ABSTRACT REASONING DEVELOPMENT:
A RESULT OF FORMAL SCHOOLING AND NATURAL DEVELOPMENT

A Thesis

Presented in Partial Fulfillment of the Requirements for

the Degree Master of Arts in the

Graduate School of The Ohio State University

By

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*****

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1996

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This study examines whether logical reasoning development in adolescents is a product of natural development or formal schooling. The investigation involved administering reasoning tests to students in grades six through twelve. Students were tested for their ability to reason abstractly through categorical syllogism problems. Results showed that sixth grade students who had not received algebra instruction were generally incapable of performing adequately on formal reasoning tasks. In contrast, the older students who had received algebra instruction performed slightly better on reasoning tasks. Consequently, a positive correlation can be drawn between students’ level of formal schooling, age, and mastery of higher-level reasoning skills. However, not even the most schooled groups of students were able to consistently master all reasoning tasks, causing one to question the typical age at which most adolescents obtain formal reasoning skills. Based on the review of literature available regarding reasoning development and research results, this study concludes that one’s development of formal thinking skills is the result of a delicate balance between formal schooling and developmental readiness.
Dedicated to my family
ACKNOWLEDGMENTS

I would like to sincerely thank my partner and friend, Beth Pardi, for her perseverance in obtaining our Master’s Degree. Her enthusiasm and work ethic kept us focused on graduation day.

I would also like to thank my adviser, Dr. Vladimir Sloutsky, for his genuine commitment in seeing our hard work come to fruition. His enduring patience and willingness to help made this opportunity a great success.

Finally, I thank my husband for his friendship and unending prayers. We did it!
VITA

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FIELDS OF STUDY

Major Field: Education
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CHAPTER 1

INTRODUCTION

Many American students perform poorly on tests of math, science, and reading achievement when compared to students of other nations. The mastery of each of these subjects is gained once students are capable of transitioning between both inductive and deductive reasoning skills. While research demonstrates that there exists no significant IQ difference between Americans and students of other countries, there are certain educational variables which account for these differences.

There are a number of views on the importance of formal schooling in the development of abstract thinking. Vygotsky, a cognitive theorist, found that schooling played a central role in whether a child would achieve formal reasoning skills. In contrast, Piaget believed that certain reasoning schemata naturally developed in humans in a distinct developmental pattern, regardless of the presence of formal schooling.

This study will demonstrate that a portion of higher reasoning skills do not develop naturally in humans, but rather are present or absent in accordance with formal schooling.
CHAPTER 2

REVIEW OF LITERATURE

The goal of this study is to examine the development of abstract thought. One may ask at what age do humans generally obtain the ability to reason abstractly? Does one's culture predetermine one's ability to achieve abstract thought? As well, one may question whether logical reasoning is simply a natural developmental stage achieved by all humans or whether formal schooling may alter the course of this development. The latter will be the primary focus of this review of past and current research on the origins of abstract thinking.

There are several approaches to the development of abstract thought. First, there are child development theorists such as Jean Piaget, who contend that all humans progress through a prescribed set of cognitive stages in an identical order, regardless of the presence or absence of formal schooling. While the speed at which these stages are achieved may vary, the order of succession through which these stages are achieved is regular for all individuals (Piaget, 1972). Piaget suggests that it's most likely that all people attain the formal operational stage of cognitive development by the age of 15-20,
while he concedes that people may reach the ability to reason abstractly in only certain areas of their professional specialization (Piaget, 1972). Because individuals may not develop their ability for formal reasoning in all areas of life, it is important that tests of formal operational ability be very relevant to the subject’s professional study. Testing of the attainment of Piaget’s formal operations includes assessment of one’s knowledge of combinatorial operations, proportions, mechanical equilibrium, and other operational schema (Piaget, 1953).

Further, one may study the age at which cognitive developmentalists believe children are capable of reasoning abstractly. While many theorists support Piaget’s assertion that formal operational thinking does not surface until adolescence (Overton, 1990), there are some who assert that children as young as three or four years of age may naturally develop the capability for abstract reasoning. One such study of preschoolers’ ability to attribute second order ignorance and false beliefs concluded that “preschoolers have the same conceptual capacity for embedding mental states as do older children” (Sullivan, Zaitchik & Flusberg, 1994). Also in support of these findings, other researchers claimed that children as young as four can reason deductively with content for which “practical knowledge is irrelevant” (Markovits, Schleifer, & Fortier, 1989).

One may question these researchers as to why so many young children appear unable to perform simple oral/written tests of logical thought involving, for example, linear syllogism: “John is taller than Mary. Mary is taller than Pete. Who is tallest? John, Mary, or Pete.” A team of researchers assert that mere memory training is necessary for these young children to more efficiently perform transitive inference
problems (Trabasso & Riley, 1974). Others report that young children are simply incapable of making clear distinctions in their responses to logical and illogical syllogisms (Moshman & Franks, 1986). Recently, a test of six logical/illogical syllogisms was administered to a group of six year olds. The results showed that while the young children performed well on the logical problems, they did not perform well on the illogical problems. This led the researchers to conclude that young children are developmentally incapable of mastering abstract logical reasoning until a later date (Markovits, Schleifer, & Fortier, 1989).

Still other researchers explain the appearance of the absence of deductive reasoning capabilities in young children in a different way. Hawkins, Pea, Glick & Scribner reported in a 1984 study that there are three main reasons for such an appearance: 1) Children do not have the cognitive ability to reason formally in a deductive manner 2) Children allow the empirical truth of the tasks to override the theoretical premises 3) Children haven’t yet learned appropriate relationships among tasks and their everyday social applications. Consequently, the researchers concluded that young children are capable of performing verbal deductive reasoning with theoretical justifications only in highly controlled circumstances because children do not yet have complete control over the rules of logic.

Similarly, Piaget provides evidence that children are unable to even begin to perform abstract thinking tasks until they pass into the concrete operational stage at age seven. According to Piaget, this is because the preoperational child is dominated by immediate sensory input and is unable to accommodate or assimilate new information on
a continual basis. However, by the age of 12, the formal operational child is beginning to
master such formal logic skills (Piaget, Inhelder, & Szeminska, 1960). In this way,
cognitive development in children may be seen as a continuous and gradual process
independent of the effects of formal education (Trabasso, 1975).

According to Piaget, the development of abstract thought represents a natural
progression in cognitive mechanisms that is relatively independent of external socio-
cultural factors, including formal schooling (Inhelder & Piaget, 1958). Many other
cognitive theorists are in agreement with Piaget that all individuals are capable of
naturally developing abstract thinking skills. In his study, The Development of Linear
Syllogistic Reasoning, Sternberg found that children in grades 3, 5, 9, and 11 tended to
employ the exact same reasoning strategies when solving linear syllogisms. However,
the older students typically employed the reasoning strategies with increased consistency.
Based on his studies, Sternberg concluded that there is a general developmental trend in
children which enables them to eventually obtain formal reasoning capabilities
(Sternberg, 1980).

Similarly, other researchers have discovered naturally occurring rules of inference
that people use to solve everyday problems (Kosonen & Winne, 1995). These innate
rules, they believe, are induced from everyday experiences. In their 1995 study of
adolescent and late-adolescents’ use of statistical reasoning, Kosonen and Winne found
that students in grades 7 and 10, along with undergraduates, all use statistical rules to
solve problems. The students in the study were able to do this even in the absence of
formal schooling regarding these rules. However, the students succeeded infrequently
and with low levels of understanding. This finding supports Kosonen and Winne’s conclusion that “primitive versions of formal rules for reasoning are induced through experience.”

There is another group of researchers who assume that an individual’s ability to reason abstractly is greatly affected by a variety of socio-cultural factors, including formal schooling (Cole, 1971; Scribner, 1977). These researchers dwell upon the theory of Vygotsky. Vygotsky’s empirical findings demonstrated the great importance of formal schooling and formal representational systems in human’s development of abstract thought.

In addition, in 1982, the Laboratory for Comparative Human Cognition reported two general approaches to cross-cultural research. They included the Universalistic approach in which one accepts Piaget’s notion that knowledge structures are invariantly attained across cultures. The other approach, Contextualism, claims that learning is context specific and organized activities in the community pre-determine which specific cognitive skills will adequately develop (Keil, 1991). Consequently, the “Functional Universalist” believes that all humans can show they’ve attained formal operational thinking skills if the test administrators identify tasks in the culture which are relevant to the people and requests tasks in a socially acceptable manner. The researchers concluded that when these adjustments were made, the performance between cultures was found to be equivalent (Cole, 1971; Scribner, 1977).

As part of the above study, a test was administered to both schooled and nonschooled western people to assess their ability to perform syllogistic reasoning. In
the instances where the nonschooled men and women reasoned through the problems theoretically, they used the exact same logic as the schooled people. However, there was apparent difficulty in enabling the nonschooled individuals to suspend their knowledge of experience in order to theoretically examine the premises. The study showed that when the nonschooled people were able to be "theoretical," they were virtually never wrong (Hawkins, Pea, Glick & Scribner, 1984).

There is a third group of researchers claiming the importance of balance between the developmental cognitive processes of children as well as the impact of formal school training on the beginnings of individual formal reasoning (Cattell, 1971; Horn, 1970). Cattell described his "Intelligence Development Approach" in terms of "fluid ability" and "crystallized ability." Fluid ability is biologically determined through incidental learning whereas crystallized ability is the knowledge children posses that is culturally determined (Cattell, 1963). In support of Cattell and Horn's findings on both fluid and crystallized abilities, Sternberg reported that transitive inference tasks (an example of fluid ability) are in no way impacted by the effects of schooling (Sternberg, 1985). If a child were to do well on a transitive inference test, it would be wholly attributable to age; not schooling.

There are many reasons for the existence of the debate over nature verses nurture in reasoning development. Kosonen and Winne, in 1995, published a study including why many researchers have little faith in formal reasoning instruction. Possible reasons include that instructional intervention training was not utilized properly and its effects were assessed as inadequate. In addition, many learners were taught rules of logic which
were contrary to naturally inferred rules. Thus, students may have had too much difficulty in understanding the new rule system. Regardless of such skepticism over formal logic schooling, many researchers are in strong support of the concept.

Crystallized abilities, those abilities which are culturally determined or formally taught, appear in a general ability pattern in all humans who are exposed to formal schooling. Four general crystallized abilities which schooled people learn are: 1) School-age intelligence- involving time and interest within the culture’s established school curriculum 2) School age achievement- effect of common time, interest, and money which differs students in athletics, foreign languages, etc. 3) Adult activity intelligence-fluid intelligence which may be applied to whatever activity area receiving common time and interest by adults 4) Adult activity achievement- produced through common expenditures of time and interest (Cattell, 1963).

In 1989, Cahan and Cohen researched the effects of formal instruction with logic on students’ intelligence test scores. The results were very convincing. Testing showed that schooling, rather than age-related factors, was the major factor underlying the increase on intelligence test scores. The results showed that the impact of formal training in logical reasoning skills correlated twice as much with a student’s amount of schooling as it did with their age. These conclusions regarding the great impact of schooling were reinforced by a separate earlier study which also determined that knowledge, rather than age, was the main determinant of a subject’s score on an IQ test (Brown & Campione, 1986).
The reasons why schooling provides a strong foundation in logical reasoning are many. Artman and Cahan, in their 1993 study entitled *Schooling and the Development of Transitive Inference*, found that formal reasoning instruction gave students an advantage in intelligence testing because it was explicitly aimed at developing intellectual abilities such as memory and computation. Secondly, they found that school instruction was similar in format to the structure of the cognitive tasks assessed. Third, there was a correlation found between the higher the child’s grade level in school and the difficulty of the cognitive demands. Finally, empirical evidence allowed the researchers to conclude that schooling does have a considerable impact on the development of a student’s cognitive skills, especially as the student progresses through schooling.

Similar success in formal reasoning education has been experienced by other researchers. For example, Kosonen and Winne, in 1995, provided explicit abstract rules instruction to groups of middle (seventh grade) and secondary (tenth grade) students. Teachers were instructed to teach students abstract rules for dealing with everyday problems. The results showed that students who received explicit rules instruction prior to testing made detectable gains in statistical reasoning over the students who did not receive such instruction.

In addition, two different experiments in which correlational reasoning skills were taught to seventh and tenth grade students showed identical results. Student performance was shown to be considerably improved through instructional intervention when provided by the students’ regular classroom teachers (Ross & Cousins, 1993).
Impressively, these students' ability to transfer such formal reasoning training to real-world applications had taken place as well (Kosonen & Winne, 1995).

Other areas of school curriculum which may benefit from adopting formal reasoning curricula involve the language arts. It was learned that readers who received explicit instruction with analogies (A is to B as C is to D), are assisted in focusing, synthesizing, and integrating material they already know with newly learned information. This enabled the reader to comprehend the text more easily (Paris, Cross & Lip, 1984). In 1985, The Report of the Commission on Reading confirmed this idea by reporting "teacher-led instruction in reading strategies and other aspects of comprehension [critical thinking] promotes reading achievement... when directly taught by the teacher" (Silkebakken & Camp, 1993).

Based upon this information regarding the positive impact that schooling has on reasoning skills, one can safely find implications for the conscientious teacher. Teachers must seize the opportunity to integrate their curriculum across many subject areas by explicitly teaching reasoning skills to their students (Kosonen & Winne, 1995). In this way, teachers may be able to improve students' abstract reasoning abilities and school performance. Indeed, one researcher's studies found the only way that students will learn how to transfer their reasoning skills to real-world applications is if teachers provide explicit problem solving training in the classroom (Klaczynski, 1993). Educators must come to appreciate the broad academic benefits available to those students who are formally trained to reason abstractly.
CHAPTER 3

METHODOLOGY

Research Design

This cross-sectional study held age and grade level as the independent variable and students' performance on reasoning tasks as the outcome variable. The reasoning test relied on the following assumptions: (a) the allocation of students to date of birth was random, and (b) grade level was solely based on chronological age and progression through grades was automatic.

Subject Selection

The students selected for this study included those who were approximately twelve through eighteen years of age. All students, of varying academic abilities, were randomly selected from within the study's designated grade levels. See Tables 3.1 (Average Age of Participants per Grade Level), 3.2 (Number of Participants per Grade Level), and 3.3 (Gender Proportion of Participants per Grade Level) on the proceeding page.
<table>
<thead>
<tr>
<th>Grade Level</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
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<tr>
<td>Average Age of Participants</td>
<td>12.37</td>
<td>12.95</td>
<td>14.45</td>
<td>15.07</td>
<td>15.94</td>
<td>17.04</td>
<td>18.28</td>
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Table 3.1: Average Age of Participants per Grade Level

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<th>Grade Level</th>
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<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>Total</th>
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<tr>
<td>Number of Participants</td>
<td>17</td>
<td>37</td>
<td>30</td>
<td>11</td>
<td>24</td>
<td>13</td>
<td>6</td>
<td>138</td>
</tr>
<tr>
<td>Percent of Total Students Participating</td>
<td>12%</td>
<td>27%</td>
<td>22%</td>
<td>8%</td>
<td>17%</td>
<td>9%</td>
<td>4%</td>
<td>100%</td>
</tr>
</tbody>
</table>

Table 3.2: Number of Participants per Grade Level

<table>
<thead>
<tr>
<th>Grade Level</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>8</td>
<td>16</td>
<td>13</td>
<td>8</td>
<td>15</td>
<td>10</td>
<td>3</td>
</tr>
<tr>
<td>Female</td>
<td>9</td>
<td>21</td>
<td>17</td>
<td>3</td>
<td>9</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td>17</td>
<td>37</td>
<td>30</td>
<td>11</td>
<td>24</td>
<td>13</td>
<td>6</td>
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<tr>
<td>Percent Male</td>
<td>47%</td>
<td>43%</td>
<td>43%</td>
<td>73%</td>
<td>63%</td>
<td>77%</td>
<td>50%</td>
</tr>
<tr>
<td>Percent Female</td>
<td>53%</td>
<td>57%</td>
<td>57%</td>
<td>27%</td>
<td>38%</td>
<td>23%</td>
<td>50%</td>
</tr>
</tbody>
</table>

Table 3.3: Gender Proportion of Participants per Grade Level
Participants attended Canal Winchester Local Schools in Canal Winchester, Ohio. The school district was located in a rural/suburban setting situated outside of Columbus, Ohio. The average household income was that of middle/upper-class. Subject participation was determined by each teacher’s willingness to allow their class to participate in the reasoning test when invited.

**Instruments and Measures**

The instrument used in this study was a paper/pencil leveled-reasoning test. Tasks from this test compared sixth through twelfth grade students’ performance in successfully utilizing inductive and deductive reasoning skills. Each of the three tasks presented below were used to test students’ mastery of contradictions and tautologies. In addition, students’ ability to objectively evaluate premises which were nonempirical in nature was tested.

The following instructions were read aloud to students by the test administrator(s) prior to taking the reasoning test:

We, a group of researchers, are conducting this test in order to determine how the comprehension of a task is related to performance on this task. This test is also being given to students of the same age in Russia and in England. We are excited to see how well Canal Winchester students will represent our schools when we compare results. We will give you 50 minutes for all the questions, so you have plenty of time to answer them.
Before answering, please read the task carefully. Do not rush to answer; make sure that you clearly understand the task. However, please do not spend too much time on one task. If you tried really hard and were still unable to answer, please write “I do not know.” Some tasks ask you to explain your answer. Please give us clear answers to these tasks.

Some questions may seem unusual, but we are really interested in ways that you think and explain your answers. Some tasks seem to be difficult, however the more effort you put forth, the better the results will be.

Please, remember that this test will not affect your classroom grade.

The following are three examples of tasks used to measure students’ understanding of transitive inference and logical necessity:

**Task #3**

Assume the first two sentences (in bold) are true. Make a conclusion using both sentences by choosing 1, 2, 3, or 4. Circle your answer.

*All fahsmooth numbers can be divided evenly by 8.*

*26 is a fahsmooth number.*

Therefore:
1) 26 must not be a fahmooth number.

2) 26 is an exception to the rule.

3) 26 can be divided evenly by 8.

4) It is probably true that all fahmooth numbers cannot be divided evenly by 8.

Task #9

Assume the first two sentences (in bold) are true. Make a conclusion using both sentences by choosing 1, 2, 3, or 4. Circle your answer.

All felismo animals are not predators.
The lion is a felismo animal.

Therefore:

1) The lion must not be a felismo animal.

2) The lion is an exception to the rule.

3) The lion is not a predator.

4) It is probably not true that all felismo animals are not predators.
Task #16

Assume the first two sentences (in bold) are true. Make a conclusion using both sentences by choosing 1, 2, 3, or 4. Circle your answer.

All birds have three wings.

All snakes are birds.

Therefore:

1) Birds must have two wings.
2) Snakes are not birds.
3) Snakes have three wings.
4) No conclusion is possible.
Testing Procedures

The test was administered on December 15th, 1995 during school hours of 8:30 AM and 3:30 PM. The Canal Winchester Middle School students completed the test in either their mathematics classroom or the school auditorium. All high school students took the test in their mathematics classroom. All students sat at an individual desk. Directions were given not to talk until all tests were finished and collected. Tasks were completed in a quiet "test-taking" environment. The time allotted for completing the test was 50 minutes. Students first completed the information sheet attached to the front of the test to provide personal identification and math background information such as their average grade received in algebra and geometry. Test directions were then read aloud to students as well as read silently by the students. Students, however, were required to silently read each task and to complete tasks independently. During the test, students were permitted to raise their hand to summon the assistance of the two test givers regarding only very general test taking questions. Students were encouraged to respond to tasks by explaining their thought processes (correctness or incorrectness of answers was not stressed). No assistance was provided when students asked questions where answers would reveal a task's correct answer. Students were simply encouraged to try their best when reasoning through each task.
CHAPTER 4

RESULTS & DISCUSSION

Task #3

Task #3 appeared to pose the greatest challenge to all grade level of students. When examining Figure 4.1, one notices an overall correlation between an increase in students' grade level and their ability to respond correctly to Task #3. However, not even the oldest grade level of students had a majority responding correctly to this task. The task used nonempirical concepts, thus requiring successful respondents to reason wholly in an abstract manner. While the oldest students (those who had taken algebra instruction) were more capable than the younger students of responding correctly to Task #3, on the whole, not even the majority of past algebra students in grades 9-12 were capable of responding correctly to this logically correct yet unbelievable task.
Figure 4.1: Incorrect/Correct Responses to Task #3
Task #9

Upon examining Figure 4.2, it is clear that there is a correlation between an increase in correct number of responses to Task #9 and an increase in grade level. Similar to Task #3, this task requires students to suspend their empirical knowledge and reason abstractly. In this task, students were noticeably more successful than in Task #3. However, the majority of students (even those who had received algebra instruction) were yet incapable of correctly solving this nonempirical transitive syllogism problem.
Figure 4.2: Incorrect/ Correct Responses to Task #9
Task #16

The results in Figure 4.3 best show the different reasoning capabilities of students who have not yet taken algebra classes (those in the younger grades) versus those who have (those in the older grades). Figure 4.3 clearly demonstrated that the majority of students in grades 6-8 are incapable of correct logical reasoning on this transitive syllogism problem. However, the majority of students in grades 9-12 responded correctly to Task #16 in which they were required to suspend their empirical knowledge in exchange for the unbelievable premises.
Figure 4.3: Incorrect/Correct Responses to Task #16

<table>
<thead>
<tr>
<th>Grade Level</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incorrect</td>
<td>16</td>
<td>28</td>
<td>21</td>
<td>5</td>
<td>9</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Correct</td>
<td>1</td>
<td>9</td>
<td>8</td>
<td>6</td>
<td>15</td>
<td>10</td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
<td>17</td>
<td>37</td>
<td>29</td>
<td>11</td>
<td>24</td>
<td>13</td>
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<tr>
<td>Percent</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Incorrect</td>
<td>94%</td>
<td>76%</td>
<td>72%</td>
<td>45%</td>
<td>38%</td>
<td>23%</td>
<td>33%</td>
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<td>Percent</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Correct</td>
<td>6%</td>
<td>24%</td>
<td>28%</td>
<td>55%</td>
<td>63%</td>
<td>77%</td>
<td>67%</td>
</tr>
</tbody>
</table>

Figure 4.3: Incorrect/Correct Responses to Task #16
Overall Discussion

When examining the result figures, it is clear that there were no overall gender differences appearing to affect students' performance on the reasoning tasks. There were, however, distinct differences in the percentage of incorrect and correct answers given on reasoning tasks by differing age groups. By examining Figures 4.1, 4.2, and 4.3, one notices a general relationship between an increase in grade level/age and that of correct responses on reasoning tasks. Similarly, there is a general relationship between increased incorrect responses and those students in lower grade levels.

These findings support Vygotsky's theory that a human's abstract reasoning ability is greatly affected by socio-cultural factors (Cole, 1971; Scribner, 1977). In addition, the results compliment a study performed by Hawkins, Pea, Glick, and Scribner (1984). These researchers administered a reasoning test to both schooled and nonschooled men and women. The results showed that the nonschooled individuals (similar to those younger students who had not yet taken algebra classes) had great difficulty in suspending their empirical knowledge for the theoretical premises of the tasks. In contrast, the schooled individuals (similar to the older students who had taken algebra classes) had no difficulty in reasoning theoretically.

Result figures show that no age group had consistently mastered the solving of transitive syllogisms. In general, students in grades six through twelve tended to treat contradictions and tautologies as empirical statements. Thus, they had difficulty not because of the logic needed to solve the problems, but rather because of the nonempirical character of the premises. Many students of differing age and formal training were not
yet capable of consistently examining language objectively. The ability to view the premises objectively was necessary to correctly evaluate nonempirical statements (Osherson & Markman, 1975). These results cause one to question Piaget's teaching that all humans reach the formal stage of reasoning between the age of 15-20 regardless of the absence of formal schooling (Piaget, 1972). If Piaget's conclusions were true, the tenth through twelfth grade students would have reasoned correctly through all of the transitive syllogism problems. As result Figures 4.1, 4.2, and 4.3 demonstrate, even the oldest students reasoned inconsistently through the reasoning tasks.

What factors account for the different results between the young and the old students? Past reasoning research has shown that the impact of formal training on logical reasoning skills correlated twice as much with a student's amount of schooling as with age (Cahan & Cohen, 1989). Further support shows that knowledge, rather than age, is the main determinant of a subject's score on reasoning tasks (Brown & Campione, 1986). Many American teachers could improve their instructional methods in math, science, and reading having learned these facts. Based upon this research as well as the results presented in this study, it is appropriate to suggest the following:

1) Detectable gains in formal reasoning skills are made due to explicit reasoning instruction with students who have studied algebra.

2) The ability to reason increases with age.


