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MEASURING COMBINATORIAL LOGIC WITH MATERIALS

FROM THREE DISCIPLINES

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ABSTRACT

The purpose of this study was to determine the effect of the content of Piagetian formal tasks upon subjects' cognitive performance level in the area of combinatorial logic. The cognitive levels of two groups of students were measured by a battery of four of five combinatorial logic tasks with different content. One of the tasks was considered as a task with content in the area of expertise of one group and in the area of non-expertise of the other group. The other four tasks were considered to be content-free. One of the content-free tasks was a valid derivative of Piaget's chemical combinations task called the Electronic Task (ET). In the chemical task a chemical that inhibits the reaction is used and such an inhibitor is also on the ET. Two of the four tasks referred to above were the ET, one with an inhibitor switch and one without.

Specific questions addressed in this study included:

1. What effect does an inhibitor element in combinatorial logic tasks have on the subjects' performance level?

2. How does the element of the content of combinatorial logic tasks influence the subjects' performance level?

The results of the study were consistent with the following propositions:

1. The existence or nonexistence of the inhibitor element in combinatorial logic tasks does not have any significant effect on

the subject's performance level.

2. Subjects completing a combinatorial logic task in the area of their expertise perform significantly better than the subjects completing the same combinatorial logic tasks which is not in their area of expertise.

3. The expertise background of the subjects makes no significant difference in their performances on the content-free combinatorial logic tasks.

It was concluded that tasks with content in the major area of expertise allow the subjects to demonstrate their maximum formal thought capability. If such tasks are not available, then measurement of formal reasoning abilities should be made by content-free tasks.

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CHAPTER I

INTRODUCTION

Cognitive development as seen by Piaget evolves from the individual's continuous and active interaction with his environment. The acquisition of knowledge by a person is seen in terms of an emergent model with qualitatively different stages of intellectual development. Although each stage has certain properties that differ from properties existing in other stages, all individuals progress through the stages in the same invariant sequence.

Consider the model of change-of-state of matter from solid to liquid: each gram of a solid object at its melting point will take a specific amount of energy to change to a liquid without changing its temperature. That procedure results in the formation of a complex substance; a liquid has many completely new properties when compared with a solid. The amount of energy necessary to produce such changes (latent energy) varies for different solids because solids have different types of molecular structure and binding energy holding the molecules together.

In intellectual development processes, an individual's interaction and careful observation of his environment induces energy, within the individual, which may cause a change in the individual's intellectual level in a manner analogous to the physical model just described. Incorporation of data obtained from the environment disturbs one's structures and leaves him/her in a higher energy state (Piaget referred to this as "disequilibrium"). The remaining energy is consumed by the individual in efforts to interpret and resolve the problem or difficulty within the data received from the environment. That process by itself causes changes within the individual's mental structures,* which in the long term, produces development among the structures. Like the latent energy described in the physical model, the amount of energy necessary to produce changes in structures differ among individuals because of their differing mental structures. In short, in the intellectual development model structures developed early in the developmental process are modified or totally changed, reorganized and integrated into a new form which has new properties and characteristics. That new form is another state of intellectual development.

As a result of his investigations, Piaget proposed four stages (periods or levels) of intellectual development:

1) Sensory-motor
2) Preoperational
3) Concrete operational
4) Formal operational

Only the last two stages will be briefly discussed here. An in-depth

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*"A structure is a system of transformation" (Piaget, 1970, p. 5).

coverage of these stages may be found in Piaget's work (Piaget, 1967).

The third stage of Piaget's developmental model, the concrete operational stage, begins at about seven years of age (Piaget, 1967, p. 123) and deals with the child learning to organize and classify actual data. The concrete operational thinker is able to organize simple structures into coherent and integrated structures. Those integrated structures (classification, serial ordering, correspondences, equalizations) finally lead to a coordinated and reversible system of logical operations. Those mental operations are termed concrete "because they operate on objects and not yet on verbally expressed hypotheses" (Piaget, 1965, p. 179). In other words, concrete operational thinkers are only capable of thinking about objects, events and phenomena in the real world; they are not capable of manipulating or understanding relationships among several abstractions or ideas about ideas.

Piaget's final stage of intellectual development is that of formal operations. At that level the subject is no longer reality bound because he/she is capable of reasoning not just on the basis of objects, but also on the basis of the purely abstract world of hypothetical possibilities. In other words, the formal thinker becomes capable of manipulating and understanding relationships among several abstractions without any reference to concrete empirical reality. The establishment of the relationships among abstract propositions requires the formation of hypotheses and the deduction of possible consequences from them, i.e., hypothetico-deductive level of thought. By hypothetico-deductive "we mean that the deduction no longer refers directly to perceived realities but to hypothetical statements--i.e., it refers to propositions which are formulations of hypotheses or which postulate facts or events independently of whether or not they actually occur" (Inhelder and Piaget, 1958, p. 251). An example of propositional logic is: "If the assumption or deduction (about such and such) is true; then it follows that (such and such is also true); therefore (this or that action is dictated or suggested)." (Renner and Stafford, 1979, p. 82)

In summation, propositions which state possibilities and are composed of associations and dissociations of possibilities are good evidence of formal thought. But while the verbal statements substituted for objects are good indicators of imposing a new kind of thought (propositional logic) on the logic of classes and relations, there is another characteristic that distinguishes the formal thinker from the concrete one. That characteristic is the subject's ability to formulate and test hypotheses based on all possible combinations of variables. Piaget explained this type of thought this way:

> . . . as soon as the proposition states simple possibilities and its composition consists of bringing together or seperating out these possibilities as such, this composition deals no longer with objects but rather with the truth values of combinations. The result is the transition from the logic of classes or relations to propositional logic. (Inhelder and Piaget, 1958, p. 292)

In other words, functioning at the level of propositional logic requires that the subject possesses a system in his mind to deal with possible combinations of variables or hypothetical relations between ideas. Such a system has been called a "combinatorial system" by Piaget. The combinatorial system, therefore, is a structural mechanism which enables the subject to combine different propositions mentally and to separate out those which confirm his hypotheses.

Further Piaget indicates that formal thought is more than propositional logic. He explains formal thought in this manner:

> The construction of propositional operations is not the only feature of this fourth period. The most interesting psychological problem raised at this level is connected with the appearance of a new group of operations or "operational schemata," apparently unrelated to the logic of propositions, and whose real nature is not at first apparent. (Piaget, 1953, pp. 20-21)

According to Piaget formal thought is composed of two types of propositional logic (Inhelder and Piaget, 1958). One type is used to solve problems which require only propositional logic. That particular logic enables the students to solve problems involving: separation of variables, implication, reciprocal implication, exclusions, and disjunction. There is, however, a second type of logic which is propositional in nature and underlies the ability to use what Piaget calls "formal operational schemata." These schemata allow the student to solve a wide-range of problems such as: combination and permutation, proportion, mechanical equilibrium, probabilities and correlation. Piaget specifies that those operations "are relative to total transformations of a system as opposed to the particular operations analyzed in the first section"* (Inhelder and Piaget, 1958, p. 106). Therefore, the correct solutions to the problems which can be solved by using formal operational schemata utilize a <u>more general</u> qualitative logical form than do correct solutions to problems which only require the first type of propositional logic.

In addition Piaget discusses other characteristics of formal operational schemata in the following way:

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*"Particular operations in the first section" refers to propositional operations in the first section of <u>The Growth of Logical Thinking from Childhood to Adolescence</u> (Inhelder and Piaget, 1958).

> . . . alongside the operations actually performed by the subject, the system itself implies a set of a potential transformations which may become manifest or remain latent depending on particular conditions . . . operational schemata are defined as the concepts which the subject potentially can organize from the beginning of the formal level when faced with certain kinds of data but which are not manifest outside these conditions . . . . These operational schemata consist of concepts or special operations (mathematical and not exclusively logical), the need for which may be felt by the subject when he tries to solve certain problems. When the need is felt, he manages to work them out spontaneously . . . . (Inhelder and Piaget, 1958, p. 308)

Brainerd (1978, p. 233) discusses the nature of the formal operational schemata as follows:

> . . . formal operational schemes are derived from propositional operations. They are thought to be actualizations of certain things that are inherent . . . in propositional operations . . ., specifically, they are thought to be methods whereby propositional operations are applied to certain reasoning situations that occur with great regularity in the environment. Formal operational schemes are, therefore, broadly defined by Piaget as latent potentialities of propositional operations that are elicited by certain common but restricted situations in the environment.

Brainerd further explains the difference between propositional operations and formal operational schemata in this way:

> The key difference between propositional operations and formal operational schemes lies in their degree of specialization. Formal-operational schemes are adapted to the demands of certain forms of information from the environment, whereas propositional operations are extremely general and equally applicable to all forms of information. While propositional operations supposedly pervade all areas of adolescent and adult thought, formal-operational schemes do not. In fact, they only come into play when certain specific reasoning situations call them forth. (Brainerd, 1978, p. 233)

Inhelder and Piaget (1958) in discussing the subjects' responses to formal tasks identified the logically necessary prerequisites for engaging in specific types of reasoning. As an example, in analyzing the reasoning of subjects who were successful with the pendulum problem (a propositional logic task), which requires the formal operation of exclusion, they state:

> . . . in comparing the correct inferences found at substage III-B, with the earlier false one, we see that the choice is again dictated by the presence of one or two conclusive combinations. Once more they presuppose a degree of mastery of the system of all possible combinations. (Inhelder and Piaget, 1958, p. 78)

In other words, the development of the combinatorial system is a prerequisite to development of the propositional logic. It is the establishment of a combinatorial system that enables the subject "to link a set of base associations or correspondences with each other in all possible ways so as to draw from them the relationships of implication, disjunction, exclusion, etc." (Inhelder and Piaget, 1958, p. 107) The relationships of implication, disjunction and exclusion that were mentioned in the above quotation and some other operations such as separation of variables and reciprocal implication are nothing more than propositional logic as it was mentioned earlier. It should also be noted that the transition from concrete to formal stage can be identified by the existence of a complete combinatorial system. According to Piaget:

> . . . the transition from concrete to formal operations is distinguished by the appearance of a complete combinatorial system whose various types of disjunction and exclusion are continuously linked to implications. (Inhelder and Piaget, 1958, p. 104)

The appearance of combinatorial systems is an indication that formal thought has begun. Further, Piaget has postulated the development of another mental ability in moving to the stage of formal thought. He called that mental ability combinatorial schemata or combinatorial operations and explained it in this way:

> . . . combinatorial operations constitute an operational schema that is quite general beginning with a particular stage in development (III-A): in other words, a method or a way of

> proceeding which on some occasions is adopted spontaneously without conscious or explicit decision and on others used intentionally when the subject is faced with problems whose solution requires a systematic table of combinations. (Inhelder and Piaget, 1958, p. 313)

In other words, combinatorial operations are those types of operations that enable the subject to conceive or imagine all possible hypothetical arrangements in a completely systematic way.

In discussing the differences between the combinatorial system and combinatorial operation, Piaget stated the following:

> At the same time that the subject combines the elements or factors given in the experimental context, he also combines the propositional statements which express the results of these combinations of facts and in this way mentally organizes the system of binary operations consisting in conjunctions, disjunctions, exclusions, etc. . . . . In other words, the system of propositional operations is in fact a combinatorial system, just as from the subject's point of view the only purpose of combinatorial operations applied to the experimental data is to make it possible for him to establish such logical connections. (Inhelder and Piaget, 1958, p. 122)

Therefore, the combinatorial system is simply all 16 possible combinations of two assertions, say p, q, and their respective negations $\bar{p}$, $\bar{q}$ (Inhelder and Piaget, 1958, p. 103). The notion of how to organize those 16 combinations in a logical and systematic way and how to establish logical connections between them is what Piaget called combinatorial schemata or combinatorial operations.

In summary, the acquisition of propositional logic presupposes the existence of combinatorial system in such a way that a complete set of combinations in the system (like the 16 possible combinations of binary operations) is nothing more than a system of propositional logic. On the other hand, the development of combinatorial operations, i.e., a systematic general method of organizing and establishing logical connections among those propositions, presupposes the development of propositional logic. In other words, without the existence of propositional operations, there is not really anything available to organize with a systematic strategy.

Regarding the assessment of the formal level of thought, the original Piaget and Inhelder tasks have been used by many investigators (Chiapetta, 1976, p. 253). However, the extensive use of science concepts in the tasks has left them open to criticism, since the tasks appear to measure science content (especially physics content) and not the underlying logical thinking ability. Piaget himself said that formal thinkers "reach this stage in different areas according to their aptitudes and their professional specializations." (Piaget, 1972, p. 10) In other words, the failure of many adults to perform at the formal level on those tasks may be because of the lack of familiarity with the scientific content typically used in the tasks rather than a lack of the ability to reason formally.

In order to clarify whether unfamiliar tasks do or do not fail to elicit optimum performance from adults, the decision was made to compare the adults' performance on Piagetian-type tasks and on tasks designed in the content area of the specialization of the subjects.

Statement of the Problem

In The Growth of Logical Thinking from Childhood to Adolescence (Inhelder and Piaget, 1958) Inhelder and Piaget described 15 experimental situations that can be used to assess the formal level of thought. Since those tasks are primarily drawn from the science content it might be true that they fail to assess a general level of intellectual development due to their content bias. Presumably, familiar materials should be more conducive to formal operations; therefore, it appears that tasks requiring formal operations within each subject's particular area of interest might be more accurate in assessing the development of formal operational skills. The central question this study will attempt to answer is: Can the assertion that the Piagetian tasks are content biased be supported? In other words, is there a significant difference between the subjects' performances on Piagetian-type tasks and on tasks measuring the same thinking characteristics designed in the major interest area of the subject?

Hypotheses

1. The Piagetian tasks are content free* and can serve as true indicators of logical abilities of concrete and formal thinkers.
2. Individuals perform poorly on Piagetian tasks because of extensive use of science content in the tasks.

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*Content free means that the subject's performance level on a particular task does not depend on the subject's knowledge of the content of that task.

CHAPTER II

REVIEW OF RELATED LITERATURE

The fourth stage of Piaget's developmental theory, the formal operational stage, has received much attention by educational researchers, among others, in recent years. Science educators' intense concern, especially in secondary schools and colleges, has mainly been related to teaching and learning based on Pigetian theory (Chiappetta, 1976). This concern is partly related also to the recent studies concerning the intellectual level of high school and college students. In the review of some of these studies Chiappetta (1976) has concluded that nearly 52% of college students do not acquire the formal operational level of thought. The fact that most of the students failed to exhibit formal operations is an apparent contradiction to Inhelder and Piaget's (1958) view that formal operations are universal for normal adolescents. Since the subjects are tested for formal operations by means of tests having science content, the subjects' failure to perform at the formal level on those tests might be because they have not been familiar with the specific science content required by the tests and not because they are concrete thinkers. Some of the studies that support the statement that adolescents and even young adults do not appear to have attained the formal operations along with studies that relate such an intellectual deficit to the content of the tasks are presented below.

Renner and Stafford (1972, pp. 291-96) studied the cognitive levels of 588 secondary school students in the state of Oklahoma. The study was addressed to investigate the performance of those students on seven Piagetian tasks. A sample of 290 of those students were in grades 10, 11, and 12. The result of their study shows that 69% of the 10, 11, and 12 graders were at the concrete operational stage. Seventeen percent were at the transitional operational stage, and 14% were at the formal operational level.

Lawson and Blake (1974) investigated the Piagetian cognitive levels among 68 high school biology students in North Central Indiana. These levels were measured by three separate instruments: (1) a battery of Piagetian tasks--exclusion (the pendulum), separation of variables (the bending rods), and proportion (the balance beam); (2) a paper and pencil biology test consisting of questions requiring concrete and formal reasoning, and (3) a 19-item version of the original 28-item Longeot test (Longeot, 1962, Longeot, 1965) also consisting of questions requiring concrete and formal reasoning. These researchers reported that 47% of the subjects were concrete operational based on Piagetian tasks. Percentages of the students classified into the concrete level on the basis of the biology test and the Longeot test were reported to be 65 and 57, respectively. Using Chi square analysis, Lawson and Blake compared the results of the three different instruments, two at a time. They found that the classification of subjects across the three measures was relatively consistent. The authors of this study concluded that Piagetian tasks are relatively content free since the subjects did not perform more formally on the Longeot and biology test. Lawson and Blake did not, however, report the reliability and validity of the two paper and pencil tests. (Ward et al., 1981, evaluated the Longeot tests as reliable tests for determining the developmental levels of large numbers of students.)

Renner (1979) directed a project in which materials and evaluation scales for assessing the level of intellectual development of students from their written responses were developed. In this project 1,108 subjects in grades 10 through 12 in the state of Oklahoma were interviewed with four Piagetian formal tasks. Those tasks were: conservation of volume, proportion (the balance beam), separation and control of variables (the bending rods), and combinatorial reasoning (chemical combinations). The subjects' performance on the last three tasks showed only 41% of the thought--not the students--found was fully formal (the unit of measure was not each individual, but rather the type of thought for each task). The volume task was excluded from the above calculation since it does not require complete formal thought for successful performance.

McKinnon and Renner (1971) determined that the majority of college freshmen were not mentally prepared to cope with science content taught at the college level. They also showed that an inquiry-oriented science course based upon Piagetian criteria, does promote logical thought. To assess the cognitive levels of 131 students in this study, the investigators used five formal Piagetian tasks. The findings showed that 50% of the entering college students were operating completely at the concrete level, 25% had not attained the complete criteria for formal thought and another 25% were completely formal.

Schwebel (1975) conducted a study to assess Piagetian cognitive levels among first year college students attending a large eastern state university. The sample involved 60 students randomly selected from a population of 2,419. The instrument used in this study was three Piagetian tasks--separation of variable (the bending rods), proportion (the balance beam), and reciprocal implication (inclined plane). The result of this study showed that 20% of the sample attained the upper level of formal thought, 17% functioned at the concrete operational level and 63% performed at the lower formal level.

Collectively, the results of the above studies show that a sizable portion of the high school and college students are not formal operational. It appears that the stage of formal operations as described by Piaget either emerges much later than he originally estimated or some other task variables may interfere with optimal performance at this level. A relatively obvious and important variable for consideration is task content. Presumably familiar tasks in the subjects' interest area should be more effective in identifying the formal operational thinkers than the intensive science-content-related tasks of Piaget. This was the position that was favored by Piaget (1972). In the 1972 paper Piaget attributed the failure of many adults to display formal operational skills to their lack of familarity with the science tasks used to assess these skills.

In consistency with this view, Diamond et al. (1977) questioned whether the subjects who do poorly on formal operational tasks have a general intellectual deficit or whether they lack an interest in physical science. In the Diamond study a paper and pencil version of Piagetian tasks, in multiple choice format, was used to assess performance on concrete and formal operations. The authors employed the Culture Fair

Intelligence Test of the Institute for Personality and Ability Testing (IPAT) (Buros, 1974, p. 82) and the Verbal Scholastic Aptitude Test (Buros, 1974, p. 74) to measure the general level of intelligence. The Kuder Occupational Interest Survey Form DD (Buros, 1974, p. 691) was used to assess scientific interest. The sample consisted of 39 college students, and their performance on Piagetian tasks was found to be significantly correlated with interest in science but not with general level of intelligence.

Lawson (1980) studied the performance of a group of college students (enrolled in Biological Science for the Elementary Teacher). In this study three different instruments were used: paper and pencil Piagetian tests, a cognitive style test called Gottschaldt Figures Test (Cruthfield et al., 1958), and four content examinations given during the course. His study involved 53 students. Lawson reported that the subjects who scored concretely on the tasks had more difficulty on the examinations than those who scored at the transitional or at the formal levels. In other words, the Piagetian "physical science" content related test can identify the general level of intelligence at least within the biological sciences.

In both the Diamond and Lawson studies, the subjects were not randomly selected. Moreover, in both studies group administration tests were used which according to Schwebel (1975) do "not provide the possibility of active experimentation and the time for reflection, both of which are important to the hypothetico-deductive process in problem solving."

Need for the Study

The statement has been made that the central purpose of American education is the development of the ability to think (Educational Policies Commision, 1961, p. 12), which requires the development of rational powers. These rational powers have been defined as recalling and imagining, classifying and generalizing, comparing and evaluating, analyzing and synthesizing, and deducing and inferring (Educational Policies Commision, 1961, p. 5).

The ability to think, or the development of rational powers, then represents the unifying purpose for education. In order that a person be able to develop his rational powers he must have opportunities to use them separately or in combinations. Therfore, the content, instructional techniques, teaching materials and all curriculum activities should be selected to provide maximum potentiality for development of all the rational powers. It is obvious that all curriculum activities should be at the proper level of the thought of the learner. In other words, instructional procedures, content, curriculum objectives, method of teaching and evaluation should parallel the cognitive stages of the learners. Thus, identifying the subject's level of thought is of great importance for selecting suitable curriculum content. In this connection, Renner (1979, p. 280) says:

> Being able to distinguish between concrete operational structures and formal operational structures for secondary school and college teachers, therefore, becomes a necessity if educational institutions claim the achievement of intellectual development as one of their goals. Educators need to be concerned because persons who operate with concrete operational structures cannot assimilate formal (abstract) information and ideas.

Piaget's pioneer work laid down the frame for understanding cognitive development. Many replications of Piaget's experiments have supported the overall intellectual development theory outlined by Piaget. Yet the review of literature in the previous section reveals that a sizable number of the adult subjects were nonformal thinkers. These findings seem to be at variance with Piagetian theory in the aspect that the results of those findings are far from the universality of the formal level of thought described by Piaget. Some explanations have been given with regard to the incidence of low formal thinking among high school and college students (e.g., Lawson and Renner, 1974).

One possibility is that our educational establishments did not provide the students with such educational experiences which promote formal reasoning. In this regard Lawson and Renner (1974, p. 558) explained:

> The idea that students . . . are inherently less abstractly or formally inclined than those in the Geneva samples seems an unlikely hypothesis. The possibility that the educational system itself is largely responsible for this low incidence of formal thinking seems to these investigators at the present time to be the most viable hypothesis.

Another explanation for the low incidence of formal thinking found among the college and high school students might be due to failure of Piagetian tasks to measure this type of thinking because of specific "science content" involved with the tasks. This possibility was supported by Diamond et al. (1977) but was not supported by Lawson and Blake (1974) and Lawson (1980).

The presence of concrete thought in secondary school students and college freshmen, indicates that many topics that require abstract hypothetical reasoning will not be learned by those students. Identifying and understanding the difference between concrete and formal thought, therefore, is a pre-requisite for effective curriculum planning. Yet in identifying the subjects' level of thought by using Pigetian tasks, as was mentioned above, some contradiction exists about the content of the task. The review of literature reveals that only few studies have regarded the question of task-content influence on the Piagetian cognitive levels. No research has employed a clinical way of interviewing and investigating the effect of task content on the subject's cognitive level performance.

Accordingly, this investigator felt the need for a study that continued the investigations reviewed here, namely a study related to the cognitive levels and the content of Piagetian tasks. In this investigation Piaget's techniques of gathering information, i.e., interviewing subjects individually and not group-administration tests, were used.

CHAPTER III

RESEARCH DESIGN AND PROCEDURES

Introduction

The studies cited in the literature review indicate that almost 50% of the adult populous fail to exhibit formal levels of thought. The failure of 50% of adults to function at a formal level might be due to the extensive use of scientific content in some Piagetian tasks and not the subjects' intellectual deficiency. An example of such a task is the balance beam which is used to measure a subject's ability to use proportional reasoning. The Diamond, et al. study (1977) cited in the review of literature section supports the idea that cognitive level performance depends on the task's content. The Lawson study (1980) discussed in the literature review section, however, shows that the Piagetian tasks can identify the general level of intelligence. For Lawson the familiarity or unfamiliarity of the subjects with the content of the tasks does not influence the subjects' cognitive level performance. In order to respond to the above obvious contradiction, this study aims to examine the effect of the content of the Piagetian tasks on the intellectual development performances of the students.

In The Growth of Logical Thinking from Childhood to Adolescence, Inhelder and Piaget (1958) described 15 experimental tasks with which subjects were interviewed individually. Piaget categorized the subjects' responses on those formal tasks into three major divisions: I (pre-operational), II (concrete operational), and III (formal operational) with two subcatagories at the concrete and formal levels. He designated the two substages by "A" and "B", with the "B" substage being more advanced than the "A" substage. These substages can be classified as follows:

IIA - early concrete

IIB - late concrete

IIIA - early formal

IIIB - late formal

According to Inhelder and Piaget the purpose of the book was " . . . to set forth a description of changes in logical operations between childhood and adolescence and to describe the formal structures that mark the completion of operational development of intelligence" (p. xxiii). As a result of their efforts many characteristics of formal structures were laid down; some of them were discussed in the first chapter of this study and will be briefly reveiwed here.

The formal thinker is broadly characterized as the one who is able to reason abstractly, i.e., one who can formally conceptualize possible transformations and their results instead of having to imagine them figuratively or carry them out physically. This sort of hypothetico-deductive thinking enables the subject to establish relationships among abstract propositions and deduce the logical consequences. The subject does so not by limiting himself to a single relationship at a time, but rather by considering all other possible relationships at the same time. In order that the subject be able to consider all relationships he/she must have structures that incorporate propositions and arrange them according to all possible combinations so as to draw from them the relationships of implication, disjunction, exclusion, separation of variables and reciprocal implication. Such a mechanism that enables the subject to establish associations, dissociations and correspondences among these possibilities in all possible ways was called a "combinatorial system" by Piaget. A combinatorial system, therefore, is a structural mechanism that the subject has to develop in order to be able to deal with propositions and to function at the hypothetico-deductive level of thought.

The mere ability to combine abstract propositions is not enough, however, for drawing the best logical explanation from some number of potential explanations in a situation. Rather a systematic and logically exhaustive procedure which permits each proposition to be combined with each of the others and systematically evaluated in that combination is necessary to tackle the problem and investigate all possible combinations in order to select the best one. Piaget postulated the development of such a mental characteristic which enables the subject to systematically combine different propositions. That is, this newly postulated characteristic enables the subject to use his combinatorial system in a systematic way: Piaget called that characteristic the combinatorial schemata. The combinatorial schemata permit and facilitate the systematic consideration of all possible combinations of variables in multifactorial experiments.

In summation combinatorial thought is as an intellectual core in which other formal characteristics have their ultimate base. "Combinatorial thought is the basic characteristic of formal operations and all of the other characteristics may be derived from it. That is, combinatorial thought is a glue that binds formal operations together." (Gray and Hofmann, 1976) Because of the vital role of the combinatorial system and combinatorial schemata in the development of formal thought, the decision was made that the combinatorial tasks be studied in this research.

To exemplify and test the use of combinatorial schema, Piaget used the Chemical Combination Task (Inhelder and Piaget, 1958, pp. 107-122). The Chemical Task (CT) consists of five bottles labled "1," "2," "3," "4," and "g," each containing a colorless liquid. The liquids used are:

1) dilute sulphuric acid

2) distilled water

3) hydrogen peroxide

4) sodium iodide

g) potassium iodide

The addition of "g" to combinations of samples from each of the four bottles may or may not produce a colored "yellow" solution. The complete solution to this task consists of the determination that solutions 1 + 3 and 1 + 2 + 3 combined with "g" produce the yellow solution, solution "2" has no effect, and solution "4" has the effect of removing or preventing the yellow coloration. But, for Piaget, the mere ability to solve the problem involving the chemicals was not the criterion for judging the ability to satisfactorily use combinatorial thinking. Rather, the ability to construct and test combinations systematically, the kind of combinations (one by one, two by two, three by three, etc.)and the number of combinations completed was the criterion for success.

Despite the fact that the task is useful to assess the development of the combinatorial logic, it has some inherent problems. For example, the chemical solutions must be prepared carefully and a great deal of time is needed to administer the task. Because of the above mentioned disadvantages in the CT the decision was made that an equivalent task designed and validated by DeLuca (1975) be used in this study. Descriptions of tasks, including DeLuca's, used in this study to measure the ability to use combinatorial logic follows.

The Electronic Task (ET)

In an attempt to reduce the negative aspects of the Chemical Task, DeLuca (1977, 1979) designed and built an electronic equivalent (Electronic Task, ET) task. The Electronic Task was considered to be content free since the students work only with switches to turn a light on. The act does not depend on the specialization and/or the major area of the students. DeLuca, in his study (1977) showed that the Chemical Task (CT) and the Electronic Task (ET) require the same combination and are logically similar. Acceptance of the ET as a valid test of combinatorial reasoning is indicated in Lawson's study (1977).

Equipment. An aluminum box with four toggle switches labeled 1, 2, 3, and 4, one normal-off, push-on switch and a light-emitting diode (LED) are the visual aspects of the ET equipment. The entire circuit and two pencil cells which provide the power for lighting the LED are housed inside the aluminum box. In comparison with the CT, the four toggle switches simulated the four chemicals. The normal-off, push-on switch simulated the indicator solution. The change from clear solution to yellow solution was simulated by the lighting of the LED. Key combinations of switches 1 + 3 and 1 + 2 + 3 will turn the light on when the push button switch is pressed. Switch 2 does not affect the light, and switch 4 is an inhibitor of the light. Switch 4 simulated the inhibitor solution (solution 4) in the Chemical Task.

The Protocol. The interviewer puts the materials in front of the student and says, "Here is a metal box with four switches, a push button, and a light bulb. By placing one or more switches in the 'on' position the light will turn on if you push the button. I would like you to work with the switches and find as many different ways as you can to turn the light on. Do you have any questions?" After the student's response the interviewer says "you may begin". During the experiment the interviewer uses a dialogue such as the following:

1. "Have you tried all possible ways to turn the light on?"
2. If the answer is no, the interviewer says, "Please continue to find all possible ways to turn the light on."
3. If the subject stops again, the interviewer goes back to the first question.
4. If the answer to the first question is yes, the interviewer says, "all right" or "good".
5. The interviewer then says, "Find out what is the function of switches #1 and #3 in turning on the light."
6. The interviewer then asks the student to identify the function of switches 2 and 4 by saying, "Find out what is the function of switches 2 and 4 in turning on the light." The subject's reasoning pattern and his proof in identifying the function of the switches are important. The subject may be questioned to insure that he/she demonstrates some form of proof for the role of those switches.

Scoring.

IIA. The subject simply tries combinations of a single switch with the push button switch (i.e., combinations of two's) or by taking them all together. If the light is turned on it will be by chance and the light will be attributed to a single switch. At this level combinations remain incomplete and "the idea of constructing combinations two by two or three by three, etc. does not occur to them." (Inhelder and Piaget, 1958, p. 112)

IIB. The IIB subject has the attributes of IIA, with the addition of some n x n combinations with the push button switch or n x n x n combinations with the push button switch. These combinations are obtained by random selection strategy or empirically and the subject still attributes the light to one particular switch.

IIIA. At this level the subject does not deal with the problem by "random selection strategy," rather he uses a systematic method in the use of n x n combinations. The subject realizes that the light results from a combination rather than coming from one switch. Moreover, the subject does not stop when he/she has succeeded in lighting the bulb, but continues to complete other possible combinations.

IIIB. The construction of combinations and proofs are organized in a more systematic way with greater speed. The subject in this category is able to determine the role of the various switches and demonstrate some form of proof for the role of each switch.

The Colored Beads Task (CBT)

The Colored Beads Task was designed by Piaget (1951, p. 163) to test for the presence of combinatorial reasoning. The Colored Beads Task was considered to be content free since working with materials such as several colored beads does not depend on the background and major area of specialization of the students. Evaluations of combinatorial reasoning by the Colored Beads Task also have been made by Hensley (Hensley, 1974, p. 32) and Kishta (Kishta, 1979). The materials in this task are five sets of colored plastic beads: blue (B), green (G), orange (O), yellow (Y), and white (W). When the subject is presented with the five sets of colored beads, he/she has the opportunity to generate all possible combinations of beads taking them two at a time, three at a time, four at a time or all five, as it has been listed in Table (1). The interviewer must check to be sure that each set contains beads of the same color, and must be sure that the sets of beads are placed in front of all the subjects in the same order (B, G, O, Y, W).

In comparison with the Chemical Task, the Colored Beads Task is equivalent to the Chemical Task in terms of logical thinking since both tasks contain the same number of elements and both tasks require the successful use of combinatorial reasoning to generate all possible combinations. With regard to the function of the involving factors in the combinations, there is not any neutral or inhibitor element in the Colored Beads Task. Moreover, while in the Chemical Task only two combinations produce the desired effect, in the Colored Beads Task all combinations are considered to be the right answer.

TABLE 1

COMBINATIONS OF THE FIVE COLORED BEADS:

BLUE (B), GREEN (G), ORANGE (O), YELLOW (Y), AND WHITE (W)

BG	GY	BGO	BYW	BGOY	BGOYW
GO	GW	BGY	GOY	BGOW	
BY	OY	BGW	GYW	BGYW	
BW	OW	BOY	GOW	BOYW	
GO	YW	BOW	OYW	GOYW	

The Protocol. The protocol for this task is a modified form of the protocol developed by Hensley (Hensley, 1974, p. 33). The rack of five sets of beads are placed in front of the subject and the interviewer says, "Here are five plastic containers, each containing beads of different colors. Your task is to make groups of beads. A group has two or more beads of different colors. Also, a group will not have more than one bead of the same color. The order in which you place the beads makes no difference. Blue and orange, orange and blue are the same. Using as many beads as you wish, I would like you to make as many different groups of beads as you can. Do you have any questions?" After the student's response the interviewer says, "You may begin." During the experiment the interviewer uses a dialogue such as the following:

1. "Have you made all possible groups of beads?"
2. If the answer is no, the interviewer says, "Please keep trying to make as many different groups as you can."
3. If the subject stops again, the interviewer goes back to the first question.
4. If the answer is yes, the interviewer says "all right" and this experiment terminates at this point.

Scoring. The scoring procedure for this task is a modified form of the scoring method used by Hensley (Hensley, 1974, p. 34). In particular, the limits of the total number of combinations necessary to pass the task at each of the four developmental sublevels IIA, IIB, IIIA, and IIIB were adopted from the Hensley scoring method.

IIA. The subject is able to make most of the bead pairs (combinations of two's). He/she might combine the beads three at a time, four at a time, or all five. Nevertheless, the IIA subject does not complete more than three combinations of higher orders.

IIB. The subject is able to generate the ten bead pairs or all of the beads together. He/she completes some higher combinations without any systematic approach, but no more than 18 total combinations.

IIIA. The new innovation which appears at substage IIIA is the introduction of systematic method in the use of n x n combinations. The IIIA subject completes between 19 and 22 combinations in a systematic way. The minimum number of combinations to pass the task at IIIA level was also reported to be 19 in Hensley (Hensley, 1974, p. 36) and Kishta (Kishta, 1979).

IIIB. The subject has the attributes of substage IIIA, but combinations are organized in a more systematic fashion from the start and with a greater speed. At substage IIIB, the subject generates more than 22 combinations.

Letters Task (LT)

This task was designed from five letters, A, B, C, D, and E. The Letters Task was considered to be content free since everyone in any major area knows of the alphabet letters. When the subject is presented with the five letters, he/she has a chance to form all possible combinations of letters (by making as many different groups of letters as possible), as it has been listed in the table on the following page.

In comparison with the Chemical Task, the Letters Task is equivalent to the Chemical Task in terms of logical thinking since both tasks contain the same number of elements and both tasks require the successful use of combinatorial reasoning to generate all possible

TABLE 2

COMBINATIONS OF THE FIVE ALPHABET LETTERS:

A, B, C, D, AND E

AB	BD	ABC	ACD	ABCD	ABCDE
AC	BE	ABD	ACE	ABCE	
AD	CD	ABE	ADE	ABDE	
AE	CE	BCD	CDE	ABDE	
BC	DE	BCE	BDE	BCDE	

combinations. With regard to the function of the involving factors in the combinations there is not any neutral or inhibitor element in the Letters Task. Moreover, in the Chemical Task only two combinations produce the desired effect, but in the Letters Task all combinations are considered to be the right answer.

The validity of the Letters Task comes from the fact that it was patterned on the Colored Beads Task. The two tasks are indeed equivalent <u>in terms of logical thinking</u> since both of them contain the same number of elements and are successfully completed in the same manner. In both tasks the subject has a chance to check what combinations he/she has made and the total possible number of combinations in each of the tasks is the same. Both tasks require combinatorial reasoning for successful performance. The protocols for both tasks have the same pattern and the scoring method for the Letters Task was adopted to be the same as the scoring method for the Colored Beads Task. In fact, the protocol for the Letters Task was developed in conjunction with the protocol for the Colored Beads Task which was a modified form of the protocol used by Hensley (Hensley, 1974).

<u>The Protocol.</u> A card with the five letters A, B, C, D, and E and a pencil are presented to the subject and the interviewer says,

"Here are five letters, A, B, C, D, and E. Your job is to make groups of letters. A group has two or more letters. Also, a group will not have more than one of each letter. The order in which you place the letters makes no difference. A and B, B and A are the same. Using as many letters as you wish, I would like you to make as many different groups of letters as you can. Do you have any questions?" After the student's response the interviewer says, "You may begin." During the experiment the interviewer uses a dialogue such as the following:

1. "Have you made all possible groups of letters?"
2. If the answer is no, the interviewer says, "Please keep trying to make as many different groups of letters as you can."
3. If the subject stops again, the interviewer goes back to the first question.
4. If the answer is yes, the interviewer says, "all right," and the experiment terminates at this point.

Scoring. As was stated earlier the scoring method for this task is the same as for the Colored Beads Task.

IIA. The subject generates some groups of letters using two letters at a time or all five letters together. The IIA subject might make two or three combinations of higher orders.

IIB. Substage IIB is characterized by the same reactions as those listed for substage IIA. In addition, he/she completes some higher combinations without any systematic approach and with no more than 18 total combinations.

IIIA. The subject has a systematic method in the use of n x n combinations. The IIIA subject completes between 19 and 22 combinations in a systematic way.

IIIB. The subject has the attributes of substage IIIA, but combinations are organized in a more systematic fashion from the start and with greater speed. At substage IIIB, the subject generates more than 22 combinations.

Tuning Forks Task (TFT)

This task was designed as a task with content and materials familiar to music students. The task consists of five tuning forks labeled 1, 2, 3, 4, and m. Tuning forks 1 and 3 are exactly the same and all the others are different in the kind of sound (pitch) they produce. The object of the task is to make different sounds by using all possible combinations of the four tuning forks with "m."

The validity of this task is established because of its logical equivalency to Chemical Combinations Task (Inhelder and Piaget, 1958). The TFT was designed by closely following the procedure outlined by Inhelder and Piaget (1958). The tuning fork labeled "m" is an analogy to the solution "g" in the Chemical Task. The other four tuning forks simulate the four chemicals in Piaget's task with the exception that in the TFT no one element acts as an inhibitor. In the Chemical Task, solution #2 is water, which has no effect on the results of the combinations of the others. Either tuning fork 1 or 3 may simulate the water in the Chemical Task since when one of them is involved in a combination, the addition of the other will have no effect on the sound produced.

Of all the possible combinations in the Chemical Task only two combinations produce the desired effect, while in the TFT all combinations are considered to be the right answer. The belief is that this difference does not really matter since the criteria for evaluating the subjects are not the right or wrong solutions, but rather the method they use to combine different elements in each task. The level of difficulty of the Tuning Fork Task seems to be at the same level as the Chemical Task. The combinations shown in Tables 3 and 4 demonstrate that both tasks are involved with the same forms of combinations (two's, three's, etc.) From the logical point of view, it seems that the subject has to go through the same mental processes in both tasks to generate the combinations shown in Tables 3 and 4. This similarity in the logical transformation can be seen easily from the similarity of the combinations involved in the two tasks.

TABLE 3

COMBINATIONS OF THE FIVE TUNING FORKS:

m, 1, 2, 3, and 4

m1	m12	m24	m123	m1234
m2	m13	m34	m124	
m3	m14		m134	
m4	m23		m234	

TABLE 4

COMBINATIONS OF THE FIVE CHEMICAL SOLUTIONS

g, 1, 2, 3, and 4

g1	g12	g24	g123	g1234
g2	g13	g34	g124	
g3	g14		g134	
g4	g23		g234	

Formal thinkers are identified in the Chemical Task by their ability to identify the role of each solution. Based on Dale's (Dale, 1970) study, solution #2 (water) was more difficult to isolate than solution #4 (inhibitor). In the Tuning Forks Task the same feature is involved and the subject will be judged upon his ability to recognize the similarity in the roles of tuning forks 1 and 3. Since tuning forks 1 and 3 play the role of water in the Chemical Task, identifying the tuning forks 1 and 3 is believed to be as difficult as isolating solution #2.

Protocol. The tuning forks are placed in front of the subject and the interviewer says, "Here are five tuning forks. I will show you how you can make sound with them. As you see, one of the tuning forks is labeled 'm.' The reason that I labeled this one differently is that I would like you to use it in all of the experiments that you are going to do. Using as many tuning forks as you wish, I would like you to make as many different sounds as you can. I will help you hold the forks if you want me to. Remember, the tuning fork labeled 'm' must be used with any tuning fork or combination of tuning forks you choose. (The order in which you produce the sound is not important for us, i.e., m + 1 and 1 + m are the same.) Do you have any questions?" After the subject's response the interviewer says, "You may begin." During the experiment the interveiwer uses a dialogue such as the following:

1. "Have you made all of the possible sound combinations?"
2. If the answer is no, the interviewer says, "Please continue to make as many different sounds as you can."
3. If the subject stops again, the interviewer goes back to the first question.

4. If the answer is yes, the interviewer says, "all right."
5. Then the interviewer asks, "How are these tuning forks similar?"

<u>Scoring</u>.

IIA. Inhelder and Piaget stated that children at substage IIA systematically combine in two, i.e., I x m, 2 x m, 3 x m, etc., or combine all elements together. But at this level the combinations remain incomplete and "the idea of constructing combinations two by two or three by three, etc. does not occur to them." (Inhelder and Piaget, 1958, p. 112)

IIB. At substage IIB, the subjects begin by making combinations of two's or by combining all elements together, but ultimately and spontaneously they use n x n combinations. Nevertheless, these combinations again remain incomplete and are obtained by random selection strategy or simple trail and error. The fact that these n x n combinations are not systematic defines the upper limit of this substage.

IIIA. At this substage the subject does not deal with the problem by "random selection strategy," rather he uses a systematic method in designing n x n combinations.

IIIB. According to Piaget the difference between substage IIIA and IIIB "is only one of degree" (Inhelder and Piaget, 1958, p. 120). The construction of combinations and proofs are in a more systematic manner and with a greater speed. The subject at this substage can easily determine that tuning forks 1 and 3 are the same and adding tuning fork #1 to the combinations that already have #3 in them will not change the sound.

The New Electronic Task (New ET)

Among the tasks mentioned so far, the DeLuca Electronic Task and the Colored Beads Task are standard ways of measuring the presence of the combinatorial logic reasoning. The other two tasks, the Tuning Forks Task, and the Letters Task, were invented for this study. In DeLuca's Electronic Task, switch #4 inhibited the light. There is no such factor in the other tasks, including the Colored Beads Task, that neutralizes or prevents the outcome of combinations of the other factors. In an attempt to find out the influence on the subjects' responses, of the presence or the absence of the inhibitor factor in the combinatorial logic tasks, the decision was made that a revised ET (The New Electronic Task) be added to the battery of tasks used in this study. The New Electronic Task was designed exactly like DeLuca's Electronic Task, but without Switch #4, the inhibitor switch. Comparison of scores on the two versions of the Electronic Task should reveal any differences in the subjects' performance levels due to the presence or absence of the inhibitor switch. If the subjects' responses on the two versions of the Electronic Task were not significantly different, then the presence or absence of the inhibitor factor in combinatorial logic tasks have no effects on the subjects' responses. If the forgoing is true, the selection of the Tuning Forks and the Letters Tasks are justified as instruments for measuring the presence of combinatorial logic reasoning. If the subjects' responses on the two versions of the Electronic Task were significantly different, then the presence or abscence of the inhibitor factor in combinatorial logic tasks would have influenced the subjects' responses. The selection of the Tuning Forks

Task and the Letters Task which have no inhibitor factor in the construction can also be justified because the Colored Beads Task designed by Piaget had no inhibitor factor in its construction.

The Protocol. The protocol for this task is similar to the protocol developed for DeLuca's Electronic Task as follows:

The materials are placed in front of the student. The interviewer says, "Here is a metal box with three switches, a push button, and a light bulb. By placing one or more switches in the on position the light will turn on if you push the button. What I would like you to do is to work with the switches and find as many different ways as you can to turn the light on. Do you have any questions?" After the subject's response the interviewer says, "you may begin." During the experiment the interviewer uses a dialogue such as the following:

1. The interviewer asks: "Have you tried all possible ways to turn the light on?"
2. If the answer is no, the interviewer says, "Please continue to find all possible ways to turn the light on."
3. If the subject stops again, the interviewer goes back to the first question.
4. If the answer to the first question is yes, the interviewer says, "all right" or "good."
5. The interviewer then says, "Find out what is the function of switches #1 and #3 in turning on the light."
6. The interviewer then asks the student to identify the function of switch #2 by saying, "Find out what is the function of switch #2 in turning on the light." The subject's reasoning

pattern and his proof in identifying the function of the switches are important. The subject may be questioned to insure that he/she demonstrates some form of proof for the role of these switches.

Scoring.

IIA. The subject simply tries combinations of a single switch with the push button switch (i.e., combinations of two's) or by taking them all together. If the light is turned on it will be by chance and the light will be attributed to a single switch. At this level combinations remain incomplete and "the idea of constructing combinations two by two or three by three, etc. does not cocur to them." (Inhelder and Piaget, 1958, p. 112)

IIB. The IIB subject has the attributes of IIA, with the addition of some n x n combinations with the push button or n x n x n combinations with the push button. These combinations are obtained by random selection strategy or empirically and the subject still attributes the light to one particular switch.

IIIA. At this level the subject does not deal with the problem by "random selection strategy," rather he uses a systematic method in the use of n x n combinations. The subject realizes that the light results from a combination rather than coming from one switch. Moreover, the subject does not stop when he/she has succeeded in lighting the bulb, but continues to complete other possible combinations.

IIIB. The construction of combinations and proofs are organized in a more systematic way with greater speed. The subject in this category is able to determine the role of the various switches and demonstrate some form of proof for the role of each switch.

Description of the Sample

The sample for this study consisted of two distinct groups. The first group (music students) were selected from freshman music majors who were studying introductory music courses such as Beginning Harmony and Beginning Aural Theory during the first semester and were enrolled in the continuation of those courses for the second semester. At the time that the music students participated in this study, they had studied and applied the tuning forks in their music courses. By the time they were tested they were completely familiar and knowledgeable about the pitch and other characteristics of tuning forks. The second group (general students) were selected from freshman English students who had completed the Principles of English Composition course during the first semester and were enrolled in the second semester for the continuation of the same course.

Methods of Collecting the Data

Since the two versions of the electronic tasks were very similar to each other, the administration of both tasks to the same subject either would be trivial or would confuse the subject. Therefore, only four tasks were administered to each subject. Those tasks were the Tuning Forks Task, Colored Beads Task, Letters Task, and one of the Electronic Tasks. The Electronic Task and Colored Beads Task are standard ways of testing combinatorial reasoning. The other three tasks were invented for this study in order to investigate the effect of the task content on the subject's intellectual level performances.

The tasks were administered individually to each subject. Brief notes were taken on the subject's responses and the entire interview was audiotape recorded. By listening to the tape after the interviews, the brief notes taken during the interviews were modified and expanded. The order of administration of the tasks was random.

Administration of the Tasks

In this study the interviews were conducted in a limited time period by the use of that special framework of questions called the "protocol". The investigator developed the protocols by administering each task to groups of ten senior Norman High School students. The tasks were administered to one group at a time. After each try, the protocols were revised until it was obvious that the students fully understood the descriptions, directions and the questions in the protocols.

The principal advisor of this study checked, corrected and technically helped the investigator during all steps of the protocol development. He also observed this investigator during several administrations of the tasks and helped him in developing the necessary skills for interviewing the subjects.

Scoring the Piagetian-Type Tasks

Scoring criteria for each of the formal operational tasks used in this study were based on those used by Inhelder and Piaget (1985). In particular regarding the approach that was adopted by the subjects, three aspects were examined--the combinations used, total number of combinations completed, and those combinations used systematically.

Successful performance on all tasks used in this study requires IIIB level of thought. Each student received one score for his performance on each task. That score was determined by alloting a IIA level a score of 1; IIB a score of 2; IIIA a score of 3; and IIIB a score of 4. The maximum score that could be achieved in each task was four points.

CHAPTER IV

PRESENTATION AND ANALYSIS OF THE DATA

The results of this investigation will be divided into two sections. Initially, a descriptive analysis of variables is presented. The inferential analysis of the data is presented in the second section.

Descriptive Analysis of the Data

The purpose of this study was to determine whether the content of the Piagetian-designed tasks will make any significant difference in the subjects' Piagetian cognitive level as measured by those tasks. The subjects' Piagetian cognitive levels were measured by a battery of four of five combinatorial logic tasks with different content. The five tasks were: (1) the Tuning Forks Task; (2) the Colored Beads Task; (3) the Letters Task; (4) the Electronic Task; and (5) the New Electronic Task. Table 5 indicates the code designations for all variables in this study.

The first three tasks, namely, the TFT, the CBT, and the LT were administered to all music and general students. The ET, however, was administered to only half of each group and the NET was administered to the other half.

Tables 6 and 7 indicate student raw scores for each group, and Table 8 indicates the means and standard deviations. The cell means for the music students performances on the TFT, LT, and ET was higher than

TABLE 5

VARIABLES' NAMES AND CODE DESIGNATIONS

Variable Name	Variable Code
Piagetian Cognitive Level	PCL
Tuning Forks Task	TFT
Colored Beads Task	CBT
Letters Task	LT
Electronic Task	ET
New Electronic Task	NET

those of the general students. On the other hand, the cell means for the general students performances on the CBT and NET were higher than those of the music students.

Inferential Analysis of the Data

Statistical Considerations

Before proceeding to test the hypotheses, consideration was given to the type of statistical errors that might be committed in testing those hypotheses. There are two types of statistical errors--Type I and Type II. A Type I error is committed when the null hypothesis is rejected and in fact it is true. A Type II error occurs when the null hypothesis is not rejected and in fact it is false.

In this research, a Type I error occurs when the null hypothesis that there are no differences among the subjects' performances on tasks with different contents is incorrectly rejected. Then, the false

TABLE 6

RAW SCORES OF THE MUSIC STUDENTS

N = 30

OBS	TF	CB	LT	ET	NET
1	2	3	1	2	-
2	3	3	4	1	-
3	3	4	4	4	-
4	3	3	3	3	-
5	4	4	4	4	-
6	4	3	4	4	-
7	3	3	3	3	-
8	3	4	4	4	-
9	4	3	3	4	-
10	3	4	4	2	-
11	4	2	3	4	-
12	3	2	2	2	-
13	3	2	2	3	-
14	4	4	4	4	-
15	4	4	3	3	-
16	3	3	3	-	2
17	4	2	3	-	4
18	3	4	4	-	4
19	4	4	4	-	4
20	4	2	4	-	3
21	4	4	4	-	3

TABLE 6 CONTINUED

OBS	TF	CB	LT	ET	NET
22	4	3	3	-	4
23	3	4	3	-	4
24	4	3	3	-	3
25	3	4	3	-	2
26	3	2	3	-	3
27	3	2	3	-	4
28	3	2	2	-	1
29	4	2	2	-	3
30	4	3	3	-	4

TABLE 7

RAW SCORES OF THE GENERAL STUDENTS

N = 30

OBS	TF	CB	LT	ET	NET
1	3	3	3	4	-
2	4	4	4	4	-
3	3	3	3	3	-
4	2	3	3	2	-
5	4	4	3	4	-
6	3	4	4	4	-
7	2	3	2	2	-
8	2	4	4	3	-
9	3	3	4	3	-
10	4	4	4	3	-
11	4	3	3	4	-
12	2	3	3	4	-
13	3	3	2	2	-
14	2	2	2	2	-
15	2	3	2	2	-
16	2	3	1	-	3
17	3	3	4	-	4
18	3	4	4	-	4
19	4	4	4	-	3
20	3	3	3	-	4
21	3	3	3	-	4

TABLE 7 CONTINUED

OBS	TF	CB	LT	ET	NET
22	2	3	3	-	3
23	3	4	2	-	4
24	2	2	2	-	2
25	2	3	3	-	2
26	3	3	3	-	4
27	3	4	3	-	3
28	3	3	2	-	4
29	2	3	3	-	4
30	3	3	3	-	3

TABLE 8

MEANS AND STANDARD DEVIATIONS

Task	n	Music Students M	Music Students SD	General Students M	General Students SD
TFT	30	3.43*	0.57	2.80*	0.71
CBT	30	3.07	0.83	3.23	0.57
LT	30	3.17	0.79	2.97	0.81
ET	15	3.13	0.99	3.07	0.88
NET	15	3.2	0.94	3.40	0.74

*Maximum score = 4
Minimum score = 1

conclusion that the subjects' performance level depends on the familiarity or unfamiliarity of the subjects with the content of the tasks would be drawn. On the basis of that conclusion, the students' cognitive level must be measured by tasks with content in their major area of interest. When, in fact, the content of the tasks would not make any difference in the subjects' performance level, it means a great deal of time, trouble and effort in order to design and construct tasks in students' area of expertise. Hence if Type I error was made, students would have not been harmed educationally but a great deal of time, energy and probably money would have been wasted.

If a Type II error was committed by accepting the null hypothesis while it was actually false, the conclusion of the study would be that there are no differences among the subjects' performance levels on the tasks with familiar and unfamiliar contents. When this conclusion is implemented in identifying the subjects cognitive level with unfamiliar content, the students would be educationally deprived by underestimating their true congitive level. In this research a Type II error was considered to be more serious than a Type I error and should be avoided when drawing conclusions from the results of testing the hypothesis.

Power and Type II Error

While Type I error can be controlled by the investigator simply by setting a lower value for the level of significance (α*), there is no direct way to control Type II error. The probability of Type II error, however, can be controlled by the power of the test (Hays, 1973, p. 357) and the level of significance. The higher the α, the higher the power of a statistical test, and the higher the power, the lower the probability of a Type II error (Hays, 1973, p. 359). In this study conclusions drawn from committing a Type I error would not hurt the students educationally while committing Type II error could hurt the students educationally. Therefore, it was decided to set the level of significance at a rather high level of 0.10 in order to increase the power and thus decrease the probability of Type II error in this study.

Hypotheses Testing

In this study the hypotheses which were tested separately follow:

1. The music and general students performance levels (cognitive

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*Level of significance is actually the probability of Type I error. Setting the level of significance at, for example, 0.10 means that the probability of wrongly rejecting the null hypothesis is 0.10. In other words, the probability of Type I error is 0.10.

levels) on the Electronic Task and the New Electronic Task would not be significantly different.

2. There are no significant differences between the performances of the two groups on the Tuning Forks, Colored Beads, and Letters Tasks.

The above hypotheses were tested by using the Analysis of Variance (ANOVA) procedure. That procedure was executed by the SAS (SAS Users Guide, 1979 edition) computer program available at the University of Oklahoma Computer Center.

To test the first hypothesis, consideration was given to the point that two different tasks were administered to two separate and distinct groups of randomly selected subjects. A two way ANOVA, therefore, was used to test music students against the general students on their performances on the two versions of the Electronic Task. To test the second hypothesis, the attention was given to the point that each subject completed each of the three tasks in a different order which was randomly chosen. A repeated measure of ANOVA (Lindeman, 1974, pp. 166-180) is the best statistical tool to test the second hypothesis because each subject was repeatedly tested and produced one score value under each task. The results of the analyses for both hypotheses are presented in Tables 9 and 10,respectively.

Consider the result of the analysis in Table 9. The F-ratio computed when the group across tasks were compared was not significant (critical $F^{0.10}_{1,58} = 2.79$). This means that there were no significant differences between the cognitive levels of the two groups of students as measured by the two versions of the Electronic Task. Therefore, the first hypothesis was accepted. The F-ratio computed when the performance on the tasks across groups were compared also was not significant

TABLE 9

SUMMARY TABLE: 2-WAY ANOVA--MUSIC STUDENTS AGAINST GENERAL STUDENTS AND THEIR PERFORMANCE LEVELS ON THE ELECTRONIC TASK AND THE NEW ELECTRONIC TASK

	Source	S.S.	d.f.	M.S.	F*
1.	Group	0.067	1	0.067	0.08
2.	Task	0.60	1	0.60	0.75
	Interaction	0.267	1	0.267	0.33
	Error	44.667	56	0.798	
	TOTAL	45.6	59		

*Critical $F^{0.10}_{1,56} = 2.79$

TABLE 10

SUMMARY TABLE: REPEATED MEASURES ANOVA--MUSIC STUDENTS AGAINST GENERAL STUDENTS, AND THEIR PERFORMANCE LEVELS (COGNITIVE LEVELS) ON THE TUNING FORKS, COLORED BEADS, AND LETTERS TASKS

Source	SS	DF	MS	F
Group	2.222	1	2.222	2.35[a]
Subject W/Group	54.889	58	0.946	—
Task	0.211	2	0.105	0.34[b]
Group X Task	4.811	2	2.405	7.83[c]
Subject X Task W/Group	35.644	116	0.307	—

[a]df = (1,58), $F^{0.10}_{1,58} = 2.79$

b and [c]df = (2,116), $F^{0.10}_{2,116} = 2.35$

(critical $F^{0.10}_{1,58} = 2.79$). The result of this analysis shows that no significant difference exists between the scores received on the ET and the scores received on the NET. This means that there are no significant differences between the two versions of the Electronic Task.

From Table 9, the interaction effect also was not significant (critical $F^{0.05}_{1,58} = 2.79$). This result indicates that the performance on either of the ET does not depend on the group of students a particular subject comes from.

The overall result of the two-way ANOVA for the music students versus general students on their performances on the two versions of the Electronic Task shows that none of the sources of variability was significant. Therefore, the cognitive levels of the students as identified by the two versions of the Electronic Task were not significantly different. In other words, removing switch number 4 (the inhibitor) from DeLuca's Electronic Task does not effect the performance level of the subject on that task.

The results of the repeated measures ANOVA for the two groups of students on their performances on the TFT, CBT, and LT are summarized in Table 10. The F-ratio computed when the group across tasks were compared was not significant (critical $F^{0.10}_{1,58} = 2.79$). This means that the overall cognitive levels of general students identified by the three tasks (TFT, CBT, and LT) were not statistically different than the overall cognitive levels of general students identified by those tasks. Therefore, the null hypothesis of no difference between the performance levels of the music students and general students was accepted.

From Table 10, the F-ratio computed when the performances on the tasks across groups were compared was not significant (critical $F^{0.10}_{2,116} = 2.35$). This result shows that no significant difference exists among the cognitive levels of all students in the sample as measured by the three tasks. In other words, the scores received on each task were not significantly different from the scores received on the other tasks.

The interaction effect in Table 10, however, was significant (critical $F^{0.10}_{2,116} = 2.35$). This result suggests that there are some differences between the groups and among the tasks. In other words, the performance level depends on the kind of task and on the group of students a particular subject comes from. Moreover, that dependency produces some differences in the subjects' performance levels which are significantly different as shown by the calculated F-value for the interaction term in Table 10. The average performance levels from Table 9 are graphed (Figure I) and help indicate the interaction effects.

From Figure I, it can be seen that there are some differences among the means of the subjects' performance levels. For music students the mean on the LT is greater than the mean on the CBT and less than the mean on the TFT. For the general students, the mean on the LT is less than the mean on the CBT and greater than the mean on the TFT. Figure I, also indicates that the means on the TFT and LT for music students are greater than those means for the general students, while the mean on the CBT for the music students is less than the mean on the CBT for the general students.

The result of the repeated measure ANOVA showed that the above differences among the means were not statistically significant when the groups were compared on their overall performances on the three tasks and when the scores on the three tasks were compared for both groups at the same time. Interaction effects, on the other hand, indicated that some of those differences were statistically significant. Figure I, for example, suggests that the two groups performance levels most probably are significantly different on the TFT, if not on the other two tasks; since the differences in the scores on the TFT are rather large in comparison to the differences in the scores on the CBT or LT.

In order to find out which of the above differences are statistically significantly different, the data in this study were further analyzed by the method of the Simple-Effects Test (Lindman, 1974, pp. 98-99). The simple-effects test resembles one-way Analysis of Variance* across levels of one factor performed separately at each level of the other factor. In other words, the simple-effects test provides the opportunity to test the music students performance levels on the three tasks separately from the general students' performance levels on those tasks and vice versa. The simple-effects test also provides the opportunity to compare the scores of two groups of students on each task separately and independently from the other tasks. The results of the simple-effects tests are summarized in Tables 11 through 15.

Consider the results of the simple-effects tests in Tables 11, 12, and 13. Only the F-ratio of the Tuning Forks Task for the two groups of students was significant (critical $F^{0.10}_{1,58} = 2.79$). Hence, the results of these analyses indicates that the differences in the TFT scores between the music and general students were significant. However,

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*The difference between the simple-effects test and one way ANOVA is only in the calculation of the F-ratio. In the simple-effects test the mean square within (error term) for the overall analysis will be used as the denominator for the F-ratio.

FIGURE I

CELL MEANS-REPEATED MEASURES ANOVA--
MUSIC STUDENTS VERSUS GENERAL STUDENTS

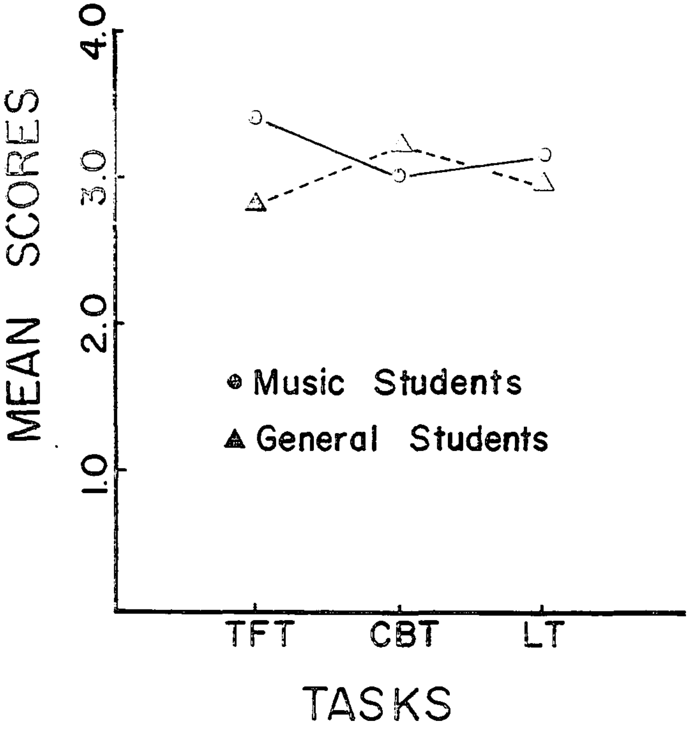

TABLE 11

TESTS OF SIMPLE-EFFECTS ON THE TUNING FORKS TASK FOR MUSIC AND GENERAL STUDENTS

Source	SS	df	MS	F
between	6.016	1	6.016	6.36*
within (error)	24.166	58	0.416	
total	30.182	59		

*The mean square of subjects w/group for overall analysis has been used as the denominator for the F-ratio. (critical $F^{0.1}_{1,58} = 2.79$)

TABLE 12

TESTS OF SIMPLE-EFFECTS ON THE COLORED BEADS TASK FOR MUSIC AND GENERAL STUDENTS

Source	SS	df	MS	F
between	0.416	1	0.4166	0.44*
within	29.233	58	0.5040	
total	29.649	59		

*The mean square of subjects w/group for overall analysis has been used as the denominator for the F-ratio. (critical $F^{0.10}_{1,58} = 2.79$)

TABLE 13

TESTS OF SIMPLE-EFFECTS ON THE LETTERS TASK FOR MUSIC AND GENERAL STUDENTS

Source	SS	df	MS	F
between	0.60	1	0.60	0.953*
within (error)	37.133	58	0.62937	
total	37.733	59		

*The mean square of subjects w/group for overall analysis has been used as the denominator for the F-ratio. (critical $F^{0.10}_{1,58} = 2.79$)

TABLE 14

TESTS OF SIMPLE-EFFECTS ON COGNITIVE LEVELS ACROSS THE TUNING FORKS, COLORED BEADS, AND LETTERS TASKS ON MUSIC STUDENTS

Source	SS	df	MS	F
between	2.155	2	1.077	3.510*
within (error)	47.399	87	0.5448	
total	49.554	89		

*The mean square within for overall analysis has been used as the denominator for the F-ratio. (critical $F^{0.10}_{2,116} = 2.35$)

TABLE 15

TESTS OF SIMPLE-EFFECTS ON COGNITIVE LEVELS ACROSS THE TUNING FORKS, COLORED BEADS, AND LETTERS TASKS ON GENERAL STUDENTS

Source	SS	df	MS	F
between	2.866	2	1.433	4.669*
within (error)	43.134	87	0.495	
total	46	89		

*The mean square within for overall analysis has been used as the denominator for the F-ratio. (critical $F^{0.10}_{2,116} = 2.35$)

the differences in the CBT scores and LT scores between the music and general students were not significant. Those results could have been predicted from Figure I because the differences in the CBT scores and LT scores for the two groups of students are rather small and about equal, while the differences in the TFT scores between the two groups are rather high in favor of the music students. Therefore, the music students performed significantly better than the general students only on the TFT as was earlier predicted.

Table 14 indicates that the music students' performance levels were significantly different (critical $F^{0.10}_{2,116} = 2.35$) across the three tasks TFT, CBT, and LT. From Table 15, it can be seen that the general students' performance levels also were significantly different (critical $F^{0.10}_{2,116} = 2.35$) across the same three tasks. In other words, the performance levels of the groups were not the same across the tasks. But, nevertheless, the simple effects tests do not show on which task(s) the music or the general students performed better.

In order to find exactly on which task(s) the music students performed better and on which task(s) the general students performed better, the data were further analyzed by comparison of the means for each group two at a time. Tukey's method (outlined in Winer, 1962) was used for the comparisons. The results of the comparisons are given in Table 16.

TABLE 16

COMPARISON OF MEANS TWO AT A TIME FOR EACH GROUP OF STUDENTS ON THEIR PERFORMANCES ON THE TUNING FORKS, COLORED BEADS, AND LETTERS TASKS

Comparison	Music Students t	General Students t
TFT vs CBT	2.56	3.02*
TFT vs LT	1.8	1.16
CBT vs LT	0.698	1.86

*critical $F^{0.1}_{3,116} = 2.13$

From Table 16, only the t-ratio computed for the TFT vs CBT was significant (critical $F^{0.10}_{3,16} = 2.13$) for both music and general students. Those significant differences can be seen from Figure I. Figure I indicates that the average performance level of music students on the TFT was higher than the average performance level on the CBT, and the average performance level of general students on the TFT was lower than their average performance level on the CBT. Therefore, the significant results in Table 16 indicate that the music students' performance levels on the TFT were significantly higher than their performances on the CBT. The general students' performance levels on the TFT, on the other hand, were significantly lower than their performances on the CBT.

The major aim of this study was to determine the effect of task content on the subjects' performance level. Data provided in this chapter provide the basis for determining that effect. The data were analyzed in two steps: first the two groups performances on the two versions of the Electronic Task were compared, then the two groups performances on the three tasks TFT, CBT, and LT were compared. Based on those analyses, the two groups of students performed significantly different only on TFT. That conclusion is drawn on the basis of the above analyses. There were not any comparisons made between the TFT and either version of the Electronic Task. Since the TFT was a content related task and conclusions of this study are based on the students' performances on that task in comparison to the performances on the other tasks, it was decided to compare the performance levels of each group of students on the TFT with corresponding performance levels of that group on the ET and NET. Therefore, the second hypothesis of this study was amended in the following way:

There are no significant differences between the performance levels of the two groups of students on the Tuning Forks, Colored Beads, and Letters Tasks. Also, no significant difference exists between the performance levels of either group of students on the TFT and either version of the Electronic Task.

For making comparisons between the TFT and either version of the Electronic Task, it should be noted that the ET was administered to 15 students of music or general students' group, and the NET was administered to a different 15 subjects within each group. In other words, considering the performance levels of students on the three tasks TFT, ET, NET, there are four distinct subgroups: music students who performed on the TFT and ET, music students who performed on the TFT and NET, general students who performed on the TFT and ET, and general students who performed on the TFT and NET. The performance levels of students in each subgroup can be tested for significant differences by using a t-test. Moreover, since in each subgroup the same subjects were administered either the TFT and ET or TFT and NET, the performance levels are not independent and a dependent t-test should be used (Minium, 1978, p. 298). Therefore, four seperate dependent t-tests were used for testing any significant differences between the TFT and NET. The level of significance (α) for such a multiple t-test, consists of splitting up the overall level of significance used in the study among the set of t-tests(Kirk, 1968, pp. 78-80). Therefore, the level of significance for either t-test should be α = 0.025. That value of α

was obtained by dividing the significance level used in previous analyses (α = 0.1) by four, the total number of t-tests. But since the t-distribution table does not contain the α-value of 0.025 for two-tailed test, the level of significance for each t-test was chosen to be 0.02. The results of the t-test analysis are summarized in Tables 17 through 20.

TABLE 17

t-TEST FOR MUSIC STUDENTS ON THEIR PERFORMANCES ON THE TUNING FORKS TASK AGAINST THEIR PERFORMANCES ON THE ELECTRONIC TASK

	N	Mean	Variance	D.F.	t
Tuning Forks Task	15	3.33	0.35	14	1*
Electronic Task	15	3.31	0.91		

*α = .02, critical $t_{14}^{0.01} = \pm\ 2.624$

TABLE 18

t-TEST FOR MUSIC STUDENTS ON THEIR PERFORMANCES ON THE TUNING FORKS TASK AGAINST THEIR PERFORMANCES ON THE NEW ELECTRONIC TASK

	N	Mean	Variance	D.F.	t
Tuning Forks Task	15	3.53	0.25	14	1.43*
New Electronic Task	15	3.20	0.83		

*α = 0.2, critical $t_{14}^{0.01} = \pm\ 2.624$

TABLE 19

t-TEST FOR GENERAL STUDENTS ON THEIR PERFORMANCES ON THE TUNING FORKS TASK AGAINST THEIR PERFORMANCES ON THE ELECTRONIC TASK

	N	Mean	Variance	D.F.	t
Tuning Forks Task	15	2.87	0.64	14	-1*
Electronic Task	15	3.07	0.73		

*$\alpha = 0.2$, critical $t_{14}^{0.01} = \pm 2.624$

TABLE 20

t-TEST FOR GENERAL STUDENTS ON THEIR PERFORMANCES ON THE TUNING FORKS TASK AGAINST THEIR PERFORMANCES ON THE NEW ELECTRONIC TASK

	N	Mean	Variance	D.F.	t
Tuning Forks Task	15	2.73	0.32	14	-3.57*
New Electronic Task	15	3.40	0.51		

*$\alpha = 0.2$, critical $t_{14}^{0.01} = \pm 2.624$

Consider the result of t-tests in Tables 17 and 18. The obtained t-value in both tables is less than the critical t (critical $t_{14}^{0.02} = \pm 2.624$). Hence the music students' performance levels on the TFT and ET or on the TFT and NET were not statistically significantly different. Table 19, shows that the general students also, did not perform significantly different on the TFT and ET. The result of t-test on Table 20, however, indicates that the general students performed significantly better on the NET than the TFT.

CHAPTER V

SUMMARY AND INTERPRETATIONS

SUMMARY

This study was generally concerned with the effect of the content of Piagetion tasks specifically designed to detect formal reasoning upon subject performance level. Most of Piaget's formal reasoning tasks use physics or mathematics content so results of studies based on those tasks are often thought to be confounded with the subject's knowledge of those academic areas. Could the measurement of reasoning using evaluation instruments--in this case specific apparatus and materials--from the subjects' area of expertise enhance that subjects' performance? If familiar apparatus and materials from the subjects' area of expertise were used, the resulting performance would not be suspect because the subject "did not know" the content.

The Piagetian cognitive levels of the students involved in this study in the area of combinatorial logic were measured by a battery of four of five combinatorial logic tasks with different content. Those tasks were: (1) the Tuning Forks Task (TFT); (2) the Colored Beads Task (CBT); (3) the Letters Task (LT); (4) the Electronic Task (ET); and (5) the New Electronic Task (NET). Complete descriptions of tasks are presented in chapter 3.

The sample selected for this study was 30 freshman music students and 30 freshman general students enrolled at the University of Oklahoma during the spring term 1981. A detailed description of the sample will be found in chapter 3. The Tuning Forks Task was considered as a task with content highly familiar to and in the domain of expertise of music students (see chapter 3). The other four tasks were considered to be content free since the content and materials used in those tasks does not depend upon the subjects' knowledge, background, and/or major area of interest. The two versions of the Electronic Task were different in only one aspect; the inhibitor switch which prevented the bulb from lighting in the Electronic Task was not present on the apparatus for the New Electronic Task. The need for this inhibitor switch was discussed in chapter 3.

The foregoing tasks and the two distinct groups of students were specifically selected to investigate the following major questions:

1. What effect does an inhibitor element in combinatorial logic tasks have on the subjects' performance level?

2. How does the element of content of combinatorial logic tasks influence the subjects' performance level?

The following hypotheses were tested:

1. The music and general students performance levels (cognitive levels) on the Electronic Task and the New Electronic Task would not be significantly different.

2. The performance levels of the two groups of students on the Tuning Forks, Colored Beads, and Letters Task would not be significantly different. Also, no significant difference exists between the performance levels of either group of students on the TFT

and either version of the Electronic Task.

The data were analyzed in the following ways:

1. A two-way ANOVA was used to test music students against general students on their performances on the two versions of the Electronic Task.

2. A repeated measure ANOVA was used to test the music students against the general students on their performances on the Tuning Forks Task, Colored Beads Task, and Letters Task.

3. The Simple-Effects Test method was used to test the performance levels of music students on each task (among the three tasks TFT, CBT, and LT) against the corresponding performance levels of general students on each task among the above three tasks separately and independently from the other two tasks.

4. The Simple-Effects Tests method was used to determine if the music students' performance levels on the TFT, CBT, and LT was statistically significantly different from each other.

5. The Simple-Effects Tests method was used to determine if the general students' performance levels on the TFT, CBT, and LT was statistically significantly different from each other.

6. Tukey's method of individual comparisons was used to determine on which task(s) among the three tasks (TFT, CBT, and LT) music students performed better. The same method was used to determine on which task(s) among the above three tasks the general students performed better.

7. The dependent t-test was used to determine if the difference in performance on the TFT and ET or TFT and NET for each of the two samples was statistically significant.

The findings from the foregoing analyses of data were:

1. The performance levels of the two groups of students were not significantly different on the two versions of the electronic tasks (Table 9).

2. The repeated measures ANOVA performed for the two groups of students and their cognitive levels on the Tuning Forks, Colored Beads, and Letters Tasks showed only the interaction effect to be significant. That interaction indicated there were some differences between the groups and among the tasks. In other words, interaction indicated the performance level depends on the kind of the task and on the group of students a particular subject comes from (Table 10).

3. The result of the Simple-Effects test on each task for music and general students showed:

a. The two groups performed significantly differently on the Tuning Forks Task (Table 11).

b. The two groups performance levels were not significantly different on the Colored Beads and Letters Tasks (Tables 12 and 13).

4. The result of the Simple-Effects test on each group across the--TFT, CBT, and LT--tasks indicated that:

a. For the music students, performance level differences on the above three tasks were statistically significant (Table 14). That test did not show on which task(s) music students performed better than the other task(s).

b. For the general students, performance level differences on the above three tasks were statistically significant (Table 15). That test did not show on which task(s) general students performed better than the other task(s).

5. Tukey's individual comparisons indicated that the music students' performance levels on the Tuning Forks Task were significantly higher than their performances on the Colored Beads Task (Table 16).

6. For the general students, the result of Tukey's individual comparisons showed that their performance levels on the Tuning Forks Task were significantly lower than their performances on the Colored Beads Task (Table 16).

7. Tukey's method did not show any significant differences between the TFT and LT or the CBT and LT for either group of students.

8. The result of the t-test showed that the music students' performance levels on the TFT were not significantly different from their performance levels on the ET or NET (Tables 17 and 18).

9. The result of the t-tests showed that the general students' performance levels on the TFT and ET were not significantly different from each other (Table 19). The general students' performance levels on the NET were significantly better than their performances on the TFT (Table 20). Each of these findings is discussed in the following section of this chapter.

Interpretations

Regardless of the kind of the statistical analyses that were done in this study, the results of the data analyses were summarized in the following tables:

TABLE 21

MUSIC STUDENTS' PERFORMANCE LEVELS ON THE TFT IN COMPARISON TO THEIR PERFORMANCES ON THE OTHER TASKS (CBT, NET, ET, AND LT)

Task	Condition	Task
TFT	>	CBT
TFT	=	NET
TFT	=	ET
TFT	=	LT

= is to be interpreted as performance not significantly different from

> is to be interpreted as performance significantly higher than

TABLE 22

GENERAL STUDENTS' PERFORMANCE LEVELS ON THE TFT IN COMPARISON TO THEIR PERFORMANCES ON THE OTHER TASKS (CBT, NET, ET, AND LT)

Task	Condition	Task
TFT	<	CBT
TFT	<	NET
TFT	=	ET
TFT	=	LT

= is to be interpreted as performance not significantly different from

< is to be interpreted as performance significantly lower than

TABLE 23

MUSIC STUDENTS' PERFORMANCE LEVELS ON TASKS TFT, CBT, LT, ET, AND NET IN COMPARISON TO GENERAL STUDENTS PERFORMANCE LEVELS ON THOSE TASKS

Music Students	Condition	General Students
TFT	>	TFT
CBT	=	CBT
LT	=	LT
ET	=	ET
NET	=	NET

= is to be interpreted as performance not significantly different from

> is to be interpreted as performance significantly higher than

As it can be seen from the above Tables, the performance levels of either group of students on the two version of the Electronic Task were not significantly different from each other. That result suggests the idea that the existence or nonexistence of the inhibitor switch does not have any effect on the subject's performance level.

Considering the major purpose of the present study which was the investigation of the effect of the task content on the subject performance level. The data in Tables 21, 22, and 23 indicate the following results:

1. Music students performed significantly higher on the TFT--a task with content in their major area of expertise--than on the CBT which was a content free task.

2. General students performed significantly lower on the TFT with content in their major area of nonexpertise than on the content free task CBT.

3. Music students' performance levels on the TFT were significantly better than the general students' performance levels on the TFT.

The above evidences support the idea that performance levels of subjects on combinatorial logic tasks with content in the subjects' area of expertise would be better than the subjects' performance levels on content free tasks or on tasks with content in their area of nonexpertise.

Considering the students' performance levels on the CBT and LT, the performance levels of either group were not significantly different on those tasks (Table 23). That result can be justified by considering the fact that the CBT and LT tasks were highly similar in design, number of variables, scoring method, and instructions given to the subjects.

CHAPTER VI

CONCLUSIONS AND DISCUSSION

As a result of the analyses reported in Chapter 4, the following conclusions can be drawn regarding the problem investigated:

1. Finding number one is that the presence or absence of the inhibitor switch in the Electronic Task does not produce a significant difference in the subjects' performance level. In other words, the presence or absence of a factor in combinatorial logic tasks that neutralizes or prevents the outcome of combinations of the other factors does not have an effect on the ability of the subjects to use combinatorial reasoning. The fact that the Colored Beads Task--designed by Piaget for measuring the ability to use combinatorial reasoning (Inhelder and Piaget, 1958)--did not have any inhibitor element supports the above conclusion. Moreover, combinatorial reasoning was defined by Piaget as the ability to systematically combine different variables (Chapter 1). Presumably, the ability to choose a special strategy or a system for combining several variables is independent of the effect of each variable on the outcome of the combinations. That result suggests that the inhibitor solution in the Chemical Combination task might not have any effect on the subject performance level.

2. Piaget theory of formal thought suggests that a general, universal structures of formal reasoning exists by adulthood. The

studies reviewed in Chapter 2 demonstrated that such a general and universal trend in the attainment of formal thought might not exist. One possibility for the nonuniversality in the attainment of formal thought--discussed in Chapter 2--might be due to the effect of the "science content" involved in Piaget's formal tasks. To investigate the effect of content on subjects' performance level, four of five combinatorial logic tasks were administered to two groups of students (music and general students). Among the tasks, the Tuning Forks Task was considered to be a task with content familiar to music students and nonfamiliar to general students. The other four tasks were considered to be content free tasks which means that their contents do not depend on the knowledge, background, and major area of expertise of the students. The result of the study (summarized in Tables 21-25) indicated that a) music students performed significantly higher than the general students on the Tuning Forks Task. b) Music students performed significantly higher on the Tuning Forks Task than on the Colored Beads Task. c) General students performed significantly lower on the Tuning Forks Task than on the Colored Beads Task. d) General students performed significantly higher on the New Electronic Task than on the Tuning Forks Tasks. Considering that the Tuning Forks Task was a task with content in the major area of expertise of music students, those significant results suggest that there is a relationship between the content of the formal combinatorial logic tasks and the formal strategy (combinatorial reasoning). In other words, regarding the evidence found in the present study for the two groups of samples, content-related combinatorial logic tasks affects the subjects' performance levels on those tasks. However, subject performances on other content-related tasks in the domain of combinatorial reasoning ability and/or other formal strategies (proportion, permutation, mechanical equilibrium, probabilities and correlation) are necessary before the hypothesis that content has a definitive effect on subjects' performance levels can be evaluated.

3. The performance levels of either group of subjects on the content free tasks (CBT, LT, ET, or NET) were not significantly different from each other (Table 23). Based on that result, the conclusion can be drawn that when the combinatorial reasoning abilities of the subjects involved in this study were measured by content free combinatorial logic tasks the expertise background of the students makes no difference in the performance levels on those tasks.

Recommendation From The Study

From the educational point of view the results of this study summarized in Tables 21-23 suggest that tasks with content in the major area of expertise of the subjects allow the subjects to demonstrate maximum formal thought abilities. Therefore, when posssible, the measurement of formal thought abilities should be made in the subjects' area of expertise. If such tasks are not available or cannot be designed, then the measurement of formal reasoning abilities should be made by content-free tasks. But tasks with specific content in the area of non-expertise of the subjects should not be used for measuring the formal thought abilities because the unfamiliar content does not allow the subjects to use their formal strategies at the maximum level.

Recommendations For Further Research

On the basis of findings and conclusions discussed previously, the following recommendations for further studies are suggested:

1. Similar studies should be made which will test if the inferences made here can be generalized to the entire population sampled here.

2. Similar studies should be conducted with science and non-science majors to investigate the effect of science content in cognitive development.

3. Further studies should be conducted which investigate the effect of task content on the cognitive level of performance using other characteristics of formal stage, such as, proportional reasoning, exclusion of variables, separation of variables, correlations and permutation, etc.

4. Further studies should be made to investigate the effect of removing the inhibitor solution from the Chemical Combination Task on the subject performance level.

5. Further studies should be conducted regarding the effect of task content on subject's performance level in another age range such as high school students.

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