973). It may also depend on the student's culture, language spoken at home, and parents' interests and motivations which may in turn affect the interests or motivations of their children.

Anderson, et al. (1985) consider motivation as one of the keys to learning to read since reading well takes some time and learners should rarely feel discouraged. Reading classes should be fun. Students may learn while enjoying what they are reading. Teachers should avoid boring reading instructions. Reading teachers should use materials the students are interested in, including materials self-selected by the students. However, this is sometimes difficult to achieve when teachers have to follow a certain curriculum and use specific texts.

Anderson, et al. (1985) concur with Duffy & Roehler (1993) when they refer to reading as a continuously developing skill. It is not mastered once and for all. It continues improving through practice. They insist that in a well-designed reading program, mastering the parts does not become an end in itself, but a means to an end, and there is a proper balance between practice of the parts and practice of the whole.

In order to achieve an adequate reading level, reading instruction in Grades 3 and 4 should expand upon the fundamentals taught in Grades 1 and 2, while preparing students to handle the heavier reading demands of the middle school grades (Duffy & Roehler, 1993). In the content areas the type of texts used become more complex. Simple story narratives are supplanted by more complex story forms, more poetry, and more folk literature. The simple expository texts used in the primary grades (Grades 1 and 2) are supplemented by specialized social studies, science and mathematics texts (Duffy & Roehler, 1993).

As students continue developing their reading skills they make more use of the strategies for reading. How they read depends on the complexity of the text, their familiarity with the topic and their purpose for reading. Since people read for different purposes: for pleasure, to study, to know what the text is mainly about, to find specific information, etc, a different strategy of reading such as scanning, skimming, reading carefully, going forward and backwards can be used. Eventually, students turn into being fluent readers. They are able to decode words quickly and accurately so that this process can coordinate fluidly with the process of constructing the meaning of the text. Thus, fluent reading presumes prior recognition knowledge of the vocabulary of the text. However, being a fluent reader does not necessarily imply that the student has understood what he/she has read.

Armbruster, Anderson and Meyer (1991) consider three cognitive processes: selecting, organizing and integrating information to be essential in meaningful reading. The first process, "selecting", involves paying attention to the information in the text and particularly focusing attention on information that is relevant to the goals or task demands of the learning situation. The second process, "organizing", involves arranging the units of selected information into a coherent mental structure, that is, building internal connections or constructing logical relations between ideas in the text. The third process, "integrating", involves connecting the coherently organized information to existing cognitive structures, that is, building external connections because they link information from the text to information that is external to the text but internal to the reader.

How can these three processes affect meaningful reading of information or expository texts? Skilled readers use these three cognitive processes but younger or poorer readers do not. Researchers have shown that poor or young readers have trouble writing summaries of informational texts (Brown and Day, 1983; Taylor, 1986; Winograd, 1984). This difficulty with summarizing may be due to difficulties in selecting or identifying important information. Summarizing is a broader, more synthetic activity for which determining importance is a necessary, but not sufficient, condition. The ability to summarize information requires readers to sift through large units of text, differentiate important from unimportant ideas, and then synthesize those ideas and create a new coherent text that stands for, by substantive criteria, the original (Dole et al., 1991). Three operations appear repeatedly across studies to identify the different operational procedures used to summarize. Some information must be selected, while other information is deleted. Some material must be condensed, while higher superordinate concepts are substituted. Material must be integrated into a coherent and accurate representation of the original material (Dole et al., 1991)

Other studies by Meyer et al. (1980) and Taylor, B. M. (1980, 1985) suggest that age and reading ability are highly correlated with recall of informational material. This relationship may result from skilled readers' greater awareness and use of the author's higher order text structure, which enables them to form a coherent organization of the text information.

As mentioned above, good readers use their general world knowledge and domain-specific knowledge to allow access to and evaluation of the content of the text. They use their knowledge of author biases, intentions, and goals to help determine importance. They use their knowledge of text structure to help them identify and organize information (Afflerbach, 1986; Englert & Hiebert, 1984; Johnston & Afflerbach, 1985; Winograd, 1984). Knowledge about the structure of the text has been found to be particularly important for helping readers differentiate important from unimportant information as well as for organizing and recalling information (Dole et al., 1991).

Reading in ESL

Reading in a second language has many times been separated from reading in the first language; however, studies in this area show that reading in a first language and reading in a second language are not so different. Verhoeven (1990) says that the strategies employed in learning to read in a second language are similar in many ways to the strategies required for first language reading acquisition. He also says that scant attention has been given to research on the acquisition of reading in a second language and that "... it is not yet known how the linguistic and sociocultural characteristics of second language learners affect the course of reading acquisition."

Although there has been a proliferation of methods, texts and perhaps needless duplication of information, there is still clearly a dearth of theoretically sound guidance in the area of literacy instruction for ESL students (Carl Braun in Gunderson, 1991). Let us go over some of the information published in this respect to see what problems ESL students face and how these problems could be solved.

Very often students have difficulties in understanding texts in their first language (Armbruster, Anderson and Meyer, 1991). One might assume it would be even more difficult for second language learners to understand these texts. As mentioned in the previous section there are several processes such as selecting, organizing and integrating information which play an important role in meaningful reading. These processes are considered (Mayer, 1989) as cognitive processes that help distinguish skilled from novice readers. A second language learner has to be able to select, organize and integrate information from a text in order to become a skilled reader, but he/she also encounters more difficulties regarding language proficiency and comprehension devices than a first language reader.

Second language readers make use of graphic, syntactic and semantic cues provided in a text to predict and confirm meaning, much as first language readers do (Clarke, 1980; Cziko, 1978, 1980; Goodman and Goodman, 1978). In addition, first and second language readers alike make use of their background knowledge to construct meaning (Anderson and Pearson, 1984; Carrell, 1988).

The teaching of reading to students who do not have full control over English structures and vocabulary is a complex process, particularly when some of those students have learned to read using a different symbol system (Mary Ashworth, Foreword in Gunderson, 1991). On the other hand, studies by Steffensen, Joag-dev and Anderson, Johnson and Carrell (cited in Carrell, 1984) have shown that the implicit cultural knowledge presupposed by a text and the reader's own cultural background knowledge interact to make texts based on one's own culture easier to read and understand than syntactically and rhetorically equivalent texts based in a less familiar, more distant culture.

The role of background knowledge in ESL reading has been formalized in the context of schema theory. This theory holds that a text does not carry meaning by itself; rather, a text only provides directions for listeners or readers as to how they should retrieve or construct meaning from their own, previously acquired knowledge. Efficient comprehension requires the ability to relate the textual material to one's own knowledge (Carrell, 1984).

While reading processes are similar for first and second language readers, two special characteristics of second language learners may make comprehension slower and arduous: limited second language proficiency (Clarke, 1980; Cziko, 1980) and background knowledge and experiences that do not correspond to the content of typical school texts (Carrell and Eisterhold, 1988).

When talking about first and second language reading, we need to think of the kinds of problems second language readers face which are somehow different from those first language readers encounter. In the first place, there are interlingual learning problems which are caused by mother tongue interference and intralingual learning problems which are caused by the structure of the second language.

In his article about acquisition of reading in a second language, Ludo T. Verhoeven (1990) points out that in the past all second language learning problems have been defined as interlingual. However, he suggests that interlingual learning problems play only a minor role in second language word recognition and that in many cases, second language learning problems appear to be related to specific interpretations of the target language, and thus can be termed intralingual. He also says that a newer way of looking at second language learning problems is to consider them as mainly intralingual and that the strategies required for second language reading acquisition are similar in many ways to the strategies required in learning to read in the first language.

Even though this may be true it is also valid to say that there are some differences as to the difficulties children acquiring reading in a second language and those acquiring reading in their first language face. Let's take an example which is considered by researchers as a critical part of reading. Readers use three representational systems in learning to recognize words: phonemic mapping, recognition of orthographic patterns, and direct recognition of words already represented in memory. Second language learners may have greater difficulty in decoding letter strings phonemically. They may lack the knowledge of oral language that most native learners bring to the task (Verhoeven, 1990).

First and second language readers may also differ in their higher-order comprehension processes. Second language learners may have insufficient capacity to retain strings of words in short- term memory because of inefficient sentence processing, their textual knowledge may be limited since they have less experience reading the second language. Thus they may have poor understanding of discourse devices, such as sentence coherence and interferences. They may have trouble linking propositions in the text to form a coherent microstructure and macrostructure (Verhoeven, 1990).

The reading acquisition of second language learners may also be affected by the attitudes they have developed towards their native language and culture. These attitudes determine the sociocultural orientation of second language learners.

Ludo T. Verhoeven (1990) carried out a longitudinal study of Turkish and Dutch children in the Netherlands in order to examine the second language reading acquisition of ethnic minority children. He came out with very interesting results. As far as word recognition is concerned, he found out that both first and second language learners were more efficient in reading familiar than unfamiliar words, and in reading meaningful words than pseudowords. They also had the same troubles in reading orthographically complex words. These two factors, orthographic complexity and word familiarity, had a different impact on first and second language learners depending on the length of instruction. That is, after five months of instruction they had a similar impact on the word recognition of the two ethnic groups but by the end of the second grade, they no longer had a differential impact on the two ethnic groups. As far as reading comprehension development is concerned, the Turkish children showed a substantially lower level of achievement than the Dutch children.

Verhoeven (1990) concluded that in the initial stage of literacy acquisition, first and second language reading comprehension processes have highly intralingual characteristics. Thus, in learning to read in the second language, it is the structure of the target language that accounts for various comprehension difficulties and not the structure of the source language.

Verhoeven (1990) refers to several aspects which have a great impact in second language reading acquisition, such as the process of word recognition and reading comprehension development. He suggests that children should be helped to build up oral skills in the second language before reading instruction in that language is started. The better oral skills are developed, the greater the chance for a child to make correct inferences from literacy instruction. Furthermore, reading texts should be matched to the oral skills of the children. Only with graded text materials will children be able to use syntactic and semantic constraints when reading in a second language.

Reading Comprehension

Any definition of reading comprehension must take into account the interaction between the reader and the text. Each reader brings to the reading process a unique combination of interests, motivation, attitudes, skills, and background of experiences. Each text also has unique characteristics that can influence comprehension. The readability of the text, concept density, passage coherence, and passage organization are just a few of these characteristics that have been shown to influence reading comprehension. Reading comprehension can be defined as the process of using one's own prior experiences and text cues to infer the author's intended meaning (Irwin, 1986; Johnston, 1981)

Research into children's comprehension problems has focused on three main theoretical approaches to comprehension deficits. The first is that comprehension problems are really word-recognition problems in disguise. The second is that poor comprehenders have difficulty in the syntactic and semantic analysis of text, and cannot make use of the structural constraints in language. The third is that poor comprehenders have difficulty with making inferences from text and integrating the ideas in it (Yuill & Oakhill, 1991).

Perfetti and Lesgold (1979) argue that because decoding in poor comprehenders is less automatic than that of good comprehenders, a 'bottleneck' is created in working memory. Since working memory is a system for temporarily storing and processing information before it is transferred to long-term memory, text comprehension depends on having an efficient working memory. The short-term retention of information in a text is important in the parsing of complex syntactic structures, and in integrating information from the current sentence with preceding sentences. Working memory is conceived of as a limited-capacity memory system. As a consequence, less-skilled comprehenders have a poorer working memory: that is, they are less able to remember and process information currently. It is this form of memory that appears to be particularly important in reading and in constructing a mental model of the text. (Yuill & Oakhill, 1991). At the same time, Cromer (1970) argues that comprehension problems lie at a higher level of processing. Thus, poor comprehenders fail to make use of syntactic constraints in the text, and tend to read word-by-word, rather than processing the text in meaningful syntactic units. Yuill & Oakhill (1991) argue that poor comprehenders also may have difficulties at the level of inferences and integration of information.

Dechant (1991) also pays attention to three levels of comprehension similar to those mentioned above. She agrees with Just and Carpenter (1987) in that the first problem readers face is to encode the word and then to access its meaning in their internal mental lexicon. The second problem in comprehension is the encoding of the meaning that is appropriate to the context. It is at this point that semantic and syntactic contexts start to play a critical role in comprehension. A third problem is comprehending units of increasing size: phrases, sentences, paragraphs and total text.

Collins and Smith (1980) have identified four major categories of comprehension failure and presented reasons as to why failure might occur:

1- Failure to understand a word

-it is an unknown word

-it is a known word that doesn't make sense in a context

2-Failure to understand a sentence

-students can find no interpretation

-students can find only a vague, abstract interpretation

-students can find several possible interpretations (ambiguous sentence)

-students' interpretation conflicts with prior knowledge

3-Failure to understand how one sentence relates to another

-students' interpretation of one sentence conflicts with another

-students can find no connections between sentences

-students can find several possible connections between the sentences

4-Failure to understand how the whole text fits together

-students can find no point to the whole or part of the text

-students do not understand why certain episodes or sections occurred

Collins and Smith (1980) have also suggested a series of six steps for resolving comprehension failure.

a) Ignore the difficulty and read on. The information may be relatively important,

b) Suspend judgement. The difficulty may be cleared up later,

c) Form a tentative hypothesis which can be tested as reading continues,

d) Reread the sentence or sentences. This may clear up or pinpoint the difficulty,

e) Reread the previous context. This may clear up the difficulty or pinpoint the contradiction,

f) Go to an expert source. This may be necessary when steps one to five have not resulted in resolving the comprehension failure.

This may be logical when dealing with skilled readers, however, in the case of younger and less skilled readers this may be a difficult way to achieve comprehension and they need to be placed in instructional settings where they can learn to be successful at comprehension monitoring. In instruction for comprehending text the goal of the teacher is to facilitate and guide the students in understanding the text content (Mason, Roehler, & Duffy, 1984).

Syntax and Comprehension

Of the above mentioned problems the one dealing with syntax will be given more attention in this section. After a period in which the study of comprehension became closely identified with vocabulary and the analysis of higher level textual processes in which syntactic processes typically were assumed to be either inscrutable or irrelevant, it is again credible to claim that comprehension depends in part on processes that are essentially syntactic (Perfetti, 1985).

When we read, there is an underlying structure that influences the ease or difficulty of understanding. Recent research clearly documents the important role that syntax plays in reading (Rayner, 1990). Once the words in a text have been identified, and their meanings accessed, readers have to use their knowledge of semantic and syntactic categories, and the rules of grammar, to derive the meaning of the sentences (Yuill & Oakhill, 1991).

Dechant (1991) emphasizes that to be a good reader, it is not enough to process the semantic context but the syntactic context as well. That is, readers must use language structure to decode meaning. She also says that it is almost impossible to read a sentence correctly or to comprehend it without mastery of the grammar of a language and that it is the rules of syntax that allow the grapho-phonic system to communicate meaning. Children with greater knowledge of the syntactic system comprehend and encode meanings better than those with less knowledge; they encode the surface characteristics of words with greater success (Dechant, 1991).

This research on the effects of syntactic knowledge on comprehension suggests that teachers need to be sensitive to different kinds of grammatical complexity because not all writers and publishers who produce books for primary and middle schools pay specific and systematic attention to grammatical structures. Vocabulary, on the other hand, tends to be rather carefully scrutinized by writers and publishers. The mistaken assumption that vocabulary is the most important linguistic factor in readability seems to underlie the following sentence, from the preface to a series of information books widely used in primary schools: *'The subject matter and vocabulary have been selected with expert assistance, and the brief and simple text is printed in large, clear type.'* (Perera, 1984). In her book, Perera (1984) emphasizes the role of syntax in reading. However, she does not deny the importance of other factors. She considers grammatical analysis as just one part in a total view of written language.

The question comes to mind as to whether we should teach syntax directly or consider it as something acquired naturally. Two main reasons could be given as to why teaching syntax may help comprehension. First, it may help students deal with the difficult structures of the language that may affect the comprehension of a passage. Second, it may help students become independent skilled readers.

However, Perera (1984) thinks that it is not advisable to teach grammar formally to children because the majority of children under the age of fourteen seem to become confused by grammatical labels and descriptions. Language competence grows incrementally, through an interaction of writing, talk, reading, and experience. This does not mean that it can be taken for granted, that the teacher does not exercise a conscious influence on the nature and quality of this growth (Perera, 1984; DES, 1975).

Although children have mastered the basic syntactic structures of their language by the age of five, there are still specific areas where their knowledge is incomplete, and knowledge of syntax develops well into the school years (Yuill & Oakhill, 1991). Chomsky (1969) found that it was not until age 8 that children could reliably understand the "easy to see" construction, and that children of this age were still confused about complement constructions with verbs such as: *ask, promise,* and *tell.* Byrne (1981) showed that poor readers of seven to eight years of age misinterpreted sentences such as *the bird is easy to bite* more often than did good readers of the same age. If children have difficulty in identifying the syntactic constituents in a text, both their understanding of, and their memory for the text is likely to suffer (Yuill & Oakhill, 1991).

A very useful approach used by Perera (1984) in order to tackle the problem of grammatical complexity is to consider the sequence in which grammatical constructions are acquired by children. Those constructions that are part of the adult language and which occur early and frequently in children's speech and writing should be easier for children to read than those constructions that appear later and more rarely. Conversely, adult constructions that appear late and occur rarely in children's language are likely to be indicators of linguistic maturity. Perera (1984) uses this approach in her book because she considers it to be particularly appropriate where the language users in question are children who are still in the process of acquiring their mother tongue (p. 12).

Once teachers have become aware of some of the syntactic constructions that may cause difficulty in reading, they are likely to recognize them whenever they occur, without necessarily carrying out a full grammatical analysis of the whole passage (Perera, 1984). Experienced teachers know what sentences are difficult for students to understand. They know that students have more problems with the passive patterns than the more common subject-verb-object pattern. Other troublesome patterns are appositives with commas and clauses as subjects. Difficulty is also associated with pronouns and sentences that require a referent, particular connectives such as *further, moreover, instead*, punctuation, and figurative language (McNeil, 1992).

Although Mann et al. (1980) found that good and poor comprehenders' immediate recall was affected to a similar extent by variation in syntactic structure, all of the structures that the researchers used were relatively simple. Indeed, Mann et al. suggest that good and poor readers may differ in their ability to recall more complex constructions such as centre-embedded sentences, and these were the focus of Yuill and Oakhill (1991) experiment on sentence understanding. Reid (1972) showed that seven-year-olds often misunderstood embedded clauses, such as: *The girl standing beside the lady had a blue dress*. Children's responses to the question: *who had a blue dress?* were correct in only 41% of the cases. By using different types of relative clauses, and by varying the length of the sentence, the researchers were able to assess whether any differences between the groups were related to their ability to understand embedded sentences generally, or were related to the processing load imposed by such sentences. Sixteen sentences were constructed, with eight different versions of each. They ensured that all the words were within the children's vocabulary. The results were that the skilled comprehenders' recall was better overall (54.2 %) than that of the less-skilled group (33.3%), both groups answered more questions correctly with auditory (76.6%) than with visual presentation (69.4%) and more questions were answered correctly for non-embedded sentences (87.7%) than embedded sentences (58.2%). The study suggests that fewer less-skilled than skilled comprehenders understood the sentences, and so the varying processing loads may not have had the chance to exert their effects on comprehension.

As the evidence given above shows, children who are native speakers of English have problems in comprehending specific syntactic structures. If the native speakers are dealing with difficult structures that are above their language level we may assume that the ESL children will face more serious problems. However, both would benefit if more attention were given to syntactic complexities and the development of language in early childhood, definitely they both would improve their comprehension. It is generally agreed that there is a need for the explicit teaching of grammar in foreign language learning situations as an aid to the development of linguistic competence (Ellis, 1987; Harley, 1989; James, 1986; Omaggio, 1984; Rivers, 1981; Rutherford and Sharwood-Smith, 1985; Scott, 1989, 1990; Shaffer, 1989; Sharwood-Smith, 1988; Van Baalen, 1983) and as a direct result to a better comprehension of the language used in textbooks.

Still there is something else that teachers should not underestimate. Language is not a unit but rather a collection of quite diverse languages, called registers, each of which needs to be learned and used in different kinds of contexts. It is possible, for instance, that young children have difficulties in understanding scientific or other specialized registers. Each of the different activities done in class requires that the students use a different register of English. The kind of talk, thinking, and activity required in a language arts lesson is different from that required in a mathematics lesson. Similarly, playground talk, talk, reading and writing about history, and talk, reading and writing about science are different. In each situation, students must negotiate the meanings that the activities, the things in the world, and the goals of the activities have for them. This process of negotiating meaning in each different setting is what linguists call registers (Sampson, 1992). The linguistic concept of register is indispensable for the teacher of English as a Second Language since in the different content-areas different registers are used.

Students are expected to learn through reading and writing. However, few students receive explicit instruction on learning from reading. If we want students to learn to read and write in a variety of registers, they must be placed in settings or simulations of settings that allow them to first engage in the social processes that underlie the generation of registers (Sampson, 1992).

Once teachers have become aware of the constructions that may cause students to have difficulty in reading, they are likely to recognize those structures wherever they occur, without necessarily carrying out a full grammatical analysis of the whole passage (Perera, 1984, p. 10). In addition, Perera (1984, p. 15) thinks it is valuable for teachers to make a grammatical analysis of extracts from books which are in use in the classroom. The teacher will be in a better position both to select books at an appropriate level and to provide detailed help with the more advanced stages of reading.

Textbook Difficulty

Wilson and Gambrell (1988) point out the difference between reading to get information from content area textbooks and reading to get information from basal readers or trade books. They emphasize two main characteristics that might cause problems for many students. First, textbooks are written by authors who are not very concerned about the readability level of the text. So a text might well have sections that are written two or three grade levels above the grade level. Second, there is a real possibility that a lot of unfamiliar concepts for students will occur in these texts.

In order to make assessments of text difficulty, many teachers use either a readability formula or a cloze procedure[1] . Both of these measures have their place and both have the advantage of yielding a score, which makes comparison between texts straightforward, but they have disadvantages too.

Perera (1984, p. 6) when referring to text assessment says that there are many published readability formulae (see Harrison, 1980, for an overview) and that the most widely used combine a measure of vocabulary difficulty with a calculation of sentence length in an arithmetical formula that produces an approximate reading age. Their most obvious weakness is that sentence length is used to assess grammatical difficulty. On the contrary, according to Perera (1984, p. 6) there is no simple relationship

[1] The close procedure is a test used to measure reading comprehension in which words are systematically deleted and students supply the deletions.

between sentence length and grammatical difficulty and when the teachers have to compare texts in order to assess readability, the straightforward measurement of length is not a reliable guide to the relative difficulties of sentences.

Long sentences may be difficult, but that does not mean that short ones are always easy and there are many instances where a sentence can be made easier to understand by lengthening it than shortening it. For example, Reid (1972, p. 398) presented two matched groups of seven-year-olds with one sentence each from the following pair:

a) *The girl standing beside the lady had a blue dress.*

b) *The girl had a blue dress and she was standing beside the lady.*

All the children then had to answer this question:

c) *Who had a blue dress? (the girl/the lady)*

Those who read the ten-word sentence (a) achieved a score of 41.4 percent, while those who read the longer sentence, the thirteen-word (b) gained the substantially higher score of 88.6 percent. Therefore, the formulae may be dangerously misleading if the inclusion of the sentence-length measure encourages users to think of length as a cause of reading difficulty.

Another disadvantage of these formulae is that they can only assign a global score to passages and cannot pinpoint specific sources of difficulty. Thus they can indicate that a particular book will be too demanding for children of a given reading age but they cannot reveal what has caused the difficulty, or provide suggestions either for supportive teaching or for text simplification (Perera, 1984, p. 6)

The second type of readability measure that Perera (1984, p. 6-7) considers is the cloze procedure. It uses specially prepared passages from the text which is to be assessed. The advantage of the procedure is that the scores are derived from readers' responses to the structure of the text and so take their knowledge and ability into account. However, cloze passages cannot show where reading difficulty lies or how it might be overcome.

In their book entitled Should Textbooks Challenge Students?, Chall and Conard (1991) carry out a very careful study of text suitability and difficulty which I think is worth summarizing here. Suitability in terms of textbooks refers to an optional match between text and reader. Thus, the easiest or hardest books in a general sense are easy or hard in terms of the reader's ability. A challenging textbook is one that is just slightly beyond the reading ability of the reader. Appropriate or optimal challenge refers to the best possible fit between the level of the text, the ability of the student, and the instruction available.

Text difficulty can be estimated from its internal features, such as frequency of unfamiliar vocabulary, difficulty of content or concepts, complexity of syntax, organization, and cohesiveness. One traditional method of predicting the difficulty of textbooks is that of the study of vocabulary. Researchers found a solution in Thorndike's frequency word counts of the English language, published in 1921 and 1931. This became the primary criteria for grading textbooks. With time, readability researchers tended to focus primarily on comprehension difficulty, for which vocabulary measures adopted from the vocabulary studies proved to be strong and consistent predictors. The more difficult the vocabulary the more difficult the text. Beyond vocabulary, most studies found syntactic features such as sentence length, sentence complexity, and the use of prepositional phrases or clauses to be predictive of readability. Readability researchers soon developed "readability formulae" (Klare, 1963, 1979).

Chall and Conard (1991) agree that readability formulae and word lists have been widely used by educational publishers and teachers to estimate the difficulty of textbooks. One of the reasons for the concern and increased attention to text difficulty in the elementary grades may be associated with a "new" school population: the children of immigrant families whose proficiency with the English language was relatively limited. Changing priorities in the larger society may also have encouraged concerns for suitable difficulty. The use of these earlier methods has been questioned during the past decade. Some researchers have continued in the conventions of readability measurement and have searched for ways to refine and improve formulas and make them easier to use. The study of readability has also been benefited from a community of purpose and interest among researchers, resulting in periodic syntheses of the relevant research are Chall, 1958; Klare, 1963, 1974-1975, 1984.

A strong force for the study of text difficulty has come from other disciplines, such as cognitive psychology, linguistics, psycholinguistics, information processing, and artificial intelligence. This focus on difficulty developed in association with the need for greater understanding of how learning occurs and the way in which humans process, store, and recall information. The idea underlying all these studies is that there is a structure to thought and memory as well as to text. The closer the two coincide, the less difficult the text is to read and remember.

There is an area of research--cohesion analysis--that has to do with the way a text "fits" together, both at the sentence level and at the text level. The assumption basic to studies in this area is that a more coherent and cohesive text is easier to understand. Coherence is achieved by means of several kinds of cohesive ties. For example pronoun reference, substitution and connectives or conjunctions. Research has indicated that children prefer to read, are able to read faster, and have better memory for sentences connected by explicit conjunctions, particularly causal connectives, than sentences in which the conjunction is left to be inferred (Katz and Brent, 1968; Marshall and Glock, 1978-79; Pearson, 1974-75 in Armbruster, 1984).

Another related area of research--propositional analysis--has produced promising results for understanding and predicting difficulty. In propositional analysis the text is analyzed into basic units of meaning that are then used to build a structure of the text which is enlarged or changed in some way with the addition of each proposition.

Conversely, content area experts hold a generally negative view of learning content by reading. For the last twenty years, the prevailing view of how science and social studies should be taught has been to emphasize inquiry and discovery modes at the expense of expository and text-based instruction. Schallert and Roser (1989) present three arguments concerning this problem: (1) that a more balanced approach be taken between activity-based and text-based instruction; (2) that reading materials, including content textbooks, be chosen that present authentic and real messages even if their use must then be supported substantially by parents and teachers; and (3) that teachers look to the content-area trade literature as a resource. They hope this will persuade content area experts to take a more favorable view of reading. They feel this result is crucial if the curriculum is to have a major role in fostering a citizenry that can read about scientific, social, and political topics intelligently (Lapp, Flood, & Farnan, 1989). In contrast, Chall & Conard (1991) affirm that textbooks provide the primary vehicle for students learning from text as well as for the development of their reading skills, and content textbooks have been a particular target of much of the recent criticism.

CHAPTER II

Linguistic Analysis of Texts

This chapter addresses two main issues: first, a discussion of the relevance of corpus linguistics; second, the results of Biber's study showing that different syntactic forms are used in different registers. Thus, a more detailed coverage of terms such as text, genre and text-type will be given.

Corpus Linguistics

Corpus linguistics can be described as the study of language on the basis of text corpora. The advent of computers made possible to store, scan and classify large masses of material. There now exists a large number of computerized corpora varying in size, design and research purpose. The great research potential offered by these corpora has given rise to a dramatic expansion of corpus-based research that few could have foreseen thirty years ago (Aijmer & Altenberg, 1991).

The corpus linguist of the 1950s could entertain without too much difficulty the idea of a corpus providing the data for an exhaustive description of a language. This was probably because the linguists of that day focused on phonemics and morphophonemics--levels where the inventory of linguistic items is small by comparison with syntax or the lexicon. When Chomsky shifted the center of attention from phonology to syntax, he was able effectively to debunk the notion that the corpus could provide a sufficiency of data. He argued that the syntax of a language is a generative system, producing an infinite number of sentences from a finite number of rules. This illustrates how the notion of what is an adequate corpus shifts significantly as one moves from one linguistic level to another. However, Chomsky in his turn could not have conceived, in the 1950s, of a corpus of 500 million words capable of being searched in a matter of minutes or hours. While it is unlikely that foreknowledge of such a phenomenon would have changed Chomsky's view of corpora at that time or even now, we can see, in historical retrospect, how the availability of vastly increasing computer corpus resources has enabled syntactic and lexical phenomena of a language to be open to empirical investigation on a scaled previously unimagined (Aijmer & Altenberg, 1991).

Since 1961, corpus linguistics has gradually extended its scope and influence. It has not revived the American structural linguist's claim of the all-sufficient corpus, but the value of the corpus as a source of systematically retrievable data, and as a testbed for linguistic hypotheses, has become highly recognized and exploited (Leech, 1991).

Those who work with computer corpora are suddenly finding themselves in an expanding universe. For years, corpus linguistics was the obsession of a small group which received little or no recognition from either linguistics or computer science. Now much is happening, and there is a demand for much more to happen in the future (Leech, 1991).

There is a substantial history of corpus-based study in linguistics. The Brown Corpus (American English), the LOB Corpus (British English), the Helsinki Corpus (historical and dialectal English), and the Melbourne-Surrey Corpus (Australian English) are some of the best known computerized corpora of written texts developed for English.

Computerized corpora have proven to be excellent resources for a wide range of research tasks. In the first place, they have provided a more realistic foundation for the study of language than earlier types of material, a fact which has given new impetus to descriptive studies of English lexis, syntax and discourse. Secondly, they have become a particularly fruitful basis for comparing different varieties of English, and for exploring the quantitative and probabilistic aspect of the language (Aijmer & Altenberg, 1991).

The availability and use of computerized corpora have expanded the domain of linguistic inquiry in significant ways. At the same time, this expansion has led to the development of more sophisticated research methodologies and new linguistic models. Many tasks which previously had to be done by hand can now be achieved automatically or semi-automatically by means of computer programs and other kinds of software. The most fruitful efforts in corpus linguistics have concerned automatic grammatical analysis of texts and recently there have also been attempts to develop automatic programs for the analysis and generation of speech, and for interpreting the meaning and coherence of texts (Aijmer & Altenberg, 1991).

The benefits of using machine-readable text corpora, especially grammatically annotated ones, are now so widely recognized that it is probably true to say that most text-based research makes use of computerized corpus in one way or another (Aijmer & Altenberg, 1991).

However, the linguistic annotation or analysis of corpora demonstrates a need for a partnership between man and machine, or between human processing, computer processing and corpus data. Neither the corpus linguist of the 1950s, who rejected intuition, nor the generative linguist of the 1960s, who rejected corpus data, was able to achieve the interaction of data coverage and insight that characterizes the many successful corpus analyses of recent years (Leech, 1991).

Biber's study

One area where computerized corpora have proved particularly useful is the study of linguistic variation and the stylistic properties of texts and genres. Douglas Biber is one of the most prominent linguists who has done extensive research on this matter. He studied the textual dimensions and relation of speech and writing and the variations within genres.

There are several issues relating to the character of texts used in corpus studies of variation. The issue of optimal text length is of immediate practical concern; text samples must be long enough to represent reliably the linguistic characteristics of the full text, but not so long as to add unnecessarily to the work required to compile and use a corpus (Biber and Finegan, 1991).

Texts for the purpose of this study will be defined as simply continuous segments of naturally occurring discourse. Most complete texts are complex in that they extend over numerous topics and purposes. A typical academic article, for example, reflects a hierarchical structure of sections and paragraphs. The sections may range from description to narration to expository analysis (Biber and Finegan, 1991).

Biber and Finegan (1991) also distinguish between 'genres' and 'text types.' They define genres as text categories readily distinguished by mature speakers of English such as novels, newspaper articles, and public speeches. Conversely, text types have a strictly linguistic basis; they are sets or groupings of texts such that the texts within each set are linguistically similar while the sets are linguistically distinct. Biber (1989) claims that genres and text types represent complementary ways of categorizing texts.

Biber and Finegan (1991) also emphasize that not all genres are equally homogeneous. In order to have a complete linguistic description of a genre, it should include both a characterization of the central tendency as well as a characterization of the range of variation. They explain that texts can have a relatively wide range of linguistic variation. Some genres include distinguishable sub-genres; for instance, science books include articles ranging from natural sciences, physics to biology. These sub-genres are often significantly different in their linguistic characteristics (Biber, 1988). On the other hand, genres show considerable differences in the extent to which they have a focused norm, even when they lack identifiable sub-genres. For example, general fiction has a much wider range of variation than science fiction (Biber, 1988). A wide range of variation can also reflect a transitional period diachronically (Biber and Finegan, 1989). In none of these cases does a wide range of variation invalidate the genre category; rather the ranges reflect various functional and developmental characteristics of that category, and they should be seen as a descriptive fact that requires explanation (Biber and Finegan, 1991).

Biber (1988) carried out a factor analysis of a large corpus of writing and talk in English; he found out that groups of syntactic features clustered together in particular genres of spoken or written English. Biber called clusters of syntactic forms that co-occurred **dimensions**. He came up with six dimensions: 1) **involved versus informational production,** 2) **narrative versus non-narrative concerns,** 3) **explicit versus situation-dependent reference,** 4) **overt expression of persuation,** 5) **abstract versus non-abstract information** and **`on-line informational elaboration.**

Biber's research is of great significance. He demonstrates that there are clear distinctions in the use of particular syntactic forms in various types of texts in the English language. The different kinds of texts exploit different syntactic forms for diverse functional purposes. If school-age students are to understand what they read and become intelligent users of English, they need instruction and practice in using those clusters of syntactic forms that occur in the particular registers of English used in the schools for academic, social and other purposes (Sampson, 1992).

Sampson (1992) points out that Biber's research helps us understand why children and adolescents do not acquire the supposed early control (by age six) over all English syntax that many linguists, unfamiliar with school-age children's language productions, have claimed. Unless children are exposed to the kinds of texts in which certain syntactic forms occur children will never get to hear and read those forms. Parents and other children do not normally talk about physics, there is no reason to suppose that children will learn the syntax and vocabulary required to talk intelligently about physics. She suggests that it is the school environment the place where teachers can expose students to such talk and writing and help them to learn its syntax.

CHAPTER III

Psycholinguistic Analysis of Developmental Changes in Children's Understanding of Syntactic Structures

This chapter will be devoted to a close analysis of children's language acquisition as presented by Katherine Perera in her book *Children's Writing and Reading,* Chapter 3.

Perera (1984) devotes a whole chapter to research on the study of the acquisition of grammar by children. She paid special attention to those aspects of grammar that are still developing when the child starts school. Particularly she focuses on structures that cause children to struggle in their comprehension or production of speech, since an awareness of these difficulties contributes to a fuller understanding of some of the problems children face in reading and writing.

Perera (1984) explains that even though chronological ages are suggested for particular levels of development, these need to be treated with great caution. Averages and norms can be very misleading when applied to individual children. However, it is generally agreed that most children pass through all the major stages of acquisition in the same order but that they do so at different rates.

Language acquisition

In order to illustrate the kind of grammatical constructions that children use at different ages, she took examples from many studies of children's language acquisition. So that we can have a better understanding of this syntactic development a chart will be included. It summarizes the most common problems school children have during the language acquisition process. For a better contrast the difficulties have been organized by age groups (five- to seven-year-olds, eight- to ten-year-olds, and eleven-year-olds and older) and grammatical structures (clause structure, phrase structure, word structure, negatives, questions, passives, coordination, nominal clauses, adverbial clauses, relative clauses, and sentence connectives).

Grammatical Structure	five- to seven-year-olds	eight- to ten-year-olds	eleven-year-olds and older
Clause Structure	-24 percent of seven-year-olds understand the SVOiOd[1] . 90 percent are successful with SVOdOi -are capable of producing quite a wide range of clause patterns but they use just a few--SVO, SVOA, SVA, SVC -use the recapitulatory pronoun -make the clause-level error of lack of concord between the subject and the verb	-nine-year-olds still use the recapitulatory pronoun[2] quite frequently. -eight-year-olds occasionally use the stem form of the verb after a third person singular subject in the present tense as well as the stem+s form inappropriately -at ten children have difficulty to interpret SVOiOd	-they use SVOdOi more than twice as often as they use SVOiOd -twelve-year-olds generally restrict the use of the recapitulatory pronoun to clauses with a particularly long subject -clause-level error of lack of concord between the subject and the verb is much rarer in older children. It is the complexity of the sentence that is responsible for the failure of concord

[1] The following are the abbreviations used in this chart:

SVOiOd: Subject + Verb + Indirect Object + Direct Object
SVOdOi: Subject + Verb + Direct Object + Indirect Object
SVO: Subject + Verb + Object
SVOA: Subject + Verb + Object + Adverb
SVA: Subject + Verb + Adverb
SVC: Subject + Verb + Complement

[2] Recapitulatory pronouns: the construction begins with a noun phrase (*These people with big cars*) which is then left outside the structure of the clause, where its place is taken by a co-referential pronoun (*they*). For example: These people with big cars, *they* should pay more tax.

Phrase Structure	-six-year-olds use prepositional post-modification only tenth as often as they use pre-modification -young children co-ordinate sentences whereas other children make use of adjectival modification -use simple noun phrases as subjects -errors in the use of the determiner in the noun phrase are fairly common at the age of six -six-year-olds tend to show pronominal vagueness -six- to seven-year-olds tend to use a WITH phrase rather than a co-ordinate phrase in subject position -six-year-olds show inconsistency of tense sequence in their speech -six- to seven-year-olds have trouble using the stem+ing form constructions like *he tried riding my bike* -the progressive form of the verb, consisting of be + stem+ing is not always fully mastered by six-year-olds -they have trouble with the use of the hypothetical future, they may use the modal but get it wrong, saying *would* instead of *would have*	-at age eight children completely master the TO construction -children at these ages increase the use of complex noun phrases -at the age of eight errors in the use of the determiner in the noun phrase are still apparent. This construction is a complicated area of English grammar -eight-year-olds sometimes show pronominal vagueness -eight- to ten-year-olds are inconsistent in the use of tense sequence -eight-year-olds still have difficulties with modal auxiliaries such as *shall*, *may*, *might* and *ought to* -errors in the use of the hypothetical past occur until the age of ten as well as improper use of the modal *would*	-the ability to handle a range of modifiers, both before and after the head noun, develop gradually, not reaching adult norms until the age of fifteen or sixteen -even at twelve children tend to use the simplest noun phrases as subjects -twelve-year-olds still occasionally use definite reference inappropriately -eleven-year-olds quite often include an adverbial within the verb phrase -twelve-year-olds use 30 percent more adverbials than six-year-olds -errors in the correct use of the determiner in the noun phrase have not been eradicated

Word Structure	-children from this age group tend to make mistakes with nouns and verbs that have irregular morphology and with the past participle of irregular verbs	-eight-year-olds still tend to make mistakes with nouns and verbs that have irregular morphology as well as with the past participle of irregular verbs	
Negatives	-they have difficulty processing negative sentences. If the two-clause sentence has a negative in both clauses then the processing becomes very difficult -they also have difficulty with the concealed negative[1], an expression that has a negative meaning without an explicit negative marker such as NO, NOT or NEVER for example: HARDLY, SCARCELY, NEITHER...NOR -they as well face problems with complex sentences where the object or complement is expressed by a nominal clause and the main clause is negated	-eight- to ten-year-olds still have problems with two-clause sentences that have negative verb phrases in both clauses -they still have difficulty with the complex sentences where the object or complement is expressed by a nominal clause and the main clause is negated. Full understanding of all the different sentence types is not acquired until late probably in the early secondary years	-eleven-year-olds and older ones still have problems when faced with two-clause sentences that have a negative verb phrase in both clauses as well as with the concealed negative and with the comprehension of complex sentences where the object or complement is expressed by a nominal clause, when the main clause is negated

[1] Concealed negative is an expression that has a negative meaning without an explicit marker such as no, not or never. For example, Tom's mother was anything but pleased.

Questions	-five- and six-year-olds still show difficulty with YES/NO and WH questions for example: failing to invert subject and operator and double marking of the past tense -five-year-olds use more lexical than grammatical tags -six-year-olds and older children show correct use of grammatical tags; however, they fail to copy the main clause operator in the tag -six-year-olds may still have difficulty with questions with HOW which may receive an answer that would be appropriate to a WHY question	-though this group of children make more use of grammatical tags, they have difficulty to copy the main close operator in the tag, to copy the tense of the main clause operator in the tag, to concord between the operator and subject pronoun, to copy the subject of the main clause in the tag and to use a positive tag after a negative main clause -eight-year-olds cannot make tag questions with the auxiliaries *might, may, ought to* and *shall*	-there are instances that children from this age group may still make mistakes when using tag questions. They may fail to copy the main clause operator in the tag, to copy the tense of the main clause operator or to copy the subject of the main clause
Passive	-five-year-olds very seldom use the passive in their own spontaneous speech. 15 percent of five-year-olds and 20 percent of seven-year-olds use full passives[1] -between the age of five and eleven, there is, on average, only one occurrence of the passive in every two hundred utterances -most passives expressions that occur in the speech of six-year-olds do not have an agent	-this age group uses one passive in every two hundred utterances -full passives are used by approximately 20 percent of nine-year-olds -nine-year-olds sometimes reverse the word order in the passive sentence -mistakes in the form of the past participle are still being made at the ages of eight and nine	

[1] Full passives are passive constructions that have an agent e.g. My sister got cut on her finger ***by my scissors.***

Coordination	-six- and seven-year-olds occasionally use BUT in their spontaneous speech. They make correct use of AND, BUT and OR though not the more literary YET as a co-ordinator -children at these ages still have difficulty to differ between AND and BUT co-ordinators and BUT and YET co-ordinators	-they have not fully master apparently simple words like BUT and YET	
Nominal Clauses	-the commonest type of non-finite clause in nominal clauses is the one with the infinitive	-children between eight and ten use non-finite nominal clauses both with the infinitive and with stem+ing form of the verb, but they do not use them in subject position. Occasionally, the extraposition construction is used, with the result that the formality of nominal clauses at the beginning of the sentence is avoided	-comprehension of non-finite nominal clauses in subject position is likely to cause problems well into the junior school years -nominal WH clauses after ASK may not be completely understood even by teenagers

Adverbial Clauses	-they have difficulty in the comprehension of adverbial clauses in general. For example, sentences introduced by BEFORE and AFTER may bring problems for this age group when the chronological order of events is not preserved	-at the age of eight children use a wide range of subordinators to introduce temporal clauses. Noticeably less frequent than the clauses of **time**, **reason** and **condition** are those of **result**, introduced by SO and **purpose**, introduced by SO (THAT) -other adverbial clauses such as those of **place**, **manner**, and **concession**, occur rather rarely in the speech of primary school children -the violation of the chronological order of events is very disturbing since the first clause would describe the second event -understanding of **reason** clauses introduced by BECAUSE seems to be affected by four factors: --children rely heavily on semantic cues, so at an early age they interpret sentences correctly when they express a familiar cause-effect relationship --children find the affective use (events and actions linked to emotional responses) easy and the concrete logical use (ideas and judgments joined in a relationship of logical necessity) hard	-teenage children tested in the understanding of BECAUSE in scientific contexts reported the rather low score of 50 percent for eleven-year-olds and 73 percent for fifteen-year-olds -the average score for fifteen-year-olds in the understanding of PROVIDED THAT is of 75 percent -comprehension of ALTHOUGH is not even fully established by fifteen

Adverbial Clauses (cont.)		--sentences with the BECAUSE clause first are generally easier than those with the main clause first. Children until the age of twelve have preference for a linguistic order that matches the sequence of events, with the cause mentioned before the effect -non-reversible sentences are easier to process than reversible ones, thus children at these ages may have difficulty in interpreting logical BECAUSE clauses accurately if they occur in second position in an unfamiliar context in potentially reversible sentences -full comprehension of IF in naturalistic sentences appears to be a late-developing ability. Hypothetical conditions are harder to interpret than real conditions for children under ten years of age -children do not understand UNLESS until they are ten years old. They do not recognize the negative meaning but treat UNLESS as if it meant IF -PROVIDED THAT is very difficult to process at these ages -nine is the earliest age at which a rudimentary understanding of ALTHOUGH can be expected	

Relative Clauses	-by the age of five, a few children are using relatives in the noun subject phrase. Children between five and seven use the majority of relative clauses in the clause elements that follow the verb--the object, complement and adverbial -the number of relative clauses is at its highest at about five years of age and then dips until the teens, when it starts to climb again -six-year-olds use relative clauses that have vague antecedents such as THE ONE and THE THING -children at these ages frequently use the wrong WH word in relative clauses -comprehension deteriorates when the relative pronoun is omitted	-at nine only 40 percent use relative clauses in the subject position -children at these ages use less relative clauses than five-year-olds. Frequently they use the wrong WH word in the relative clause and even a non-standard form such as WHAT which is not a relative pronoun	
Sentence Connectives		-children do not use in their speech connectives such as NEVERTHELESS, THUS, ACCORDINGLY, LIKEWISE, BESIDES, MOREOVER, CONSEQUENTLY, INSTEAD, HENCE, HOWEVER, SIMILARLY, FURTHER, THAT IS	

<u>Summary</u>

In terms of fluency the period between five and twelve years of age is characterized by a steady reduction in the number of incomplete utterances that occur in speech (Loban, 1963). Even though there has been little research done in the development of the verb phrase after about three years of age, from the limited information available it seems that, unlike noun phrases, children's verb phrases do not develop markedly in length or complexity between the ages of five and ten. Evidence of linguistic maturity is to be found in the varied and error-free use of modal auxiliaries; in the correct handling of sequences of verbs in a discourse, and in the selection of appropriate verb forms for the expression of hypothetical reference; also in increasing use of adjectival pre-modification, in the development of prepositional post-modification, in the use of expanded noun phrases in subject position, in the correct choice of determiners, and in the appropriate use of definite and indefinite reference (Perera, 1984).

Studies mentioned by Perera (1984, p. 89-158) suggest that complex sentences that contain negatives may well cause comprehension difficulties in reading, particularly when the subject matter is unfamiliar, so that the child's knowledge is not secure enough to act as a support to grammatical processing.

As far as passive constructions are concerned, in general passive sentences are harder to understand than active ones. It seems likely that reversible passives are harder to understand than non-reversible ones because, in reversible sentences, both the correct and incorrect interpretations are plausible, so comprehension depends entirely on accurate processing of the grammatical relationships with no help from the meaning (Perera, 1984). In the case of reversible passives the two noun phrases can be interchanged, giving two different but perfectly sensible sentences e.g. *The dog was chased by the cat. / The cat was chased by the dog.* In non-reversible passives, on the other hand, if the noun phrases are interchanged, a nonsense sentence results e.g. *Goliath was killed by a stone./ * A stone was killed by Goliath.*

When summing up the section on nominal clauses, Perera (1984) points out that evidence of linguistic maturity will be found in the occurrence of clauses in subject position--particularly if they are non-finite--and also, to a lesser extent, in the use of non-finite clauses that have the stem+ing form of the verb. She adds that comprehension of non-finite clauses in subject position is likely to cause problems well into the junior school years; and WH-clauses after *ask* may not be confidently understood even by teenagers.

Moberly (1978) found that comprehension was affected when substitution items were separated by a sentence or more from the lexical expressions they were replacing, but that this distance effect did not apply to reference items. In regards to ellipsis, she also noted that comprehension deteriorated significantly if the antecedent was more than one sentence away.

Perera (1984, p. 156) in her conclusion to Chapter III "The Acquisition of Grammar" emphasizes that during the Seventies, it was commonplace for books on language acquisition to suggest that, apart from vocabulary, children had virtually completed the learning of their mother tongue by the age of five. She shows in her book that, although children have acquired a remarkable amount of language by the time they start school, the developmental process continues, albeit at a slower rate, until children are in their teens (Perera, 1984).

The following are some of the grammatical constructions that are more likely to occur after five than before--some, indeed, are not at all frequent until adolescence:

--complex Noun Phrases, particularly in subject position;

--modal auxiliaries such as **shall, may, ought to;**

--nominal clauses as subjects;

--adverbial clauses of **place, manner, concession,** and **hypothetical condition;**

--non-finite adverbial clauses (apart from those of **purpose**);

--relative clauses introduced by **whom, whose** or a relative pronoun plus a preposition;

--clause substitution;

--some types of ellipsis; and

--all but the commonest sentence connectives

It is clear, Perera (1984) adds, that when the child starts school there are still many grammatical constructions that are not fully understood, for instance:

--SVOiOd clause pattern;

--reversible passives;

--the **ask/tell** distinction; and ellipsis of the verb or object in compound sentences

She also points out that it is generally several years before the following constructions are interpreted in an adult way:

--concealed negatives;

--sentences where both the main and the subordinate clauses are negated;

--sentences where the clause sequence conflicts with the chronological sequence;

--adverbial clauses introduced by **although, unless** and **provided that**;

--hypothetical and inferential **if** clauses;

--many sentence connectives; and

--discourse-level ellipsis that is remote from its antecedent

It has been a mistake, as shown by the research done, to think that the acquisition of language is a smooth, unbroken, forward process. Children may correctly produce certain grammatical structures at one age only to lose it and reacquire it again, which is known as the inverted curve, for example:

--irregular past tenses;

--pronominalization;

--the use of subordinate clauses (between the ages of five and six there is a noticeable increase in the number of them used, but this level stays fairly constant for several years until about eleven)

Perera (1984) also explains that reading plays a predominant role in the development of language abilities in the child. Teachers need to know the different stages children's language acquisition goes through. It is clearly unreasonable for young children--who are still struggling to master the mechanics of reading--to be faced with grammatical constructions that are remote from the language they speak. A balance has to be maintained, whereby pupils learn the basics of reading by using books that have language which is close to their everyday speech, but progress, with help and support, to more complex material that will ultimately enrich their writing and spoken language (Perera, 1984).

In this study I have examined the age group between eight- and ten-year-olds since this is the age range of children in the third and fourth grades. The results of the studies on language acquisition constitute a relevant aspect for the further analysis of the corpus selected for this study. Research shows us those grammatical structures that would interfere with children's comprehension. It is not a matter of leaving those structures out, but working on them and helping children understand the difficult ones.

As has been noted children between the ages of eight and ten have problems with certain constructions within the:

- clause structure,
- phrase structure,
- word structure,
- negatives,
- questions,
- the passive,
- coordination,
- nominal clauses,
- adverbial and relative clauses, and
- sentence connectives

These structures may cause more comprehension problems. They may be used as points of reference when the syntactic analysis of the corpus for the present study is carried out. On the other hand, eight- and nine-year-old children do not differ in the difficulties they would find since they have approximately the same language development at this stage.

Statement of the problem

We may assume that if books increase in syntactic complexity in fourth grade, these children would have to deal with structures that they may never have faced before in their lives. It is the role of the teacher to pinpoint those structures and teach children to comprehend them. At the same time, since not all children acquire language at the same rate, teachers may also need to know the syntactic structures that might be more difficult for the least able and English as a Second Language children. Many of these structures may be the same as those that children between the ages of five and seven find difficult.

In a study by Chall & Conard (1991) on books published between 1974 and 1982 they found out that fourth-grade books ranged in difficulty from a fourth- to an eighth-grade reading level. The science books were consistently harder to read than the social studies books. Furthermore, science books specified for below-average readers were as difficult, and oftentimes more difficult, than those intended for above-average readers. They also found out that the lower the grade the harder the books were in comparison to students' reading abilities and that most of the science and social studies textbooks for the fourth grade were above the reading levels of the majority of the children using them.

In their final analysis, Chall & Conard (1991) state that perhaps the best explanation for the relative difficulty of fourth-grade science and social studies texts is the change in content and in reading tasks in the fourth grade. In the first three grades, the reading matter is usually familiar. At about fourth grade, when reading becomes a tool for learning, the textbooks contain more worldly knowledge and more abstract, literary, and technical words and ideas which make a textbook difficult to read.

They think that there is still another reason to look at fourth-grade texts: this is the grade when the reading achievement of lower-income children has been found to begin to decelerate (Chall, Jacobs, & Baldwin, 1990). This deceleration seems to stem mainly from a lack of familiarity with abstract literary and technical words--words used increasingly in the content-area textbooks in the intermediate and upper elementary grades. Through grade three when the reading matter tends to be more familiar and unspecialized, the reading scores of low-income and mainstream children are similar. Since deceleration seems to come at about fourth grade, it is particularly important to pay more attention to the study of the causes of this problem so that teachers can help the students make the transition from grade three to grade four for all children and specially for those whose reading scores have a tendency to decelerate at this point

It was previously stated that lack of familiarity with abstract literary and technical words plays a role in comprehension problems; however, syntactic structures may play their role as well. It is possible that the child is not familiar with the structures that he encounters because of the natural development of language and the age of the child, which may constitute barriers for understanding.

Although Chall & Conard (1991) put emphasis on the effect that this transition from grade three to grade four has on lower-income children, it is not necessarily the case. It may be assumed that all children have similar difficulties; and ESL students may be those who will encounter more difficulties since they are not only unfamiliar with specialized registers of the language but with the structures as well.

Hypotheses

Null Hypothesis: The percentage of a given sentence type or group of similar sentence types is the same in a Grade Four textbook published by a given publisher as in the Grade Three textbook published by the same publisher.

Because no prior work has attempted to characterize the nature of the syntax used in elementary school textbooks, any number of possibilities exists to explain why it appears to be the case that Grade Four science textbooks are more difficult for children to comprehend than Grade Three science textbooks. This study looks at just one register of English--the scientific. Grade Three and Four books will be inspected to see if the following hypotheses of interest hold:

1- The ratio of kernel (simple) to non-kernel (transformed sentences, sentences with embedding) decreases in the Grade Four textbooks. This decrease, resulting in a higher percentage of syntactically complex sentences may contribute to children's increased comprehension difficulties.

2- Because increased syntactic complexity does not necessarily lead to longer sentence length, common measures of reading level do not reflect this complexity. Hence, it is hypothesized that three measures of reading level carried out on the texts will show little or no differences between Grade Three and Grade Four texts.

Chapter IV
Methodology of the Study

The main objectives of this chapter are to describe the selection of the texts used in the study and how data were collected and organized. Finally, the results from the readability tests carried out on the texts are given and compared to previous tests done by the publishers of the textbooks.

Text Selection

In order to investigate the hypotheses previously stated methods employed in corpus linguistics are used. The corpus of the present study consists of three sets of texts chosen from Third and Fourth Grade Science textbooks. Two of the sets are part of the recommended Science Curriculum in the Province of British Columbia, the third one is a complementary text. Each set consists of a Grade Three and a Grade Four textbook. The criterion for the selection of the chapters to be syntactically analyzed was that they were topic related. One chapter from each book was chosen:

Set 1

Barnard, J. D., & Lavatelli, C. B. (1970). The Macmillan Science Series. Cambridge, Ontario: The Macmillan Company.

Science: Being Curious. Changing Food. (Grade Three)

Science: Comparing Things. Understanding Energy. (Grade Four)

Set 2

Blecha, M. K., Beugger, P., Gega, P. C., Green, M., & Wield, A. V. (1977). Toronto, Ontario: Doubleday Canada Limited.

Exploring Science. Heat and Temperature. (Grade Three)

Exploring Science. Work and Machines. (Grade Four)

Set 3

Rockcastle, V. N., Salomon, F. R., Schimidt, V. E., & McKnight, B. J. (1977). Don Mills, Ontario: Addison-Wesley Publishing Company.

Stem Science. Heat and Temperature. (Grade Three)

Stem Science. Friction-Rubbing andRolling/Heat. (Grade Four)

The next step was to classify the texts so that it would be clear which text we were referring to when further analyzing them. The first number refers to the grade level and the second number to the set of textbooks:

Grade Three Textbooks

Changing Food	Book 3-1
Heat and Temperature	Book 3-2
Heat and Temperature	Book 3-3

Grade Four Textbooks

Understanding Energy	Book 4-1
Work and Machines	Book 4-2
Friction-Rubbing and Rolling/Heat	Book 4-3

Collection and Organization of the Data

The texts were electronically scanned and converted to plain text, eliminating tables, charts and pictures or drawings from the originals. Each text was divided into sentences which were syntactically analyzed. As a result we came up with two types of sentences: kernel (simple) and embedded (complex) sentences. This allowed us to know the number of sentences that we had and at the same time, the number and type of clauses that each sentence was composed of. From the Third Grade texts we analyzed 832 clauses and from the Fourth Grade ones 1051, for a total of 1883 clauses.

In order to prepare the data this information from each text was organized in charts where all sentences were numbered[1] and classified. An example is presented below in Table 1. This is part of the Sentence Analysis chart for Book 3-1, just 10 sentences are included here to show the procedure followed to carry out the syntactic description of the sentences.

[1] Complex sentences are lettered a, b, c, d, according to the number of subordinate clauses each Complex sentence had. Let us look at an example: sentence 3 in table 1 is a Complex sentence with two subordinate adverbial clauses. 3a describes the whole sentence, 3b describes the first subordinate clause and 3c describes the second subordinate clause.

Table 1 ***Syntactic Analysis***

	BOOK 3-1	TEXTBOOK: <u>SCIENCE: being curious</u>
	GRADE: Third Grade	CHAPTER 6: Changing Food
Nº	Sentences	Syntactic Description
1	There are many kinds of foods.	'THERE' TRANSF.
2a	You will find out how foods get to your body cells.	S.V.O., ADV. CL.
2b	how foods get to your body cells	S. V. A. (subord. HOW)
3a	You will learn how foods must change so that your cells can use them.	S.V.O. A., ADV. CL., ADV. CL.
3b	how foods must change	S. V. (subord. HOW)
3c	so that your cells can use them	S. V. O. (subord. SO THAT)
4a	Do you think that cake and soda make a good lunch?	Y/N QUEST. TRANSF, THAT CL.
4b	that cake and soda make a good lunch	S. V. O.
5a	You probably know that they do not	S. V. O. A., THAT. CL. (ellipsis)
5b	that they do not	NEGATIVE TRANSF. S. V.

6	But do you know why?	Y/N QUEST. TRANSF. (BUT adversative connector)
7a	Do you know why you need to eat certain foods every day?	Y/N QUEST. TRANSF, ADV. CL.
7b	why you need to eat certain foods every day	S. V. N.F. A. (subord. WHY)
8	Are all foods the same?	Y/N QUEST. TRANSF.
9	Look at this school lunchroom.	COMMAND TRANSF. V. O.
10a	See the girls and boys eating here.	COMMAND TRANS. V. O. A. REL. CL.
10b	[who are] eating here	(ellipsis) S. V. A.

Organizing the data in charts was very helpful to determine the type of syntactic categories that had been used in the texts. For the syntactic classification Perera's and the *Collins Cobuild Grammar* criteria were followed. The sentences and clauses were classified into the following categories: *Kernel, Command, Wh- question, Yes/No question, 'There' transformation, Passive, Negative, Adverbial, Relative, Nominal, Phase, That, Extraposition, and Cleft.*

Once the grammatical description of all sentences was done the data were divided into the different categories. Table 2 is an example of how the adverbial clauses for Book 3-1 were organized and subclassified. The same procedure was followed with the rest of the categories mentioned above.

Table 2 ***Syntactic analysis of Adverbial Clauses: Book 3-1***

N°	Subord[1]	Subject	Verb	Object	Complem[2]	Adverb
25b	when	you	eat	fat		
112a	when	copper sulfate	dissolves			in water
122b	when	you	do	this		
144b	when	the solution	cools			
179b	when	the indicator	is added			
199b	when	it	is mixed			with an acid
200a	when	it	is mixed			with a base
104b	until	each dish	is		half full	
138c	until	the water	has boiled			for a minute
146b	until	[it]	is		half full	
147b	until	it	is		half full	

[1] Subordinator
[2] Complement

159b	until	the dish	is		half full	
160b	until	it	is		half full	
175b	until	it	is		clear	
2b	how	foods	get			to your body cells
3b	how	foods	must change			
118b	how	this	was done			
181b	how	the solution	is		alike	in each group
3c	so that	your cells	can use	them		
41b	to		get	all the nutrients		
151b	to		squeeze	a few drops of the purple solution		
172b	to		do	this		
183b	if	you	tasted	the vinegar and the lemon juice		
182b	unless	you	are		sure	
188b	unless	you	are		sure	
46a	where	they	are used			

48b	where	they	are used		in the body
30b	faster than	it	can digest	fat	
7b	why	you	need to eat	certain foods	every day

The sentences were ordered not by the sequence of numbers but according to the type of clause each subordinator introduced.

Next, the number of clauses for each category in each text were counted and the percentages calculated. First, a comparison was established between the categories of Grade Three texts, then, between the categories of Grade Four texts. Finally, a comparison between Third and Fourth Grade texts was established. Tables 3, 4, and 5 summarize how the data were organized and processed.

Table 3 ***Comparative Analysis: Grade Three***

	Book 3-1 (307 clauses)		Book 3-2 (297 clauses)		Book 3-3 (228 clauses)	
Type of clause	N°	%	N°	%	N°	%
Kernels	75	25	91	31	57	25
Commands	55	18	17	6	33	14
Adverbials	28	9	52	18	28	12
Wh questions	26	8	43	14	28	12
Relatives	26	8	25	8	24	11
Y/N questions	13	4	4	1	15	7
Phase	15	5	11	4	13	6
Passives	17	6	30	10	24	11
Negatives	15	5	9	3	3	1
That	13	4	16	5	8	4
Nominals	5	2	-	-	2	1
There	4	1	4	1	3	1
Extrapositions	2	1	2	1	1	1
Clefts	1	1	1	1	-	-

Table 4 ***Comparative Analysis: Grade Four***

	Book 4-1 (333 clauses)		Book 4-2 (309 clauses)		Book 4-3 (409 clauses)	
Type of clause	N°	%	N°	%	N°	%
Kernels	93	28	73	24	105	26
Commands	19	6	16	5	20	5
Adverbials	83	25	39	13	92	22
Wh questions	28	8	54	17	21	5
Relatives	23	7	33	11	62	15
Y/N questions	7	2	10	3	19	5
Phase	18	5	21	7	27	7
Passives	31	9	48	16	49	12
Negatives	23	7	5	2	17	4
That	9	3	7	2	10	2
Nominals	2	1	-	-	4	1
There	30	9	9	3	7	2
Extrapositions	2	1	-	-	3	1
Clefts	-	-	-	-	1	1

Table 5 *Comparison between Grades Three and Four*

	Grade Three (832 Clauses)		Grade Four (1051 Clauses)	
Type of clause	Nº	%	Nº	%
Kernels	223	27	271	26
Commands	105	13	55	5
Adverbials	108	13	214	20
Wh questions	97	12	103	10
Relatives	75	9	118	11
Y/N questions	32	3	36	3
Phase	39	5	69	7
Passives	71	9	128	12
Negatives	27	3	45	4
That	37	4	26	2
Nominals	7	1	6	1
There	11	1	46	4
Extraposition	5	1	5	1
Clefts	2	1	1	1

Analysis of Kernel Sentences

A sub-classification of Kernel sentences was done. Kernels were sub-classified in the following form:

Subject + Verb (S.V.)

Subject + Verb + Object (S.V.O.)

Subject + Verb + Object + Adverb (S.V.O.A.)

Subject + Verb + Adverb (S.V.A.)

Subject + Verb + Indirect Object + Direct Object (S.V.Oi.Od.)

Subject + Verb + Indirect Object + Direct Object + Adverb (S.V.Oi.Od.A.)

Subject + Verb + Complement (S.V.C.)

Subject + Verb + Complement + Adverb (S.V.C.A.)

We first analyzed the Kernel sentences of Grade Three texts (Table 6) and then those of Grade Four (Table 7). Finally we compared Third and Fourth Grade Kernel sentences (Table 8). As with the previous analyses the sentences were counted and the percentages calculated.

Table 6 ***Analysis of Kernels: Grade Three***

	Book 3-1		Book 3-2		Book 3-3	
Type of Kernels	Nº	%	Nº	%	Nº	%
S. V.	2	3	-	-	-	-
S. V. O.	10	13	13	14	12	21
S. V. O. A.	26	34	32	35	18	32
S. V. A.	13	17	36	40	12	21
S. V. Oi. Od.	3	4	1	1	-	-
S. V. Oi. Od. A.	1	1	-	-	-	-
S. V. C.	14	18	3	3	12	21
S. V. C. A.	7	9	6	7	3	5
Total	75	24	91	31	57	25

Table 7 ***Analysis of Kernels: Grade Four***

	Book 4-1		Book 4-2		Book 4-3	
Type of Kernels	Nº	%	Nº	%	Nº	%
S. V.	1	1	-	-	1	1
S. V. O.	18	19	23	32	32	30
S. V. O. A.	29	31	14	19	40	38
S. V. A.	34	37	10	14	18	17
S. V. Oi. Od.	-	-	-	-	-	-
S. V. Oi. Od. A.	-	-	-	-	-	-
S. V. C.	6	6	24	33	10	10
S. V. C. A.	5	5	2	3	4	4
Total	93	28	73	24	105	26

Table 8 ***Comparison of Kernels: Grades Three and Four***

	Grade Three (224 Clauses)		Grade Four (271 Clauses)	
Type of Kernels	Nº	%	Nº	%
S. V.	2	1	2	1
S. V. O.	35	16	73	27
S. V. O. A.	76	34	83	61
S. V. A.	61	27	62	23
S. V. Oi. Od.	4	2	-	-
S. V. Oi. Od. A.	1	1	-	-
S. V. C.	29	13	40	15
S. V. C. A.	16	7	11	4
Total	223	27	271	26

Analysis of Embedded Sentences

The next analysis was that of Embedded or Complex sentences. There were embedded sentences that had only one subordinate clause and others with more than one subordinate clause. We counted the number of Embedded sentences with one subordinate clause in all Grade Three and Grade Four texts (Table 9) as well as the number of Embedded sentences with more than one subordinate clause for each text (Table 10), then percentages were calculated. Table 11 shows the total number and the percentages of Embedded sentences in Grade Three and Grade Four texts.

Table 9 ***Analysis of Embedded Sentences with One Subordinate Clause***

Book	Nº	%
Book 3-1 (201)	64	32
Book 3-2 (184)	74	40
Book 3-3 (161)	40	25
Total (546)	178	33
Book 4-1 (203)	84	41
Book 4-2 (200)	65	33
Book 4-3 (209)	70	33
Total (612)	219	36

Table 10 ***Analysis of Embedded Sentences with More Than One Subordinate Clause***

Book	Nº	%
Book 3-1 (201)	11	5
Book 3-2 (184)	18	10
Book 3-3 (161)	13	8
Total (546)	42	8
Book 4-1 (203)	42	21
Book 4-2 (200)	19	10
Book 4-3 (209)	68	33
Total (612)	129	21

Table 11 ***Percentage of All Embedded Sentences***

Book	Nº	%
Book 3-1 (201)	75	37
Book 3-2 (184)	92	50
Book 3-3 (161)	53	33
Total (546)	220	40
Book 4-1 (203)	126	62
Book 4-2 (200)	84	42
Book 4-3 (209)	138	66
Total (612)	348	57

Analysis of Adverbial Clauses

Tables 12 and 13 summarize the analysis of Adverbial clauses in Grade Three and Four texts respectively. For this analysis we classified the Adverbial clauses into different types and grouped them according to the subordinators that introduced each of them. In Table 14 we compare the Adverbial clauses in Grade Three texts to those in Grade Four texts. A final comparison between Grade Three and Grade Four, taking into account the type of Adverbial clause is presented in Table 15.

Table 12 ***Analysis of Adverbial Clauses: Grade Three***

	Book 3-1 (28)		Book 3-2 (52)		Book 3-3 (28)		Total (108)	
Subordinator	N°	%	N°	%	N°	%	N°	%
When	7	24	19	37	6	21	32	29
Until	7	24	-	-	-	-	7	6
Whenever	-	-	-	-	1	4	1	1
Before	-	-	-	-	1	4	1	1
While	-	-	-	-	1	4	1	1
As (time)	-	-	3	6	3	11	6	6
To	3	10	14	27	5	18	22	20
So That	1	3	1	2	-	-	2	2
In Order To	-	-	-	-	1	4	1	1
If	1	3	7	13	5	18	13	12
Unless	2	7	-	-	-	-	2	2
Whether Or	-	-	1	2	2	7	3	3
How	4	14	5	10	3	11	12	11
As (manner)	-	-	1	2	-	-	1	1
Where	2	7	1	2	-	-	3	3
Why	1	3	-	-	-	-	1	1

Table 13 ***Analysis of Adverbial Clauses: Grade Four***

	Book 4-1 (83)		Book 4-2 (39)		Book 4-3 (92)		Total (214)	
Subordinator	N°	%	N°	%	N°	%	N°	%
When	29	35	8	21	23	25	60	28
Only When	1	1	-	-	1	1	2	1
As (time)	2	2	1	3	1	1	4	2
After	2	2	-	-	2	2	4	2
Before	1	1	-	-	2	2	3	1
Once	1	1	-	-	-	-	1	1
Until	2	2	-	-	-	-	2	1
Each Time	1	1	-	-	-	-	1	1
Whenever	3	4	1	3	-	-	4	2
To	19	23	14	36	29	32	62	29
So That	-	-	-	-	2	2	2	1
In Order To	1	1	-	-	-	-	1	1
So	2	2	-	-	-	-	2	1
If	6	7	5	13	5	5	16	7
Unless	-	-	-	-	2	2	2	1
As Long As	1	1	-	-	2	2	3	1
Why	-	-	-	-	1	1	1	1
As (reason)	-	-	4	10	1	1	5	2
Since	-	-	-	-	4	4	4	2
Because	3	4	1	3	1	1	5	2
As...As	1	1	-	-	1	1	2	1
How	2	2	4	10	11	12	17	8

As (manner)	-	-	-	-	-	-	-	-
Even If	2	2	-	-	2	2	4	2
As If	1	1	-	-	-	-	1	1
Just As	1	1	-	-	-	-	1	1
Although	-	-	1	3	1	1	2	1
Even Though	1	1	-	-	-	-	1	1
Where	1	1	-	-	1	1	2	1

Table 14 ***Comparison of Adverbial Clauses: Grades Three and Four***

	Grade Three (108 Clauses)		Grade Four (214 Clauses)	
Subordinator	N°	%	N°	%
When	32	29	60	28
Until	7	6	2	1
As (time)	6	6	4	2
Whenever	1	1	4	2
Before	1	1	3	1
After	-	-	4	2
While	1	1	-	-
Only When	-	-	2	1
Once	-	-	1	1
Each Time	-	-	1	1
To	22	20	62	29
So That	2	2	2	1
In Order To	1	1	1	1
So	-	-	2	1
If	13	12	16	7
Unless	2	2	2	1
Whether ... Or	3	3	-	-
As Long As	-	-	3	1
How	12	11	17	8
As ... As	-	-	2	1
As (manner)	1	1	-	-

Why	1	1	1	1
As (reason)	-	-	5	2
Since	-	-	4	2
Because	-	-	5	2
Although	-	-	2	1
Even If	-	-	4	2
As If	-	-	1	1
Just As	-	-	1	1
Even Though	-	-	1	1
Where	3	3	2	1

Table 15 ***Comparison According to the Type of Adverbial Clause: Grades Three and Four***

	Grade 3 (108)		Grade 4 (214)	
Type of clause	N°	%	N°	%
Time	48	44	81	38
Conditional	18	17	21	10
Purpose	25	23	67	31
Reason	1	1	15	7
Result	-	-	-	-
Concessive	-	-	9	4
Place	3	3	2	1
Manner	13	12	19	9

Table 15 shows that the Adverbial clauses of Purpose and Concession are the ones that have an increase in the percentages in Grade Four compared to Grade Three.

Analysis of Relative Clauses

As with the Adverbial clauses, we also sub-classified the Relative clauses into different types. Tables 16 and 17 show the results of this comparison.

Table 16 ***Analysis of Relative Clauses: Grade Three***

Relative Pronoun	Book 3-1 (26)		Book 3-2 (25)		Book 3-3 (24)		Total (75)	
	N°	%	N°	%	N°	%	N°	%
That	13	50	6	24	6	25	25	33
Which	3	12	4	16	1	4	8	11
Who	-	-	4	16	1	4	5	7
Whom	-	-	-	-	-	-	-	-
Whose	-	-	-	-	-	-	-	-
Ellipsis of the Pronoun	10	38	11	44	15	67	37	49

Table 17 ***Analysis of Relative Clauses: Grade Four***

Relative Pronoun	Book 4-1 (23)		Book 4-2 (33)		Book 4-3 (62)		Total (118)	
	N°	%	N°	%	N°	%	N°	%
That	3	22	5	15	11	18	21	18
Which	1	4	5	15	3	5	9	8
Who	-	-	-	-	-	-	-	-
Whom	-	-	-	-	-	-	-	-
Whose	-	-	-	-	-	-	-	-
Ellipsis of the Pronoun	17	74	23	70	48	77	88	75

As can be seen the percentage of Relative clauses in which the relative pronoun is omitted is significantly higher in Grade Four texts (75 %) than in Grade Three texts (49 %).

Analysis of Phase Constructions

A Phase construction is a structure in which you use two verbs in a clause in order to talk about two processes or events that are closely linked e.g. She ***helped to clean*** the house.

They ***remember buying*** the tickets.

These are Phase constructions which express two actions performed by the same person. There are also Phase constructions that express two actions done by different persons; in this case the verbs are separated by an object e.g. I don't ***want them to feel*** I've slighted them.

Tables 18 and 20 show the analysis of the first type of Phase constructions. Tables 19 and 21 show the analysis of the latter type of Phase constructions.

Table 18 ***Analysis of Phase Constructions That Express Two Actions Done by the Same Person (Phase Verbs Together): Grade Three***

Book 3-1 (15)		Book 3-2 (11)		Book 3-3 (13)		Total (39)	
N°	%	N°	%	N°	%	N°	%
8	53	8	73	5	38	21	54

Table 19 ***Analysis of Phase Constructions That Express Two Actions Done by Different Persons (Phase Verbs Separated by an Object): Grade Three***

Book 3-1 (15)		Book 3-2 (11)		Book 3-3 (13)		Total (39)	
N°	%	N°	%	N°	%	N°	%
7	47	3	27	8	62	18	46

Table 20 ***Analysis of Phase Constructions That Express Two Actions Done by the Same Person (Phase Verbs Together): Grade Four***

Book 4-1 (18)		Book 4-2 (23)		Book 4-3 (23)		Total (69)	
N°	%	N°	%	N°	%	N°	%
6	33	14	61	13	46	33	48

Table 21*Analysis of Phase Constructions That Express Two Actions Done by Different Persons (Phase Verbs Separated by an Object): Grade Four*

Book 4-1 (18)		Book 4-2 (23)		Book 4-3 (28)		Total (69)	
N°	%	N°	%	N°	%	N°	%
12	67	9	39	15	54	36	52

Analysis of Passive Sentences

The Passive structure is another structure analyzed in this study. We distinguished between Passives with agents and Passives without agents. Tables 22 and 23 show the analysis of the first kind in Grade Three and Four texts. As can be observed, there is a higher percentage of Passive sentences with agents in Grade Four than in Grade Three texts.

Table 22 ***Analysis of Passives with an Agent: Grade Three***

Book 3-1 (17)		Book 3-2 (30)		Book 3-3 (24)		Total (71)	
N°	%	N°	%	N°	%	N°	%
-	-	4	13	-	-	4	6

Table 23 ***Analysis of Passives with an Agent: Grade Four***

Book 4-1 (31)		Book 4-2 (48)		Book 4-3 (49)		Total (128)	
N°	%	N°	%	N°	%	N°	%
3	10	1	2	7	14	11	9

Tables 24 and 25 analyze the percentages of the second type of Passive sentence. As observed the percentage of Passives without agents in Grade Three texts is slightly higher than in Grade Four texts.

Table 24 ***Analysis of Passives without an Agent: Grade Three***

Book 3-1		Book 3-2		Book 3-3		Total	
(17)		(30)		(24)		(71)	
N°	%	N°	%	N°	%	N°	%
17	100	26	87	24	100	67	94

Table 25 ***Analysis of Passives without an Agent: Grade Four***

Book 4-1		Book 4-2		Book 4-3		Total	
(31)		(48)		(49)		(128)	
N°	%	N°	%	N°	%	N°	%
28	90	47	98	42	86	117	91

The other type of clause--Commands, Wh and Y/N questions, Negatives, That, Nominals, There, Extraposition, and Clefts--did not require an extra analysis other than that shown in Tables 3, 4, and 5. These clauses either showed little difference between Grade Three and Four texts or cannot be sub-classified; that is why no further analysis was necessary.

Readability

The last analysis done to the texts was the readability analysis using the software *Correct Grammar*. This software checks a text sentence by sentence and gives a report of the document's overall readability. It can be used to compare one document with others. The first part of the report tells you the number of paragraphs, sentences, words, and syllables in a text. Each of these--length of paragraphs, of sentences, and of words--is a key factor in determining the readability of a text. The next item reported is use of the passive voice. The next information provided is the number of long sentences. The last part of the report consists of several readability scores.

Over the years a number of language authorities have tried to establish objective standards for evaluating English prose. The underlying premise is that, in general, a document communicates most effectively if the average sentence is short and direct and uses straightforward vocabulary. The best known of these authorities is probably Rudolf Flesch, who proposed numerical measures of the readability and interest level of texts.

The Flesch Reading Ease Score is based on the number of words in each sentence and the average number of syllables per word. On this scale, "standard" writing has an average of 17 words per sentence, with 147 syllables per 100 words. Writing at this level earns a score of about 70 to 80. The highest score 100, represents the easiest writing level, about fourth grade. Scores of 0 to 30 are considered college graduate level.

The Flesch-Kincaid system attempts to represent readability as a school grade level. Writing at the "standard" Flesch level of 70 to 80 translate to about 7^{th} or 8^{th} grade level writing.

The third readability score was developed by Robert Gunning. This score is known as The Gunning Fog index and reports on the difficulty of writing. It considers sentence length but emphasizes word length as a measure of "Fog Level." Multi-syllable words tend to make a text more difficult to read, and thus raise the fog level. The Fog index is also given in school grade level, usually higher than the Flesch-Kincaid score.
The following reports were obtained after doing the readability analysis to each text.

Consulting the Elementary Science Curriculum Guide we found out that two of the books used in this study had been previously analyzed using the Fry readability method. Similarly to the readabilityindices of *Correct Grammar* the Fry approach quantifies the number of syllables and sentences, but just in a 100-word sample and by means of a graph, converts these data into grade level equivalencies. *Correct Grammar*'s advantage to this approach is not only that you can quantify the number of syllables and sentences in a text of any length, but also it gives three levels of readability using the Flesch Reading Score, the Flesch-Kincaid score and the Gunning Fog index. These three measures of reading level provide a more reliable assessment of reading difficulty. The following is a summary of the readability analysis carried out on the texts:

Table 26 ***Correct Grammar Readability Analysis***

Scores	Book 3-1	Book 3-2	Book 3-3	Book 4-1	Book 4-2	Book 4-3
Flesch Reading Ease score	71.6	81.5	69.4	74.2	79.4	72.8
Grade level required	6	5	7	6	6	6
Flesch-Kincaid grade level	5.4	4.3	5.7	5.7	4.4	5.4
Gunning Fog Index	8.0	6.2	7.3	8.1	6.5	7.6

The figures indicate that the readability levels of these texts are very similar. The books are all considered to be easy or very easy by the Flesch Reading Ease score, the grade level required ranges from 4 to 7. The Gunning Fog Index, usually higher than the Flesch-Kincaid grade level, goes from 6.2 to 8.1. If we compare Third Grade texts to Fourth Grade texts from the same editor, we see that there is a very slight difference between them; however, there is a remarkable imbalance among the texts from the same grade.

Even though readability analysis has been a common method of measuring the grade levels of school textbooks, the reliability of this type of measurement has been questioned. Complex syntactic structures have been left out and only Passive sentences seem to have a relevance for this type of analysis. Readability analysis should be followed by more precise ways of determining the grade levels of texts. Language development in children and the syntax of texts are very important factors to take into account when choosing a text since the complexity of its syntax may be an obstacle in the child' s reading comprehension process.

CHAPTER V

Analysis and Interpretation of the Data

This chapter has two main objectives. First, to present the global charts of analysis of patterns by means of which the collected data are analyzed into several categories. The main reason is to show that given the nature of the texts themselves, there is a difference between Grade Three and Grade Four textbooks. The second analysis looks specifically at those clause structures which psycholinguistic research shows are difficult for children between the ages 7-10.

As has been already stated the main objective of this study is to investigate whether or not there is a difference between the syntax used in Third and Fourth grade textbooks. The readability analysis carried out on these textbooks shows that there are no significant differences between Grade Three and Grade Four texts. The following tables, however, support the hypothesis of interest (H_1) that there is an increase in the use of syntactically complex sentences used in Fourth grade textbooks.

Statistical Analysis

To carry out the statistical analysis the chi-squared test was used. This test demands that the *n* independent observations are capable of being classified into a number, say *k*, of non-overlapping categories and that the probabilities of observations falling into these categories can be calculated when the appropriate null hypothesis (H_0) is assumed true.

What was needed was a method of comparing the observed frequencies with the mean or expected frequencies when the H_0 is true, i.e. we seek a statistic that measures the discrepancies between the observed and expected frequencies. If the H_0 is true, then the observed frequencies will tend to be relatively close to the expected frequencies, resulting in a corresponding small value of χ^2; on the other hand, if there are large discrepancies between the observed and expected frequencies, indicating that H_1 is true, then χ^2 will tend to be large.

If the H_1 is true, then χ^2 will tend to take large values, leading us to critical regions of the form $\chi^2 \geq$ critical value[1]. The appropriate number of degrees of freedom of the null distribution is $k-1$, where k is the number of categories.

The calculation of χ^2 was performed by carrying out the following sequence:

(1) For each category, the differences Ob.–Ex. were calculated.

(2) The differences were squared to get $(\text{Ob.–Ex.})^2$.

(3) Each $(\text{Ob.–Ex.})^2$ was divided by the appropriate Ex.

(4) The quantities $(\text{Ob.–Ex.})^2/\text{Ex.}$ were summed to obtain the value of χ^2.

Let us analyze the following three tables. Tables 1, 2, and 3 give the contrast between third and fourth grade textbooks[2] based on the following seven categories: *Kernels; Wh-Q, Y/N-Q, Negatives; Adverbials; There, Extraposition, Cleft; Passive; and That, Relative, Nominal.*

Some grammatical structures have been grouped into one category due to similarities they all share. Wh-Q, Y/N-Q, and Negative constructions all require the use of auxiliaries. There, Extraposition, and

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[1]Critical values are obtained from the chi-squared distribution table since for large samples the null distribution of χ^2 is approximately chi-squared. The chi-squared distribution table for this study is found in *Distribution-Free Tests.*

[2]The books that are compared are from the same publisher

Cleft constructions deal with moving the topic of the sentence to highlight it in some way.

Table 1 ***Contrast between Book 3-1 and Book 4-1***

Book 3-1 (307)	Kernels	Wh-Q, Y/N-Q, Negat.	Adv.	There, Extrap. Cleft	Passive	Phase	That, Rel., Nom.
Observed	75	54	28	7	17	15	44
%	25%	18%	9%	3%	6%	5%	14%
Book 4-3 (409)							
Observed (Ob)	105	57	92	11	49	27	29
Expected (Ex)	102	74	37	12	25	20	57
Ob – Ex	+3	–17	+55	–1	+24	+7	–28
$(Ob - Ex)^2$	9	289	3025	1	576	49	784
$(Ob - Ex)^2/Ex$	0.09	3.9	81.7	0.08	23	2.5	13.8

$\chi^2 = 0.09 + 3.9 + 81.7 + 0.08 + 23 + 2.5 + 13.8 = 125.07$

The degree of freedom is $k-1$, where k is the number of categories. We have seven categories, so $k = 6$. Our value of χ^2(125.07) falls in the 1% region of the chi-squared distribution table (16.812), i.e. 125.07 ≥ 16.812. Table 1 shows that there is a significant difference between the syntax used in Book 3-1 and Book 4-1.

Table 2 ***Contrast between Book 3-2 and Book 4-2***

Book 3-2 (297)	Kernels	Wh-Q, Y/N-Q, Neg.	Adv.	There, Extrap. Cleft	Passive	Phase	That, Rel., Nom.
Observed	91	56	52	7	30	11	41
%	31%	19%	18%	2%	10%	4%	14%
Book 4-2 (309)							
Observed (Ob)	73	69	39	10	48	21	40
Expected (Ex)	96	59	56	6	31	12	43
Ob – Ex	–23	+10	–17	+4	+17	+9	–3
$(Ob - Ex)^2$	529	100	289	16	189	81	9
$(Ob - Ex)^2/Ex$	5.5	1.7	5	2.7	9.3	6.8	0.2

$\chi^2 = 5.5 + 1.7 + 5 + 2.7 + 9.3 + 6.8 + 0.2 = 31.2$

Table 2 shows that there is a significant difference between the syntax used in Book 3-2 and Book 4-2. Our value falls again in the 1% region (16.812), i.e. $31.2 \geq 16.812$.

Table 3 ***Contrast between Book 3-3 and Book 4-3***

Book 3-3 (228)	Kernels	Wh-Q, Y/N-Q, Neg.	Adv.	There, Extrap. Cleft	Passive	Phase	That, Rel., Nom.
Observed	57	46	28	4	24	13	34
%	25%	20%	12%	2%	11%	6%	15%
Book 4-3 (333)							
Observed (Ob)	93	58	83	32	31	18	34
Expected (Ex)	83	67	40	7	37	20	47
Ob – Ex	+10	–9	+43	+25	–6	–2	–13
$(Ob - Ex)^2$	100	81	1849	625	36	4	169
$(Ob - Ex)^2/Ex$	1.2	1.2	46.2	89.3	0.97	0.2	3.6

$\chi^2 = 1.2 + 1.2 + 46.2 + 89.3 + 0.97 + 0.2 + 3.6 = 142.67$

The statistic in Table 3 is an evidence of the great difference that exists between Book 3-3 and Book 4-3 in terms of syntax. The value of the χ^2 of 142.67 falls in the 1% region (16.812), where $142.67 \geq 16.812$.

The results observed from the comparison of these categories in Tables 1, 2 and 3 well and truly indicate that we have strong evidence to support the hypothesis of interest that there is a significant difference in the syntax of the Third and Fourth Grade textbooks in these publisher's series.

Rather than leaving the syntactic analysis at this stage we thought that it would be very fruitful to see what else could be deduced from our data. We wanted to know if there was also a difference between the syntax used by the different publishers within the same grade level. Thus we came up with the following tables:

Table 4 ***Comparison between Book 3-1 and Book 3-3***

Book 3-1 (307)	Kernels	Wh-Q, Y/N-Q, Neg.	Adv.	There, Extrap. Cleft	Passive	Phase	That, Rel., Nom.
Observed	75	54	28	7	17	15	44
%	25%	18%	9%	3%	6%	5%	14%
Book 3-3 (228)							
Observed (Ob)	57	46	28	4	24	13	34
Expected (Ex)	57	41	21	7	17	11	32
Ob – Ex	0	+5	+7	–3	+7	+2	+2
$(Ob - Ex)^2$	0	25	49	9	49	4	4
$(Ob-Ex)^2/Ex$	0	0.6	2.3	1.3	2.9	0.4	0.1

$\chi^2 = 0 + 0.6 + 2.3 + 1.3 + 2.9 + 0.4 + 0.1 = 7.6$

The result shows that there is no syntactic difference between these two textbooks because the value of χ^2 does not fall in the 1% or 5% critical regions. $\chi^2 \leq 16.812$.

Table 5 ***Comparison between Book 3-1 and Book 3-2***

Book 3-1 (307)	Kernels	Wh-Q, Y/N-Q, Neg.	Adv.	There, Extrap. Cleft	Passive	Phase	That, Rel., Nom.
Observed	75	54	28	7	17	15	44
%	25%	18%	9%	3%	6%	5%	14%
Book 3-2 (297)							
Observed (Ob)	91	56	52	7	30	11	41
Expected (Ex)	74	53	27	8	18	15	42
Ob – Ex	+17	+3	+25	–1	+12	–4	–1
$(Ob - Ex)^2$	289	9	625	1	144	16	1
$(Ob - Ex)^2/Ex$	4	0.2	23	0.1	8	1.06	0.02

$\chi^2 = 4 + 0.2 + 23 + 0.1 + 8 + 1.06 + 0.02 = 36.38$

Here we can observe that there is a difference between these two textbooks because the value of χ^2 falls in the 1% critical region.

$\chi^2 \geq 16.812$.

Table 6 *Comparison between Book 3-2 and Book 3-3*

Book 3-2 (297)	Kernels	Wh-Q, Y/N-Q, Neg.	Adv.	There, Extrap. Cleft	Passive	Phase	That, Rel., Nom.
Observed	91	56	52	7	30	11	41
%	31%	19%	18%	2%	10%	4%	14%
Book 3-3 (228)							
Observed (Ob)	57	46	28	4	24	13	34
Expected (Ex)	71	43	41	5	23	9	32
Ob – Ex	–14	+3	–13	–1	+1	+4	+2
$(Ob - Ex)^2$	196	9	169	1	1	16	4
$(Ob - Ex)^2/Ex$	2.8	0.2	4.1	0.2	0.04	1.8	0.1

$\chi^2 = 2.8 + 0.2 + 4.1 + 0.2 + 0.04 + 1.8 + 0.1 = 9.24$

Once more the result shows that the value of χ^2 is smaller than 16.812 or 122.592, thus it does not fall in the 1% or 5% critical regions.

Table 7 ***Comparison between Book 4-1 and Book 4-3***

Book 4-1 (333)	Kernels	Wh-Q, Y/N-Q, Neg.	Adv.	There, Extrap. Cleft	Passive	Phase	That, Rel., Nom.
Observed	105	57	92	11	49	27	29
%	27%	14%	22%	3%	12%	7%	7%
Book 4-3 (409)							
Observed (Ob)	93	58	83	32	31	18	34
Expected (Ex)	90	47	73	10	40	23	45
Ob – Ex	+3	+11	+10	+22	–9	–5	+11
$(Ob - Ex)^2$	9	121	100	484	81	25	121
$(Ob - Ex)^2/Ex$	0.1	2.6	1.4	48.4	2	1.1	5.3

$\chi^2 = 0.1 + 2.6 + 1.4 + 48.4 + 2 + 1.1 + 5.3 = 60.9$

Table 7 compares two Fourth Grade textbooks. According to the value of $\chi^2 = 60.9$ there is a difference between the syntax used in these two textbooks; $60.9 \geq 16.812$, thus it falls in the 1% critical region.

Table 8 ***Comparison between Book 4-1 and Book 4-2***

Book 4-1 (409)	Kernels	Wh-Q, Y/N-Q, Neg.	Adv.	There, Extrap. Cleft	Passive	Phase	That, Rel., Nom.
Observed	105	57	92	11	49	27	29
%	27%	14%	22%	3%	12%	7%	7%
Book 4-2 (309)							
Observed (Ob)	73	69	39	9	48	21	40
Expected (Ex)	83	43	68	9	37	22	22
Ob – Ex	–10	+26	–29	0	+11	–1	+20
$(Ob - Ex)^2$	100	676	841	0	121	1	400
$(Ob - Ex)^2/Ex$	1.2	15.7	12.4	0	3.3	0.05	18.2

$\chi^2 = 1.2 + 15.7 + 12.4 + 0 + 3.3 + 0.05 + 18.2 = 50.85$

The difference between these two textbooks is significant. The calculated value of $\chi^2 = 50.85$ lies in the 1% critical region. $\chi^2 \geq 16.812$.

Table 9 *Comparison between Book 4-2 and Book 4-3*

Book 4-2 (309)	Kernels	Wh-Q, Y/N-Q, Neg.	Adv.	There, Extrap. Cleft	Passive	Phase	That, Rel., Nom.
Observed	73	69	39	9	48	21	40
%	24%	22%	13%	3%	16%	7%	13%
Book 4-3 (409)							
Observed (Ob)	93	58	83	32	31	18	34
Expected (Ex)	80	73	43	10	53	23	43
Ob – Ex	–13	–15	+40	+22	–22	–5	–9
$(Ob - Ex)^2$	169	225	1600	484	484	25	81
$(Ob - Ex)^2/Ex$	2.1	3.1	37.2	48.4	9.1	1.1	1.9

$\chi^2 = 2.1 + 3.1 + 37.2 + 48.4 + 9.1 + 1.1 + 1.9 = 102.9$

The results from the comparison between Book 4-2 and Book 4-3 show that there is a difference between the syntax used in these two textbooks. The value of χ^2 is higher than 16.812 and thus falls in the 1% critical region.

To sum up the comparison between textbooks from the same grade level, we can say that even though there are some instances in which the value of χ^2 is smaller that the value of the 1% and 5% critical regions (Tables 4 and 6) it has been shown that there are differences in most cases (tables 5, 7, 8 and 9). It is also evident that in the cases of Fourth Grade textbooks there is a significant difference among them.

The next step in our syntactic analysis was to choose some syntactic constructions which have been shown in the psycholinguistic literature to cause comprehension difficulties in children and compare them to see if there were differences that could support our hypothesis of interest. The first construction analyzed was embedded sentences with one subordinate clause and with more than one subordinate clause. In this case there are only two categories, thus $k = 1$, and so the approximate 1% and 5% critical regions are $\chi^2 \geq 6.635$ and $\chi^2 \geq 3.841$ respectively.

Table 10 ***Comparison of Embedded Sentences between Book 3-1 and Book 4-1***

Book 3-1 (201)	with one subordinate clause	with more than one subordinate clause
Observed	64	11
%	32%	6%
Book 4-1 (203)		
Observed (Ob)	84	42
Expected (Ex)	65	12
Ob – Ex	19	30
$(Ob - Ex)^2$	361	900
$(Ob - Ex)^2 Ex$	6	75

$\chi^2 = 6 + 75 = 81$

This value of χ^2 falls in the 1% critical region since $\chi^2 \geq 6.635$, which shows that there is strong evidence to support the H_1.

Table 11 ***Comparison of Embedded Sentences between Book 3-2 and Book 4-2***

Book 3-2 (184)	with one subordinate clause	with more than one subordinate clause
Observed	74	18
%	40%	10%
Book 4-2 (200)		
Observed (Ob)	63	19
Expected (Ex)	80	20
Ob – Ex	–17	–1
$(Ob - Ex)^2$	289	1
$(Ob - Ex)^2/Ex$	3.6	0.05

$\chi^2 = 3.6 + 0.05 = 3.5$

The value in this case shows that there is no significant difference between books 3-2 and 4-2 since $\chi^2 \leq 3.841$, thus it does not fall either in the 1% or 5% critical regions.

Table 12 ***Comparison of Embedded Sentences between Book 3-3 and Book 4-3***

Book 3-3 (161)	with one subordinate clause	with more than one subordinate clause
Observed	84	13
%	41%	8%
Book 4-3 (209)		
Observed (Ob)	70	68
Expected (Ex)	86	16
Ob – Ex	–16	52
$(Ob - Ex)^2$	256	2704
$(Ob - Ex)^2/Ex$	3	169

$\chi^2 = 3 + 169 = 172$

The value of χ^2 falls in the 1% critical region, which indicates that there is strong evidence to support the H_1.

From the above analysis we may conclude that in the case of books 3-2 and 4-2 (Table 11, Chapter IV) there is no evidence of a significant difference in terms of embedded sentences in this series. However, there is strong evidence as shown in Tables 10 and 12 (Chapter IV) that there is a significant difference between books 3-1 and 4-1 and books 3-3 and 4-3 with respect to the number of sentences containing multiple subordinate clauses.

Another syntactic construction which is of interest is the adverbial clause. The types of adverbial clauses were grouped into four categories: *Time; Conditional; Purpose, Reason, Result; and Concession, Place, Manner.* The appropriate number of degrees of freedom is k -1, where k is the number of categories. In this case we have $k = 3$, so by consulting the chi-squared distribution table with three degrees of freedom we get the 1% (11.345) and the 5% (7.815) critical regions.

Table 13 ***Comparison of Adverbial Clauses between Book 3-1 and Book 4-1***

Book 3-1 (28)	Time	Condition	Purpose Reason Result	Concession Place Manner
Observed	14	3	5	6
%	50%	11%	17%	21%
Book 4-1 (92)				
Observed (Ob)	29	9	38	16
Expected (Ex)	42	9	14	17
Ob – Ex	–13	0	+24	–1
$(Ob - Ex)^2$	169	0	576	1
$(Ob - Ex)^2/Ex$	4	0	41.1	0.05

$\chi^2 = 4 + 0 + 41.1 + 0.05 = 45.15$

This value of χ^2 falls in the 1% (11.345) critical region which shows that there is evidence to support the H_1.

Table 14 ***Comparison of Adverbial Clauses between Book 3-2 and Book 4-2***

Book 3-2 (52)	Time	Condition	Purpose Reason Result	Concession Place Manner
Observed	22	8	15	7
%	42%	15%	29%	13%
Book 4-2 (39)				
Observed (Ob)	10	7	19	5
Expected (Ex)	16	6	11	5
Ob – Ex	–6	+1	+8	0
$(Ob - Ex)^2$	36	1	64	0
$(Ob - Ex)^2/Ex$	2.3	0.2	5.5	0

$\chi^2 = 2.3 + 0.2 + 5.5 + 0 = 8.3$

Here the value is smaller than 11.345, thus it does not fall in the 1% region; however, it is higher than 7.815, thus it falls in the 5% critical region, and so we have some evidence to support H_1.

Table 15 ***Comparison of Adverbial Clauses between Book 3-3 and Book 4-3***

Book 3-3 (28)	Time	Condition	Purpose Reason Result	Concession Place Manner
Observed	12	7	6	3
%	43%	25%	21%	11%
Book 4-3 (92)				
Observed (Ob)	42	7	25	9
Expected (Ex)	40	23	19	10
Ob – Ex	+2	–16	+6	–1
$(Ob - Ex)^2$	4	256	36	1
$(Ob - Ex)^2/Ex$	0.1	11.1	1.9	0.1

$\chi^2 = 0.1 + 11.1 + 1.9 + 0.1 = 13.2$

The value of $\chi^2 = 13.2$ falls in the 1% critical region, which means that there is strong evidence to support the H_1.

In conclusion, with respect to adverbial clauses, we may say that there is enough evidence to support H_1 over H_0. The calculated values shown in Tables 13 and 15 lie in the 1% critical region since they are higher than 11.345, which strongly indicates that there is a significant difference in the syntax of these two sets of textbooks. We can see that the value of $\chi^2 = 8.3$ from Table 14 does not fall in the 1% region but in the 5% critical region; however, there is still some evidence to reject H_0 in favour of H_1.

There are some other syntactic constructions that psycholinguistic research shows are difficult for children between the ages 8-10. The following analysis looks specifically at one of these clause structures: the *Passive* structure.

It has been mentioned in **Chapter III** of the present study that between the ages of eight and ten, children use one passive in every two hundred utterances and full passives (passives with an agent) are only used by approximately 20% of nine-year-olds. The following charts are a summary of the data collected in this respect. I counted the number of passives with and without agents in Third and Fourth Grade textbooks. When I compared the percentages of the number of full passives that are used in Third Grade textbooks with those used in Fourth Grade textbooks there was a difference.

Table 16 ***Comparison of Passives with an Agent: Grades Three and Four***

Grade 3 (71)		Grade 4 (128)	
No	%	No	%
4	6	11	9

Table 17 ***Comparison of Passives without an Agent: Grades Three and Four***

Grade 3 (71)		Grade 4 (128)	
No	%	No	%
67	94	117	91

Though Tables 16 and 17 show that the majority of passive constructions used in the textbooks are not full passives, 6% in Third Grade textbooks and 9% in Fourth Grade textbooks, the percentage of full passives increases in Fourth Grade textbooks. As observed in Tables 3 and 4 (Chapter IV) there is a high percentage of passive constructions in these textbooks. Six percent of the sentences in Book 3-1 are passives, 10% in Book 3-2 and 11% in Book 3-3. If we compare the percentage of this structure in Fourth Grade, an increase is observed: 9% in Book 4-1, 16% in Book 4-2 and 12 % in Book 4-3.

Summary

To summarize what the statistics show, we may say that there is an observable difference in the syntax of Third and Fourth Grade textbooks analyzed in this study. It is clear, as well, that Fourth Grade textbooks prove to have differences among them as shown in Tables 7, 8, and 9.

In terms of specific syntactic structures, we see that Complex (Embedded) sentences with multiple subordinate clauses need close attention. As presented in Tables 10 and 12 there is evidence of a significant difference between Third and Fourth Grade textbooks from the series Science: Being Curious and Stem Science.

The Adverbial clause is another syntactic structure that shows a difference. This difference is specially relevant in the series Science: Being Curious and Stem Science as can be seen in tables 13 and 15.

We can observe that the Passive structure in these series also shows an increase in its use in Fourth Grade textbooks compared to Third Grade textbooks. There is 0% of Passives with agents (full passives) in Book 3-1, whereas there is 10% in Book 4-1 from the series Science: Being Curious; in the series Stem Science there is 0% in Book 3-3 and 14% in Book 4-3. With respect to Passives without an agent, there is not a big difference between the textbooks from the series mentioned above; however, there is a difference in the series Exploring Science. In Book 3-2 87% of the Passives have no agent, whereas in Book 4-2 98% have no agent.

General Conclusions

As has been previously stated, language development influences reading comprehension achievement. Children in Grade Three have the same language development as children in Grade Four. According to the studies analyzed by Perera (1984), there is a period from the ages of eight to ten in which children's acquisition of the structures of the language remains unchanged. As mentioned by Perera (1984) the difficulties a child has at the age of eight are similar to those difficulties a nine-year-old and a ten-year-old have, and it is not until the age of eleven that children overcome most of these difficulties.

The present study shows that there is a syntactic difference between textbooks used in Grade Three and Grade Four. As the data collected indicate there is a higher percentage of non-kernels in Grade Four textbooks (81.1%) than in Grade Three textbooks (74%). This supports the hypothesis of interest that the ratio of kernel to non-kernel decreases in Grade Four textbooks. Adverbial clauses, Relative clauses, Phase structures and Passive constructions are the syntactically complex structures which showed the most relevant differences between Grade Three and Grade Four textbooks. This increase in the percentage of syntactically complex structures may contribute to children's comprehension difficulties, since these are the structures children between the ages of eight and ten have not fully mastered yet.

Textbook writers must take syntax into account. It is known that the number of words in a sentence and sentence length cause comprehension problems. However, parallel to readability analyses, syntactic analyses should also be carried out on the texts which are recommended in the school curriculum. This is not to suggest that if there is some difference between the syntax of Grade Three and Grade Four textbooks, these texts should not be used, but teachers must be aware of this problem. In cases in which the syntax of the textbooks is very complex, it should be simplified in the classroom, so that both the less able as well as the most able children can understand the main concepts introduced to them and not be affected in the comprehension process. Although it is agreed that children should be exposed to challenging textbooks, this may hinder their comprehension if not properly resolved.

At first, the purpose of this study was to evaluate how the syntax of the science textbooks affected the reading comprehension process of English as a Second Language students; however, the study shows that not only ESL children may be affected by difficult syntactic structures but native speakers as well. Perera's analysis of the development of language in children suggests that children may face comprehension difficulties when dealing with syntactic structures that are beyond their capability. It is very obvious, thus, that for ESL students these difficulties are paramount.

This is the first study of this kind ever done on this matter, there is an enormous amount of work that can still be done. The study only analyzed the syntax of six chapters from six Science textbooks, the same procedure can be used to analyze whole textbooks. On the other hand, the study offers the rational for a more detailed investigation of specific syntactic structures and the comprehension problems children have when reading science texts; that is, when reading the scientific register of the language. This kind of research can be extended to Social Studies textbooks and any other textbooks which are planned to be used in the school setting, since close attention must be paid to the relationship that exists between language development, age of the children and the texts chosen.

This study shows that readability scores alone are not reliable sources of evaluating textbook difficulties and that there is a need to include other kinds of analyses, such as syntactic analyses. It is very helpful since it provides with another way of evaluating the complexity of texts. Syntactic analyses can be carried out to the whole text or sections of it. Syntactic difficulty should be considered as one of the possible causes that affect comprehension of Fourth Grade textbooks. It also shows how important it is to consider the child's linguistic development when assessing textbook difficulties.

Limitations of the study

The findings concerning syntax in the study are only one part of a very complicated picture of children's understanding of content-area material in school textbooks. Areas of understanding not dealt with here include the following ones.

Textbook authors provide a wide variety of graphics to aid understanding. The role of photographs, charts, tables, and diagrams, for instance, has not been explored in this study.

Children bring their own "folk" or "child" theories of the world to the science classroom. They come with ideas and interpretations concerning the phenomena they are studying even when they have not received systematic instruction in these subjects. From a young age, and prior to any teaching or learning of formal science, children develop meaning for many words used in science teaching and views of the world which relate to ideas taught in science. These ideas and interpretations are the result of children's everyday experience in all aspects of their lives: through practical physical activities, talking with other people around them and through the media (Driver, Guesne and Tiberghien, 1989, p. 2; Osborne and Freyberg, 1991, p. 5).

As a result, students approach experiences presented in science classes with previously acquired notions and these influence what is learnt from new experiences in a number of ways, such as observations made of events, the interpretations offered for such observations and the strategies students use to acquire new information, including reading from texts and experimentation (Driver, Guesne and Tiberghien, 1989, p. 4). In addition, children's ideas are usually strongly held, even if not well known to teachers, and are often significantly different to the views of scientists.

These ideas are sensible and coherent views from the children's point of view, and they often remained uninfluenced or can be influenced in unanticipated ways by science teaching (Osborne and Freyberg, 1991, p. 5).

Osborne and Freyberg (1991) agree that these general conclusions have been implicit in several theorists, from Piaget (1929) onwards. However, the consequences of such earlier findings have often been ignored by curriculum developers and teachers and, until recently, by other research workers in the field of science education as well.

Another limitation is that this study was an analysis of text structures, and, as such, causal links to comprehension difficulties can only be inferred. The next step in this line of research is to test whether the assumption regarding comprehension difficulties due to syntactic structures actually occurs.

Appendix

Book 3-1

Science: Being Curious.

Chapter 6: Changing Food

There are many kinds of foods. You will found out how foods get to your body cells. You will learn how foods must change so that your cells can use them.

Do you think that cake and soda make a good lunch? You probably know that they do not. But do you know why? Do you know why you need to eat certain foods every day?

Are all foods the same?

Look at this school lunchroom. See the girls and boys eating here. Can you tell which girls and boys are eating a good lunch? Why do you think those foods make a good lunch?

These are some of the foods you may like to eat. Do you think all of these foods are alike in any way? All these foods have **nutrients** (NOO-tree-ents) in them. Nutrients help you grow. They help you have energy. There are six kinds of nutrients that your body needs. Each has a special job to do.

One of the nutrients is called **protein**. You need protein to help you grow. Here are some of foods that have much protein in them. What foods do you see?

Another nutrient is **fat**. You get some of the energy you need when you eat fat. The picture bellow shows foods that have fat in them. Can you name them?

Still another nutrient is **carbohydrate.** This nutrient also gives you energy, But your body can digest carbohydrates faster than it can digest fat. The foods in the picture are rich in carbohydrates. Can you name them?

Your body needs three other nutrients. They are **minerals, vitamins,** and **water.**

Minerals help you grow well. Vitamins keep the parts of your body working well. Water helps to digest food and carry the food and oxygen to your cells. Water helps to carry wastes from your cells.

Some foods have six nutrients in them. But most foods have only some nutrients in them. You should eat many different kinds of foods to get all the nutrients that you need.

Your body like a machine needs fuel to work. Foods are the fuel for your body.

How nutrients get to where they are used.

Your bones need nutrients. Your teeth need nutrients. So your skin and all the organs of your body.

How do nutrients get to where they are used in the body? First, the solid food that you eat is changed into liquid. This takes place in your mouth, stomach, and small intestine. The liquid goes from your small intestine into your blood. The blood then carries the nutrients to all parts of the body.

Suppose you have cereal for breakfast. You add sugar and milk to the cereal. The sugar disappears. The sugar dissolves in the milk. The milk looks the same. You taste the milk. How has it changed? You cannot see the sugar in milk.

You cannot see the nutrients in blood, but they are there. They are **dissolved** in the blood. They are in a **solution.**

Evidence of a change

Look at the bag in the water. Is there a change in the water? How do you know there is a change in the water? You can gather more facts about the changes you see. Gathering facts helps you find evidence that a change has taken place. Here are some facts you can find out about the solution.

How do you know that he copper sulfate is dissolving? How long did it take before the copper sulfate began to dissolve? Where does the dissolving take place? Let the dish stand for one hour. Is the copper sulfate in the water the same color throughout?

Separating substances

Can you get the copper sulfate back again? Can you separate the water from the copper sulfate?

Do this to find out.

Pour a little of the copper sulfate solution into another clear dish. Let it stand for a few days. What happens to the water? What happens to the copper sulfate?

Make a sugar-water solution. Add a teaspoonful of sugar to the water in a dish. Make a sugar-milk solution. Add a teaspoon of sugar to the milk in a dish.

How are the solutions different? Let both dishes stand for a few days. The pictures show what happened to the solutions.

What happened to the water in the sugar-water solution?

What happened to the water in the sugar-milk solution?

What happened to the sugar in the sugar-water solution?

What happened to the sugar in the sugar-milk solution?

The sugar-water solution is made up of sugar and water. The sugar-milk solution is made up of sugar, water and solid milk materials. The solid materials in this solution do not evaporate. Only the water can evaporate out of the solution. Could you make whole milk out of the milk solids left in the dish? What would you have to add?

What substances dissolve in a liquid?

Not all substances dissolve in a liquid. Whether or not a substance will dissolve in a liquid is a property of that substance and that liquid. It is one of the facts about a substance that is helpful to know.

One of the properties of sugar is that it will dissolve in water. Why is it helpful to know this?

You can experiment with flour, tincture of iodine, instant coffee, Epsom salts, salad oil, and cocoa.

Pour water into six clear dishes until each dish is half full of water. Add a half teaspoonful of flour to the first dish and stir with a spoon. Add a different substance to the water in the other five dishes. Stir each solution with a spoon. Which substances dissolve in water?

Color Changes

The picture shows some blue crystals. They are crystals of copper sulfate.

When copper sulfate crystals dissolve in water they make the water blue.

Perhaps you are not surprised that the water turns blue. You started with crystals of copper sulfate that were blue to begin with. You did not get a new color.

But look at the pictures of these two solutions. They were made from substances that had no color. You will find out how this was done.

<u>Indicators</u>

Your teacher will give you three liquids. The first liquid is water, the second is ammonia, and the third is white vinegar. She will also give you a mystery substance and a medicine dropper.

See what happens when you do this. Pour each liquid into a separate dish. DO NOT SMELL THE AMMONIA OR THE VINEGAR.

Squeeze a few drops of the mystery liquid into each dish.

What happens when the mystery liquid hits the water? the ammonia? the white vinegar?

You can see that something different happens to the colorless liquid in each dish. You get a change of color in the water. You get a pink color change in the vinegar, and a blue color change in the ammonia.

The mystery substances an **indicator**. An indicator tells you that a special kind of change is taking place.

<u>Making an indicator</u>

You can make an indicator. This is what you do. Gather together the following materials: one head of purple cabbage, vegetable knife, cooking cup or pan, water, stove.

Slice the cabbage into very fine pieces. Pour a very small amount of water into the cooking cup. Put the pieces of cabbage into the cooking cup.

Place the cooking cup on the lighted stove and heat until the water has boiled for a minute. Some **dye** from the cabbage will dissolve in the water. Put out the flame in the stove. Let the solution cool. The solution is a purple color. You will test the indicator in the next activity.

Testing an indicator

When the solution cools, you can test it. This is what you will need: white vinegar, ammonia, indicator in bottle, medicine dropper, three clear dishes, water.

Pour water into a clear dish until is half full. Pour vinegar into a second dish until it is half full. Half fill the last dish with ammonia. DO NOT SMELL THE LIQUIDS. Label the dishes *water*, *vinegar*, and *ammonia*.

Use the medicine dropper to squeeze a few drops of the purple solution you made in the last activity into the white vinegar.

Squeeze a few drops into the ammonia and water.

Tell what happens in each case.

Does the purple solution act like an indicator?

Testing other substances

You can try your homemade indicator on other substances, too. Try it on sour mil and baking soda. Do it this way.

Put a small amount of baking soda in a clear dish. Add water until the dish is half full. Pour some milk into a clear dish until it is half full.

Using a medicine dropper, squeeze a few drops of your homemade indicator into each dish.

What color changes did you get?

Which substance changes like the vinegar? How are they alike?

Which substance changes like ammonia? How are they alike?

Using indicators to classify substances

Suppose you had to put into a group different substances that are alike in some way. The chemist tries to do this in his work. He uses indicators the same way that you did. He separates substances into groups that are alike in some way.

Can you put vinegar, sour milk, household ammonia, baking soda, and lemon juice into two groups? Use the mystery indicator to do this.

Add a teaspoon of baking soda to a dish half full of water. Stir the solution until it is clear. Pour vinegar, sour milk, lemon juice, and ammonia into separate dishes. DO NOT SMELL ANY OF THE LIQUIDS. Add a few drops to the mystery indicator to each liquid in a dish. What happens to the color of each liquid when the indicator is added? Separate the liquid solution into two groups. Tell how the solutions in each group are alike.

NEVER TASTE LIQUIDS UNLESS YOU ARE SURE THEY WILL NOT HARM YOU. If you tasted the vinegar and the lemon juice, you would find that they are alike in one way. Both are sour. They belong to a group of substances called acids. Acids are alike in another way, too. They turn some indicators red.

NEVER FEEL LIQUIDS UNLESS YOU ARE SURE THEY WILL NOT HARM YOU. Feel some water in which household ammonia has been dissolved. It feels slippery to the touch. That is one of its properties. It belongs to a group of substances called bases. Bases turn some indicators blue. That is one of their properties.

Indicators are dyes that are different colors in acids and bases. Litmus is a dye indicator. It is made from plants called **lichens.** Litmus is red when it is mixed with an acid. Litmus is blue when it is mixed with a base. The mystery indicator you used in the earlier experiments was litmus.

Barnard, J. D., & Lavatelli, C. B. (1970). Science: being curious. The Macmillan Science Series. Cambridge, Ontario: The Macmillan Company.

Book 3-2

Exploring Science

Chapter 3: Heat and Temperature

1 Where does heat come from?

Heat is all around you.
It helps many ways.
Heat cooks your food at supper time.
It warms you nights and days.

Where does heat come from?
It comes from near and far.
You can make it with your hands
Or get it from the stars!

Heat from a star

The poem on page 66 says many things about heat. One thing it says is that heat can come from a star. That star is the sun. When do you feel heat from the sun?

As you may know, the sun can heat many things. It can heat the earth. It can heat the air around you. Why do you think this is important?

Heat from rubbing

Rub your hands together about ten times. Rub hard and fast. Feel the heat!

Try rubbing other things together. Which of these things can make heat when they are rubbed? What other things do you think can make heat when they are rubbed?

Heat from electricity

Think about some things that make heat in your home. A toaster makes heat to toast your bread. An iron makes heat to iron your clothes. How do you think toasters and irons make heat?

Toasters and irons must be plugged into an outlet to work. They must be plugged in to get *electricity* [ih-LEHK-TRIHS-uht-ee]. It is this electricity that makes heat. Look at the picture below to see how this happens.

What other things do you know of that make heat from electricity?

Heat from burning

Look at the pictures below and on the next page. Which of the things shown are giving off heat? Why?

Heat from burning is used in many homes. How might people use this heat in their homes?

Heat from burning is also used in factories. It is used to make many things. Steel for cars is made by using heat from burning. Windows are also made by using heat from burning. What other things do you know of that are made by using heat from burning?

Heat from the earth

As you may know, most heat comes from above the ground. But some heat comes from deep inside the earth.

Heat from the earth sometimes comes up through openings in the ground. One kind of opening is called a *Volcano* (vahl-KAY-noh). Another kind is called a *geyser* (GY-zur).

People can use this heat from the earth. ft can be used to make electricity. Why might this be important?

2 How heat moves

Think about a warm, sunny day. If you were in sunlight, you might feel warm. But suppose you were to walk into the shade. Do you think you would become cold? Why or why not?

Heat moves in air

You may not always be in sunlight or near other things that give off heat. But you can still feel heat from these things. Heat can move in air. Why do you think this is important?

Think about your kitchen when the oven is turned on. Heat from the oven warms some of the air around it. As this air becomes warm it rises.

As the warm air rises cool air in the room moves down. It also moves to the oven. This cool air then becomes warm and rises. In this way, heat from the oven keeps moving to other parts of the room. Look at the first drawing on page 75 to see how this happens.

Heat makes water in the pan below move in the same way it makes air in the room above move. As water is heated (red arrows), it rises. The cooler water (blue arrows) moves down. How do you know when all the water is heated?

Heat moves through objects

Have you ever cooked something in a pan? If so, you may know that the whole pan does not become warm right away. First, the bottom of the pan gets warm. Then, heat moves through the bottom to the sides. Heat may even move through the sides to the handle.

What are some other objects you know of that heat can move through?

Heat can also move from one object to another. If you put a hot cup of soup on a table, heat from the cup would move to the table. At what other times might heat move from one object to another?

Keeping heat from moving

When you are cold, you may want heat to move. You may want it to move from a heater to you. When else might you want heat to move?

Sometimes, however, you may want to keep heat from moving. If you put a hot pan on a table, What might happen to the table? Why? At what other times might you want to keep heat from moving?

There are many things you can use to keep heat from moving. Suppose you wanted to pick up a hot pan. What things might you use to keep the heat from burning your hand?

People who build homes and other buildings know how to keep heat from moving. They know how to make buildings so that heat does not move through the walls. When would you want heat to stay inside a building? When would you want heat to stay outside a building?

Between the inside and outside walls of this building is a layer of insulation. How does the insulation help keep air inside the building comfortable in summer and winter?

3 How heat changes things

Think about the last time you put butter on a hot roll. Heat from the roll warmed the butter. How did the butter change when it became warm?

Heat can change other things too. What other things have you seen changed by heat? How have they changed?

Heat melts things

Suppose you held some ice in your hand. Heat from your hand would change the ice. The ice would change to water. This kind of change is called *melting*.

Heat can melt many things. What are Some other things you can think of that heat can melt?

Heat boils things

There is another way in which heat can change things. Suppose you were heating Some water on a stove. if you were to add enough heat, the water would change to steam. This kind of change is called *boiling*.

Heat can boil other things too. What are some other things you can think of that heat can boil?

Heat makes things take up more room

Have you ever played on a sidewalk? If so, you may have seen spaces, or cracks, every few feet. People who build sidewalks leave these spaces. These people know that a sidewalk takes more room when it is warm than when it is cold. The spaces in a sidewalk allow for it to take up more room on a hot day.

There are many other things which take more room when they are heated. Which of these things can you think of?

4 Measuring temperature

Suppose you got letters from two friends. One friend was in Nassau. The other was in Inuvik. They both wrote telling you that it was a cold day. What if they both wanted to go outside. Do you think one would put on more clothing than the other? Why or why not?

What is temperature?

You most likely use words like "hot" and "cold" to tell about many things. Feeling something with your hands is one way of telling whether it is hot or cold. This is one way to measure [MEHZH-ur] how hot or cold some-thing is. But things which feel hot to you may not feel hot to someone else. And things which feel cold to you may not feel cold to someone else. Why might this be so?

If you wanted to know just how hot or cold something is, you would have to find out its *temperature*. The temperature of something tells you just how hot or cold it is.

Temperature is measured in *degrees* [dih--CREEz]. Something that is hot will measure more degrees than something that is cold.

When you are well, your temperature is about 37°C. The drawing on this page shows what is meant by Celsius. Water boils when its temperature is 100°C What do you think is the temperature of the air around you?

What is a thermometer?

The best way to measure temperature is to use a *thermometer* [thuh(r)-MOM-uht-ur]. Look at the thermometers pictured on this page. These thermometers show the air temperature of two rooms. You can read each thermometer by finding where the top of the red line ends. What number is at the end of each red line? Which room is the warmer?

The red line in these thermometers is a red *liquid* (LIHK-wuhd). This liquid is in a gass tube. When these thermometers were made, the liquid was put in the bulb at the bottom of each tube.

When heated, the red liquid in a thermometer is like most other things. That is, it will take up more room when it is wan than when it is cool. So, when the red liquid is heated, it will rise in the tube. When the red liquid is cooled, it will fall in the tube.

There are many other kinds of thermometers. Some are shown on this page and the next. Which kinds of thermometers have you seen?

Workers Who Use Science

Many times, heat from burning is helpful. You might cook or keep warm with this heat. Other times heat from burning is not wanted. Every year, many things are burned in fires.

Many people work to keep fires from starting or spreading. These people are called *fire department workers. Fire inspectors* are fire department workers who look in buildings to help make sure fires will not start. They make sure that things which might catch fire are not close to heaters. They also look for things which might start fires, such as worn electric wires.

Fire fighters are fire department workers who -know how to put out fires after they start. These people sometimes have to go through rooms filled with smoke and heat. They know that hot air rises. By keeping down low, they may get to the --fire and put it out.

To find out more about fire department workers, try to find answers to these questions:

What do fire fighters wear to protect themselves?

What do fire department workers teach others about preventing fires?

What is used to put out different kinds of fires?

Along with sources of your own, visiting or writing to a local fire department may be helpful.

Blecha, M. K., Beugger, P., Gega, P. C., Green, M., & Wied, A. V. (1977). Exploring science, blue book. Toronto, Ontario: Doubleday Canada Limited. Reproduced with the permission of Prentice Hall Ginn Canada Inc. March 8,1996.

Book 3-3

Stem Science

Chapter : Heat and temperature

Temperature

Knowing how to measure temperature is important.

You should know what the temperature is to decide what clothes to wear outdoors.

When it is cold outside, your home and school must be kept warm.

Many things happen when the temperature changes.

Men who predict the weather must know about changes in temperature.

Your body temperature usually changes when you are sick. Knowing your temperature can be important to a doctor.

In what other ways are changes in temperature important?

Our skin helps us tell whether something is hot or cold. It also helps us tell whether one thing is warmer than another. But how good is our skin at helping to tell small differences in temperature?

Is skin a good thermometer?

By now, you probably think it is not. You probably found it hard to tell small changes in temperature with your fingers.

Also, it is very difficult to remember how warm something feels from day to day. Or, while you move from place to place.

Observing temperature changes

Our skin helps us observe some temperature changes . But there may be a better way of doing this.

How do temperature changes cause some kinds of matter to change? Do you remember how air in a rubber-covered jar changes when it is warmed? Lets observe this again, in a different way.

Expanding air. You have just made a simple *air thermometer*. It lets you observe changes in temperature. As the air inside the bottle becomes warm, it expands. It pushes some liquid out the neck. As the air inside the bottle cools, it contracts. This lets liquid come up in the neck.

A scale for your air thermometer. The height of the liquid can be used to show changes in temperature. In order to read your air thermometer you must make a simple scale.

First, put a piece of tape along the neck of the bottle. Put the air thermometer in a place that is hot and sunny. Mark the level of the liquid when it stops moving. Label this HOT.

Next, put the air thermometer in a cold place for about half an hour. Again mark the level of the liquid. temperature. Label this COLD.

On a strip of paper mark the distance between the HOT and COLD levels. Cut the strip to this length. Fold it in half again. Now open your strip. Place it against the tape on the neck of your bottle. Be sure one end of the strip is at the level marked HOT and the other at COLD. Make a mark on the tape at each fold in the strip. Beginning with COLD, number this scale from 1 to 5.

Check your air thermometer several times each day. How high is it in the early morning? At noon? In the afternoon?

Mike's experiment. Mike was surprised that air expanded and contracted so much with changes in temperature. He wondered whether liquids would do the same. So he did an experiment.

First, he found three similar bottles, tike those in the picture. Using colored water, he made one into an air thermometer. This would show how air in a bottle changed as the temperature changed.

Mike filled the second bottle with colored water. Then he filled the third with rubbing *alcohol* that had color added. Both bottles were filled to the same level in the neck as the air thermometer.

Next, Mike put a mark on all three bottles to show where the liquid came. When all the bottles were ready, he put them in a cold place and waited.

In a half hour Mike took them out to see what had happened.

Which material had contracted the most?

Was there a difference between the water and rubbing alcohol?

Mike then put the bottles in a warm, sunny place. After a half hour, he *examined* them again. Here is what he saw.

Which material had expanded the most? Is this the same material that contracted the most when cooled? What kind of matter is this? How is it different from the other materials?

Thermometers

You have observed that some kinds of matter change when the temperature changes. For this reason they can be used in thermometers. Thermometers show changes in temperature.

You have already made an air thermometer. What about thermometers that use liquids or solids? How are these made? Let's look again at some liquid in a bottle.

A problem. The two bottles you just observed are simple liquid thermometers. The liquid level in each changed as the temperature changed. But one showed a greater change than the other. Suppose that you wanted a liquid thermometer to show very small changes in temperature. Which one of these containers would be best?

Liquid thermometers. Here are some liquid thermometers. What happens to the level of the liquid in each as the temperature changes? What causes this change?

Solid thermometers. Some thermometers use a solid material instead of a liquid. The metal strip in this oven thermometer expands or contracts whenever the temperature changes. This makes the needle move.

Why might a solid thermometer be better than a liquid thermometer in an oven?

What would happen to some liquids in very hot places? In very cold places?

The Celsius thermometer. You put a simple scale on your air thermometer. It had only a few levels marked on it. Most thermometers have many more marks than this. The are marked in units called degrees. A degree is a standard unit of temperature. It is usually written like this: ° (as in 16°C).

The thermometer on this page is a Celsius thermometer.

High temperatures. Meat is often cooked at temperatures much higher than that of boiling water.

Sunlight shining through a magnifying glass can make a bright spot on a piece of paper. The temperature of the spot may be hotter than a cooking oven. Put a piece of paper in a metal pan. Set the pan near a sunny window. Use a magnifying glass to direct the sunlight. Make a bright spot on the paper. What happens?

Some metals and other materials can be heated to more than 1000°C.

Low temperatures. Sally's ice melted at 0°C. In many places, it gets colder than this in winter.

You can make a colder temperature right in your classroom. Put a thermometer into a cup filled with pieces of melted ice. How low does the temperature go?

Shake some salt on the ice. Carefully mix it in. Now, what is the lowest temperature you observe? Will adding more salt make the temperature still lower? How much lower?

Temperatures of Large and Small Things

Ellen is getting ready to feed her baby brother. Before she starts, She must be sure the milk is the right temperature. She tests it by shaking a drop in her wrist. Does this drop have about the same temperature as the milk in the bottle?

Taking a sample. The sailor is testing a sample of water in the ocean. A sample is a small bit of something that is like a larger amount. The water in the can has the same temperature as the part of the ocean from which it came.

Do you think this would true of all samples? What would happen to the water if it were left in a warm place for an hour? Then would it be fair test of the ocean's temperature?

Temperature and amount. Can a little of something be warmer than a lot? These men are listening to a report of the ocean temperature. There is less liquid in the cup than in the ocean. But can the liquid in the cup be warmer than the ocean? There is less liquid in the glass than in the ocean. Can the liquid in the glass be colder than the ocean?
Does temperature have anything to do with size?

Size and temperature change. Does a large amount of something cool faster than a small amount? Does it warm faster? You can find out by testing two different amounts of water.

Along the left side of a chart like the one above write "Temperature in degrees Celsius."

Along the bottom write "Time in minutes."

Be sure the lines going across are spaced the same distance apart. These show each 5°C mark on your thermometer. Be sure, too, that the lines going up and down are spaced the same distance apart. These show every ten minutes that pass.

Now you are ready to experiment.

Speeding and slowing Temperature change.

This girl is having a hot drink. The liquid stayed hot all morning in its container.

The ice cream is being put into a special bag. Heat cannot go to it so easily. The bag helps to keep the ice cream from melting.

Candy left in a closed car may melt if the sun shines on it. But food can be kept cool if stored in the right way. What are some ways to keep things hot, or cold?

Why does heat reach some things easily? What keeps heat away from others?

Insulators and conductors. The team that kept the ice cube the longest time used the best *insulator*. Their wrapper let the smallest amount of heat reach the ice. Here a lady is using an iron on a dress. Wires inside the iron get very hot. If heat moved easily through the handle, it could burn the lady's hand. The handle must be a good insulator. Heat does move easily trough the bottom of the iron to the dress. The bottom must be a good *conductor* of heat.

Metals and good conductors of heat. Your experiments show that iron and copper conduct heat better than some other materials. In fact, most metals are good conductors. Some are better than others. Silver is best. Copper is not as good as silver, but it is better than iron.

The bottom of an electric iron is made of metal. This conducts heat better than the handle which is not metal.

Many cooking pans are made of metal, too. What are the pans in your kitchen made of? What are their handles made of? If the handles are metal also, what must you use to keep from burning your hands?

Insulators often contain air. Materials such as wood, foam plastic, and cloth are good insulators. Each of these has many tiny spaces in which air is trapped. These air spaces slow the *conduction* of heat through the material.

Look at a piece of cloth with a magnifier. Can you see air spaces in it?

Break apart a foam plastic cup. Can you see air spaces in it, too?

Take apart an insulated ice cream bag. Is the material between the layers of paper solid or loose? Why?

How do you think a sleeping bag helps to keep a person warm?

Feathers keep many small air spaces between a bird's skin and the weather outside.

What other materials can you think of that are used as insulators? What makes them good insulators?

Book 4-1

Science: Comparing Things

Chapter : Understanding energy

Using Energy

Using Simple Machines

What Stops Things That Are Moving?

Pick up your science book. You have just done some work! Did you require any energy to do this work? Yes, but not much. Energy is the ability to do work. You need more energy when you go swimming that when you lift a book. But no matter what work you do, you use energy.

Using Energy

Look at the pictures below. See how the falling water turns the wheel. The falling water is doing work. There is energy in the falling water. Look at the next two pictures. Does the wind have energy to do work? Does the wood have energy to do work? What work is each doing?

Light is one form of energy. Electricity is another. Heat is another. And sound is still another. All these forms of energy can do work.

You use energy all the time. It takes energy to move any part of your body. For example, it takes energy to keep your heart beating. It takes energy just to move your eyes back and forth across this page as you read.

But where do you get your energy from? You get your energy from the food you eat. All food actually has energy stored in it -energy that comes from sunlight. When you read about green plants, you will learn that energy from the sun is in the food you eat. You will also learn that all living things depend directly or indirectly on green plants for their energy.

You eat many foods. In the cells of your body, some of your food is "burned". When this happens, the energy stored in the food is set free. Your cells use this energy to do work. You can pick up things, play games, and do hundreds of things -all because food gives you the energy to do work.

Machines Use Energy to Do Work

Suppose you wanted to travel across the United States. Of course, you could walk about 3,000 miles across the country, but it would take too much energy for you to do that. It would be much easier to use the energy of machines. Machines make use of different kinds of energy. Machines can make use of mechanical energy, electrical energy, and heat energy.

We use electrical energy to run big machines, like printing presses and elevators, and to run small machines, like vacuum cleaners and washers. We use heat energy to cook our meals. Scientists use nuclear energy to run submarines. Do you know what else they use nuclear energy for?

Many kinds of energy are used daily to get things done -to do work. Make a list of all the work you did today in which you used energy that did not come from your own muscles.

Where Does Energy Come From?

Anything that can burn has energy stored within it. Coal, oil, and gas have energy stored within them. When they are heated, the energy is released.

Most of the energy in our world comes from the sun. Without the sun there would be no food, coal, oil, or gas -our principal sources of energy.

Energy Can Change Its Form

One example of how energy can change its form is found in the automobile engine. When someone starts an automobile engine, gasoline begins to burn inside the engine. The burning gasoline produces heat. The heat, which is a form of energy, makes certain parts of the engine move. These moving parts of the engine make other parts of the car move. Scientists say that when an object moves, that object is using mechanical energy. Do you see how the energy inside an automobile engine is changed from heat energy to mechanical energy? You will learn later how other forms of energy can be changed.

Energy Has Many Forms

Rub your hands together. You are now using the energy of motion, or mechanical energy. Keep rubbing. Are your hands getting warmer? You are changing mechanical energy into heat energy.

Here is another example of energy being changed from one form to another. Pump air into a bicycle tire. After you push the plunger down and pull it up a few times, feel the pump. Is it warm? Explain what happened.

Stored Energy

You have been reading about **energy in action**. There is another kind of energy. It is called **stored energy**. Stretch a rubber band. The stretched rubber band has stored energy within it. Let one end go. It snaps back and hits your finger. The stored energy becomes energy in action.

Pathfinders in science

James Prescott Joule (1818-1889) England

We know that heat is a form of energy. But we didn't always know it. Someone had to find out.

At the end of the eighteenth century, scientists thought that heat was something taken in by an object when the object's temperature rose. When the object's temperature fell, the heat supposedly escaped into the atmosphere. Since the weight of an object is not changed by heating, scientists reasoned that heat was weightless. This explanation worked very well for materials that were heated over a flame, but it didn't really explain the heat given off by friction.

In the 1840's an amateur scientist, James Prescott Joule, set up an experiment in which a small paddle wheel kept turning in a certain amount of water. He was able to measure the amount of heat given off by the friction of the paddle wheel turning in the water. He also measured the amount of mechanical energy caused by the friction. Joule discovered that a certain amount of mechanical energy always produces the same amount of heat.

Next, he answered the question, "What does heat have to do with friction?" Joule found that a certain **amount of motion** (or friction) always turns into the **same amount of heat**. One kind of energy is simple changed into another. Every bit of mechanical energy given off becomes heat energy. This experiment showed that heat is another form of energy and *not* a "substance".

Joule's work led to one of the basic laws of science. His experiments showed that when one form of energy is changed into another, no new energy is created and no old energy is destroyed. One kind of energy is simple changed into another kind. In 1847, another scientist, Heinrich von Helmholtz, put these findings into words as the *Law of the Conservation of Energy*. This law says that energy can be changed from one form to another but cannot be created or destroyed.

Stored Energy to Energy in Action

A blown-up balloon has energy stored within it. Stick the balloon with a pin and the stored energy becomes energy in action.

Bob did not know about stored energy. Knowing about stored energy might have helped him. Before going away on vacation, Bob placed some blankets in a box on a very high shelf. Finding it hard to keep the cover closed on the box, he placed a large book on top of the box. When he came home from his vacation, he needed the blankets. He stretched up on his tiptoes and pulled the box down. But he forgot about the book. Down it came, hitting Bob on the forehead.

Bob found out that the book had energy stored in it. And this energy was released when the book fell. The book did work -although Bob was not very happy about the work it did.

Lift a weight. The weight now has stored energy. How did it get there? Drop the weight. What happens to the stored energy? The stored energy is changed into mechanical energy -the energy of motion. Energy can do useful work, but it can also cause accidents if you are not careful.

Setting Things in Motion

A moving object has energy. It can do work. But what starts an object moving? Bicycles, roller skates, wagons, toy cars, sleds, and swings do not start to move by themselves. Things stay where they are unless something starts them moving.

Could your book move by itself? What could happen to make it move? What things could you do to move it?

How would you move your chair? Would you move the teacher's desk in the same way? Would you move a heavy desk in the same way if the floor were covered with a thick rug?

It always takes something called **force** to set anything in motion. Force is the push or pull on an object. When you walk, run, skate, ride a bicycle, hammer nails, throw a ball, or turn the pages of this book, your are using force. Even if you push against a wall and it does not move, you are still using force. You just are not using enough force to move the wall. It takes more force to move something heavy than to move something light.

Scientists say that work is done only when a force actually *moves* an object. When you push as hard as you can against a wall, are you doing any work? You might think so, but a scientist would say that you are not. Since the wall you push against does not move, you are not doing any work.

Why doesn't the wall move? The force you use is not great enough to move the wall.

Energy, *force*, and *work* are words that you have used for a long time. But now you are using them in new ways -the ways scientists use them. You have found that these words all have something to do with each other. Before reading on, can you tell how they are related to each other? Which of the three must always come first?

Here is an example of how energy, force, and work are related. You have *energy* in your muscles. When you use your muscles to throw or "push" a baseball, you are producing a *force*. Since the baseball moves through the air, you have done *work*.

Can you now explain how energy, force, and work are related in each of these groups of words:

1. Gasoline, snow plow, snow
2. Boy, rock, windowpane
3. Horse, corn and oats and hay, wagon
4. You, pencil, notes
5. Cat, milk, tree

Would you say that in each case the work done was *useful* work? Does work have to be *useful* to be work?

Using What You Have Learned

Here is a picture of a busy street. There are many kinds of machines and many kinds of energy being used. Look carefully and list in your notebook the different kinds of machines and the kinds of energy you find.

Using Simple Machines

Suppose you want to move a heavy rock. You can move it the way the rock in the picture is being moved. You are using a machine to help you -an iron bar. You may not think of an iron bar as a machine, but it is one. The iron bar is really a simple machine called a **lever**.

Not all levers are iron bars, but levers generally work in the same way as the iron bar that you see in the picture. When a carpenter uses his hammer to pull a nail, the hammer is really a lever. When you use a shovel to dig, the shovel is a lever. When you use a shoehorn to put on your shoes, the shoehorn is a lever.

You can lift a heavy pile of books with a lever right in your classroom. A broom handle or stick can be a lever.

How Do Wheels Help Things Move?

Many things are too heavy for people to move. But sometimes these things can be moved with the help of wheels. The pictures show some ways of using wheels to help move things. How are the wheels of each thing moved? The **pulley** in the picture is a simple machine. A pulley is used for lifting objects.

Sometimes wheels are moved by the force supplied by other wheels that are turning. This happens when you use an eggbeater, or when the little wheels turn inside a watch or a clock.

Wheels are moved by the force supplied by other wheels when you ride on your bicycle. The muscles of your legs supply the force that makes the sprocket wheels turn. When two sprocket wheels like those on a bicycle are joined by a chain, what happens when one of them is turned?

The experiment that begins on the next page will help you find out about sprocket wheels on a bicycle and how they work together. Do you know how a sprocket wheel got its name?

How Do Steam and Other Gases Make Things Move?

Some wheels are moved by the force that our muscles produce. The wheels on your bicycle and on a wagon are moved this way. But many wheels are moved by another force -the force of a gas. In Tom Peterson's class, the teacher and students tried to see how this happens.

Tom put a cork in a empty can like the one in the picture. His teacher heated the can for a few minutes. What happened to the cork? As the air inside the can got hotter, the air took up more space. Since there was not enough room for the air in the can, the air pushed harder against the cork and the sides of the can. The air pushed so hard that it blew the cork out of the can. What would happen if you pumped air *out* of the corked can?

Do you know what sometimes happens to the lid of a pot when the water boils inside the pot? The lid bounces up and down. Do you know why? When you boil water, the water turns to steam. Since steam takes up more room than water, it pushes upward on the lid. The steam pushes with so much force that it raises the lid.

The force produced by large amounts of steam is used to turn the wheels of big machines. Can you think of other ways in which steam is used to move things?

When gasoline burns, it changes to a gas very quickly. The stored-up energy is then released as heated gas. It pushes with great force against anything in its way. The force that is made by releasing this energy is used to turn the wheels of cars. It is also used to turn the propellers or airplanes. Can you tell about other things?

How Gravity Makes Things Move

There is still another force that makes things move. Hold a pencil in front of you. What happens if you let go? The force that makes the pencil fall is called **gravity**. It is the gravity of the earth that makes things fall to the ground unless there is something to hold them up.

If there were no force of gravity, things would not weigh anything. When we say that a girl weighs 70 pounds, we mean that the earth's gravity is pulling her towards the earth with a force of 70 pounds. A 5-pound bag of sugar is pulled toward the earth with a force of 5 pounds. A pound of candy is pulled toward the earth with a force of 1 pound.

Here are some interesting questions about gravity for you to think about.

1. What force of gravity is pulling your body toward the earth?

2. Sometimes birds high in the air seem to float without moving their wings. Why doesn't the force of gravity pull these birds to the earth?

3. If it were not for the force of gravity, what would happen at a ball game when a batter hit a high fly?

On page 38 you learned one of the ways to measure the force of gravity. Scientists have instruments that can measure gravity more accurately. Do you know the names of any of these instruments? How are the two scales in the pictures different from each other?

When Things Fall from High Places

Which would be more likely to hurt you -a fall from the bottom step of a ladder or a fall from the top step? Which would hit the ground harder -an apple falling from the top of a tree or an apple falling from your hand?

You can show what happens to things falling from high places by measuring how deep they sink into mud. The experiment on the next page will help you.

In the experiment both marbles weigh the same. The marble dropped from six feet falls farther and faster than the other marble. The faster a marble falls the harder it will hit.

Gravity is a force. Like other forces, it speeds things up as long as it acts. The longer you pump on a swing, the faster it will go. Pumping supplies the force. Even if the pumps are the same size, you will swing faster, so long as you keep on pumping.

The force of gravity is acting all the time on earthbound objects. For example, when an apple falls from a branch, gravity pulls the apple to the ground. Its constant pull speeds up the apple as it falls. The farther the apple has to fall, the more it speeds up. You can see this happening.

What do the experiments so far tell you about what happens when you bump into a fence while running for a ball? Would you hit against the fence as hard if you were walking?

Why is there danger in going too fast on bicycles, roller skates, wagons, sleds, or other moving things? Why is there danger to yourself and to others if you run in the school halls?

Using What You Have Learned

1. With a pulley you can lift things up by pulling down. If you don't have a pulley, use an empty thread spool and a coat hanger wire to make a pulley. Hang your pulley in the center of an open door. Run a string over the pulley so that the ends of the string nearly touch the floor. The picture shows how the pulley should look. You can now lift up different things by pulling down on the string.

2. With a string, tie a book to one end of a long, heavy rubber band. Tie the other end of the rubber band to a coat hook or something else that sticks out from the wall. When the book stops bouncing up and down, measure how far it hangs from the coat hook.

Now lift the book until it no longer stretches the rubber band at all. Then let go. Notice how far it stretches the rubber band on the first bounce.

Why does the book stretch the rubber band farther than it did when it was just hanging?

3. You can show how rollers make things easier to move. Get a box about the size of a chalk box. Put stones or other heavy things inside it. Put the box on the floor and fasten a rubber band to one end of it. Hold a ruler beside the band and pull on the band until the box just begins to move.

How long was the band stretched when the box started to move?

Now put two round pencils under the box and pull on the rubber band. How long was the band stretched this time when the box started to move?

What Stops Things That Are Moving?

You know that nothing will move unless force makes it move. In the same way, nothing will stop unless some force makes it stop. Someone on roller skates will keep moving for a while after he has been pushed. A bicycle wheel will keep moving for some time after you have stopped turning the pedals.

Just as you must apply force to make things move, you must apply force to make things stop. You remember that to make an object move, you had to apply force in the direction you wanted the object to move. But to make an object stop, you apply force in the direction opposite to its motion. The size of force you apply must be larger than the force that is acting on the object.

A car will coast for a time by itself, but after a time it will slow down and stop. In the same way, a boy on roller skates cannot coast forever. The car and the boy on roller skates stop because there is a force opposing their motion, even though you cannot see it. This force is called **friction** (FRIK-shun). Friction is created whenever two things rub against each other. For example, there is friction when your bicycle tires roll over the roadway. There is friction when ice skates glide over the ice. There is friction when a boat moves through the water. Even when you simple rub your hand lightly over the top of your school desk, friction is created.

How Does Friction Stop Things?

Nothing is ever perfectly smooth, even though some things look smooth. Every surface has little bumps and hollows on it. If you look through a magnifying glass at something that is smooth, such as your skin or a page from a book, you will see that it is not as smooth as you though it was.

These little bumps and hollows act as a force which can slow down and stop a moving thing. The little bumps and hollows on one object rub and catch against the bumps and hollows of another object. This slows down the motion of the moving object

If the two objects have many bumps and hollows in them, there is a great deal of friction. When two very smooth objects move against each other, there is not much friction. That is why ice skates slide easily on ice. For the same reason, a car or a bicycle skids on ice and keeps on moving longer that it would move on a dry road.

When we want to make objects move more quickly, we can use what we know about friction. Can you tell why cars go faster on smooth highways than on rough roads? Can you explain why railroad trains run on steel tracks? Can you tell why children's playground slides are so smooth?

You can find out what happens when there is very little friction. The next experiment will help you find out.

Look at a bicycle or car tire. Notice the grooves in the rubber. Can you tell why the tires are made this way?

Tires will skid on icy, wet, or oily roads. Old, smooth tires will skid more easily than new ones. Can you tell how tire chains help to keep a car from skidding?

Highway workers spread sand on icy roads because sand makes the roads rough. This roughness makes more friction, and cars can stop more easily.

Can you think of some ways to prevent accidents while riding a bicycle, while driving a car, or while walking on a slippery road?

Scientists have shown that once a thing is moving, it will keep on moving until it is stopped by something. Why does the piece of wood in the experiment finally stop?

Have you ever heard of a "runaway" car on a railroad track? How far will it go before it stops? What stops it?

Do you know how the brakes on an automobile work? Is the automobile stopped by friction?

We can use what we know about friction to travel more safely. The next experiment will show you how.

Barnard, J. D., & Lavatelli, C. B. (1970). Science: comparing things. The Macmillan Science Series. Cambridge, Ontario: The Macmillan Company.

Book 4-2

Exploring Science.

Chapter 3: Work and Machines.

1 Work, work, and more work

What does the word *work* mean to you? Does it mean lifting your book? Does it mean pushing a cart or pulling a sled? Doing these things may not seem like work. But whenever you move something, you are doing work. When have you seen people doing work? What are they moving? What work have you done today? What did you move?

How strong?

As you may know, lifting a pencil is a lot less work than lifting a desk. This is because you use less *force*, or strength, to lift the pencil. Why do you think this is so?

Much of the work you do each day needs little force. But some work you do needs a lot of force. What work have you done that needed a lot of force?

How far?

Imagine tying a rope around an elephant and trying to pull the elephant away. Pull and tug! You would most likely use a lot of force. But would you do any work? Why or why not?

Force is not the only thing that is important in doing work. The *distance*, or how far, something is moved is also important.

Suppose you pulled a friend in a wagon down your street. Now think of pulling your friend to the other end of town! You would need the same amount of force to keep the wagon moving during both trips. But you would do more work on the second trip. Why?

How easy?

As you have learned, some work needs a lot of work. And some work is done over a long distance. Because of these things work can be hard for people to do. So, people may use *machines*. Machines are things which help make work easier. In what ways do you think machines help make work easier?

When people think of machines, they often think of cars or buses. But even a fork is a machine. You may be surprised, but there are machines all around you. What are some things around you that are machines?

2 Simple Machines

People have been using machines for many years. Machines were first used for doing simple work like lifting and carrying water. Later, people used machines to make things like clothes. In fact, people learned to use machines for making other machines!

Do you think people will always use machines? Why or why not?

Inclined planes

Today there are hundreds of different machines. But no matter what machines people may use, all machines are made up of just a few kinds of *simple machines*.

One kind of machine is the *inclined plane*. Inclined planes let you use less force when you move something. The pictures on this page show how inclined planes help people do work.

There are many kinds of inclined planes. one kind is the staircase. A hill is also a kind of inclined plane. Look at the drawing below. Which rider is using less force to get up the hill? Why?

Wedges

Have you ever pushed a tack into a board? If so, you may know that the point on the tack helps you get into the board. Imagine pushing a tack with no point. Do you think you would use more force? Why or why not?

The point on a tack is a simple machine. It is called a *wedge* [WEHJ]. Wedges are used to push things apart. They may also be used to cut things. A knife is another kind of wedge. Which part of the knife cuts? Using a sharp knife can help make work easier than using a dull one. Why do you think this is so?

There are many other kinds of wedges. Some of them are pictured on this page. How can each one help people do work?

Screws

Have you ever used a jar with a top you had to twist on and off? If so, you were using anther simple machine. The part of the top that holds it to the jar is a simple machine called a *screw*.

Besides jar tops, there are other kinds of screws used to hold things together. Look at a door. Screws hold the door to the wall. The handle or knob is held on by the screws. What are some other things held together by screws?

Screws can also be used to lift things. The seats of some chairs have screws. When the seat is turned, it may go up. The second picture on this page shows a screw being used to lift a platform. What other things might be lifted by a screw?

Another way in which screws are used is to push or pull things. Propellers on boats are screws which push against the water. How does this help a boat move? Propellers on airplanes are also screws. How do you think a propeller helps a plane move?

Levers

Imagine trying to lift a desk without even touching it. Do you think you can do it? You can, if you use a lever. A lever is another kind of simple machine. The picture on this page shows how a lever works. How are these levers helping these children do work?

When using a lever, it is often helpful to think of it as having three parts. The drawing below shows these parts.

In the center of this lever is the fulcrum. The fulcrum is the point on which the lever rests. On both sides of the fulcrum, there is an "arm." One arm has the load, or what you want to move. It is called the *load arm.* The other arm is the arm you force down. It is called the *force arm.* Think about playing on a seesaw. Where is the fulcrum? Where is the force arm? Where is the load arm?

There are different kinds of levers . Some levers, like the seesaw, have the fulcrum in between the force and the load. Some other levers have the force in between the force and the fulcrum. A wheelbarrow works like this. Where is the fulcrum on a wheelbarrow? Where are the force and the load?

Another kind of lever has the force in between the fulcrum and the load. Tweezers work like this. When you pick up something with tweezers, where is the force? Where is the fulcrum? Where is the load?
The pictures on this page show some levers in use. What work has been done with each lever? What work have you done with a lever?

Wheel and axle

Another simple machine is the *wheel and axle* [AK-suhl]. This machine is made of a wheel and a rod. The rod is the axle. It is joined to the center of the wheel. The picture below shows two kinds of wheels and axle machines. How are they alike?

A doorknob is also a kind of wheel and axle. Think of opening a door. As you turn the knob, the axle turns and opens the door. Try opening a door by turning just the axle. How does a knob help you turn the axle?

The pictures on this page show some other kinds of wheel and axle machines. Point out the wheel and axle in each picture. How does each wheel and axle help make work easier?

Sometimes the wheel on a wheel and axle has teeth. This kind of wheel is called a *gear*. Look at the picture of the bicycle on this page. How does the gear help turn the wheels?

A gear can also turn another gear. Gears are used this way inside of watches. The hour hand has a gear. The minute hand has a gear. Why do you think the minute hand turns faster than the hour hand?

Pulleys

As you may know, when you use a lever, you use force in one direction. The load moves in another direction. Another simple machine works in this way. It is a *pulley* [PUL-ee]. A pulley is made up of a wheel and a rope.

When you use a pulley, you use force in one direction. The load then moves in another direction. Look at the pictures on the next page to see how a pulley works. In which direction are the forces used? In which direction are the loads moved?

Many times it is hard to get at something to move it. For this reason, you might want to use a pulley. Pulleys can help raise flags on high poles. They can help lift things out of water. When else might a pulley be used?

Most often, a pulley by itself cannot help you use less force to move something. But two pulleys can. Three, four, or even more pulleys can be used together to help make work still easier. When have you seen pulleys been used? What work was being done?

3 Teams of machines

As you may have read earlier, all machines are made up of simple machines. In fact, most machines you use and see everyday are made up of two or more simple machines. These machines are called *compound machines*.

Isn't that simple?

One compound machine that you probably use is a pair of scissors. Scissors may seem simple. But one pair is made up of two levers. They are joined at the fulcrum. On each lever there is also a wedge used for cutting. Some scissors are pictured on this page. Point out the levers, the fulcrum, and the wedges.

Another compound machine is the pencil sharpener. It has wedges, screws, wheel and axles , and gears all working together. Imagine, all these things just to put a point on your pencil! See if you can point out all the simple machines in the drawing below.

Find the hidden machines

There are many other compound machines. Some of them are pictured on this page. What work does each one do? What simple machines make up each one?

Using compound machines

Have you ever seen a building or a road being built? If so, you may have seen many compound machines being used. Building and road workers have to dig down into the ground and move rocks and earth. They may use a bulldozer or a power shovel to do these things. What are some other compound machines used for building roads and buildings?

Many compound machines are also used around homes and parks. Each summer, grass is cut, trees are cut down, and bushes are moved and planted. In the fall, leaves may have to be taken away. In winter, snow and ice may have to be taken away from streets and sidewalks. What compound machines are used to do these things?

Although compound machines can help people do work, they can also help people have fun. Machines are often used in sports. When people fish, they may use a fishing rod and reel. A fishing rod and reel is a compound machine. Bicycling and skiing are other sports in which compound machines are used. What compound machines are used in each of these sports? What are some other sports in which compound machines are used?

Many toys and games are also made of compound machines. What are some toys and games you have seen that are made up of such machines?

Why work at all?

Did you ever think about not doing any work? Sometimes that is fun to think about. You might think about having a machine do everything. It could write your schoolwork for you. It could clean your room. It could wash and dry dishes and put them away. What other work would you like to have done for you?

While machines can help you do some work, they cannot do all the work. Each day you have to lift some things. Each day you have to push or pull other things. What might some of those things be?

Why lift?

When you lift something, you use your force to lift against another force. That other force is called *gravity* [GRAV-uht-ee]. Gravity is the force which pulls things to the earth.

When you drop your pencil, the force of gravity pulls it down. When you pick it up, you use your force to lift against gravity. Do you think gravity pulls down on all things with the same force? Why or why not?

People use many machines to work against gravity. Inclined planes, elevators, and even space rockets are such machines. What are some other machines which work against gravity?

Though people often work against gravity, gravity can also be helpful to them. In what ways do you think this is so?

Why push and pull?

Besides lifting things, you also push and pull things each day. One reason why you push or pull things is to start them moving. Things cannot move by themselves. That is, all things will stay still until a force causes them to move.

You have most likely felt this while riding in a car. When the car started to move, you seemed to be forced back. This is because you were sitting still. The car forced you to move along with it.

The force needed to start things moving may come from you, a machine, or even the wind. What are some machines that are used to start things moving?

Just as a force is needed to start something moving, a force is needed to stop something from moving. So you may have to push or pull something to stop it from moving.

You may have had to pull on a wagon to stop it from rolling down a hill. Or you may have had to push a door to stop it from swinging into you. What are some other things you might push or pull to stop them from moving?

Why keep pushing and pulling?

As you may remember, pushing and pulling are forces needed to start and stop things. These forces are also needed to keep things moving.

Dragging it out. Suppose you were to push or pull a box across the floor. The box would rub against the floor. This rubbing is called *friction* [FRIHK-shuhn]. It is friction which would make the box slow down and stop. To keep the box moving, you would have to keep pushing and pulling it. What are some other things you have had to keep pushing or pulling because of friction?

People have learned a way to get less friction when they push or pull things. They put loads on things that have wheels. Carts and wagons are such things. Why do you think there is less friction when you use a wheel?

Another problem with friction. Besides making things hard to move, friction can cause another problem. Did you ever fall on a sidewalk? If so, you may have seen and felt what friction can do. As your hands or knees rubbed against the walk some of your skin may have been rubbed off. Friction can wear things away. Look at your pencil. What things on it have been worn away by friction?

Many machines have moving parts. As these parts move they rub against each other. Friction can wear away these parts of machines. People who use machines have learned another way to make less friction. They put oil on the moving parts of machines. Why do you think oil helps make less friction?

Friction... the good side. Think about riding down a hill on a bicycle. As you near the bottom you see a stop sign. You stop. You look both ways and then go. A simple thing? Your hand or foot pressed the brakes. The brakes rubbed against the wheel. This rubbing caused friction which helped you stop. When else is friction helpful in stopping?

Have you ever slopped on a wet floor? If so, you know how important friction is in walking. Why do you think people pour sand on icy roads? At what other times might people want to make more friction?

Workers Who Use Science

Machines can help people do many kinds of work. There is even a machine which can run other machines. This machine is called a *computer* [kuhm-PYOOT-ur].

Computers can run the machines that make things. They can run machines that make clothes. Many books, such as the one you are reading, were made with the help of a computer.

Though computers can run other machines, many people are needed to help run computers. *Computer programmers* are people who set up computers to do a certain kind of work. These people may "teach" a computer how to run other machines.

Computer operators are people who run computers. They make sure a computer is working the way it should.

To find out more about people who use computers, try to find answers to these questions:

What else do computer programmers and computer operators do?

What other kinds of machines can computers run?

How fast computers work?

Can computers be used to think?

Along with sources of your own, writing to computer companies and computer-training schools near you may be helpful. Information in reference books under the heading *computers* can also help you find answers to your questions.

Blecha, M. K., Beugger, P., Gega, P. C., Green, M., & Wied, A. V. (1977). Exploring science, brown book. Toronto, Ontario: Doubleday Canada Limited. Reproduced with the permission of Prentice Hall Ginn Canada Inc. March 8,1996.

Book 4-3

Stem Science.

Chapters: Friction--Rubbing and Rolling

Heat

Friction--Rubbing and Rolling

Today, people had trouble walking and driving in the city. Why? What could have been done to make walking and driving less dangerous?

Walking and driving are easier when it is warm. There is more friction between shoes and the sidewalk, tires and the street.

Friction and moving objects

The boy is having a hard time. There is much friction between the box and the floor. Friction often holds moving things back.

What things can you think of that are hard to slide because of friction?

Why are the boy's feet slipping? What are some things that slide too easily because there is not enough friction?

What could the boy do to make his job easier?

In each picture, what objects are shown sliding past each other? Which surfaces are rubbing together? How could you tell that there is friction between these surfaces?

Objects rub together whenever they touch and slide past one another. When they rub, the friction between them tends to slow down or stop the movement.

Friction and Nonmoving Objects

There may be friction even when there is no movement. In fact, there objects hard to move because of friction.

For example, how easy is it to start a desk moving across a rough floor? Not very! Sometimes it takes a strong push or pull. Even then, the desk slows down and stops when the push or pull stops. This is because of friction between the floor and the desk.

If there were no friction, it would take much less than a push to start the desk moving. Then, once it started to move, it would keep sliding until something stopped it.

What other objects are hard to move because of friction?

Ball and roller bearings. Bearings like these are used in the wheels of bicycles, automobiles, and other machines. Some bearings have rollers in them. Some bearings contain small balls.

Ball bearings and roller bearings help the wheel turn more easily. What important idea do they make use of?

Lubricants Reduce Friction

Lubricants are slippery substances that are often used to reduce friction. When lubricants are put between surfaces that rub or roll together, they make things easier to move. Lubricants also help to prevent squeaks and reduce wear.

Where have you seen lubricants being used?

Have you ever used lubricants? For what?

Sometimes lubricants are not wanted. In the wrong places they can be dangerous!

Friction often causes wear. These objects show wear caused by friction. What other examples of this can you think of?

When lubricants are used to reduce friction, they also reduce wear. This is one reason for putting oil and grease on the moving parts of a car. Otherwise the metal would wear away. You can see what happened to the bearing on the right when it was not greased.

Friction with Liquids and Gases

With a drinking straw, stir some water in a glass. Make it spin rapidly. Sprinkle pencil shavings in the water to show how fast it spins.

Then take out the straw. What is touching the water besides the pencil shavings?

Notice that the water slows down. Perhaps you can see that the water next to the glass slows down the most. This is because there is friction between the water and the glass.

After the water has stopped spinning, turn the glass around and around. Keep turning it steadily. Why do you suppose that after a while the water turns, too?

You can also make the water spin by blowing on the surface through the straw. This is because there is friction between the air and the water.

Using Friction to Move

Have you ever tried to start up fast like this boy? When he pushes backward with his foot, the rug slips. There is not enough friction between the rug and the floor to keep the rug in place.

Here two other boys hold the rug to keep it from slipping. When the runner pushes backward against the rug, They pull forward on it. If they pull hard enough, the rug does not slip.

Suppose there were no friction between the rug and the floor. Then the boys would have to pull harder to keep the rug in place. If they pull forward as hard as the runner pushes backward, The rug would not slip. The runner could start up fast.

If the rug had a rubber back, the boys might not have to hold it. Then friction between the rug and the floor would be greater. It might be enough to keep the rug in place.

Pairs of forces. Here there is no rug that must be held in place. There is the sidewalk, instead. It is set in the ground. When the runner starts up, he pushes backward against the sidewalk. What keeps it from moving? What keeps his foot from slipping?

To start up, the runner pushes backward against the sidewalk with his foot. He causes a backward push, or *force*, against the sidewalk. At the same time, the sidewalk causes a forward push, or force, against his foot. There is a *pair* of forces between the runner and the sidewalk. These forces are equal but act in *opposite* directions. They act on two different things--one acts on the sidewalk and the other on the runner.

What makes this pair of forces possible?

Energy Changes: An Important Idea

When you cause objects to rub or roll together, you do work. You use energy.

Where does this energy come from?

It comes from the food you eat and the air you breathe. Food and air are chemicals. They store *chemical energy*. When your muscles move, they change this chemical energy into the *energy of motion*.

What becomes of this energy of motion? Remember what happens when you rub things together. Friction causes the energy of motion change to *heat*. Heat is energy, too, but energy in still a different form.

Energy can be changed from one form to another.

Heat

Move your hands back and forth quickly as if rubbing them together. But do not let them touch each other. Then hold them to your cheeks. How warm do they feel?

Now hold your hands together, so they touch. But do not move them back and forth. Again hold them against your cheeks. How warm are they?

Next, rub your hands together, hard. Then touch them to your cheeks as before. What difference do you feel?

Objects can be heated in many ways. One is by friction.

When your hands do not touch, there is no friction. They do not get warmer.

When your hands do not move, there is no friction. They do not get warmer.

But when you rub your hands together, there is heating. They get warmer.

A fire can warm things. So can an electric toaster. And when the sun shines on objects they get warmer, too.

Heat from friction. Whenever two surfaces touch, there is friction between them. If they rub or roll against each other, they warm up as a result of this friction.

Sometimes enough heat results from friction to start a fire. Long before there were matches, some people rubbed sticks to start fires.

When cardboard is cut with a knife, the knife gets warm because of friction. After several long cuts, the knife may get almost too hot to hold.

Heat from collisions. When objects collide their temperature increases. In most everyday collisions, there is very little heating. You usually cannot feel or measure it. But when large objects collide at high speed, the temperature change can be felt or measured. And when two objects collide over and over again the temperature can be measured.

Suppose you used a very small hammer to hit the wood. Would there still be heating? Would there be more or less heating?
Suppose the hammer were only as big as a pin head. Would there be some heating?

Yes! Even if you heat the wood only once, there would be some heating. A tiny collision, repeated millions of times, produces a lot of heating.

Heat from bending. Temperature increases when two objects rub or collide. There is also heating when an object is bent, twisted, or changed in shape.

Energy change. In all experiments with rubbing, colliding, and bending, you have to do work to make the objects warm. You do work when you rub your hands together.

You do work when you move a hammer to hit a block of wood. And you do work on a paper clip in order to bend it.

Each time you do work you use mechanical energy. Some of this mechanical energy is moved to make things move. But some energy goes into heating whenever objects rub together, collide or bend.

Movement of heat. Feel the paper clip now, a while after you bent it. Is it still hot? What about the piece of wood you hit with the hammer? How warm is it now?

The paper clip lost some energy in the form of heat to other objects and the air around it. Some of the air in the wood heats the air around it. This happens when things are warmer than their surroundings. Their heat moves to things around them.

But this energy is not really lost. It spreads out and makes the air and other things warmer.

Heat from Chemical Energy

Burning is one of the most important ways to produce heat. Burning can start and continue only when there is:

. fuel--something to burn

. oxygen--usually from the air

. a high enough temperature to cause the fuel to burn

Kindling temperature. To make a fuel burn, its temperature must be raised. The temperature at which fuel starts to burn is called *kindling temperature*. Even though there is plenty of oxygen, a fuel will not burn until heated to its kindling temperature.

Different materials have different kindling temperatures. Which seemed to have a higher kindling temperature the candle or the twig?

The kindling temperature of paper is about 180° C. Water usually boils at about 100° C. A higher temperature is needed for paper to burn than for water to boil.

Oxygen for burning. Oxygen is needed for most fuels to burn. If something keeps oxygen from the fuels, they cannot burn.

Oxygen is one of the gases in air. So air supplies the oxygen that fuels need to burn. For this reason, a fire will usually keep burning as long as it gets air. If oxygen cannot get to it, then the fire will go out. This happens even if there is plenty of fuel, and it is at the kindling temperature.

Gasoline engines burn fuel. They need oxygen just as a candle does.

Gasoline engines have an opening where air enters. This opening lets in oxygen needed for the gasoline to burn inside the engine.

Products from burning fuels. Most of the fuels we use contain carbon and *hydrogen*. For example, fuel oil, bottled gas, gasoline, and candle wax all contain these chemicals.

These fuels contain stored energy, or chemical energy. When there is enough oxygen the hydrogen in a fuel burns and forms water. When there is enough oxygen the carbon in a fuel burns and forms carbon dioxide. As this happens the energy in the fuel is changed to another form of energy, *thermal energy*. Heat is given off.

Slowing and stopping burning. Sometimes fires get out of hand. Then they are dangerous. They can destroy houses and kill people. They can destroy forests and kill animals and plants. It is important to know how to stop a fire.

Burning can usually be slowed or stopped by doing any of these things:

. taking away the fuel

. keeping oxygen away

. lowering the temperature

When charcoal burns it give off heat and light. But finally only cold ashes are left. In producing heat, the fuel looses some energy. This energy does not disappear. It is gained by other things. They become warmer. But the fuel is not likely to get back the energy it lost.

Where did the charcoal get this energy?

What do you think happens to the sun as it sends out more and more energy? Do you think the sun has a big enough supply of energy so it will never "run down?

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