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THE INFLUENCE OF A COLLEGE INQUIRY-CENTERED COURSE IN SCIENCE

ON STUDENT ENTRY INTO THE FORMAL OPERATIONAL STAGE

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THE INFLUENCE OF A COLLEGE INQUIRY-CENTERED COURSE
IN SCIENCE ON STUDENT ENTRY INTO THE
FORMAL OPERATIONAL STAGE

CHAPTER I

INTRODUCTION

Professors of science and mathematics at the college level have increasingly voiced concern about the declining numbers of students enrolling in those courses, and other courses related to them, during a period of time when the enrollment figures in the colleges and universities across the nation show a marked increase.[1] This concern is well justified when enrollment statistics are compared with the projected demand by business and industry in the next decade for college graduates who have a background in science and mathematics.[2] In addition, the numbers of students in high school science courses do not show increases in enrollment that would provide a sufficient number of college students to adequately supply this burgeoning demand.

Another common complaint of professors concerns the inability

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[1]K. A. Simon and W. V. Grant, Digest of Educational Statistics: 1968, U. S. Department of Health, Education, and Welfare, Table 38, p. 34.

[2]Physics Manpower, 1960-69, American Institute of Physics, New York, N. Y., 1969, p. 73.

of freshman college students to argue logically about the importance of a given scientific principle when the context in which it is used is slightly altered. Apparently this complaint has some basis, since every study made of the revision of college science teaching calls for emphasis upon topics that lead to an increase in "critical thinking"[3] or enabling students to "function intelligently in relation to their knowledge."[4]

This investigator has suspected for some time that many college freshman physical science students exhibit this inability to think logically about the most elementary scientific questions. Because of this suspicion and the complaints voiced by other professors of science, an investigation was undertaken to determine whether these students did think logically. During the spring semester 1969, more than twenty students were randomly taken from available physical science classes and tested using as a criteria four of the tasks developed by Jean Piaget and Barbel Inhelder (these tasks will be discussed in a later section) and outlined in the book Growth of Logical Thought.[5] Approximately 50 per cent of these students did not demonstrate possessing Piaget's criteria for logical thought. Thus, the complaints of the professors are well founded as shown by this preliminary investigation. Abstract courses

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[3]Kenneth D. George, "A Comparison of the Critical Thinking Abilities of Science and Non-Science Majors," Science Education, Vol. 51, No. 1, Feb., 1967, pp. 11-17.

[4]Pauline Gratz, "An Interdisciplinary Approach to Science Teaching for General Education on the College Level," Science Education, Vol. 50, No. 3, April, 1966, pp. 285-292.

[5]Jean Piaget and Barbel Inhelder, Growth of Logical Thinking, Basic Books, Inc., 1958.

that have been developed by professors who presume that the great majority of students do think logically are not achieving the purposes intended. The development of logical thought processes would, therefore, seem to be a most important goal for any course, particularly if it were shown that these processes had not yet been fully developed in freshman college students.

According to Piaget, logical thought processes develop in stages with the highest level culminating in the formal operational stage.

> "During the formal stage, . . ., the adolescent comes to control formal logic. Rather than reasoning with directly given data alone, he begins to reason with propositions and logic."[6]

There are several elements appropriate to formal thought including hypothesizing, verifying, restructuring, interpreting, synthesizing, and predicting. These elements differ only slightly from the definitions of the ability to think given by various authorities. For example, the Educational Policies Commission defines the ability to think as being composed of:

> ". . . the processes of recalling and imagining, classifying and generalizing, comparing and evaluating, analyzing and synthesizing, and deducing and inferring."[7]

The elements of recalling and imagining suggest the design of investigations and the formation of tentative hypotheses, classifying and generalizing relate to the actions of verifying, while comparing, evaluation, and analyzing reflect the act of interpretation. Synthesis in both definitions infers internalization as part of a new and broader mental structure with predicting and inferring being the enhanced capacities arising

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[6] Ibid, Translator's Introduction, p. xvii

[7] Educational Policies Commission, The Central Purpose of American Education, National Education Association, Washington, D. C., 1961, p. 12.

therefrom.

The requirements for fully developed logical thought, according to Piaget, include contributions from three distinct areas of influence upon the learner, as well as a fourth contribution arising as a result of the mediating processes created by the interaction of the first three. These areas of influence are:

1. maturation
2. social transmission
3. experience acquired in interaction with the physical environment
4. equilibration[8]

The interaction of these areas of influence upon the learner result in revised and advanced levels of logical thought which Piaget has termed "equilibration."[9] Piaget indicates that the capacity for logical thought is fully developed between the ages of eleven and fifteen. Most college students, therefore, should have realized a level of maturation which is sufficient to allow them to demonstrate the most advanced levels of thought. If the student has not yet developed the capacity for formal thought, the conclusion must be that one or both of the remaining requirements have not been met either through lack of emphasis by social transmission, or that these students lack experience in interaction with the physical environment, or some combination of the two such that the equilibrative process is incomplete.

The following question must then be asked: Can entering college students who have not achieved the final stage of formal thought develop

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[8]Jean Piaget, "Cognitive Development in Children: Piaget," Journal of Research in Science Teaching, Vol. 2, 1964, pp. 176-86.

[9]See Chapter 2 for a discussion of this term.

it if they are exposed to educational experiences that (1) indicate the importance of logical thought through the social-transmission process and (2) that provide adequate opportunity for interaction with the physical environment including opportunities designed to lead to hypothesizing and verification, restructuring, interpreting, synthesizing, and predicting?

The steps of hypothesizing, verification, restructuring, interpreting, synthesizing, and predicting define the elements involved in the inquiry method of instruction. The National Science Teachers Association Curriculum Committee points to the importance of the inquiry method in science teaching this way:

> "One of the . . . tasks in teaching science is to teach the inquiry processes of science. Inquiry skills provide the learner with tools for independent learning."[10]

Often times the words inquiry and discovery are used interchangeably in the literature. Bruner, for example, says that discovery as applied to students means " . . . discovery of regularities of previously unrecognized relations and similarities between ideas with a resulting sense of self-confidence in one's abilities."[11] Karplus and Thier discuss discovery in conjunction with invention and interaction and differentiate among those terms in this way:

> "In <u>interaction</u>, the children seek evidence of interaction between a dry cell and a motor, a light bulb and other components . . . . a conceptual <u>invention</u> is a new idea for interpreting experience, an idea which resulted from a mental leap. A <u>discovery</u> is the recognition of a relationship between an idea and an observation, or between two observations."[12]

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[10]National Science Teachers Association Curriculum Committee. <u>Theory Into Action</u>, National Science Teachers Association, Washington, D. C., 1964, p. 9.

[11]J. S. Bruner, <u>The Process of Education</u>, Vintage Books, 1960, p. 20.

[12]Robert Karplus and Herbert D. Thier, <u>A New Look at Elementary School Science</u>, Rand-McNally & Co., 1967, p. 40.

Since the word inquire means "to ask," inquiry from that definition and the foregoing is a much more inclusive term than discovery, invention, or interaction. In fact, interaction, invention, and discovery very succinctly define inquiry. But so do the processes of hypothesizing, verifying, restructuring, interpreting, synthesizing, and predicting. For the purposes of this study the latter definition will be used. It is, however, the exact equivalent of defining inquiry as interaction (or exploration), invention and discovery.

Statement of the Problem

The purpose of this investigation is to determine whether or not college students who have not reached the level of formal thought and who have participated in a science course which has the goal of leading students to hypothesize, interpret, verify, restructure, predict, and synthesize reach the stage defined as formal operational by Jean Piaget before similar students who have not had such an experience. The two groups, test and comparison, were drawn by random chance from the 1969-70 O.C.U. freshman class. The following hypothesis was tested:

When students who have not achieved the stage of formal thought, as defined by Jean Piaget, are exposed to a course emphasizing hypothesizing and verification, restructuring, interpreting, synthesizing, and predicting (inquiry), they will show no significant gains in their capacity to think logically as compared with a similar group that has not had such experiences.

The logical thought processes, as well as those prior stages of thought leading to this level, have been elaborated upon by Piaget and

Inhelder.[13] The formal operational stage of thought is characterized by the ability of a student to examine a problem without the necessity for physical manipulation of variables, create hypotheses and in so doing recognize a particular phenomenon as but one example of the whole range of such possibilities. Phillips says:

> "As he grows older and gains more experience, the child's construction of reality becomes more precise and extended, and that makes him aware of gaps in his understanding that had been masked by the vagueness of his previous constructions. He fills those gaps with hypotheses, and he is able to formulate--and often even to test--hypotheses without actually manipulating concrete objects.[14] . . . he is concerned with reality, but reality is only a subset within a much larger set of possibilities."[15]

The student exhibiting this kind of thought can be discriminated from those who have not yet achieved this capacity. The pre-formal thought student may, in time, move to the formal level of operations; however, he must mature in many ways, or perhaps have certain discrete educational experiences, to do so.

Related Research

Although no published results of experimentation on science classes using the Piagetian criteria for movement from pre-formal to formal thought by college-age students could be found, several studies have been made of the increase in critical thinking students undergo due to exposure to a science course. Yoesting and Renner[16] compared first-year college students

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[13]Piaget and Inhelder, op. cit., p. 337.

[14]John L. Phillips, Jr., The Origins of Intellect, Piaget's Theory, W. H. Freeman Company, 1969, p. 100.

[15]Ibid, p. 101.

[16]Clarence Yoesting and John W. Renner, "Is Critical Thinking an Outcome of a College General Physical Science Course?", School Science and Mathematics, March, 1969, pp. 199-206.

involved in an elementary physical science class with similar students who had not been involved in such a course and found that there was a significant increase in critical thinking by the physical science students, though not significant at the one per cent level imposed.

Stafford and Renner,[17] working at the University of Oklahoma, carried out Piagetian studies with first-grade children to determine whether or not the boundary between pre-operational and concrete levels of thought can be lowered by means of appropriate educational experiences using as a test vehicle the conservation tasks developed by Piaget. Their results indicate that the rate of attainment of the conservation skills depends upon the child's educational experiences. Thus, Stafford and Renner believe that a child who had been exposed to the kinds of experiences advocated by Piaget apparently had the prerequisite maturation necessary to actuate the thought processes essential to conservation and logical thought and simply needed the added educational experiences to develop these skills.

The present research investigated the effect of a science course in influencing the attainment of logical thought processes in freshman-level students; however, it differed significantly from Yoesting and Renner's research in the means by which growth in logical thought was measured. In addition, the course taught to the experimental group at Oklahoma City University differed significantly in both content and methodology from the course whose effect was investigated by Yoesting and Renner. That course was a somewhat revised conventional physical science course

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[17]Donald G. Stafford and John W. Renner, "Inquiry, Children, and Teachers," The Science Teacher, April, 1970, pp. 55-57.

that provided additional opportunity for inquiry-oriented experiences within a normal lecture-laboratory framework. The research differed from Stafford's work in the sense that the acquisition of a higher stage of operations was involved as well as the means by which the acquisition of these skills was obtained. The work was similar to Stafford's in that the testing instruments used were designed to evaluate the student's stage of mental growth according to the Piagetian criteria and are not part of conventional educational measurement.

After a thorough search of the literature, this investigator believes that the kinds of testing that were undertaken in this experiment have not been attempted prior to this time with pre-formal thought college-age students. There is great importance in knowing whether such college freshmen who have opportunities for verification, restructuring, integrating, interpreting, synthesizing, and predicting exhibit an increase in their capacity to think logically.

Origin of the Problem

The investigator became aware of the problem of development of logical thought in students when he taught a college course in physical science to the non-science major. Dissatisfaction with the structure of the course by the investigator grew because of the seeming inability of the students to grasp fundamental concepts relating to physics and chemistry which resulted in continual revision of the course within the framework of conventional approaches. In 1967, additional impetus for revision of the courses in science was provided as the result of a series of discussions by the Oklahoma City University president with graduating students. Many of them emphasized the lack of relevance of science to their concerns.

From this came the suggestion that the courses in science for the non-science major be revised.

Preliminary testing by this investigator of a limited number of college students on a series of Piagetian tasks provided additional support to the seriousness of the problem.[18] These tests were designed to show whether or not students think logically in abstract terms when confronted with problem-solving situations. The results of these tests indicated that almost 50 per cent of all entering college students may not have achieved the formal, or abstract, stage of thought. Additional support for this conclusion was drawn from long-term testing carried out by Professor Jean Boyle of the Department of English, Oklahoma City University. She used a comparison of American Council of Education Cooperative English Test and the scores from the American College Test. Professor Boyle stated that "It is my conclusion that from two-thirds to three-fourths of the freshmen tested were below average in ability to make reasonable inferences, recognize possible assumptions, draw logical deductions, and recognize sound arguments."[19]

Should the preliminary findings that only one of every two students thinks logically on Piaget's tasks hold true in subsequent testing, the implications for colleges and secondary school systems of this country would be quite significant. The curricula of secondary school systems would need to be re-evaluated to insure the inclusion of activities designed to promote logical thought while colleges would have to come to

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[18]The Piagetian tasks are discussed in Appendix I.

[19]Personal communication.

grips with the fact that a reasonably large percentage of their incoming students were not yet capable of the degree of abstract thinking assumed possible.

Need for This Research

Oklahoma City University has implemented a new series of basic general educational courses in all areas. As has been indicated, the proposed course "Forum for Scientific Inquiry" was the test vehicle for this study since major emphasis was placed on hypothesizing, verification, restructuring, interpreting, synthesizing, and predicting. Should favorable increases in intellectual growth occur as is postulated, the implications for similar courses at both secondary and college level would become quite clear. Science courses, if approached from this standpoint, should promote favorable growth in intellect as the student passes through pre-college education and specifically aid in developing the formal operational abilities of students while they are in college.

The new course which has been implemented at Oklahoma City University will be taken by about 300 non-science students per year. According to a study conducted by the Oklahoma State Regents for Higher Education,[20] which considered all incoming freshmen in all schools of higher education in Oklahoma, these students rank quite high on American College Test scores when compared to all institutions of higher education in Oklahoma. According to the data given in this 1964 report, "the median ACT score for first-time freshmen in all state institutions was 18, compared with a median of 20 for private institutions (21 for OCU), and 17

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[20]J. J. Coffelt and Dan S. Hobbs, In and Out of College, Oklahoma City, State Regents for Higher Education, 1965, p. 23.

for municipal institutions."[21] If the percentages of pre-formal thought college students, as determined in the preliminary investigation, are found to hold up under more extensive testing, the implications become all the more devastating should a positive correlation be shown to exist between ACT score and capacity to think logically. That is to say, should the preliminary hypothesis hold that approximately 50 per cent of the college population to be tested does not think logically, then an even greater percentage of pre-formal thought students will probably be found among those student populations whose average ACT scores are less than 21.

Another interesting facet to the proposed investigation of development of logical thought in college freshmen rests with the fact that almost 30 per cent of OCU's student population comes from east of the Mississippi River, primarily from states on the eastern coast. A correlation between regional influences and logical thought becomes possible; thus, some conclusions might be drawn about variance in regional educational methodology, or the influence of large school systems on students' capacity to think logically.

Formulation of the Problem

The basic working hypotheses are stated as follows:

1. No more than 50 per cent of the entering college freshmen have achieved the level of formal operations as defined by Piaget.

2. Those students who have not achieved this level of operations can be influenced to move toward logical thought processes by means of a

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[21] Ibid.

properly constructed course in science which involves the elements of restructuring, interpreting, synthesizing, and predicting and will exhibit significantly greater growth in logical thought processes than do similar students who have not been exposed to such a course. Specifically, these questions must be answered:

1. To what extent do freshmen college students exhibit the characteristics of the concrete operational student?

2. To what extent does an inquiry-oriented science course act to enhance a student's ability to think logically?

3. What is the difference between groups before and after exposure of the experimental group to the inquiry-oriented course? For example, men vs. women, Oklahoma students vs. eastern students, Arts and Science students vs. Business or Music School students.

Statistical Hypotheses

In order to test the research hypothesis, it was necessary to state two statistical hypotheses. These hypotheses were tested in terms of the criterion variable, growth in logical thought.

(1) Fifty per cent of freshman college students perform on the Piagetian tests at a level less than has been defined by Piaget as characteristic of the formal thought student. Null Form: All college students perform on the Piagetian tests at a level that has been defined by Piaget to be characteristic of the formal thought student.

(2) Students who are at the pre-formal thought stage and who are exposed to an inquiry-centered course in science will exhibit significantly greater growth in logical thought as compared with a like group who have not been so exposed. Null Form: Students who are at the pre-formal

thought stage and who are exposed to an inquiry-centered course in science will exhibit no significantly greater growth in logical thought as compared with a like group who have not been so exposed.

Null hypothesis (2) was tested at the 0.10 significance level. The major element of concern here was not with rejecting the null hypothesis when it was actually true, rather the possibility that the null was false must not be overlooked. The reason for this is that acceptance of the null hypothesis--that there was no growth in logical thought--when in actuality there was growth that the testing procedures could not discriminate would, in fact, do educational harm. Failure to recognize a positive effect on the experimental group by the new course because of the inability of the test to adequately discriminate growth in logical thought would tend to prohibit further use of this approach to teaching science. Rejection of the null form, that is, concluding that logical thought processes did improve as the result of exposure to the course when they actually did not would do far less harm than in the first instance. This rationale merits setting the level of significance at 0.10 while fully recognizing that it is possible to overestimate the value of the science course.

CHAPTER 2

PIAGET'S TESTS FOR DETERMINING LEVEL OF THOUGHT

Investigators who use the testing procedures devised by Piaget and Inhelder need an understanding of the changes that take place in children's explanations as they move toward the stage of formal operations; the experimenter, in other words, must have an understanding of Piaget's concept of mental development if he is to successfully evaluate growth in logical thought.

A child observes and interacts with some given event. The "structure" of the event includes the means (looking, grasping, moving the object) and the end (stimulation from the event). The "function" of the action involves reception, registration, and accommodation of each element of the event to all others. According to Piaget's theory of mental development, a child exposed to an event will interact with that event in some way that is characteristic of his stage of development, and as he interacts with the event, some level of understanding of that event occurs. That is, the child physically interacts and receives some sensory input data from the event which he then internalizes. By this means, he acquires a new level of understanding. This new level of understanding is dynamic because new assimilations and accommodations were necessary to bring it about. The learner has, therefore, really internalized the assimilations and accommodations. An enhanced capacity for logical thought has come into being in the learner which, in time, will be further enlarged upon as newer assimilations and accommodations occur. Phillips explains those processes this way:

> "Accommodation and assimilation are called "functional invariants" because they are characteristic of all biological systems, regardless of the varying contents of these systems. They are not, however, always in balance, one with the other.
>
> Temporary imbalances occur when a child is imitating (accommodation over assimilation) and when he is playing (assimilation over accommodation)."[22]

This temporary level of understanding might be called an equilibrium point, that is, that point where the child is in equilibrium with his environment. There are many such points along a learning continuum, always increasing in their complexity as new information is assimilated. The result of this change in structure is a movement from one level of complexity to another. This change is called "equilibration" and always leads to a new state of mental equilibrium. The importance of the process of equilibration cannot be underestimated for

> " . . . when a state of relative equilibrium has been attained, the structure is sharper, more clearly delineated, than it had been previously. But that very sharpness points up inconsistencies and gaps in the structure that had never been salient before. Each equilibrium state therefore carries with it the seeds of its own destruction, for the child's activities are thenceforth directed toward reducing those inconsistencies and closing those gaps."[23]

An understanding of formal thought processes requires that one understand the action of theorizing. Concrete operational students manipulate variables that are related to some given concrete object; however,

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[22]John L. Phillips, op. cit., p. 9.

[23]Ibid, p. 10.

formal operational students do not necessarily need to manipulate the object physically in order to understand the consequences of an action. While the concrete operational learner manipulates objects and theorizes in terms of them, his state of equilibrium is far below that of the formal operational student on the continuum mentioned earlier; therefore, his statements will relate to hypotheses about the objects and not to the broader principles which underlie his observations.

The formal operational learner constructs his thinking in a very different way from that of the concrete operational learner. As was stated earlier, he operates in a way that permits him to see some particular event as but one example of a range of hypothetical possibilities. For instance, a ball allowed to fall is simply an instance of a particular object moving in the way all objects would move under ideal conditions. Another characteristic of this final stage of equilibrium is the capacity to create hypotheses and devise tests to validate or refute them. After devising an hypothesis and testing it, the student may find that the reality does not match the model. In the reconciliation of contradictions, the formal stage of thought is exhibited, because only at the formal stage does restructuring of thought occur to bring contradictions into balance or equilibrium.

Formal thought also permits the individual to proceed without the necessity of physical manipulation; a learner may hypothesize and deduce without proceeding from a reality. Thus, it is that " . . . formal operations constitute solely the structure of the final equilibrium to which concrete operations tend when they are reflected in more general systems linking together the propositions that express them."[24]

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[24]Piaget and Inhelder, op. cit., p. 251.

Four tasks were used by this investigator in the initial phase of examination of formal thought in college students. A fifth task, called "the conservation of volume task", was added to the research to be sure that students had achieved the highest level of the concrete stage of operations.

Those five tasks to determine formal operations provide the tools for testing a hypothesis designed to answer the question: Do freshman college students who enroll in a liberal arts science course think logically? The hypothesis can be made that all college students have reached the formal stage of thought when tested on the Piagetian tasks. The characteristics of these tasks are important because each one reveals the capacity of the student to classify, hypothesize, and verify or restructure his thinking to eliminate observed contradictions so as to fully assimilate the meaning of the task and acquire confidence in it as part of a broader general law.

Validation of the Tasks and the Results

The failure of an appreciable number of students to achieve that highest stage of logical thought means that the tasks may be invalid or that some one of the three criteria influencing the formation of logical thought--maturation, the social transmission, and experience acquired in interaction with the environment--has not been met. Validity of the tasks and the procedures for using them have been adequately demonstrated by Piaget, at least on European students; however, to further demonstrate the validity of the tasks, a select group of American students, who, by all standards of comparison must think logically, yet not have the science background to have factually encountered the tasks, was chosen for testing from the freshman classes of the Oklahoma City University School of Law. The testing procedures were assumed to be valid if each student in this select group exhibited the highest stage of operational thought on 75 per cent of the tasks used. The 75 per cent level was chosen because Piaget[25] suggested it as an acceptable criterion at the pre-operational to concrete operational boundary of thought. Thus, the concrete to formal operational boundary should have the same criterion.

The rationale for selection of this population for validation of the tasks included the following considerations:

1. The sample chosen must differ only from the undergraduate population tested in that the sample group has had more opportunities for acquiring the requisite values necessary to formal thought.

2. The occupational choice made by the validation sample would reasonably lead to the conclusion that these persons are logical thinkers.

3. The argument for using this group for validity studies of the tasks is based upon the idea that students in time do acquire the necessary experiences and societal judgments to recognize the role that each of these tasks attempts to test. Thus, by showing that adults do undergo the transitions Piaget describes, validity of the tasks and the procedures for using them can be reasonably indicated. In addition, an upper limit may be placed upon the time at which students achieve the highest plateau of logical thought. If these adults do not respond to this test in the manner expected, serious doubts must be placed upon the whole procedure for discriminating logical thought processes. Those individuals who choose

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[25]Jean Piaget, Judgment and Reasoning in the Child, Totowa, New Jersey, Littlefield, Adams and Co., 1966, p. 100.

the profession of law must use the various components of the inquiry process of questioning, hypothesizing, formulating and rejecting hypotheses, and drawing conclusions from among many choices. In addition, they represent an extension of the undergraduate population inasmuch as they have been afforded more opportunities for those experiences so vital to formal thought.

Twenty-two individuals were tested from among a freshman law class of about fifty. The choice of students from this group to be tested was based entirely upon availability. After selecting this group for validity studies, the investigator found that the time available for testing purposes was very limited and that certain accommodations had to be made in order to be able to do any testing at all. After discussing the problem with those who were involved in the initial testing of the undergraduate freshmen, it was decided that Task IV, The Separation of Variables, could safely be deleted without seriously affecting the tester's capability to judge the response of the person being tested.

The results of the testing are shown in Table 2-1 and indicate that fully 82 per cent of those tested were well within limits prescribed for formal thought; nine per cent fell within the doubtful range, and the remaining 9 per cent were definitely giving concrete operational responses. The conclusion to be reached from this validation research is that the Piagetian tasks do isolate those individuals who operate at the formal level.

TABLE 2-1

Classification of Level of Thought of Twenty-Two Law School

Freshmen Using Four Piagetian Tasks

Student No.	Task Cons. of Volume	Reciprocal Implication	Elimination of Contradiction	Exclusion	Level of Thought
1.	2	4	4	4	Formal
2.	2	3	3	2	Formal
3.	2	2	4	4	Formal
4.	2	4	4	3	Formal
5.	2	4	4	4	Formal
6.	2	4	3	4	Formal
7.	2	2	3	1	?
8.	2	2	3	3	Formal
9.	2	4	4	1	Formal
10.	2	2	4	2	?
11.	2	4	4	3	Formal
12.	2	3	4	4	Formal
13.	2	2	2	1	Concrete
14.	2	2	4	3	Formal
15.	1	2	3	3	Formal
16.	1	2	2	1	Concrete
17.	0	4	4	2	Formal
18.	2	3	4	4	Formal
19.	1	4	3	2	Formal
20.	1	2	3	4	Formal
21.	2	3	3	1	Formal
22.	2	4	4	3	Formal

CHAPTER 3

REVISION OF ELEMENTARY COLLEGE SCIENCE COURSES FOR NON-SCIENTISTS

Introductory courses in science aimed at the first-year college student who will most likely not major in science differ in detail across the country, but in general are similar in their approach in that they are designed to accommodate large numbers of students at minimal cost. The drawbacks to this approach have been recognized and the literature abounds with suggestions for alleviating the situation; however, very little concrete revision of such science courses, together with an evaluation, has come out of these efforts.

As has been previously stated, a course in science designed around inquiry should offset the lack of experience in interaction with the environment, as well as the lack of the effect that positive social transmission would otherwise have. The design of science courses, particularly for the non-science major, has been of increasing concern for many college curriculum designers. Oklahoma City University has shared this concern for some time since it has been thought that the traditional approach used failed to bring about the favorable attitude changes expected.

Revision of the Present Offerings in Science for the Non-Scientist

John M. Fowler,[26] writing in Physics Today, states that many multidisciplinary courses in science have failed because of a lack of commitment on the part of the teaching staff and the difficulty of subject matter. Another problem, and one which is of immediate concern to this investigator, is to find a way to relate science to the world in which the college student lives or will live.

Traditionally, colleges and universities have existed for the purpose of transmitting knowledge. By so doing, they tend to live in a world of the past with too little regard for what is or will be. I. I. Rabi says that " . . . the aim of science is to make the universe, including man himself, understandable to mankind." Rabi further states that change is the common ingredient in these students' lives and that the "essence of the scientific spirit is to use the past only as a springboard to the future.[27] This means that the orientation of science teaching should be toward the scientific processes, and the concomitant scientific information which forms part of the discipline's history. A course in science approached in this manner would seem to stand the best chance for success, with success being measured by growth in the learner's capacity to think logically about and with the processes of science.

Several speakers at a conference held at Hope College, Holland, Michigan, October 20-21, 1967,[28] reached the following points of agreement

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[26] John M. Fowler, Physics Today, "The Interdisciplinary Curriculum," March, 1968.

[27] I. I. Rabi, Think, "Science for Non-Scientists," I.B.M., Jan.-Feb., 1968, Vol. 34, No. 1.

[28] Hope College Conference, Holland, Michigan, Oct. 20-21, 1967.

in explanation of the failure of various interdisciplinary programs in science:

1. Faculty background. There are simply not enough persons available with sufficiently broad academic backgrounds to teach such courses.

2. Faculty turnover. Once a faculty member who has taught such a course leaves, there is no one to replace him. Thus, continuity and curricular stability are lost.

3. Often a false image of the disciplines involved, e.g., physics and chemistry, is transmitted to the student. Since such great emphasis is given to areas of obvious overlap, the "purer" aspect of chemistry and physics suffers.

Reasons 1 and 2 would seem to create a defeatist cycle that would make the whole idea completely impractical; yet, this type of course keeps showing up in various college catalogs; those colleges, therefore, must believe there is some merit in them.

At Oklahoma City University, where this research was done, the non-science student is required to take 8 hours of science. This is usually done by taking a four-hour biology course and a four-hour conventional physical science course. These two courses were retained in the catalog in order to answer the second part of the newly revised science requirement--a laboratory course in science following the student's exposure to a new course called "Forum for Scientific Inquiry," which was taught for the first time in the fall semester, 1969. This course is for six hours credit and is required of all students, both science and non-science alike. The non-science student will take a second and purely optional course in a laboratory science.

The course Forum for Scientific Inquiry was a team effort of the entire science department, thus answering the first objection of the Hope College Conference findings. A great deal of effort was expended to meet the second objection. A third requirement built into the course was the necessity for the student actively to classify, hypothesize, verify, restructure, interpret, and synthesize.

Guidelines Used in Developing the Course
"Forum for Scientific Inquiry"

1. The course would be team-taught by appropriate members from all areas of science. Although this doesn't necessarily mean that the approach taken is inherently better than a single teacher's approach might be, it does mean that there will be available to the student expert advice upon a subject of his own choosing.

2. Forum for Scientific Inquiry would specify no particular set of facts of science as being necessary.

3. The lecture method would largely be abolished. More discussion, small group seminars, and independent library study would take its place.

4. The laboratory approach would be more broadly interpreted to mean those experiences necessary to provide the basic understanding of a particular problem that a student would be engaged in solving.

5. The text would become optional or discarded with a greater dependence upon articles and journals of interest.

Those planning the course believed that these guidelines would do much to overcome the objections previously determined at the Hope College Conference.

Structure of Forum for Scientific Inquiry

The new course "Forum for Scientific Inquiry" was designed in three major parts to coincide with the block diagram shown below which is the semester format all six general education courses in the College of Arts and Sciences now follow:

6 weeks	2 weeks	6 weeks (2) (2) (2)

The first six weeks of the semester science students met in formal session for two 1-hour periods per week at which time one of the ten professors teaching the course presented a topic around which that week's work was built. The topics chosen for the first six-week period included:

1. The Nature of Science
2. The Nature of Mathematics
3. Scientific Concepts of Broad Applicability
4. Science as a Human Endeavor
5. Science as a Creative Enterprise
6. Science and Responsibility

The six topics shown are not mandatory and will change from semester to semester dependent upon the particular group of professors involved in the course; however, the topics are mutually agreed upon by all involved before the semester begins. By this means new faculty members can easily be integrated into the group.

Following the one-hour presentation, students met in small groups with one professor (the entire six weeks) to discuss and research the topic of the week. Six paperback books, selected by the coordinating group of professors, were used to supplement the material; however, no test was given over any of this material. Students were asked to examine particular aspects of a problem, to find out what was known, then suggest how they might interpret these data to advance a solution or approach a better understanding of the problem. Twice a week these small groups met under the leadership of a fellow student with the professor serving only to suggest alternatives; he was never to present himself as an authority figure. Each professor had a varying degree of success; however, all of the professors involved in the course believed that the solutions and understandings of problems were achieved through inquiry by the students themselves. During the coordinating faculty sessions held weekly, several professors qualitatively expressed an increasing confidence in the students' capacity to think more logically as compared with their initial efforts.

Following the first six weeks, all freshman students were involved in a two-week, small-group seminar (maximum of 10) offered by various professors in the College of Arts and Sciences. Although the topic was chosen by a professor, a student was allowed to select the seminar that was of most interest to him. Notice that no effort was made to direct the student's activities toward a particular professor of science, or English, or any other professor, even though the student might be enrolled in the science or English course.

The last six weeks of the course were broken into three sessions of two weeks each. For two of the three sessions the student attended a seminar of his own choice dealing with topics that the class as a whole had selected as being relevant to them. Each of the ten professors took a particular topic for the three sessions. By this means, each student would come into contact with three different professors as he selected from among the various topics available to him. One of the three sessions was a mathematics laboratory and was the only common experience that all the students in the course had. Each student received a two-week introduction to the use of the computer in the mathematics laboratory. For four two-hour periods the student was given practical rudiments of programming, shown how a program was written, then permitted to carry out the programming and verification of a simple series of calculations.

The concluding effort of the student was to write a paper based upon one of the first six-week topics discussing the particular topic's value as applied to his own thinking. Grading in the course was based upon a three point system of honors credit, credit, and no credit. Much of the effort by the student was self-generated and, in general, this teaching technique was very well received by them. A qualitative outcome of this course appeared to be a much higher level of extra-class discussion carried on elsewhere. Many students reported holding dormitory and luncheon discussions of great length.

The ten faculty members involved in the course concluded that the approaches taken were sound and did result in greatly added interest and understanding by college students of the nature of science and the persons involved in scientific endeavors. Quantitative evaluation of the course was based upon an increase in the students' capacity to think logically, and the results of that investigation are shown in the following chapters.

CHAPTER 4

SELECTION OF THE SAMPLE AND ADMINISTRATION OF THE TESTS OF LOGICAL THINKING

Sample Selection

The 1969-70 freshman class of Oklahoma City University was chosen as the population from which both experimental and control samples would be drawn. Selection of this student group provided several advantages in that random assignment could be achieved with relatively little objection on the part of either students or faculty, achievement test scores were known for this group and past achievement test scores had been accumulated for similar freshman classes, not only at Oklahoma City University but also for all institutions of higher learning in the state of Oklahoma. Thus, should there be a correlation between achievement test scores and growth in logical thought certain statements could be made for a much larger population than the some 300 freshmen students at Oklahoma City University.

To select the experimental and control groups, slips numbered from one through three hundred were devised stating whether or not a freshman student would enroll in the course "Forum for Scientific Inquiry" first or second semester. These slips were then evenly divided and arranged in a stack according to a table of random numbers. Each freshman student, upon receiving an enrollment packet, also received the next slip on the top of the stack and his name was written on it. This slip showed whether he would or would not enroll in the course "Forum for Scientific Inquiry" and was presented to his adviser during the normal enrollment. These advisers had previously agreed to this procedure and with few exceptions enrolled the student according to the instructions given. Those students not enrolled in the first semester science course became the control group. Excluded from the sampling procedure were the students of the nursing school and a few members of the School of Music who could not arrange their schedules according to this procedure. Although this technique did not assure complete randomization, the vagaries of enrollment gave additional assurance that both samples were reasonably representative of the freshman class.

Research Design and Testing of the Samples

During the first week of the 1969 fall semester, 143 first-semester freshman college students, evenly divided between the experimental and control groups, were tested by this investigator and six persons from the Science Education Center of the University of Oklahoma, all of whom had previously gained broad experience with Piagetian testing of students of all ages and stages of logical thought. The tasks consisted of conservation of volume, reciprocal implication, elimination of contradiction, separation of variables, and exclusion. At the conclusion of the semester the same tasks were again administered with 131 students completing the post-test phase.

Each of the tasks was scored from 1 to 4 depending upon the student's level of achievement as determined by the investigator:

Pre-concrete Operations	II	0
Concrete Operations	IIa	1
	b	2
Formal Operations	IIIa	3
	b	4

The five task scores were summed up. By this procedure, a statistical mean was obtained that would demonstrate growth by the entire test group, even though some members of the group may have moved only within a particular category of operations.

Every effort was made to insure a neutral attitude by the observer. With the exception of a few of the students known by the investigator to be in the experimental course, no information was obtained by the person administering the tasks as to the status of the person being tested. During the course no specific mention of any of the principles involved in the five tasks was made.

The basic research approach for the study is a randomized experimental group-control group design with a pre-test of all subjects and a post-test at the conclusion of the one-semester course of those subjects who had not achieved Piaget's stage of formal operational thought. The design could be pictured according to this configuration:

		Pre-test	Post-test
Experimental	East		
	West	dependent variable growth in logical thought	
Control	East		
	West		

The data for each statistical average were grouped into the appropriate cell as shown in the above design, then subjected to analysis of variance calculation to yield statistics on the variance between all cells as well as the variance between the two larger groups. F-tests were calculated on the variance obtained in order to determine which variances were significant at the 0.10 level.

Growth in logical thought in terms of the statistical mean for each of the two groups was compared. Should the value arrived at by means of the F-test be less than the 0.10 level of significance, the null hypothesis must be rejected and the alternative hypothesis accepted.

Data processing consisted of classification by geographical region, size of high school, tabulation of number and kind of science courses, as well as the results obtained from the testing procedures.

Testing of the Samples for Randomness

Comparisons of the two groups were made using the composite ACT[29] and SAT[30] scores and the pre-test Piagetian data. The results of this comparison are shown in Table 4-1.

Although the females outnumber the males in these samples by 1.4:1, this is representative of the normal distribution of the freshman population of O.C.U. Notable also is the higher average Piagetian score by the males in both samples; however, this may be explained in terms of the normal social transmission of values. Males are expected to be more aware of science; thus, they may receive greater exposure to the kinds of

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[29]American College Testing, Iowa City, Iowa.

[30]College Entrance Examination Board, Princeton, New Jersey.

processes that result in enhanced capacity for logical thought.

When the average pre-test Piagetian scores for the two samples completing the post-test phase were compared, no significant difference was found between the two samples as indicated by an F-ratio of less than .13. Composite ACT scores were 22.3 for the experimental group and 22.6 for the control group while SAT verbal scores favor the control group by 10 points, i.e., 459 to 469.

TABLE 4-1

Comparison of the Samples on Pre-test Piagetian Data

	Experimental		Control	
	n	Piagetian Score	n	Piagetian Score
Females	42	9.76	36	9.03
Males	27	12.44	26	13.19
Males and Females	69	10.81	62	10.77
Total of Both Samples		n = 131	P = 10.79	

In terms of the operationally defined stages of formal, post-concrete, and concrete thought, the percentages are shown in Table 4-2:

TABLE 4-2

Level of Thought		Experimental	Control
	Score	Per Cent	Per Cent
Formal	(14 - 18)	20	24
Post-concrete	(11 - 13)	33	21
Concrete	(10 or less)	47	55

Notice that the control group exhibited a slightly higher number of formal and concrete operational stage students. Should a student score 14 or more points on the five tasks, he was judged as definitely being at the formal operational stage since he scored at least 3 points on the tasks for which four points were possible. If a student scored an average of 2 points or less on each of the five tasks, he was judged to be at the concrete stage of operations. Those students scoring more than 10, but less than 14 points, were judged to be moving from the concrete stage to the formal stage of thought.

The conclusion to be derived from the previous data is that no real difference existed between the two samples prior to the treatment; therefore, any difference after the treatment would be caused by the treatment itself.

Record of Testing

Each student was graded from 0 through 4 using the form shown in Appendix II as a guide; however, in no instance were the persons conducting the tests bound to this schema, though each agreed that this was a reasonable representation of the appropriate response.

Additional information about the student was gained through the use of a questionnaire which is shown in Appendix III.

CHAPTER 5

PRESENTATION AND INTERPRETATION OF THE DATA

The data collected in this investigation were intended to provide a means of comparing the two groups, Experimental and Control, not only in terms of experiences in science and scholastic capabilities, but also to permit the study of a variety of relationships which are of great concern to educators today.

The initial discussion will consider the effectiveness of the course "Forum for Scientific Inquiry" in promoting logical thought processes among entering college freshmen. The remainder of the chapter will be devoted to comparisons of the capabilities of entering college freshmen against various criteria.

Evaluation of the Effect of the Course Forum for Scientific Inquiry

The major hypothesis asks whether concrete operational students who participated in an inquiry-oriented course in science exhibit greater growth in their capacity to think logically than does a like group who do not participate in such a course.

This hypothesis was evaluated by comparing the pre-test and post-test results obtained when the experimental and control groups were tested on five Piagetian tasks designed to determine the increase in the students' capacity to think logically. The treatment instrument was the newly devised science course "Forum for Scientific Inquiry." The pre-test data for the two groups showed no significant difference between the two groups as shown by various critera. Table 5-1 provides a comparison of the two groups after the Experimental group was exposed to the new course. This comparison shows the relative movement of students within the two groups in terms of growth of logical thought processes.

TABLE 5-1

A Comparison of the Growth in Logical Thought Processes of the Two Groups After the Course "Forum for Scientific Inquiry"

Group	Stage	Pre-test		Post-test		Net Gain		
		Females	Males	Females	Males	Females	Males	Total
Experi-mental	Formal	4	11	14	16	10	5	15
	Post-Concrete	14	6	17	8	3	2	5
	Concrete	24	10	11	3	-13	-7	-20
Control	Formal	4	14	7	17	3	3	6
	Post-Concrete	6	6	11	7	5	1	6
	Concrete	26	6	18	2	-8	-4	-12

The data in Table 5-1 show a net gain for the experimental group that resulted in 15 students moving into the formal stage of thought compared with 6 for the control group. The post-concrete gain was respectively 5 and 6 with the experimental group showing a net movement of 20 out of this category compared with 12 for the control group, a net gain of more than 50 per cent for the group exposed to the influence of the new course "Forum for Scientific Inquiry." Another comparison in terms of the mean

Piagetian scores for the two groups is shown in Table 5-2.

TABLE 5-2

Pre-test and Post-test Piagetian Mean Scores

for Both Experimental and Control Groups

Group	Experimental		Control	
	n	Piaget Score	n	Piaget Score
Pre-test	69	10.81	62	10.77
Post-test	69	12.32	62	11.14

After obtaining individual pre-test-post-test differences and summing them up for each group, an F-ratio of 6.24 was obtained. This value is significant in favor of the test group at the .001 level of confidence; therefore, the null hypothesis must be rejected and the alternative hypothesis accepted.

The Forum for Scientific Inquiry course was designed to bring about a change in students' capacity to think logically; thus, in the short time of one semester students did begin to accept the responsibility for their learning experiences; they did begin to contribute more mature views and judgments to the questions being evaluated. This effect was felt when the two groups were evaluated at the conclusion of the course as shown by the net increase in scores on the five Piagetian tests. The conclusion that is reached about the course "Forum for Scientific Inquiry" is that it did provide many opportunities for questioning, hypothesizing, verifying, restructuring, interpreting, synthesizing, and predicting; thus, students became more logical in their thought and probably as the result of these opportunities.

Piaget has pointed to the influence of the social milieu as well as experience. A stated purpose of the experimental course was to let the student evaluate the importance of science in his life, reach some conclusions as to it's importance in his future as well as show that science is an endeavor carried on by people who are little different than himself. As has been pointed out, many opportunities were provided whereby the student could gain experience in casting hypotheses, then evaluating them. Courses such as the one taught at Oklahoma City University must be expanded to include not only all the potential collegiate population of the nation, but also all students at the secondary level in all areas of study if the full powers of the rational mind are to be achieved.

The Relative Capability of the Entering College Freshman to Think Logically

The data in Tables 5-3 and 5-4 are presented without discussion. The cumulative data of Tables 5-5, 5-6, 5-7, 5-8, and 5-9 are discussed in detail together with accompanying graphs intended to further enhance their meaning.

Tables 5-3 and 5-4

All scholastic scores, as well as other pertinent data gathered from the student, were verified from transcripts provided by the high schools. The headings used at the top of the columns are fairly self-explanatory with a few exceptions. Student Number is only for individual identification of the student. Age is chronological age to the nearest birthday. Major indicates the declared major where clearly identified in the student's mind. M, NS, and C under the heading ACT SCORES identifies the Mathematics, Natural Science, and Composite parts of that score. The letters m and v following the three digit SAT SCORES stand for the mathematics and verbal portions of the score. Size Graduating Class is coded according to the following schema:

A	0.........25 students
B	26.........50
C	51........150
D	151........300
E	301........500
F	501......1,000
G	more than 1,000

B, C, and P under the heading Science Courses Taken stand for those Biology, Chemistry, and Physics courses taken in high school. I, II, III, IV, V, and Total designate the pre-test and post-test scores for each of the individual Piagetian tasks. The letter a identifies the pre-test score and b the post-test score. The cumulative scores for these five tests are shown under the Total heading.

Tables 5-5 through 5-10

Tables 5-5 through 5-10 present the raw data of Tables 5-3 and 5-4 in various ways to show the characteristics of the student who comes to OCU as a freshman with the view of determining the more significant parameters by which judgments of the student's capacity to think logically may be made.

TABLE 5-3

Experimental Group

Student No.	Age	Major	ACT Score (SAT Verbal)			Size Grad. Class	Science Courses Taken			Piagetian Tasks I		II		III		IV		V		Total	
			M	NS	C		B	C	P	a	b	a	b	a	b	a	b	a	b	a	b
Females																					
7	18	Psy	22	22	24	D	X			2	2	2	2	2	2	2	0	2	1	10	7
11	17	Chem	32	30	30	D	X			2	2	4	4	3	3	4	4	4	4	17	17
12	18		27	25	27	D	X	X		2	2	2	2	2	3	3	4	1	4	10	15
22	17	Math	32	32	32	E	X	X		2	2	4	4	2	2	2	4	4	4	14	16
36	17	Educ	22	27	25	C	X	X		2	2	2	3	1	2	2	2	4	4	11	13
37	17	Art	376m	662v		D	X			2		2		2		4		3		13	-
44	16	Math	33	28	27	F	X	X	X	0	2	4	4	3	4	3	4	4	4	14	18
47	18	Spch	27	25	21	D	X			2	1	2	2	1	2	3	3	1	2	9	10
53	17	Phil	28	29	28	F	X			2	1	2	2	3	2	2	4	2	2	11	11
55	19	Nurs	18	19	19	D	X	X		2	2	1	4	1	1	1	1	4	4	9	12
56	17	Biol	614m	526v		E	X	X	X	2	2	3	2	3	3	2	3	3	4	13	14
59	17	Math	26	24	24	D	X			2	2	1	2	1	3	0	1	2	3	6	11
63	17	Jour				E	X			1	1	1	0	0	1	0	3	2	4	4	9
66	18	Soc	22	29	26	C	X	X		2	2	2	2	3	3	3	2	2	2	12	11
69	18	Chem	34	23	26	D	X	X	X	0	2	3	4	2	3	3	3	1	3	9	15
70	18	Biol	23	17	21	E	X	X		2	2	4	4	2	3	4	2	3	1	15	12
73	18	Educ	34	33	30	C	X	X		0	2	4	4	2	4	1	3	1	4	8	13
74	18	Biol	22	17	30	F	X			2	0	1	2	2	2	1	1	1	2	7	7
82	18	Educ	8	9	11	F	X			0	2	2	3	1	1	3	3	4	4	10	13
83	17	Art	26	14	20	D	X			2	2	3	2	2	2	2	3	1	1	10	10
84	18	Engl	26	17	23	E	X		X	2	2	4	2	1	1	2	4	4	4	13	13

TABLE 5-3 CONT'D.

Student No.	Age	Major	ACT Score (SAT Verbal)			Size Grad. Class	Science Courses Taken			Piagetian Tasks											
										I		II		III		IV		V		Total	
			M	NS	C		B	C	P	a	b	a	b	a	b	a	b	a	b	a	b
Females (cont'd.)																					
87	18	Biol	380m	315v		D	X			2	2	1	2	1	2	1	1	2	4	7	11
88	18	Educ	15	18	19	E	X			2	2	2	2	3	4	2	4	1	4	10	16
89	21	Mus								2	2	2	2	1	1	3	3	3	4	11	12
90	19	Spch	22	19	20	F	X			2	2	3	3	1	2	2	2	1	4	9	13
91	21	Mus	15	25	22	E	X	X		2	2	1	4	2	3	4	3	4	4	13	16
95	18	Educ	25	29	27	F	X	X	X	0	2	4	4	4	3	2	4	1	2	11	15
96	17	Psy	22	17	20		X	X		0	2	1	2	1	1	4	4	4	2	10	11
98	19	Art	6	13	13	E	X			2	2	1	1	1	0	1	1	1	4	6	8
99	17	Chem	554m	367v		A			X	2	2	2	3	1	3	3	4	3	3	11	15
102	18	Sox	20	21	20	E	X			2	2	1	1	4	2	3	2	1	1	11	8
105	18	Psy	21	16	19	F	X		X	0	2	1	2	1	0	1	0	1	2	4	6
106	18	Educ	22	23	22		X	X		2	2	3	4	4	4	2	2	1	4	12	16
108	18	Engl	18	23	22	C	X			0	2	2	2	1	3	2	4	1	4	6	15
112	18	PoSc	18	12	18	F	X			2	2	2	2	2	2	1	2	1	0	8	8
113	18		19	17	20		X			2	2	1	2	1	3	3	2	1	2	8	11
120	18		30	26	27	F	X	X		2	2	2	1	2	3	3	4	2	0	11	10
121	18	Engl	25	26	24	F	X	X		2	2	2	2	1	1	3	4	3	2	11	11
122	20	Mus	20	26	23	C	X	X		2	2	2	2	2	4	3	2	2	3	11	13
125	18	Hist	17	16	18	F	X			1	1	2	2	1	4	2	2	1	2	7	11
137	19	Engl	551m	541v		E	X			1	2	1	2	2	3	4	4	1	4	9	15
141	19	Rel	22	27	26		X			2	2	2	1	1	2	4	4	4	1	13	10

TABLE 5-3 CONT'D.

Student No.	Age	Major	ACT Score (SAT Verbal) M	NS	C	Size Grad. Class	Science Courses Taken B	C	P	Piagetian Tasks I a	I b	II a	II b	III a	III b	IV a	IV b	V a	V b	Total a	Total b
Females	(cont'd.)																				
145	18	Art	24	19	22	F	X			2	2	0	1	1	4	1	3	1	4	5	14
148	17	Educ	16	19	17	F	X			0	2	1	3	1	3	1	1	1	2	4	11
Males																					
4	17		25	32	26	D	X			2	2	4	4	4	4	4	4	4	4	18	18
10	18		682m	584v		D	X	X		2	2	4	4	3	4	4	4	1	4	14	18
19	17	Math	23	23	27	C	X	X	X	2	2	4	4	3	3	4	4	4	4	17	17
38	17	Phys	34	31	29	F		X	X	2	2	4	4	4	4	4	4	4	4	18	18
58	18	Engl	25	27	27	D	X	X		2	2	4	4	4	4	4	4	4	4	18	18
61	18	Biol	596m	387v			X	X	X	2	1	2	4	2	2	3	4	3	4	12	15
75	18	PMed	490m	387v		G	X			2	2	2	2	2	1	1	2	1	4	8	11
78	18		23	26	25	C	X	X		2	2	4	4	3	3	4	4	4	4	17	17
85	23	Psy	609m	546v		G		X	X	2	2	3	3	4	4	4	4	3	3	16	16
86	19	Biol	353m	381v		F	X	X		1	2	2	2	2	2	2	2	4	1	11	9
94	18		15	20	18	F	X			0	2	1	3	1	2	3	3	4	4	9	14
104	23	Soc	12	21	16	A	X		X	2		2		3		3		3		13	-
110	18		12	10	14	F	X			1	2	1	2	2	3	2	2	3	3	9	12
111	18	Psy	20	26	23	C	X	X	X	2	2	4	4	3	3	3	3	4	4	16	16
115	20	PMed	5	1	7	C	X	X	X	2	1	2	2	1	3	2	1	1	2	8	9
116	18	Engl	28	19	24	F	X	X	X	2	2	3	4	3	2	3	3	2	2	13	14
117	18	Phil	30	28	26	F	X		X	2	2	4	4	4	4	4	4	4	4	18	18
118	18		26	26	27	E	X	X		2	2	2	3	3	3	3	4	4	3	14	15

TABLE 5-3 CONT'D.

Student No.	Age	Major	ACT Score (SAT Verbal)			Size Grad. Class	Science Courses Taken			Piagetian Tasks											
										I		II		III		IV		V		Total	
			M	NS	C		B	C	P	a	b	a	b	a	b	a	b	a	b	a	b
Males (cont'd.)																					
123	20	PoSc				F				0	1	2	2	3	3	4	4	1	2	10	12
126	20		17	20	17		X		X	2	2	3	4	3	2	2	3	3	1	13	12
131	19	Educ	501m	397v		F	X			0	0	2	3	2	4	1	4	2	4	7	15
138	18	Law	26	25	24	B	X	X	X	2	2	4	4	4	4	4	4	3	3	17	17
139	18	Bus	26	23	23	E	X			2	2	2	3	3	4	2	2	2	2	11	13
140	19	Rel	24	25	25	F	X	X		0	2	2	2	4	4	4	4	3	4	13	16
143	18	Biol	25	19	23	G	X	X	X	0	2	1	4	1	2	1	2	4	1	7	11
144	18	Educ	415m	425v		F	X			2	2	1	2	1	4	2	3	1	1	7	12
146	19	Rel	25	22	22	F			X	2	2	1	1	1	2	2	4	2	4	8	13
147	22	Bus				G	X			2	1	2	3	1	1	1	3	1	1	7	9
149	20	Educ	271m	456v			X			2		2		3		2		3		12	-

TABLE 5-4

Control Group

Student No.	Age	Major	ACT Score (SAT Verbal) M	NS	C	Size Grad. Class	Science Courses Taken B	C	P	Piagetian Tasks I a	I b	II a	II b	III a	III b	IV a	IV b	V a	V b	Total a	Total b
Females																					
1	18	Bus	26	27	24	F	X			2		2		2		2		1		9	-
5	18	Mus	23	25	24	F	X	X		2	2	2	3	1	1	1	2	3	3	9	11
13	18	Mus	446m	367v		E	X			2	1	2	2	2	1	2	1	1	4	9	9
14	17	PoSc	31	31	29	C	X			1	2	3	2	3	2	4	4	3	1	14	11
16	17	Biol	27	25	26	F	X	X		2	2	1	1	2	3	3	4	4	4	12	14
21	18	Soc	521m	413v		F	X	X		2	2	2	2	2	0	1	2	2	3	9	9
23	18	PMed	24	21	22	D	X	X	X	1	2	1	2	2	2	3	3	1	2	8	11
25	18	Mus	527m	466v		F	X			2		1		1		2		1		7	-
26	18	P.D.	14	18	15	F	X			2	2	2	1	1	1	2	2	1	1	8	7
27	18	Mus.	17	25	22	F	X			0	2	1	1	2	1	3	3	3	1	9	8
30	17	Math	27	14	20	A	X	X		0	2	2	1	1	1	1	2	1	1	5	7
31	18	Mus.	14	19	20	D	X			0	1	2	2	1	1	2	2	3	2	8	8
32	18	Soc.	20	19	21	C	X	X		1	1	2	0	1	2	3	3	1	1	8	7
33	18	P.D.	28	15	19	F	X	X		2	2	4	2	2	2	3	2	3	1	14	9
39	17	Bus.	361m	361v		E	X			2	1	2	3	2	1	3	2	1	4	10	11
41	18	PoSc.	15	16	15	F	X			1		0		2		3		2		8	-
42	19					F	X			0	0	2	1	2	2	2	1	1	1	7	5
45	18	Mus	31	28	30	F	X	X		2	2	4	4	1	3	2	2	1	4	10	15
46	18	Mus	25	28	27	D	X			1	2	2	2	1	2	1	1	1	2	6	3
48	18	Bus.	14	22	21	E	X		X	1		1		1		1		1		5	-
49	18	Biol.	609m	635v		E	X	X	X	1	2	3	4	2	4	3	4	2	2	12	15

TABLE 5-4 CONT'D.

Student No.	Age	Major	ACT Score (SAT Verbal) M	NS	C	Size Grad. Class	Science Courses Taken B	C	P	Piagetian Tasks I a	I b	II a	II b	III a	III b	IV a	IV b	V a	V b	Total	
51	18	Bus	652m	413v		D	X	X	X	2	2	4	4	0	2	2	4	2	2	10	14
52	18	Mus	410m	538v		F	X	X		2		2		1		2		1		8	-
54	18	Mus	17	19	19	D	X	X		2	1	2	1	1	1	2	4	2	4	9	11
57	18	Soc	22	21	24	B	X	X		2	2	2	2	3	2	2	3	2	3	11	12
60	18	Engl	21	21	21	C	X	X		2	2	1	2	1	2	3	4	1	2	8	12
62	17	Soc				E	X			2	2	1	1	1	0	2	1	2	1	8	5
67	17	Spch	25	31	29	D	X			2	2	4	4	4	4	3	3	3	3	16	16
71	17	Spch	20	16	20	F	X	X		2	2	1	1	0	0	0	1	0	4	3	8
72	18	Engl	12	25	22	F	X			2	2	1	1	1	1	1	0	0	3	5	7
76	18	Mus	24	26	27	D	X			2	2	2	2	2	2	2	3	2	2	10	11
79	18		22	15	16	F				2	1	2	0	1	1	3	3	3	1	11	6
107	18	Mus	24	13	15	E	X			0	2	3	3	1	2	1	2	1	3	6	12
109	18	Lang					X			0	1	1	1	1	0	2	1	2	0	6	3
128	18	Biol	16	22	17	B	X	X	X	2	2	2	1	2	0	1	1	1	0	8	4
129	22	Psy	510m	405v		E	X	X		2		1		3		3		4		13	-
130	19	Educ	21	21	19	C				2		2		2		3		1		10	-
132	19	Mus	1	15	11	D	X			1	2	2	1	1	0	2	4	1	1	7	8
133	18	Biol	27	29	27	C	X	X		2	2	3	4	3	4	3	4	3	4	12	18
134	19	Soc	25	23	24	A	X	X		2	2	2	2	3	2	3	3	0	4	10	13
135	19	Engl	25	27	26		X	X		2	2	2	4	2	3	2	3	4	4	12	16
142	21	Mus	21	22	24	B	X			2	2	1	1	2	2	1	2	1	4	7	11

TABLE 5-4 CONT'D.

Student No.	Age	Major	ACT Score (SAT Verbal)			Size Grad. Class	Science Courses Taken			Piagetian Tasks											
										I		II		III		IV		V		Total	
			M	NS	C		B	C	P	a	b	a	b	a	b	a	b	a	b	a	b
Males																					
2	18	Bus	461m	410v		E	X	X		2	2	4	4	2	2	1	2	4	3	13	13
3	18	Mus	25	18	22	D	X			2	2	4	2	1	4	2	3	1	2	10	13
9	17	Bus	554m	545v		C	X	X		2	2	4	4	3	3	4	4	4	2	17	15
15	18	Mus	502m	446v		D	X	X		1	1	3	2	2	1	3	3	3	2	12	9
17	27	Bus	455m	326v		D	X	X	X	0	2	4	4	4	3	3	4	1	4	12	17
18	18	Bus	19	14	13	E	X			2	2	3	3	4	4	4	3	4	2	17	14
20	42	Jour								0	0	4	4	4	4	4	4	4	4	16	16
28	17	PoSc	20	17	22	D	X			2	2	1	2	1	3	1	4	1	3	6	14
34	17	Spch	473m	476v		E	X	X		1	2	2	1	1	2	2	4	3	3	9	12
35	17	Bus	426m	414v		D	X	X		2		2		1		3		3		11	-
40	21		399m	605v						0	2	3	2	1	2	4	2	4	3	12	11
43	18	Spch	472m	414v		D	X	X		2		3		2		2		3		12	-
50	18	Chem	28	32	27	E	X	X	X	2	2	4	3	3	3	4	3	4	3	17	14
64	18	PoSc	32	31	28	F	X	X	X	2	2	4	4	4	4	4	4	2	2	16	16
65	19	Bus	627m	584v		C	X	X	X	2	2	4	4	3	3	4	4	4	4	17	17
68	18	Spch	29	30	28	D	X	X		2	2	4	4	3	3	4	4	4	4	17	17
77	18		26	18	23	D				2	1	2	1	3	2	4	4	1	3	12	11
80	18	Rel	29	29	29			X	X	2	2	4	4	3	4	3	4	2	4	14	18
81	18	Law	25	15	21	F	X			2	2	4	4	2	2	3	3	4	4	15	15
92	18	Art	26	27	24	E	X			2	2	4	3	4	4	2	3	2	4	14	16
93	17	Bus	25	15	16	F	X			2	1	2	2	1	3	2	3	2	2	9	11

TABLE 5-4 CONT'D.

Student No.	Age	Major	ACT Score (SAT Verbal) M	NS	C	Size Grad. Class	Science Courses Taken B	C	P	Piagetian Tasks I a	I b	II a	II b	III a	III b	IV a	IV b	V a	V b	Total a	Total b
Males (cont'd.)																					
97	19	Ph Ed	7	12	9	E	X			0	2	1	3	0	0	0	3	0	0	1	8
101	17	Rel	26	30	25	F	X	X	X	2	2	4	4	4	3	3	3	2	4	15	16
103	18		26	29	25	F	X	X		2	2	4	4	4	4	4	4	4	4	18	18
114	18		271m	630v		D	X		X	2	2	3	3	4	4	4	3	4	2	17	14
119	18	Phys	23	28	22	B	X	X	X	2	2	2	4	2	4	3	3	4	4	13	17
127	18	PMed	15	25	20	F	X			2	2	2	2	2	3	2	3	2	2	10	12
136	19	Spch	553m	469v		G	X			2	2	3	4	2	4	4	3	3	3	14	16

TABLE 5-5

Mean Piagetian Scores of

Experimental vs Control Group

	Experimental		Control		Average	
	n	Piaget Score	n	Piaget Score	n	Piaget Score
Female	43	9.84	43	8.95	86	9.40
Male	29	12.44	28	13.07	57	12.80
Average	72	10.88	71	10.56	143	10.74

These data have been discussed in Chapter 4 with respect to significant differences. The average score of 10.74 for all students, however, clearly indicates that a great number of students are still in the concrete stage of thought on these tasks. The mean score for females of 9.40 leads to the conclusion that they do not possess the thought processes required to properly evaluate a problem, isolate appropriate variables, and reach sound conclusions. Although the males in these groups exhibit a greater understanding of the thought processes required to explain the tasks, their scores indicate that their ability to achieve Piaget's highest level of operational thought is incompletely developed. Although these values are considered for the 141 students, 12 of whom did not complete the post-testing, the values remain much the same for the 131 students considered in Table 4-1.

TABLE 5-6

A Comparison of Experimental
and Control Groups by
Levels of Operation

Piaget Score		Experimental No.	Experimental Per Cent	Control No.	Control Per Cent	Total No.	Total Per Cent	Total Per Cent
14-18	Female	4	5	3	4	7	5	22
	Male	11	15	14	20	25	17	
11-13	Female	16	22	7	10	23	16	27
	Male	8	11	8	11	16	11	
0-10	Female	24	33	32	46	56	40	51
	Male	10	14	6	9	16	11	
Total		73	100	70	100	143	100	100

Table 5-6 provides a clear indication of the number of concrete versus formal operational students. A student who scored 2 points or less for each of the five tasks was considered to definitely be at the concrete stage of thought. Should a student score 14 or more points on the five tasks, he was judged as definitely being at the formal stage of logical thought. The score of two on task one and a score of three, which is indicative of formal operational thought, on each of the four remaining tasks leads to this value. Those students who scored from 11-13 were probably beyond the concrete stage of thought. As can be seen from Table 5-6, 51 per cent of all the students initially tested were definitely at the concrete stage of thought with another 27 per cent possibly at this stage.

The implications of this table are that only one in four of the students who matriculate to Oklahoma City University are definitely able to fully exercise all the capabilities required of the final stage of formal thought.

TABLE 5-7

Pre-test Piagetian Scores Less Than Three

Versus Individual Tasks

Score	I			II			III			IV			V		
	E	C	To	E	C	To	E	C	To	E	C	To	E	C	To
0	14	10	24	1	1	2	1	3	4	2	2	4	0	4	4
1	5	10	15	18	14	32	26	24	50	13	11	24	26	23	49
2	54	50	104	30	27	57	19	23	42	21	22	43	12	15	27
	73	70	143			91			96			71			80

Table 5-7 considers the number of students in the Experimental (E) and Control (C) groups scoring less than 3 on a particular task. Since the maximum score on Task I was 2, all students are included in this evaluation. Tasks II through V exhibit varying totals dependent upon the student's capacity to consider the logic of the particular task.

Task I relates to conservation of volume and shows that twenty-four of one hundred forty-three (17 per cent) tested did not conserve quantity, while another fifteen did not conserve volume. Thus, thirty-nine (27 per cent) of those tested were at the lowest concrete operational stage or less as shown by this task.

Task II involving the student in the problem of reflection of a ball and the necessity to relate incident and reflected angles would seem to have been relatively easy; however, it was not since the number of students falling in the concrete operational category was second only to the problem of density. Many of the students recognized an angular relationship as existing, but did not equate the two angles in any way.

Task III involving floating and sinking objects was apparently the most difficult for students to consider logically because of the necessity to relate weight and volume in some meaningful way. More than one-third of the students did not relate weight and volume. Typical of this kind of response was a recognition of weight. There was also recognition of the role of volume in many cases, but seldom was there a proportionality expressed. Of the entire group of 143 students tested, less that number who were judged to be formal operational, only four students were able to verbalize a rule to distinguish the difference between objects that would tend to float and those that tend to sink.

Task IV, the separation of variables, gave evidence that 50 per cent of entering college freshmen students could not recognize the action of a potential variable and find a way to prove the action of that variable.

Task V requires that the student recognize relevant versus irrelevant variables. More than one-third of the students tested could not eliminate potential variables of no consequence, while another 18 per cent were not able to separate variables but did order the effects of weight.

TABLE 5-8

Piagetian Scores Versus Science Courses Taken in High School

Group	Piaget Score	Biology Chemistry Physics	Biology Chemistry	Biology	Total
Females	14-18	1	3	3	7
	11-13	5	12	6	23
	0-10	6	14	36	56
Males	14-18	12	7	6	25
	11-13	6	6	4	16
	0-10	3	1	12	16
Total Avg. Piaget Score		33 (12.85)	43 (11.72)	67 (9.35)	143 (10.74)

An evaluation of Table 5-8 with both groups combined clearly indicates that, although the average Piagetian score for the composite Physics group is only two points above the average of 10.74 for all students, there is an abnormally high number of students who have achieved the highest stage of logical thought, particularly among the males. This comparison shows that 12 of 21 males scored sufficiently high to be considered formal operational; however, only 1 of 12 females who took Physics did so. The effect of a Physics course upon female logical thought patterns appears to be negligible when compared with all female students who took a science course in high school. Among all the males, 25 of 57 are classified as formal operational, while only 16 of this number could definitely be classed as concrete learners. Among all the females, only 7 of 86 could definitely be classed as formal operational, while 56 of this number fell in the concrete operational category.

TABLE 5-9

Percentage Science Enrollment by Size of

High School Graduating Class

Size of Class	Number of Students	Per Cent of Males		Per Cent of Females	
		Chemistry	Physics	Chemistry	Physics
A-C	0 - 150	87	87	72	8
D-E	151 - 500	54	18	34	17
F-G	Over 500	40	40	41	14

Of the 143 students involved in the pre-test, a total of 43 (30 per cent) took Chemistry as their last high school science course. Another 33 (23 per cent) continued after chemistry to take Physics; however, only 12 of 86 (13 per cent) females continued to this latter course, while 21 of 57 (35 per cent) males did so.

Upon closer examination of Table 5-9, one finds that in the small high schools a high percentage (87 per cent) continued beyond Biology to Chemistry and Physics. In the larger high schools only 40 per cent of the male Biology students continued beyond Biology; however, that 40 per per cent did continue from Chemistry into Physics.

Among the females going beyond Biology, one sees that a similar relationship holds for Chemistry enrollment; however, there is a drastic drop in Physics enrollment, particularly among females in the small schools.

TABLE 5-10

Significance Levels for Certain Criteria Using

Samples Within the Student Population

Criteria Compared	Piagetian Score	Piagetian Score Compared Against	F Score	Significance
Size High School				
A	11.00	10.74	.14	Not Significant
B	11.20	10.74	.25	Not Significant
C	12.00	10.74	1.25	Not Significant
D	11.06	10.74	.37	Not Significant
E	10.68	10.74	.08	Not Significant
F	10.13	10.74	1.00	Not Significant
G	10.40	10.74	.25	Not Significant
College of Enrollment				
Arts & Science	10.70	10.74	.18	Not Significant
Business	11.38	10.74	1.16	Not Significant
Music (All Students)	9.00	10.74	3.76	Significant
Females Only	8.75	9.57 (All females except Music School)	2.95	Significant
Region				
Oklahoma	10.67		.85	Not Significant
East	11.34			

Table 5-10 presents the data for certain groups of students within the student population tested. The Piagetian score of 10.74 was the average score for all students taking the pre-testing.

The major difference among Piagetian scores versus size high school seems to be created by the influence of an abnormally high percentage of males in the C size high school who have had more experience with the logical thought processes than their fellow students. Also, the schools of F size seem to have done a very poor job of moving students toward more logical thought processes. Otherwise, there is little indication that school size has a great bearing upon the capacity to think logically.

When Piagetian scores are considered versus the college of enrollment, a slight difference exists in favor of the Business School student with the students of the Music School showing a very low score that is statistically significant (at the .0005 level). When the girls of the Music School were compared with the other females of the test population, significance at the .005 level was again obtained. Noticeable in this computation was the very restricted standard deviation of 2.00 versus 3.05 for the remaining members of the female population.

With the test and control groups combined, there were 31 students from east of the Mississippi, primarily from the New York and New Jersey area, and 95 students from Oklahoma. When those two groups of students were compared for the significant difference between their average Piagetian scores, geography was found not to be an important factor in whether or not a college student has reached the formal operational level.

<u>College Aptitude Test Scores As Predictors of Logical Thought</u>

The major emphasis placed upon college aptitude tests such as the Scholastic Aptitude Test (SAT) and the American College Test (ACT) by college and university admissions boards would suggest that these are good predictors of a student's capacity to think logically. Graphs 5-I, 5-II, 5-III, 5-IV and 5-V show the relationships between the various categories of these tests and the Piagetian test. The Pearson Product-Moment correlation coefficient (r) was obtained for each set of values using the z scores obtained for that particular set. Where a group within a particular set was chosen for study, new z scores were calculated using that particular n and standard deviation.

Piagetian Versus ACT Scores

<u>Graph 5-I</u> shows the Piagetian-Natural Science values plotted and the corresponding r values. When the scores of the students who took the ACT were plotted against their Piagetian scores, an r = .49 was obtained; however, when only those students who scored the ACT average of 22 or less were considered, an r value of .06 was obtained.

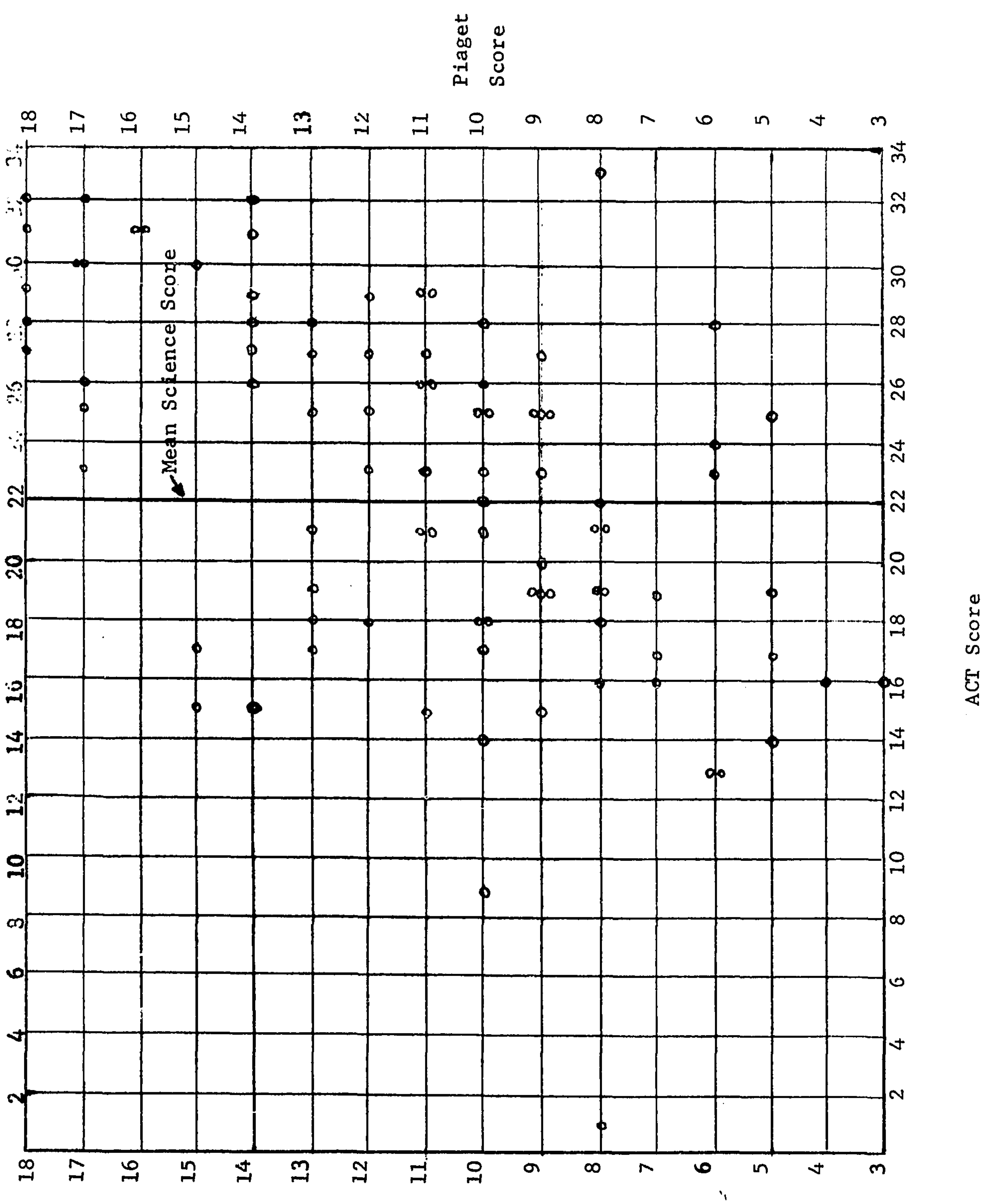
<u>Graph 5-II</u> shows the Piagetian-Math correlation with its corresponding r = .43 for all students taking the ACT. Again, when only the ACT scores of 22 or less were considered, r = .26 was obtained.

<u>Graph 5-III</u> shows the Composite ACT-Piagetian plot, r = .43 for all students and an r = -.05 for those students who scored 22 or less.

<u>Graphs 5-IV and 5-V</u> show the plots for those students who took the SAT math and verbal exams. Respective r values of .16 and .43 were obtained. No calculations of r values were made for those students scoring at the average or less on the SAT tests because of the small number involved.

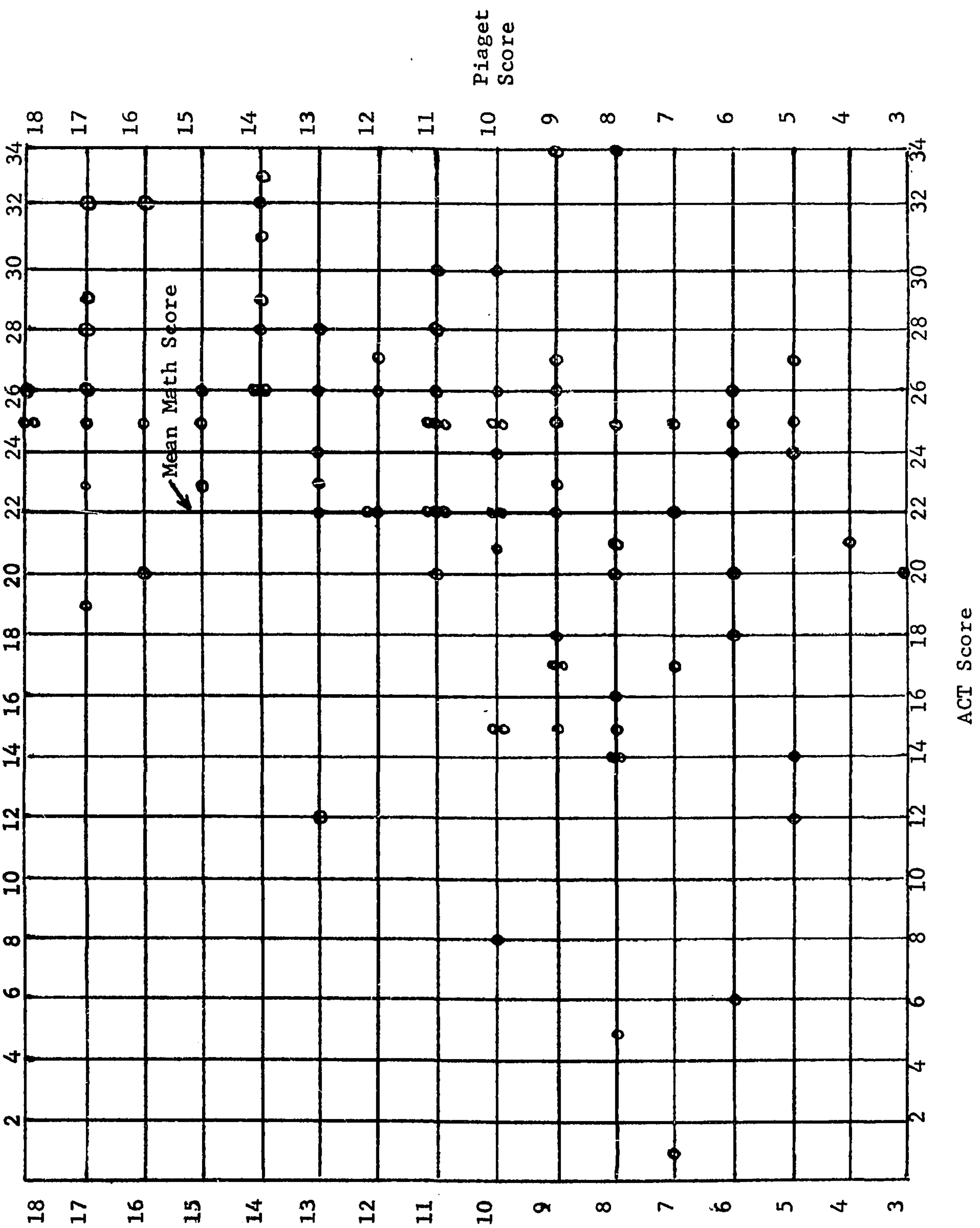
Graph 5-I

Piaget Score Versus Natural Science ACT Score



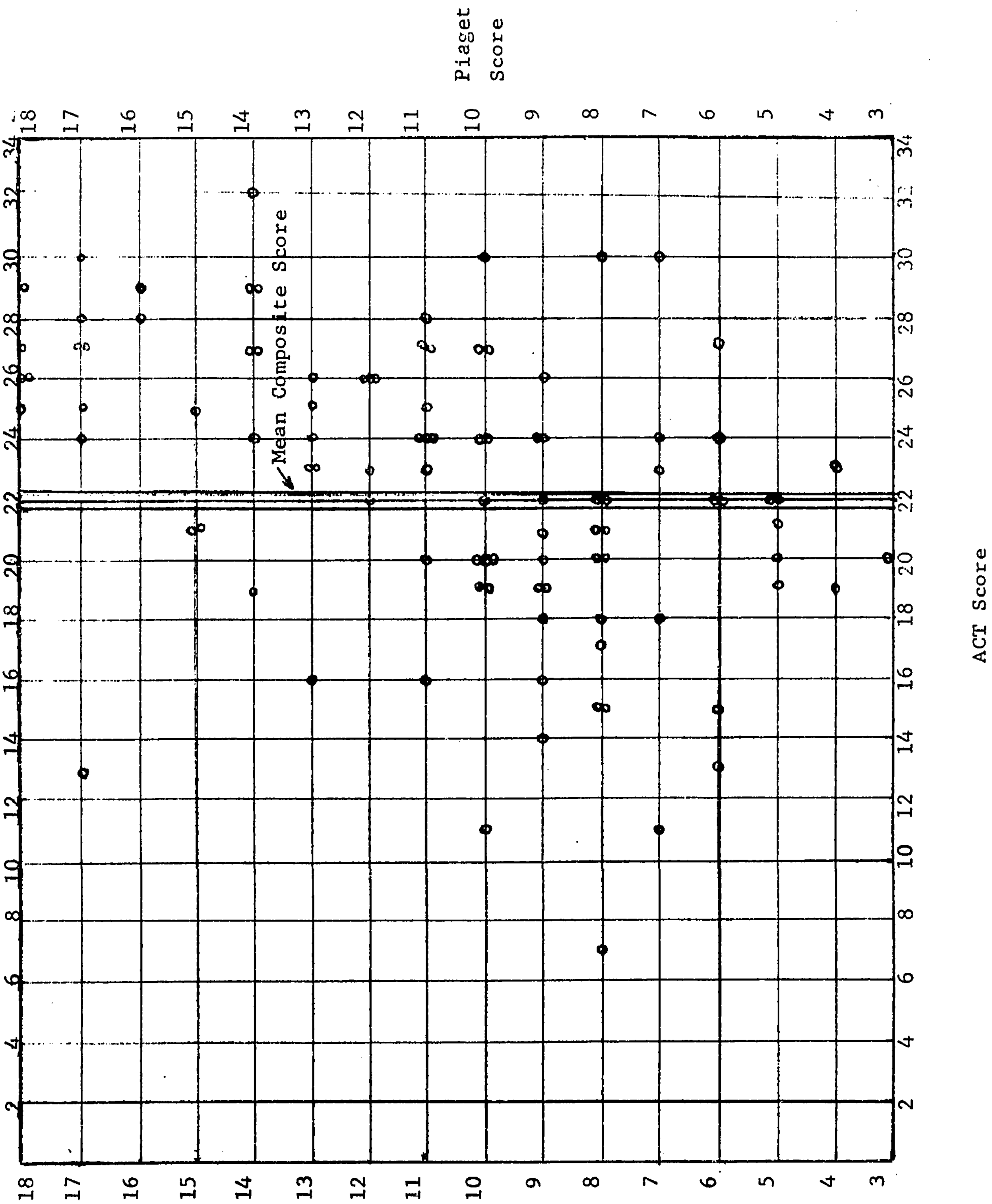
Graph 5-II

Piaget Score Versus Math ACT Score



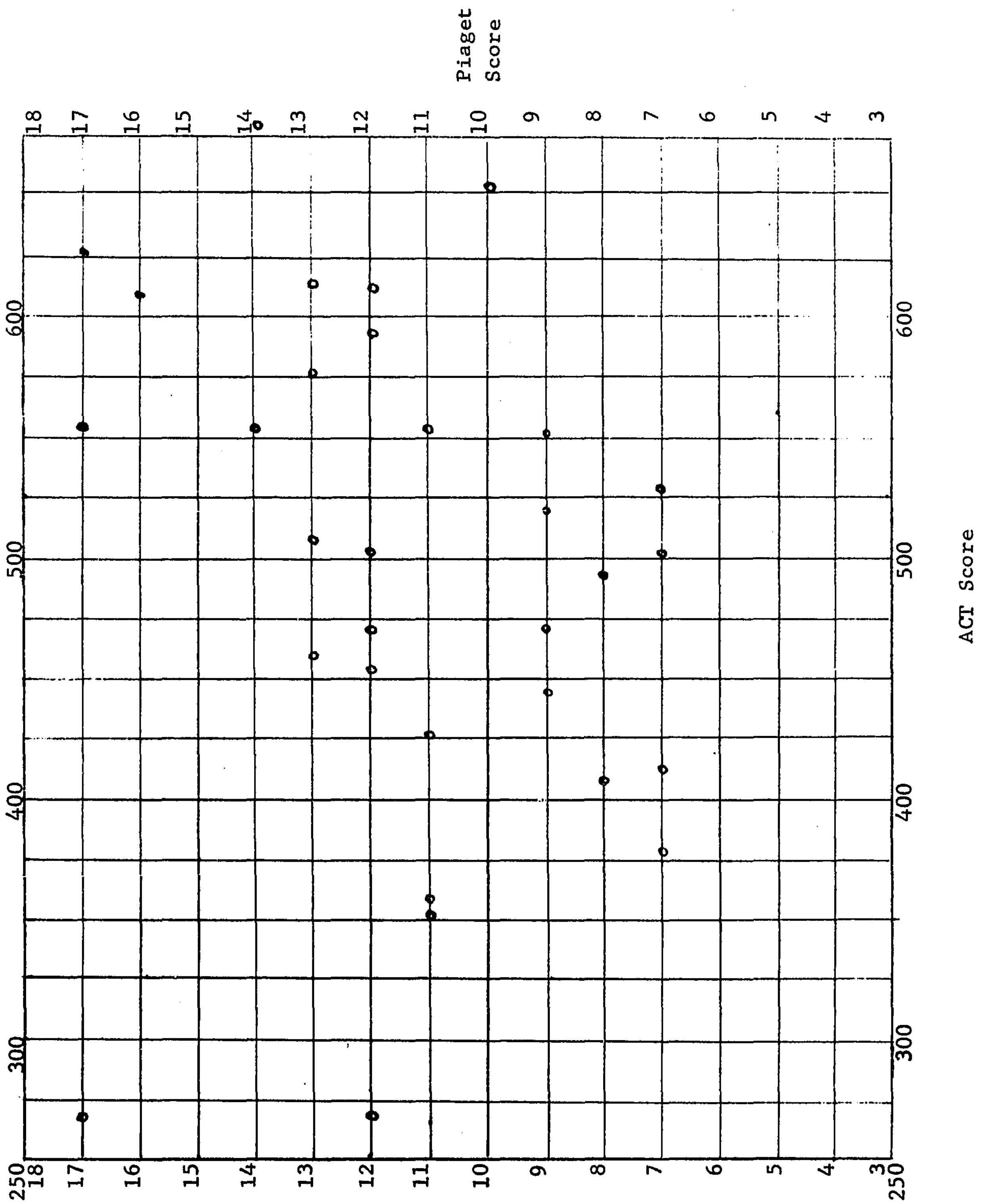
Graph 5-III

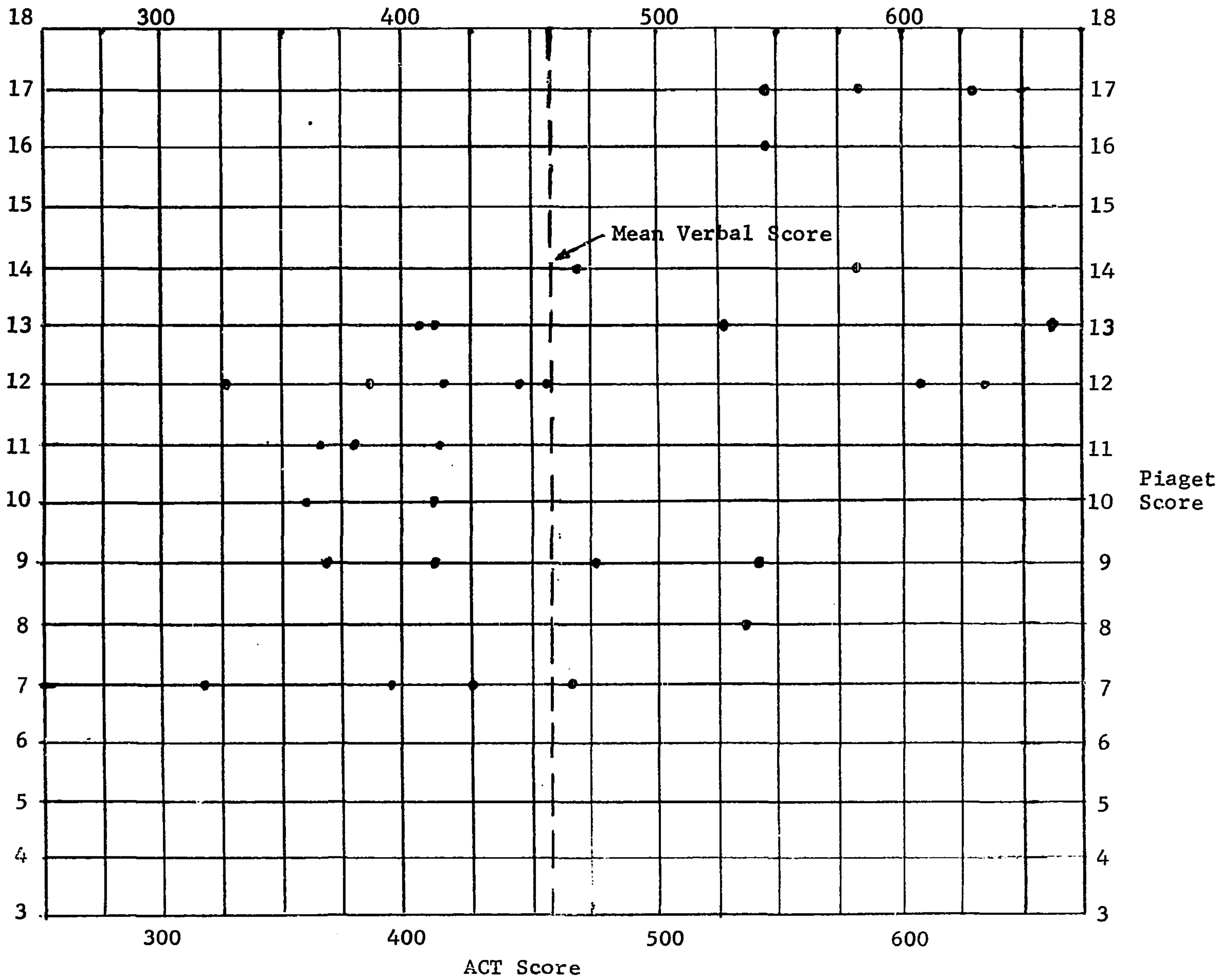
Piaget Score Versus Composite ACT Score



Graph 5-IV

SAT Math Versus Piagetian Score





Graph 5-V

SAT Verbal Versus Piagetian Score

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

The Entering Freshman College Student

Chapter 5 presented the tabular data and a short evaluation of the most relevant statistical findings. Each table provides a partial answer to the pervasive question, "Do students who come to the colleges and universities as freshmen think logically?" These partial answers will be examined in greater detail with the view of answering this most important question. In addition, this chapter will deal with the question of leading students to think more logically through science experiences at the college freshman level.

An examination of the data of Tables 5-5 and 5-6 leads to the almost inescapable conclusion that three of four entering college students do not think logically about the simplest kind of problem. The mean score for 143 students of 10.74 clearly indicates this. The data of Table 5-6 shows that 51 per cent of all students initially tested were definitely at the concrete stage of thought with another 27 per cent probably at a stage between concrete and formal operational thought.

In order for students to achieve the highest plateau of thought described by Piaget and Inhelder, it is entirely possible that students in the secondary schools must have much greater exposure to the kind of courses that emphasize the inquiry approach. The course "Forum for Scientific Inquiry" was of this type and was shown to enhance the student's capacity to think logically. Therefore, introduction of courses such as this in the secondary systems may permit more American students to approach the highest stage of logical thought at the ages Piaget and Inhelder found for European students. If the argument is made that the tests themselves are tests of skills acquired in the student's secondary school experience, the conclusion drawn from Table 5-7 is that something is wrong with this experience if fifty to seventy per cent of all entering college students cannot:

a. discriminate between potential variables found in the simplest kind of situation.

b. determine the difference between an object that may float or sink and formulate some means of discriminating between the two possibilities.

c. recognize that a change of shape does not also mean a change in volume.

d. decide how to go about eliminating a potential interfering factor so as to reach a conclusion about one particular variable.

This can only mean that students come from the high schools unprepared to viably interact with their environment to any great degree and, consequently, cannot derive greatest benefit from their college experiences. Beyond this, there is every indication as shown by Table 5-5 that matriculating female students are selected on some basis other than capacity to think logically, and that logical thinking does not have a high order of priority in the learning sequence in our public schools for either males or females. The question that should be asked at this point is, "Can the indictment made in the previous statements be supported by means other than those of this study?"

Every major study made of education has led to recommendations emphasizing the importance of logical thought as an educational objective; however, many studies of teacher practices have shown otherwise. New courses in science, inquiry-oriented in approach, have not yet made a significant impact in this country in the secondary school systems as indicated by the indifference shown by teachers attending National Science Foundation Institutes. Gruber[31] found that only 25 per cent of those attending NSF institutes showed interest in inquiry-oriented science teaching. This attitude may be prevalent throughout much of elementary and secondary educational thought in all areas of teaching as indicated in a study by Torrance[32]. He found that only 1.4 per cent of elementary and 8.4 per cent of secondary social studies teachers listed independent and critical thinking as important educational objectives. Therefore, one should not be surprised at the results of this investigation which clearly show that only in courses similar to the "Forum for Scientific Inquiry" (where students are allowed to devise hypotheses in light of new information, i.e., the inquiry situation), does the student learn to think independently and critically. The conclusion that little inquiry-oriented teaching is occurring in the public schools has been suggested by this particular investigation and little or no evidence exists in the literature to refute it.

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[31]H. E. Gruber, "Science As Doctrine or Thought?, A Critical Study of Nine Academic Year Institutes." Journal of Research in Science Teaching, 1: 124-128, Issue No. 2, 1963.

[32]E. P. Torrance, "Social Studies Objectives of Minnesota Elementary and Secondary School Teachers," Unpubl. Dissertation, U. of Minnesota.

Many of the procedures used in schools today are obviously (as the data just presented show) at variance with the major educational objective of learning to think logically. With whom does the fault lie? Again, one must point to the institutions where those teachers received their education. Apparently, teachers are not made aware of the educational value of inquiry teaching in methodological courses. Their practice teaching experience does not seem to reflect this, nor are these ideas reinforced in any positive way in their content courses; yet the ability to think critically can be taught as indicated by the results of this investigator's research and by Yoesting[33] and others. These investigations show that the ability to reason logically can be measurably enhanced in college freshmen, even in the short period of one semester; therefore, one must conclude that the criteria required for logical thought as advocated by Piaget and Inhelder have not been met by beginning American college students prior to this time. Students do not acquire the necessary experience in their secondary education to think logically nor are they made aware that society considers logical thought to be an important outcome of their educational experience.

The importance of the family in social transmission was shown in a 1963 study by Renner[34] who found that among 1,716 secondary students, parents were the most important influencing factor in determining students' future occupational choices.

In a study of the factors affecting achievement in science by

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[33]Clarence Yoesting, op. cit.

[34]J. W. Renner, "The Guidance Counselor and the Future Scientist, Engineer, and the Technician," Oklahoma Teacher, November, 1963, p. 11.

secondary school students who were matched on all relevant factors except for socio-economic background, Mallinson[35] found that, at the ninth grade level, both groups were extremely idealistic concerning their aspirations about future occupational choice. Both groups aspired to occupations which required training beyond high school, yet:

> " . . . the members of the college-bound group seemed to be influenced by a positive family interest in their future education; by family background that include broader educational experiences; and by family aspirations for their continued education."[36]

A further outcome of this important report indicated that both groups were below average on the critical thinking portion of the test, although the college-bound group did score higher. Renner's report, as well as Mallinson's again points to the requirement of social transmission prior to the development of logical thought patterns and the apparent lack of emphasis upon "critical thought" patterns by the secondary school systems. Mallinson concludes that:

> "The two must influential factors affecting a student's achievement in both high school and college appear to be his native intelligence and the support of a family that believes in the importance of education. Good, bad, or indifferent, these factors are predetermined and can be altered little, if any, by high school and college curricula, teachers, or methods of teaching."[37]

The conclusions drawn by the Mallinson report give too little credit to the formative years as described by Piaget. Stafford and Renner clearly demonstrated that early school experience can offset the differential of socio-economic background if that background includes emphasis

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[35]G. G. Mallinson, "Factors Affecting College Students' Achievement in Science," U. S. Office of Education, 1969, p. 16.

[36]Ibid, p. 19

[37]Ibid, p. 41

upon societal importance and enrichment through many concrete experiences needed to bring about formal thought. Mallinson's conclusions are further jeopardized by the results of this investigator's research. Students can be encouraged to think more logically through educational experiences _provided that_ the experiences are inquiry-oriented.

Table 5-9 points to the fact that the size of the high school seems to have little bearing upon the ability to think logically. This conclusion is further supported by the Mallinson report in its findings of no significance between high school size and science achievement in college.[38] Apparently, the teaching skills differ very little in large versus small schools in terms of capacity to teach the student to think logically, even though other studies have found a positive correlation between high school size and attendance at NSF Institutes by teachers of science with a resultant growth in knowledge of scientific principles by teachers and their students. The negating factor as shown by Gruber[39] and Torrance[40] is the lack of emphasis upon the inquiry orientation so necessary to logical thought. The universality of this lack of emphasis is shown by the lack of significant difference between East Coast and Oklahoma Piagetian averages.

Ultimately, the conclusion must be drawn that the factors so necessary to the development of logical thought processes are no more operative in the large school wherever located than in the small one.

The graphical analysis of ACT and SAT scores versus Piagetian tests for logical thinking leads to some interesting conclusions. The student

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[38]Ibid, p. 26

[39]Gruber, op. cit., p. 124-8.

[40]Torrance, op. cit.

who makes an above average score on the ACT or SAT test will have a greater likelihood of being able to think logically; however, there is little evidence that those who make low scores on these tests are lacking in the capacity to think logically as shown by the very low correlations between the Piagetian test and the ACT or SAT tests.

The Coffelt and Hobbs[41] report indicates that the average OCU student has a higher composite ACT score than does the average student of the several four-year state institutions. That fact, together with the correlation coefficient of .43 shown in Graph 4-3, when the composite ACT scores are compared with Piagetian scores, leads to the conclusion that a higher percentage of the students attending the four-year institutions must still be in the concrete stage of thought as compared with the OCU students. In addition, the -.05 correlation for this graph for OCU students scoring less than 22 would also lead to the conclusion that there are a great number of students in four-year institutions who do think logically, yet who are not recognized as having this capability because of the nature of the ACT test. Thus, the conclusions to be drawn from this are:

1. The percentage of students enrolling in the 4-year state colleges who think logically, as compared with students from OCU, is less.

2. The number of students of the four-year state colleges who do think logically, yet who were unrecognized by the ACT scores to be logical thinkers, is a very large figure.

3. Additional study must be undertaken to find a means to determine the students who do think logically.

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[41]Coffelt and Hobbs, op. cit.

If the ability to think logically is a desirable characteristic for college-bound students, the present means of selecting such students leaves much to be desired. This is particularly true if one considers the potentially capable students who are lost to higher education because of the system that operates in our public schools to identify and reward the grade-oriented student driven to carry on the memorization process it requires.

The Effect of an Inquiry-Oriented Science Course

The course "Forum for Scientific Inquiry," as shown by the very significant F-ratio obtained, did enhance the students' capacity to think logically, thus leading to the conclusion that Piaget's criteria for logical thought had not yet been met for these students. Because of this finding, the statement could be made that these students differ materiallly from those students from whom Piaget drew his conclusions regarding ages of acquisition of formal thought patterns. There is some doubt that the screening process operating in our social system to identify college-bound students differs materially from the process which identifies and rewards the European college student; consequently, there must be some other mechanism in operation to bring about an earlier acquisition of logical thought patterns in European students. This mechanism could only be a greater reliance upon inquiry methods of teaching in the European school system.

Recommendations

The elementary and secondary school systems of this nation need to recognize the role played by inquiry in the advancement of the student's capacity to think logically. Courses in all areas, not just science, must be implemented which place greater emphasis upon the acts which define the inquiry orientation.

Teacher education institutions must materially alter the methodological procedures by which new teachers are trained. Only a few educational institutions have recognized the importance of inquiry approaches to learning. Methodological courses must be altered to give new teachers real in-depth experiences in inquiry-oriented situations, as well as to give greater emphasis to classroom recognition and advancement of the various stages of mental development in children.

Higher education, in general, must take cognizance of the fact that a minority of it's incoming students are logical thinkers and revise their courses in all areas using much the same criteria as was used in the development of the course "Forum for Scientific Inquiry."

Additional study of adolescents at the secondary levels and in college must be undertaken to determine whether educational experiences can materially enhance a student's capacity to think logically. Educational testing should be undertaken which would attempt to influence societal transmission of values in all ages and socio-economic classifications of children.

College admission boards should decide whether logical thinking is to be a major criterion for admission and actively seek a better instrument for satisfying it.

These recommendations are very sweeping in their dimensions, yet the scope of the problem as shown by this investigation can call for no less.

APPENDIX I

The Five Piagetian Tasks

1. Conservation of Volume. The purpose of the conservation of volume task is to determine whether or not the student has reached the highest plateau of the concrete operational stage. Before a learner can exhibit the qualities of formal thought, he must possess the operations of ". . . reversibility--the permanent possibility of returning to the starting point of the operation in question."[42] This quality is vital to the conservation of volume because of the necessity of visualizing a constant volume even though a given object is changed in shape. In addition, ". . .the conservation of volume throughout changes of form presupposes the ability to handle proportions."[43]

The learner is given two beakers of water filled to the same level and two identical volumes of plasticene. After altering the shape of one of the plasticene balls, the student is asked to determine how the two water levels in the beakers would change when each piece of plasticene is placed in one of the beakers. Thus, ". . . the conceptualization of a volume of water equal to that of the object to be compared is the product of a subtler separation of variables which once more required hypothetico-deductive thought."[44]

2. Reciprocal Implication.[45] In this test, the student is asked

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[42]Piaget and Inhelder, op. cit.

[43]Ibid, p. 36.

[44]Ibid, p. 37

[45]Ibid, Chapter 1, pp. 3-19.

to launch a ball by means of a movable tubular spring device against a bumper so as to rebound and strike an object that is also movable. A concrete operational student will "establish a correspondence between the slope or direction of the plunger (and consequently of the first segment of the ball's trajectory) and the inclinations or directions of the second segment."[46] The concrete operational student has not yet attempted to create a general hypothesis which will successfully account for all future displacements of the object. The student who has achieved the stage of formal thought will discover the necessary correspondences between the two successive segments of the trajectory and he will create a workable hypothesis to account for all such future moves. An important requirement for the formal thought student is "necessity"; that is, he expresses confidence in the general law he has posed, whether it is for this particular task or any of the others to be discussed.

3. Elimination of Contradiction.[47] This task requires that the student derive the law of floating bodies by means of concepts which are not accessible at the level of concrete operations. He must construct a classification scheme including objects which float in water and a class of bodies which does not float, plus two other eventual classes--that of bodies which may float in certain situations and not in others and that of bodies which remain suspended. Ultimately the student derives a single and noncontradictory law relating to the density of the object compared to the density of water. Before he does so, he must resolve several contradictions relating to volume and weight of the objects; however, it

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[46] Ibid, p. 9.

[47] Ibid, Chapter 2, pp. 20-45.

is only in the final state of equilibrium that he is capable of separating out variables according to combinations not given by direct observation, and composing these relationships according to the operations of implication and conjunction.

4. Separation of Variables.[48] The flexibility of a rod depends upon several properties including the material of which it is made, its length, its thickness, and its cross-sectional form. If the weight which can be hung on the tip of the rod is included, there are five potential variables, one of which must be manipulated by the learner while holding the remaining four constant. The student must classify the variables, then separate out the experimentally relevant variables, place explicit multiplicative schemes together (thinner and longer), and finally create a hypothetico-deductive reasoning scheme which carries with it the active attempt at verification, all of which are necessary before the learner can correctly determine which of the rods would be more or less flexible because of the effect of these intervening variables.

5. Operations of Exclusion.[49] In the previous test the student was asked to separate out relevant variables in order to determine their respective effects in a multi-factor setup. In the test involving the oscillation of a pendulum, the student is given several irrelevant variables along with the relevant. He must then discriminate the appropriate relevant variable by means of testing and eliminating those variables which have no effect upon the oscillation of the pendulum. The formal operational student will be able to recognize the causal role of the relevant variable and

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[48]Ibid, Chapter 3, pp. 46-66.

[49]Ibid, Chapter 4, pp. 67-79.

adequately test for the effect it has.

APPENDIX II

STUDENT'S NAME ______________________________ No. _____

Conservation of Volume — Score

1. Does the student conserve change of form? _____
2. Does the student conserve these proportions when asked what the effect on the water level is? _____

IIa IIb _____

Reciprocal Implication

- IIa Element of Reversibility
  1. Recognizes some angular relation _____
- IIb Subject gives a more accurate expression of rebound direction to the plunger's direction _____
- IIIa Subject expresses equivalence of angles between the two directions _____
- IIIb Student exhibits generality, as well as necessity and is confident of the law derived _____ _____

Elimination of Contradiction

- IIa Does subject use multiple explanations? _____
  Does he begin to reject ideas of absolute wt? _____
  Subject accurately classifies _____
- IIb Subject exhibits preliminary relating of wt. to volume (but does Not) _____
- IIIa Hypothesizes but does not verify exhibits ideas of proportionality _____
- IIIb Relates wt. of object to wt. of equivalent volume of water _____
  Expresses confidence in generality of law _____ _____

Separation of Variables

- IIa Subject categorizes and classifies _____
  Does not manipulate relevant variables _____
- IIb Subject exhibits multiplicative schema _____
  Subject does NOT verify action of one variable _____
- IIIa Subject attempts to verify hypotheses _____
  Subject uses active searching behavior in attempting to verify the action of a variable _____
- IIIb Gives a rigorous proof of the action of one variable _____ _____

Operation of Exclusion

- IIa Serial orders, uses correspondences, but does not separate variables _____
- IIb Accurately orders the effects of weight _____
  Does not separate variables _____
- IIIa Subject is not yet making "all other things equal" even though he is using hypothesis type formulation and appropriate searching behavior _____
- IIIb Isolates all variables _____ _____

TOTAL _____

APPENDIX III

Additional information about the student was gained through the use of this questionnaire:

No.________

Name____ Age________________

High School________________________________ City______________ St.

ACT or SAT Score________________________

Number of students in graduating class:

0-25   25-50   50-150   150-300   300-500   500-1000   <1000

Science Courses in High School and grade at which taken:		Grade Level
	Physical Sciences	________
	Earth Sciences	________
	Biology	________
	Chemistry	________
	Physics	________
	Other:	
	________________	________

Mathematics taken in High School and grade at which taken:		Grade Level
	Algebra I	________
	Algebra II	________
	Plane Geometry	________
	Trigonometry	________
	Other:	
	________________	________

What other science courses
<u>in college</u> have you had?____

Proposed major (if decided)____

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