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Title: RELATIONSHIPS BETWEEN PIAGETIAN COGNITIVE DEVELOPMENT AT THE FORMAL LEVEL AND SCIENCE BACKGROUND AMONG PROSPECTIVE ELEMENTARY SCHOOL TEACHERS

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Gene F. Craven

Results of recent studies on Piagetian cognitive development, though equivocal, showed that the architectonic of formal operational schemata is not possessed by a sizeable percentage (up to 52%) of adolescents and young adults. The purpose of the present study is two fold: (i) To assess the cognitive levels of a sample of prospective elementary teachers, and (ii) To investigate which of ten independent variables were most highly correlated with, and useful in explaining performance on five Piagetian formal tasks.

The independent variables examined were: age, attitude toward science, attitude toward science teaching, high school GPA, college GPA, Scholastic Aptitude Test (Verbal and Quantitative), Sequential Test of Educational Progress (Science Series II, Form IA), Science-Product and the total number of binary operations (logical operators)

which are isomorphic with the INRC transformations. The criterion variable was performance on five Piagetian tasks requiring the following strategies for their successful solutions: elimination of contradiction, operations of exclusion, reciprocal implication, combinatorial logic, and syllogistic reasoning. Data were collected through paper-pencil tests, individual interview, and from the subjects' high school and college transcripts.

The sample consisted of 44 prospective elementary teachers who were sophomores enrolled in "Educational Theory and Practicum", the second (theory) phase of a sophomore-block in education at Oregon State University. The ages of the six males and 38 females ranged from 19 to 30 years with a mean age of 21.6 years. The study was conducted over a period of five weeks during the spring term of the 1975-76 academic year. Pearson product moment correlation coefficient, t-test, and a stepwise technique of multiple regression analysis were employed to evaluate (i) the degree of relationships, (ii) the differences in the mean scores on Piagetian tasks of low and high SCI-PROD subjects, and (iii) which of the predictor variables accounted for how much of the variance on the criterion variable.

The Findings

Sixty-eight percent of the subjects were formal operational. No significant relationship was found between ATS, ATST or SAT-V and scores on Piagetian tasks. Significant relationships ($p < .01$) were found between STEP-SCI, SCI-PROD, SAT-Q and scores on Piagetian tasks.

A significant difference ($p < .10$) was found between high and low subjects with respect to SCI-PROD and mean scores on the Piagetian tasks. The ten predictor variables accounted for 40 percent of the variance in performance on the five Piagetian tasks.

Conclusion

Incidence of formal operations was not universal among the subjects. Both concrete and formal operational strategies co-existed and were applied differentially depending on the nature of the tasks. Subjects who exhibited concrete operational strategies in response to one task were also often capable of the rigorous hypothetico-deductive approach in reponse to a different task.

Implication

Instructional materials for prospective elementary teachers should be designed to promote a balance between accommodation (conformity to the environment, i.e. concrete operations) and assimilation (transformation of the environment, i.e. formal operations). These materials should be sequenced within the rubrics of multiple concretisation and multisensory approaches. Both the materials and the approaches should mirror the variable but definite proportions of concrete to formal operational students in the learning situation.

Relationships Between Piagetian Cognitive Development at The Formal Level and Science Background Among Prospective Elementary School Teachers

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This dissertation is dedicated to

the loving memory

of my late senior brother

Samuel Ayodele Ehindero

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I. INTRODUCTION

One of the problems confronting science education today is the crisis in learning--the inherent disproportionality existing between the knowledge available and necessary to know and the student's cognitive capacity to know and comprehend. Rodgers (1975) had remarked:

> Not only do we have a general knowledge explosion but we also have a chain reaction of such explosions in present and over-proliferating special areas of concern to scholars. This situation has the negative effect of making more information available than can be handled...producing useful knowledge that renders past, present and other knowledge obsolete before it is known to, or tried by, a large number of the general public. (p. 2)

This situation has led, in science education, to an emphasis on educating the mind as a vehicle of learning rather than as a storehouse of knowledge. Equally significant in this direction is a shift in science instructional strategies toward self-initiated learning, discovery and inquiry--all capitalizing on the inherent ability of the learner to actively pursue his own learning. A factor in this emphasis is a growing understanding of the intellectual states and cognitive styles of the learner--an understanding made possible partly by a reblooming of interest in Piaget's cognitive developmentalism.

Piaget's constructivism provides a framework by which the power of logical operations can be assessed among prospective teachers. In his metalogical program Piaget postulates four sequential psychogenetic levels--sensori-motor, pre-operational, concrete and formal operational stages, each representing cognitive processes characterized by progressive differentiation (analysis) and functional integration (synthesis). A mobile equilibrium dynamics operates to define the direction (toward greater mobility and stability) and provides a touchstone for the affirmation that the various morphologies are distinct. Thus, concrete operations obey laws of logical reversibility while formal operations demonstrate aspects of hypothetical possibilities and combinational laws.

Science educators want to capitalize on the metalogical and hypothetical connections between Piaget's genetic epistemology and knowing on one hand, and the learner's developed cognitive potential in logical reasoning to select curricular content at the high school and university levels. However, recent studies in the United States, Tomlinson-Keasey (1972), Clayton and Overton (1973), Lawson (1973), Kogan (1974), Juraschek (1974), Lawson and Renner (1974), and Chiappetta (1976) indicate that a sizeable percentage of high school students and prospective elementary teachers have not yet attained the hypothetico-deductive stage postulated in Piaget's holistic structuralism. Blackington (1973) has put the situation in a better perspective when he commented that:

> ...there is much evidence to indicate that students--especially those getting degrees and/or certification in education--have been less substantially educated than one might hope...As we look to more fruitful ways to develop logical thought, we must look at the teacher as well as the culture and the college student. They are the people who will have to more productively

> arrange for and constitute a part of the conditions for those increased reasoning skills and disposition. (p. 268)

Piaget's theorizing, as briefly described above, seems to satisfy some of the decisive desiderata of a theory of human problem-solving relevant to science education. Such a theory should have the inherent potential to predict the performance of a problem solver when confronted with specified tasks and to explain how the strategies adopted are acquired developmentally and subsequently utilized. The present study investigated how prospective elementary school teachers approach problem solving situations as a function of their constituted experiential histories in science and their current cognitive level.

Statement of the Problem

The present study investigated possible relationships between thought processes at the formal operational level, experiences in science courses (quantitative and qualitative) and attitudes toward science and science teaching among prospective elementary school teachers. McKinnon (1970), Juraschek (1974), and Lawson and Renner (1974) have reported that less than 50 percent of college students exhibited formal operational thought processes. Farrell (1969) stated that formal operational students possess the capacity to utilize formal operations but are not compelled to do so. But since science educators are charged with the responsibility of enhancing the general intellectual development of the learner, it becomes imperative that we investigate how adequately this responsibility is being discharged. This study therefore sought answers to the following questions: What percentage of prospective elementary school teachers manifest formal operational thought processes as measured by Piagetian Task Instrument (PTI)? Is there any relationship between attitude toward science and science teaching measured by the Redford Likert-type scale and formal operational thought processes measured by the PTI? What relationships exist between number (as opposed to number of years) of college science courses experienced, success in these courses (GPA in science) and performance on Piagetian tasks? What relationships exist between SAT verbal and quantitative and PTI scores? What variables are most important in predicting performance at the formal operational level?

Definition of Terms

Attitude--As used in this study refers to both mental readiness and implicit predispositions which exert some generally consistent influence on a fairly large class of evaluative responses vis á vis science and science teaching.

Formal Operation--Characterized by (i) the changed relation of the real to the possible; (ii) potentiality for combinatorial analysis; (iii) hypothetico-deductive reasoning (determining between "what is" in the context of "what might be"). It sequentially follows the ability to systematically check all possible combinations; and (iv) propositional thinking--ability to manipulate a proposition using raw data and to operate on that proposition via logical operators. In this study formal operations and logical operations will be used interchangeably.

Science Background--Refers to the individual's experiences in science including the number of, and success in, science courses taken in colleges and universities. Quantitative science experience refers to the number of science courses taken while qualitative science experience refers to success in these courses, i.e. calculated GPA in science. A third dimension of the science background (science product, SCI-PROD) refers to the product of the number of courses in Science and the corresponding GPA in those courses. It also includes scores in STEP-SCI and attitude toward science and science teaching.

STEP-SCI--is the Sequential Test of Educational Progress Form 1A, which is an achievement dimension of science background. It tests science skills, knowledge and comprehension and their applications.

Piaget Task Instrument (PTI)--refers to the five tasks (mostly science related) with which the subjects interact. These tasks assessed the cognitive stage of the students. Each of these tasks is described in detail in Chapter III.

Operations--These are psychological structures reversible, internalisable, and coordinated into a structured whole.

Need for the Study

In their publication "Priorities for Research in Science Education", the National Association for Research in Science Teaching

(NARST) and the National Institute of Education Commission (1975) stated that:

> The self-image and aspirations of teachers, and their images of science, of children, of learning, and of effective activity are suspected (emphasis mine) of being highly predictive of the kinds and effectiveness of the transactions which occur in schools and subsequent outcomes. Therefore, teacher's characteristics and their influences upon the transactions and outcomes has the highest priority for research.

The Commission also emphasized the need for empirical studies on attitudes, among various (science) experiences and performance on specific (Piaget-type)tasks.

Independently, but simultaneously, the NARST Commission on research has assigned the highest priority to:

> ...empirical tests of the relationships between teacher attitudes and performance on specific tasks and the outcomes of students attitudes and performance on other specific tasks....Relevant research would include not only the development and testing of new instructional materials, but more basic studies of the ways, means, and amounts of various experiences which modify the attitudes of students and enhance their decision-making skills. Careful studies are needed for attitudes and their associated values as mediators between knowledge and action.

Further, the Commission stated that:

> Knowledge of the attitudes of students and the determinants in those attitudes during schooling, toward science and the interaction of science and society is of critical importance if the social imperatives cited above are to be considered seriously...cognitive growth and the development of logical thought continue to be centrally important as outcomes of education in science.

Beard (1969) in his book for teachers noted:

> To teachers it is of some importance not only to know the order of stages in thinking...but also to know what misconceptions to expect among children of different ages and at what age the majority of children in a given environment reach each stage. Such information is valuable as a guide to teaching methods.

Piaget (1970) has suggested that any profitable research at the post-adolescence stage should be geared toward the educational history of the subjects:

> ...if one wishes to continue the study of stages beyond adolescence, the only method would be to use history, for example, the history of scientific thought.

And, I hasten to add, of scientific attitudes and images. Piaget (1969) has also highlighted the need to understand the relationship between the affective states of the individual and his cognitive state, "this affective and social impuse of adolescence has often been described. But it has not always been understood...". Kneller (1966) identified at least five main questions for critical examination when discussing the possible roles of formal operations in the twin processes of teaching and learning:

a) At what age does the learner develop the power to perform the various formal operations?

b) What logical operations are involved in the course of classroom discourse?

c) What standards should the teacher and learner follow in appraising whether the product of a logical operation is sound?

d) What logical operations are performed by the teacher in the course of expounding the subject matter?

e) What logical operations are performed by the learner when studying by himself in order to master and use different kinds of subject matter?

These questions demand empirical answers, otherwise, we are likely to either over-estimate prospective teachers' and students' intellectual capabilities for formal operations or under-estimate their powers to grasp ideas intuitively while not being able to follow the abstract reasoning on which they are based. In either case, the result is an unnecessary delay of academic progress.

Satterly (1975) has put the situation in a better perspective. According to him:

> In seeking to promote states of development of help to the teacher, then, it is necessary to carry out a separate study of the development of the distinct types of capacity that make up intellectual development...

The importance of the attitudinal set possessed by the classroom teacher during and after her professional training cannot be over emphasized. Many ambitious programs in science education have failed partly because of the attitudinal set of the classroom teacher. Schwiran (1969) stated that:

> ...effectiveness in teaching elementary school science is to some extent a function of the teacher's attitude toward science, which is in itself a consequent of significant and professional experiences the teacher has had.

In a nationwide survey by Blackwood (1964), a lack of interest in science was one of the barriers to effective elementary science teaching. Stollberg (1962) emphasized that a teacher who possesses a neutral or negative attitude toward science can either avoid the teaching of science or pass this attitude along to other students. He concluded "...unless the teacher is attracted toward science all the content and all the teaching methods we may have learned can well serve no good purpose whatever". Clearly what is required now is a detailed investigation of formal operational thought processes capitalizing on the science background and science attitudes of prospective elementary school teachers. According to Wiersma (1972):

> Whatever an individual's opinion or observation, teacher education is an area on the educational scene that has generally not been systematically researched or based on empirical data...Indeed, with performance accountability already looming on the horizon, teacher educators will increasingly be required to possess some hard facts about the "products" they turn out.

This study is aimed at gathering such hard facts among prospective elementary school teachers. Hard facts which are required not only in assessing their cognitive levels but also in computing the possible relationships between the cognitive levels and experiences in science courses, and attitudes toward science and science teaching.

Hypotheses

The study attempted to gather empirical evidence to test the growing conviction among science educators that an individual enters a problem-solving situation with unique sets of constitutional and cognitive strategies; and that the individual's experiential histories, namely: in science and science related areas, attitude toward science and science teaching, are significantly related to individual performances on Piagetian tasks. Piaget has stipulated certain criteria necessary for the successful solution of science-related Piagetian tasks and it is widely assumed that students possessing favorable attitudes towards science and science teaching would translate these attitudes operationally in solving tasks requiring formal thought processes. Among these are the ability to generate a universe of potential hypotheses about a problematic situation in advance and willingness to shift constituted strategies with a shift in the *a priori* probabilities of hypotheses as experience accrues. Data gathered from the subjects were used to test the following null hypotheses:

Ho_1--There is no significant relationship between performance on the Piagetian tasks and the age variable of the subjects.

Ho_2--There is no significant relationship between performance on the Piagetian tasks and attitudes toward science and science teaching.

Ho_3--There is no significant relationship between performance on Piagetian tasks and scores on Sequential Test of Educational Progress STEP Series II, Science Form IA.

Ho_4--There is no significant relationship between performance on Piagetian tasks and science product, i.e. calculated science GPA multiplied by number of college science courses taken.

Ho_5--There is no significant difference between scores on Piagetian tasks of students classified as high and those classified as low with respect to the variable science GPA multiplied by number of college science courses (i.e. SCI-PROD).

Hypotheses 3 and 4 in effect tested the relationship between current achievements in science and scores on Piagetian tasks.

Limitations of the Study

The sample size of the subjects is small and limited to prospective elementary school teachers regularly enrolled in Oregon State University.

All the variables contributing to the success of the individual students are not and cannot be accounted for by the study. The study recognizes the inherent inadequacy of the criteria used viz GPA, number of science courses experienced, PTI, the attitude scale, are only some of other possible measures available.

In classifying the prospective teachers as either formal or non-formal, the study recognizes the possibility that some subjects may be operating somewhere along the continuum formal to non-formal.

The sole criterion for classifying subjects to various cognitive stages is performance on the Piagetian tasks.

In an attempt to eliminate experimenter variance during the interview session, the investigator administered and scored all the Piagetian tasks.

Delimitations

1) No cause and effect relationship was investigated.

2) Other variables that may influence the science background of the subjects were not investigated, e.g. student's socio-economic status, sex, the history and general academic environment of Oregon State University, individual student's self-perception, influences of other curricular disciplines, e.g. logic and philosophy.

Assumptions

1) The present subjects are a sample in time and place and hence prospective elementary school teachers of similar science background and cognitive variables would be expected to be located in classes preceding and following this class at Oregon State University.

2) Prospective elementary school teachers with similar cognitive and attitudinal variables would be found in other colleges and universities in academic environments similar to Corvallis and offering similar science programs.

3) The particular responses selected by the subjects in the attitude scale and the strategies adopted in solving the Piagetian tasks and the STEP-SCI tests reflect their reinforcement histories in science and related academic areas.

Significance of the Study

Oregon State University has a comparatively high High School GPA requirement for student admission and the School of Education requires a fairly high science preparation in it's teacher education program. It would be significant, therefore, to investigate the cognitive levels of students under these policies. Moreover, most of the students enrolled in the elementary education program are from the state of Oregon, where little or no Piaget-type assessment has been undertaken. Compared to other states in the Union, where few Piagetian assessments at the formal level have been studied, could the same results be obtained?

Findings emanating from this study should be considered exploratory and therefore tentative, it was hoped that its results would generate searching questions among science educators as well as other Piagetian researchers as to whether some of the variables in a subject's science experiences correlate well with the cognitive status of the individual. Are some of these variables useful in explaining variability in performance on Piagetian tasks? Bruner (1960) has suggested that "the teaching of probabilistic reasoning, so very common and important a feature of modern science, is hardly developed in our educational system before college". Probabilistic reasoning requires similar thought processes as formal reasoning. The problem which this study sought to investigate was whether it was in fact the case, even among college students, that prospective elementary school teachers have attained the architectonics of formal or probabilistic reasoning postulated by Piaget. What percentage (proportion) of subjects in the present study have acquired these schemata?

Results of the study may shed light on the relative importance of some measures of science achievement, aptitude and attitudes in relation to, and in predicting performance on Piagetian formal operational tasks.

II. REVIEW OF THE LITERATURE

Piagetian Theory

Piaget's cognitive developmentalism is predicated upon the reconciliation of two opposing philosophical theories--empiricism and rationalism. The former he calls geneticism without structure and the latter structuralism without genesis. For Piaget, intelligence is both a potential infra-structure of the pattern of thought as well as the organization and adaptation in mutual contradiction. For one to adapt cognitively, there must be a mutual interpenetration of the twin processes of assimilation and accommodation. Four sequential stages of cognitive development are postulated in Piagetian theory, namely: sensorimotor, pre-operational, concrete, and formal operational stages. Develcpment within each of the stages follows a fairly predictable path (a) an initial experimenting phase during which strategies of experimental interpretations are acquired, (b) the progressive accumulation and elaboration of advanced techniques predicated upon experimentation, and (c) a restructuring and consequent extension of existing psychogenetic structures to incorporate the already acquired strategies.

Each of these stages emphasizes the role of activity, proposing that functional adaptation can only occur through and be guided by organizational schemata in intelligence. In other words, intelligence in Piagetian paradigm, constitutes the faculty of which thinking is the activity. The formal operational stage is regarded as the pinnacle of human thought in Piaget's theorizing. It is the perfection of the equilibration dynamics characterized by the logical manipulation of propositions according to operations that conform structurally to fully achieved lattice properties and complete groupings. Following the loss of egocentrism at the pre-operational and concrete levels, the attainment of objectivity and the acquisition of achitectonics of formal operations, released the individual from the limitations imposed by his own actual experiences so that he can now think logically in hypotheticalness. He now acquires the ability to imagine theoretical possibilities other than the <u>status quo</u> and to systematically manipulate these possibilities. According to Piaget (1969):

> At the formal level, the liberation of thought mechanisms from content results in the formation of a combinatorial system and also in the elaboration of a fundamental structure that marks both the synthesis of the previous 'groupings' and the starting point for a series of new advances. (p. 135)

Blasi and Hoeffel (1974) used the above criteria to differentiate between concrete and formal operational levels and their associated strategies:

> Since what is possible is understood by relating it to the impossible on the one hand, and to the real or actual on the other, the difference between the two stages is frequently described as consisting in an inversion of relations. At the concrete stage, the possible is seen as an extension of the real, while at the formal stage the real is seen as one case or one determination of the possible. (p. 349)

However, Piaget (1968) indicated that in terms of their functional dimensions, formal operations are not too significantly different from concrete operations except in terms of the ability to generate a universe of hypotheses or propositions. From what has been said so far, two cognitive skills underlie formal operationals--the ability to subordinate the real to the possible and the ability to reflect on one's thought (second degree operation or reflective abstraction).

Piagetian Research

Relatively few studies have explored cognitive processes at the formal levels. This contrasts with the plethora of research generated by Piagetian conservation tasks at the concrete level. The situation becomes disappointing if one considers that still very few studies have investigated formal operations with respect to science background--(achievement, aptitude and attitude). This condition mitigates against any theoretical or empirical validation of students' performance at the formal operational level.

Recent studies in the United States indicated that a large proportion of college students (assumed to be formal operational) are indeed concrete operational. McKinnon and Renner (1971) administered five Piagetian tasks to 131 University of Oklahoma freshmen and reported that 25 percent were formal operational, 25 percent were "transitional" and 50 percent were predominantly concrete operational. In addition, these investigators concluded that an inquiry-oriented science course, which the subjects were exposed to, was instrumental in the transition from predominantly concrete thinkers to hypothetico-deductive level of thinking. This conclusion was based on the questionable assumption that exposure to an inquiry-oriented science course for only one semester sufficed to effect such transformation from one psychogenetic level to the next. Almy, _et al._, (1966) called attention to the sterility and limitations of such attempts:

> There is no guarantee that instruction in specific concepts necessarily hastens the transition from one level of thinking to the next. But even if evidence accrues that it does, the question of whether such (attempts) from a long-term view, enhances or stultifies the individual abilities for speculative, imaginative, or even creative thinking still needs investigation. (p. 130)

A follow-up study by McKinnon and Renner would have done much in evaluating the effects of their inquiry-oriented science course. The question may even be raised whether it was desirable to deliberately transform concrete to formal thinkers. Some psychologists are skeptical about the inherent potentialities of formal operations. In an extensive analysis of formal operations in adolescence, Blasi and Hoeffel (1974) remarked:

> In simply attending to the label concrete, one may underestimate the power of adaptation to reality, in particular, future reality, which is present in the concrete form of understanding possibility...together with the adaptational power of concrete thinking, it is equally important to realize the limits of the formal concept of possibility...which presupposes a structure of thought based on perfect compensation. (p. 351)

Elkind (1962) assessed the ability of 240 University students on Piagetian conservation tasks involving mass, weight and volume. He reported that 58 percent conserved volume, i.e. were formal operational. Noelling (1961) conducted a longitudinal study on the same subjects tested by Piaget and his co-workers but with special emphasis on the structure of logical thinking. He concluded that the structure of thought and those of mathematics (and science) are homologous. He linked abstraction to the process of compensation with its reversibility and also the invariants found not only in thinking but in the structure of logic, mathematics and science. Karplus and Karplus (1970) used a Piaget-type task to assess the intellectual level of 449 randomly selected subjects from fifth graders to physics teachers. Although the results obtained remain equivocal, there was a general relationship between age, cognitive development, and performance. But since only one Piagetian task was used for the assessment, the empirical status of such a study is questionable. Griffiths (1973) presented Piagetian tasks to physics and chemistry students in a community college and a University. He reported that 50 percent of the subjects were concrete operational or lower while 25 percent had not fully attained the hypothetico-deductive level of thinking.

Some studies have investigated the relationships between certain variables and performance at the various cognitive levels in Piagetian theory. Piaget (1968) called attention to certain affective variables in cognitive development:

> ...there is a close parallel between the development of affectivity and that of the intellectual functions... In all behaviour, the motives and energizing dynamics reveal affectivity, while the techniques and adjustment of the means employed constitute the cognitive sensorimotor or rational aspect. (p. 33)

Schwiran (1969) investigated the relationships between personal and professional characteristics of elementary teachers and their attitudes toward science. He reported that age was moderately ($r = .24$) related to attitudes and that teachers 40 years of age and over demonstrated more favorable attitudes toward science. Prospective teachers taking more science courses were shown to possess more positive attitudes toward science in the Schwiran Science Support Scale. The relationships between success in science and attitudes toward science were not investigated. Kane (1968) using Osgood's Semantic Differential Technique with prospective science and mathematics teachers concluded that attitudes toward science and mathematics and toward the teaching of these subjects were no less positive than attitudes toward other subject matter domain in the school curriculum.

Winter (1964) called attention to the importance of non-cognitive variables in the assessment of the professional:

> One important aspect of the personal behavior of the beginning professional should be determined by his attitudes toward the scientific enterprise of the contemporary world.

Tomlinson-Keasey (1972) studied three groups of 89 subjects with age range of 11.9 years to 54 years. A pre-test, post-test experimental design was used to assess the subject's performances on three Piagetian formal operational tasks. Sixty-seven percent of the college co-eds, mean age 19.7 years were formal operational. When a stringent criterion was used to assess formal operations, only 23 percent were operating at the IIIB formal stage. Caution should be exercised in interpreting this result since all the subjects were females. Elkind (1962) found that only 52 percent of college females subjects could conserve volume compared to 74 percent of the males. He suggested that sex of the subjects might be a factor in performance on Piagetian tasks. Ball and Sayre (1972) investigated the relationships between scholastic grades, IQ and performance on five Piagetian tasks among 419 junior and senior high school students. Trained interviewers administered the Piagetian tasks and interviewer reliability was calculated to be 98 percent. However, the major problem with this method of determining interviewer agreement is that agreement is likely to be high (as the authors in this study claimed) because only five tasks were rated by the observers. Theoretically, as the number of categories to be rated decreases, the percent agreement among the raters increases. Ball and Sayre (1972) reported a low and positive correlation between I.Q. and formal operations. A significant correlation ($r = .31$) was found between scholastic success in science and performance on Piagetian tasks.

Chiappetta (1974) used a Piagetian task to assess the cognitive level of 15 K-8 female teachers, 53 percent were concrete operational and 47 percent were formal operational. The use of only one Piagetian task, and the small size of the subjects were limitations of this study. Lawson and Renner (1974) administered five Piagetian tasks to 143 college freshmen and found that only 22 percent, 27 percent, and 51 percent were formal, transitional and concrete operational, respectively. The criteria for identifying the transitional subjects were not given. Juraschek (1974) studied three groups of college students' performance on three Piagetian tasks. The groups consisted of 141 prospective elementary teachers, 19 secondary school mathematics student teachers and 11 honors calculus students. The three tasks used included the equilibrium in the balance, quantification of probabilities and colourless chemical liquids. Among the prospective teachers, 48 percent were formal operational, 52 percent were concrete operational. A correlation (r = .34) was reported between PTI scores and number of years of high school mathematics, a correlation of .68 was also found between PTI scores and SAT mathematics. Both correlations were significant at the .01 level. Schwebel (1973), using the colourless chemical liquids, combinatorial logic and balance tasks to assess the levels of cognitive development among college students, reported that only 11 were formal operational out of a total of 58 University freshmen. He also found no correlation between SAT composite scores and PTI scores.

Lawson, et al. (1975) investigated the relationships between performance on four Piagetian tasks, attitudes toward science and science teaching, aptitudes and achievement in science and non-science related areas. Moderate to high correlations were found between Piagetian scores and SAT (quantitative and verbal). PTI scores and the attitude measures correlated moderately. The authors concluded that they had no reason to suspect that such positive correlations would not be found in other samples of college or high school students. It is here argued that different results may be obtained depending on the type of experiences and educational background of the students. Guyer (1965) indicated that requirements for elementary education majors differ with different institutions and that larger colleges and Universities have wider offerings and more stringent requirements in science and science related disciplines than do small liberal colleges.

Schwiran (1969) reported a significant relationship, beyond the .01 level, between the type of undergraduate institution and positive attitude toward science. Barrilleaux (1960) studied the relationships between science achievement, interest, and I.Q. among graduating high school students. He reported that with I.Q. range of 139-186, a positive relationship existed between the relative intensity of science interest and the probability of success. Plitz (1962) reported that some teachers lacked confidence in teaching science due to personal feelings of inadequacy and fears related to natural phenomena. It is unlikely that such teachers would be successful in teaching science which requires those very characteristics in which they were emotionally bankrupt. In his review of Piagetian studies, Chiappeta (1976) concluded that between zero to 52 percent of college students were still in the concrete operational stage. In that same review Chiappetta applied the concept of regression to Piagetian cognitive functioning and remarked:

> Demonstrating intellectual competence below one's potential is referred to as the "regression effect" in this review...Regression appears to occur when individuals are confronted with subject matter that is new to them. Supposedly individuals return to their general level of development after sufficient experience with the new subject matter. (p. 256)

While inconsistencies may be detected in a student's responses to Piagetian tasks, this should not be regarded as regression. A distinction should be made between performance and competence, this distinction is useful in explaining the confusion inherent in Chiappetta's conclusion. In a theoretical analysis of Piagetian structuralism, Bearison (1974) remarked that only performance type regression can occur resulting from debilitating influences (due to circumstances in which structural activity is evaluated) or due, in psychoanalytic terms, to developmental imbalance. Competence type regression alluded to by Chiappetta would be synonymous to the operativity of ontogenetically prior structures of cognitive processes. This condition (competence regression) does not and cannot occur in Piaget's constructivism. Conditions promoting regression are neurological deterioration or decrement, experiential and social isolation, terminal drop and other developmental imbalances; not when an individual is confronted with new subject matter as Chiappetta would want us to believe. Only longitudinal studies can provide empirical evidences to reveal the existence of cognitive regression. According to Papalia, et al. (1974), "there has not as yet been a longitudinal study to provide conclusive evidence that particular cognitive abilities were once present and actually dropped with age". And until such empirical evidences are provided, Chiappetta's concept of "regression effect" as it applies to Piagetian theory in particular and science education in general should be viewed with extreme skepticism.

The body of research reviewed and evaluated so far suggested that only three investigated cognitive development among prospective elementary teachers. The available studies reported results that are equivocal. The state of knowledge revealed by these studies is not at a sufficiently definitive level to be used by science educators for pedagogical and curricular decisions. None of the studies investigated the relationship between cognitive development and success in college science among prospective elementary teachers. None attempted to identify or to investigate the usefulness of science achievement and aptitude measures in predicting performance on Piagetian formal tasks. There is need in science education for empirically-oriented studies, such as the present one, to shed light on cognitive development and associated variables as they relate to prospective elementary teachers. The need to accrue evidences relating cognitive development to measures of college science achievement, aptitudes and attitudes is also urgent in science education. These demands spelled and defined the objectives of the present study.

III. RESEARCH DESIGN AND METHODOLOGY

Introduction

This study was designed to assess the current levels of cognitive development among prospective elementary school teachers and to investigate possible relationships between the assessed cognitive levels and the subjects' ages, measures of science achievement and aptitude, attitudes toward science and the teaching of science. Also, the study sought an answer to the following question: In what order and which variables in the student's science background would explain how much of the variability in performance on Piagetian tasks? In other words, the study sought to isolate factors in the subjects' science background which are useful in predicting performance on Piagetian formal operational tasks.

It is the investigator's view that once these factors are known, then efforts currently being made by science educators to promote the architectonics of formal operations in their students can also be applied towards promoting those desired and identified manipulable predictor variables in the subjects' science background which are significantly related to formal operations. However, it should be recalled that Piaget identified four variables--socio-cultural transmission, biologically constrained maturation, physical and logico-mathematical experiences, and equilibration dynamics--as determinants of the individual's cognitive status. The present study did not investigate all these factors, in fact only two of these, (a) previous and current experiences in science (aspects of physical and logico-mathematical experiences) and (b) maturation (age) were investigated. Furth (1969) referring to Piaget's theory cautioned:

> the genesis of the mechanisms of knowledge cannot be explained by any of the classical factors of developmental theory; it is not due solely to maturation (we observe only phenotypes, never genotypes), it does not result solely from learning on the basis of experience (the capacity to learn is itself tied to development); and it does not result solely from social transmissions (a child transforms the elements received while assimilating them). (p. 189)

It is within this context that the potentialities and limitations of the present study should be evaluated.

Sample Selection

Prior to the selection of the subjects in this study, contacts were established with the School of Education, particularly the Professors in charge of the elementary education program at Oregon State University. Next, contacts were made with the prospective elementary school teachers enrolled in three separate classes to which these subjects had been randomly assigned through computer sectioning of classes. The objectives of this study were detailed to the subjects who were currently enrolled in a sophomore block course, on "Educational Theory and Practicum" during the spring term of 1976. This six hour course, emphasizing educational theory, followed a one-half experience as an aide in an elementary school classroom for one quarter. These criteria qualified them for participating in the study. As a result of these contacts 50 sophomores (prospective elementary teachers) signed up to participate in the study. Of this number, six dropped out. The 44 individuals who were the subjects of the study consisted of 38 females and six males. Their ages ranged from 19 years to 30 years with a mean age of 21.6 years. They all had had experiences as teachers' aides and had taken courses in college science.

None of the subjects was previously known to the investigator who also interviewed the subjects. The subjects were volunteers from the entire set of Spring term Theory and Practicum students and thus were assumed to be representative of prospective elementary teachers at Oregon State University. Their mean college GPA was 2.91 which is in good agreement with the mean GPA of 2.96 which the Office of the Registrar reported for sophomore students in the School of Education for the 1975-76 academic year.

In accordance with the policy of Oregon State University's Committee on human subjects, the investigator obtained written permission from each student before relevant data were obtained from their academic records (transcripts) in the Registrar's office. Records relating to high school grade point average, age, scholastic aptitude test scores (verbal and quantitative), college GPA, and number of college science courses taken were obtained from the subject's transcripts. The variable science product (SCI-PROD) was arrived at by multiplying the individual subject's calculated science GPA by the corresponding number of college science courses taken.

The Clinical-Descriptive Experimental Procedure

With reference to the aims of this study stated previously, it was necessary to adopt a technique which is systematic, insightful, rigorous, and yet inherently flexible. In this study, Piaget's clinical-descriptive technique was supplemented by statistical procedure, hence a clinical-descriptive-statistical technique. Two theoretical objectives determined Piaget's adoption of the clinical method in his genetic epistemology, namely: the qualitative description of cognitive phenomena as a function of time and the subsequent explication of these phenomena to establish psychological operations. These objectives require both logical and empirical techniques. In its original form, Piaget's méthod clinique consisted of an examiner questioning a subject on certain natural phenomena in an interview format similar to a psychiatrist trying to uncover the source of his patient's beliefs and to explore the nature of the pathological imagination. Often the questions asked were fixed and rigidly followed.

However, this method has been criticised by some psycholgists. Isaacs (1930) maintained that Piaget's méthod clinique was inadequate, that the questions asked were too difficult and suggestive. That the subjects were made to undergo conditions inimical to the manifestation of their real ability. Other critics complained that the intellectual capability of the subjects was underestimated because the subjects were required to answer questions which tended to appeal to their imagination rather than to their intelligence.

Since the questions were rigidly prepared in advance in some cases, many critics maintained that the format distorted the subjects' psychological propensity by redirecting it.

Inhelder, Sinclair and Bovet (1974) have defended the method. They traced the various metamorphoses which it had undergone--from purely clinical to clinical experimenter and finally to critical exploration. According to these authors, "Piaget's clinical method (now known as the method of critical exploration) has proved to be most appropriate for the study of cognitive development". They then cautioned:

> this method yields reliable data only if the experimenter has acquired a very thorough theoretical background and mastery of the interview technique. It is essential that he be fully aware of the various hypothesis which can be formulated about the child's reasoning and of the different techniques that can be used to test these hypotheses. He must know how to observe and listen to the child react to responses which will frequently surprise him.

Furth (1969) has also provided some criteria to guide the interview in his questioning techniques. Questions should be designed to avoid two pitfalls, (a) imposing on the students ideas which are not theirs, and (b) accepting as pure currency each of their responses. In recognition of these criteria, the present investigator framed questions which were adapted to the subjects' levels of comprehension. These questions were asked to avoid imposing any preconceived ideas on the results. Efforts were made (by questioning the answers of the subjects) to encourage the subjects to generate a universe of arguments to support their responses. This procedure (which was applied to all subjects) provided opportunities to (a) assess the subject's consistency and genuineness in solving each task, and (b) to evaluate the extent of completion of the subject's operational schemata. The same sequence was used to present the tasks to the subjects. An account of the subjects' responses and their explanations of them were carefully recorded. On the efficiency of this method Inhelder (1962) commented:

> By means of this exploratory method--one which calls for both imagination and critical sense--we believe we obtain a truer picture of the child's thought than we would by the use of standardized tests which involve the risk of missing unexpected and often essential aspects of this thought.

This comment does not imply that the procedure is devoid of standardization. The logical sequence in which the investigator asked questions, presented the tasks, and recorded the responses is inherently standardized. The investigator was only being careful not to sacrifice flexibility and logicality of the technique for standardization. Trained observers should have been used, but the major difficulty in using trained observers is that observer variances may introduce errors into the study. Calculating inter observer reliability (agreement) was also not considered since agreement would be theoretically high, especially when the number of tasks to be rated was small (five Piagetian tasks). This fact possibly explains the high inter observer reliability reported by Ball and Sayre (1972) and Waite (1974).

Scoring Procedure

The scoring procedure adopted in this study was based on criteria established by Inhelder and Piaget (1958). Other investigators such as Lawson (1973), McKinnon (1970), Juraschek (1974), and Ball and Sayre (1972) have used similar criteria in their studies. Each Piagetian task was scored from 1 through 4 depending on the subject's performances.

Levels		Score(s)		
II^A	-	1	Early	Concrete Operational Level
II^B	-	2	Full	
III^A	-	3	Early	Formal Operational Level
III^B	-	4	Full	

The maximum possible score on all five tasks is 20, and the minimum is four. The sum of the five task scores for each subject represented the PTI score on which the assignment to cognitive level was based.

PTI Score		Cognitive Level
4-10	-	Concrete II^A
11-14	-	Concrete II^B
15-17	-	Formal III^A
18-20	-	Formal III^B

The criteria for classifying each subject as either concrete or formal on each tasks are given below. They were arrived at after extensive readings of Piaget and other Piagetian researchers.

All interviews and scoring were done by the investigator as a measure against experimenter variance. Some investigators such as Ball and Sayre (1972) and Juraschek (1974) used trained interviewers to score the Piagetian tasks; and computed inter-observer agreement. The main difficulty with this procedure is that agreement is likely to be high (as these authors have claimed) because there were only few tasks (three to five Piagetian tasks) in which subjects were rated.

Piagetian Task Instrument (PTI)

An analysis of the several tasks designed by Piaget and his Geneva co-workers (1958) reveals three cognitive skills central to successful performance at the formal operational level. The first is the ability to perceive inherent contradictions or discrepancies in one's strategy and logically eliminate them, e.g. by means of proportionality and logical multiplication. The second is a process of analytical decontexualization--solving problems involving several variables which must be identified and separated from their context in order to be dealt with analytically. The third is the ability to generate a universe of hypotheses within a problem situation and to logically manipulate out inferences based on the veracity or falcity of the various hypotheses. In general, the tasks require a set of intellectual schemata viz hypothetico-deductive reasoning and inductive generalization. The ability to combine these two strategies into a unique integrative procedure is a *sine qua non* to the formal operational individual. The tasks were presented in a logical sequence so that the "simpler" ones preceded the more complex ones. This sequence is likely to motivate the subjects to complete all the tasks.

Task 1--This is a paper-pencil task. The original form of the task was described by Inhelder and Piaget (1958) thus:

> The experimental apparatus consists of a kind of billiard game. Balls are launched with a tabular spring device that can be pivoted and aimed in various directions around a fixed point. The ball is shot against a project wall and rebound to the interior of the apparatus. A target is placed successively at different points, and subjects are simply asked to aim at it. Afterwards, they reported what they observed. (p. 4)

The subjects were required to formulate and discover the equality between the angles of incidence and reflection. The subjects were also required to translate their rough global observations into an analytic breakdown of the angles. At the concrete operational stage subjects do not generate hypotheses to explain their observations but remained tied up to stating simple one-to-one correspondence. According to Inhelder and Piaget (1958):

> ...the difference between the concrete level subjects (who do not go beyond the formulation of term-by-term correspondences between the inclinations of the plunger and the course of the ball from the buffer to the target) and the formal level subjects (who look for necessary reciprocity immediately) can be wholly accounted for by distinguishing the step-by-step operations based on simple correlations found in class and relational groupings from the combinatorial operations based on the "structured whole" which constitute propositional logic. (p. 17)

The present investigator designed four paper-pencil test questions, the performance on which can be used to differentiate between concrete and formal operational subjects according to the criteria provided above. The questions in Task 1 are provided in Appendix A.

Task 2--Inherent in Piaget's theoretical postulation is the view that reasoning consists of a potentially infinite sequence of hypothetical syllogisms. Syllogisms are assumed to be deductively guaranteed and capable of induction. Task 2 consisted of syllogistic reasoning test. Piaget's assertion is that if reasoning is to constitute an advance in knowledge, it must involve transitions from a proposition, p, to some other proposition, q, which is more than a purely formal transformation of p. Transitions of this nature are encountered in all forms of mediated inferences, syllogistic reasoning not excluded.

The form in which the syllogisms are presented to the subjects is a departure from the status quo. While other investigators, Ball and Sayre (1972), Waite (1974) have provided syllogisms which required their subjects to state and justify whether the syllogisms are valid or not, the strategy adopted in the present study was to provide the subjects with syllogisms and to require that they select a valid conclusion from a number of given alternatives (multiple choice). In all cases the subjects were required to justify their choice.

Other variations which the present investigator considered in this task are (a) the number of premises in the argument, (b) the content of the syllogisms, whether the terms of the premises were symbolized (e.g.; p, q, r) as used by Ball and Sayre (1972) and Waite (1974) or whether they were meaningful objects or classes of objects, and (c) the form in which the premises are stated, whether they were hypothetical or categorical [all hypothetical (conditional) propositions have their categorical equivalents].

Instead of using symbols to represent premises, meaningful terms were used. The premises were made to be false so that the investigator could recognize genuine deduction when and if it was made. The statements were put in hypothetical and categorical forms. Because the syllogisms were presented in multiple-choice format, it was possible to confront the subjects with, among other choices, invalid conclusions and statements which provide bases for their rejection. This is an appropriate technique of testing the subjects' recognition of falacy. It is better than the commonly used procedure of simply presenting the subject with one conclusion and requiring him to pass a direct judgment on its validity. See Appendix B for Task 2.

Task 3--Oscillation of a pendulum and the operation of exclusion.

This was a multifactor experimental set-up. A pendulum consisting of a weight suspended by a string was presented to each subject. The independent variables were the length of the string, the weight of the object, the amplitude of oscillation and the force of push. The subject was required to identify and isolate the casual factor (dependent variable) for the frequency of the oscillation of the pendulum. In doing this the subject, if formal operational, should be able to vary a single factor while holding "all other things equal", Inhelder and Piaget (1958). Several different weights were provided and the subjects were free to manipulate the apparatus.

Task 3. Criteria for Operations of Exclusion.

II^{A}--(a) Fails to exclude weight and height (probably due to faulty ordering) and either does not or has difficulty finding correct effect of the length of the string.

Method also fails either to vary only one, or to vary and infer correctly; or

(b) Fails to find correct role for all three variables (and may also fail to order one or more) but method, although shaky, shows some ability to vary only one and infer correctly.

II^B--(a) Fails to exclude both weight and height (perhaps because of uncertain seriate ordering) and fails in method, at <u>least</u>, to vary only one, to make a test, and possibly fails to vary and/or infer correctly as well, or

(b) Fails to find correct effect of the length of the string, although is able to exclude one of weight and height--method shows failure on one of the two aspects. Varies only one and varies and infers correctly.

III^A--(a) Fails to exclude weight and height (possibly because of uncertain ordering) but method has few faults and may show some untested inferences, or

(b) Excludes one of weight and height with difficulty and has some shaky aspects to method and no untested inferences, or

(c) Excludes both weight and height with difficulty, but method is shaky throughout, although may show some untested inferences.

III^B--Finds correct effect of each factor by isolating all of the variables. Method is sound--varying a single factor while holding "all other things equal". May not infer from minimum testing, however, must show some untested inference.

Task 4--The law of floating bodies and elimination of contradiction.

This task tested the subjects' sensitivity to logical inconsistency and illustrated that the conception of logical consistency itself evolves gradually through the ontogenetic ladder. Each subject was presented with a number of disparate objects--wood, wax, aluminum, zinc, needle, candle, corks, in which different weights were embedded, an empty cube with plastic walls whose density is approximately one. The subject's tasks were to (a) classify these objects with respect to their floating potentialities; (b) to explicate the empirical basis for such classification; and (c) to verify his classification by the observation of the behaviour of these objects in several jars of water. Finally the subject was required to summarize his observations and generate a non-contradictory principle explaining them.

Inhelder and Piaget (1958) have provided the criteria for the successful solution of this problem:

> ...given that the law to be found is that objects float if their density or specific gravity is less than that of the water, two relationships are essential to the solution of the problem: density, i.e. the relation of weight to volume, and specific gravity, i.e. the relation between the weight of the object (its density if it is solid, or the weight of its matter plus that of the air which it contains) and an equivalent volume of water. (p. 21)

Task 4. Criteria for Elimination of Contradictations

II^{A}--Renounces the idea of absolute weight. Conceptualizes weight as being relative to the specific matter of the problem situation. Classifies correctly by utilizing a double-entry classification paradigm, hence generating four possible classes of objects, viz, small light object, small non-light object, large light objects, or large heavy objects.

II^{B}--Makes preliminary efforts to relate weight to volume by utilizing logical multiplication (for equal volumes and different weights or for equal weights and different volumes), especially co-univocal multiplication of relations. Shows evidence of residual dynamistic thinking, hence relates weight of an object with that of the total volume of water in the receptacle.

III^{A}--Conserves volume (i.e. as an invariant) via the concept of proportionality (as appossed to additive compensation) suggesting the invention of a situation devoid of empirical correlates. Verbalizes and then discards crude hypothesis without verification.

III^{B}--Accurately formulates the relationhsip between the weight of an object and its volume (or the weight of the volume of water displaced using the schema "all other things being equal"). Generalizes the law to other situations and shows confidence in his generalizations.

Task 5--Combinatorial logic. This task tests the process of hypothetical thinking which consists of the formation of hypotheses involving the abstract operation of logical combination and recombination of concepts, culminating in combinatorial intensions and conditioned references. The task presupposes the basic rule in Piagetian theory that the logic of classes is genetically prior to the logic of propositions and that every problematic situation conveys a structural incompleteness, the function of the hypotheses generated therefore is to fill the gaps thereby propagating a profitable configuration. Although the task can be solved by trial and error, the systematic evaluation of the role each chemical plays in creating the proper yellow solution (and subsequently bleaching it) requires combinatorial operation, propositional logic and the transformation of propositions.

The apparatus used in the task consisted of five flasks containing colorless, odorless liquids, several test-tubes and five eye droppers. Flasks A. B, C, D and X contained dilute sulphuric acid, distilled water, sodium thiosulphate, oxygenated water and potassium iodide solution, respectively. Combining A, D and X produces a yellow colored solution. The reaction requires that oxygenated water (D) oxidizes potassium iodide (X) in the presence of an acid medium (A). The water (B) is neutral, but the thiosulphate (C) is a bleaching agent preventing the color from forming. Thus, the yellow color could be generated either by combining A + D + X or A + B + D + X.

Each subject was presented with two test-tubes containing perceptually identical liquids, one contained water, the other A + D, the subject was unaware of their contents. The investigator added a few drops of X to each in the presence of the subject. The tube containing A, D and X turned yellow while the other remained unchanged. The subject's task was to produce the yellow color and to identify the functions of each liquid. The investigator, meanwhile, recorded the subject's overt and non-verbal procedures.

Task 5. Criteria for Combinatoral Logic

II^A--Employs co-univocal multiplication of classes in combining each liquid with X and all (of the liquids) with X only. Other possible combinations are not attempted without prompting. Utilizes quantitative, prelogical and phenomenalistic reasoning to account for his failure to obtain the required color.

II^B--Attempts almost all combinations but rather unsystematically (through trial and error). Requires occasional prompting to make exhaustive combinations. Cannot adequately explain the quo modo behind the appearance of the color, seeking the cause in particular elements rather than in their combinations. The negative effect of liquid D cannot be methodically verified.

III^A--Uses co-univocal multiplication of classes of the liquids to obtain the color. Shows evidence of deductive conclusion. Searches for other possible combinations. Employs both reversible operation of negation (inversion) and coordinates this with operational reciprocity in establishing the role of liquid D.

III^B--Organizes his proofs well and carefully intergrates his strategies of discovery (in addition to the strategies utilized by the stage III^A subject). Requires virtually no prompting in establishing the role of each liquid.

The Attitude Scale (Rationale for its use)

A Likert-type attitude scale developed by Redford (1969) for prospective elementary school teachers was used in this study. It is a five-scale category instrument with 40 items, 20 measuring attitude toward science and 20 measuring attitudes toward science teaching. A scale with few scale categories (e.g. true, false) may not allow the propsective teachers to make full use of their capacities to discriminate while a scale with a large number of categories (e.g. Osgood's Semantic Differential) may be beyond the subject's capacity thus increasing error of measurement.

In a theoretical analysis using Kelly's correction for coarse grouping on the correlation coefficient, Symonds (1924) concluded that the optimal number of categories to maximize scale reliability is between five and seven. He also remarked that the increase in reliability when more categories are used is negligible. The Redford scale contains relatively heterogenous items. Bendig's (1953, 1954) empirical studies suggested that the reliability of a heterogenous scale can be increased not only by increasing the number of items (40 in the Redford scale instrument) but also by increasing the number of the item scale (five in Redford scale).

Redford (1969) used the split-half reliablity test and the Spearman-Brown prophecy formula to establish the reliability of the scale. A reliability of .88 was calculated for the attitude toward science scale and .84 for the attitude toward science teaching scale. Komorita and Graham (1965) reported that by using a relatively large number of response choices, there is a corresponding increase in the precision of the measuring instrument. Increasing the number of scale points also permits an extreme response set (Cronbach 1946, 1950) to be evoked, the use of a small number of scale points eliminates or minimizes this response set.

All of these advantages in the Redford scale, added to the simplicity and convenience in administration and scoring, resulted in the investigator's decision to use this instrument.

The Sequential Test of Educational Progress

The Sequential Test of Educational Progress (STEP Series II, Science Form 1A), a multiple-choice test, was administered and scored by the investigator. It consisted of two parts measuring the knowledge, comprehension, and application of basic concepts and processes of science. Each part required 30 minutes of working time. Part I contained 46 items designed to tap important facts, principles, concepts, and processes of science. Twelve items required knowledge, 11 required comprehension, 22 required application, and none required higher abilities, i.e. analysis and synthesis. Part II consisted of 30 items capitalizing on the utilization rather than the possession of knowledge and ability. One item required knowledge, 8 required comprehension, 15 measured application, and 7 tapped the students' higher mental abilities (analysis and synthesis). The contents of both parts were drawn from concepts in biology, chemistry, earth science, and physics.

IV. PRESENTATION OF THE DATA

Regression Analysis and Stepwise Procedure

In addition to investigating the possible relationships between scores on Piagetian tasks and certain independent variables concerning the subjects' science background, this study also examined factors in the subjects' science background useful in predicting performance on Piagetian formal tasks. With such objectives, correlation and regression analyses techniques were recommended by the statistician as being adequate and powerful enough to analyse the data. Ostle and Mensing (1975) have enumerated, among others, four uses of regression analysis: (1) To reduce the length of a confidence interval when estimating some population mean (or total) by considering the effect of concomitant variables; (2) To eliminate certain "environmental" effects from our estimates of treatment effects, i.e. we may wish to examine adjusted y values; (3) To predict y (criterion variable) knowing values of $X_1,...X_k$ (predictor variables) whether or not a casual relationship exists; and (4) To influence the outcome of the criterion variables assuming a casual relationship.

An important step in predicting performance at the formal operational level is a systematic selection of the predictor variables to be included in the prediction model. In this respect, the stepwise regression procedure is extremely important. Theoretically, the first predictor variable selected and included in the model by the stepwise regression procedure is one which minimizes the residual sum of squares and has a regression coefficient that is significantly different from zero. Two criteria are required for the selection of the second variable (and subsequent variables), namely: that when selected and combined with the first variable (and preceding variables), the residual sum of squares is at a minimum and that the partial test of significance of the coefficient for the second variable suggests that the coefficient is different from zero. However, the model suggested by the stepwise procedure may not be the true functional relationship, it nevertheless can be used to construct a predictive model. Also, since it is often tedious to identify more than a small number of predictor variables accounting for incremental validity, the concept of a suppressor variable (Horst, 1966) has surfaced in regression precedure. In classical term, a suppressor variable is one wholly uncorrelated with the criterion variable, but which by virtue of a correlation with a predictor, improves the prediction of the criterion (PTI). This concept potentially limits the predictability of the stepwise technique and this limitation is recognized in this study. Table 4-1 provides the raw scores for testing the various hypotheses.

Test of Major Hypotheses

Hypotheses 1 and 2 were tested at the .05 level of significance. Hypotheses 3 and 4 were tested at the .01 level while hypothesis 5 was tested at the .10 level of significance.

Hypothesis 1, in null form, states that there is no significant relationship between performance on the five Piagetian tasks

Table 4-1

Subject Number	Age in Months	Elimination of Contradiction	Operation of Exclusion	Reciprocal Implication	Combinatorial Logic	Syllogism Reasoning	Piaget Total	High School GPA	College GPA	SCI GPA	SCI TOT	SCI-PROD	STEP-SCI	LOG OPER.	ATST	ATS	✓ SAT-Q	✓ SAT-V
1	232	2	4	3	3	3	15	3.47	2.70	2.0	4	8	20	4	52	65	51	59
2	247	2	4	2	3	1	12	2.78	2.19	2.0	22	44	15	3	63	70	400	380
3	238	3	4	4	3	4	18	3.06	2.61	3.0	44	132	35	2	42	39	600	460
4	231	2	4	3	2	2	13	2.52	3.33	2.0	10	20	36	3	65	57	340	390
5	235	2	4	3	4	3	16	3.76	3.08	4.0	27	108	40	3	41	49	410	350
6	240	3	4	4	4	3	18	3.80	3.90	4.0	20	80	56	2	60	65	560	550
7	242	1	4	4	2	3	14	2.80	2.76	2.0	17	34	35	4	66	69	300	270
8	234	2	3	3	4	4	16	3.90	3.96	4.0	9	36	40	3	51	69	490	510
9	230	2	3	1	2	3	11	3.01	2.88	2.0	8	16	29	3	61	60	280	500
10	241	3	4	4	3	3	17	2.26	2.66	2.0	15	30	38	5	70	56	430	440
11	228	2	3	1	3	2	12	3.21	2.94	2.0	14	28	37	3	42	52	410	390
12	234	2	4	4	4	3	17	3.60	2.14	2.23	17	38	40	4	56	54	560	460
13	243	2	4	1	2	1	10	2.05	2.81	1.33	12	16	43	2	44	52	390	360
14	238	2	2	1	2	2	9	2.87	3.03	2.0	8	16	29	3	43	51	290	350
15	232	2	4	4	3	3	16	3.25	2.34	2.53	28	71	39	4	73	62	420	450
16	241	2	3	2	4	2	13	3.77	2.85	3.0	12	36	54	3	54	58	410	510
17	253	3	4	3	2	3	15	3.86	3.29	2.31	29	67	54	2	44	59	620	510
18	231	3	4	2	4	4	17	3.26	2.90	3.0	14	42	50	3	51	46	410	340
19	250	3	4	4	4	3	18	3.94	3.46	3.50	24	84	30	5	61	62	520	496
20	240	2	4	3	4	3	16	3.25	3.32	3.50	10	35	53	3	54	52	510	490
21	235	2	4	3	3	4	16	2.55	2.88	2.0	16	32	28	2	53	56	430	350
22	249	3	3	4	2	1	13	2.85	2.20	2.58	31	80	32	3	47	52	480	470

Table 4-1 (cont.)

Subject Number	Age in Months	Elimination of Contradiction	Operation of Exclusion	Reciprocal Implication	Combinatorial Logic	Syllogism Reasoning	Piaget Total	High School GPA	College GPA	SCI GPA	SCI TOT	SCI-PROD	STEP-SCI	LOG OPER.	ATST	ATS	SAT-Q	SAT-V
23	238	4	4	4	4	4	20	3.08	2.85	2.91	35	102	63	3	54	60	510	490
24	254	2	4	4	4	4	18	2.65	3.84	4.0	12	48	54	2	70	70	270	230
25	235	2	3	2	3	4	14	2.69	2.32	2.0	17	34	30	3	55	51	420	510
26	252	3	4	4	4	4	19	3.85	2.64	2.17	17	37	35	2	55	70	560	590
27	238	3	4	4	4	3	18	3.59	3.45	3.84	19	73	37	4	42	55	590	550
28	244	2	4	3	4	4	17	2.80	2.31	2.0	15	30	34	2	56	64	390	350
29	238	2	4	4	4	4	18	3.18	2.54	3.0	8	24	42	3	66	63	320	430
30	288	2	4	4	3	3	16	3.85	3.80	2.0	21	42	48	3	67	60	550	580
31	238	2	3	1	3	3	12	3.65	3.41	4.0	20	80	27	4	56	64	510	480
32	240	3	4	4	4	3	18	3.24	2.39	2.0	57	114	55	3	56	59	500	450
33	243	2	4	4	3	3	16	3.33	3.40	2.0	12	24	26	5	36	50	300	340
34	250	3	4	4	2	3	16	3.73	2.70	2.80	15	42	40	3	60	60	560	400
35	237	3	3	2	4	3	15	3.47	3.81	3.30	20	66	44	3	67	68	510	480
36	234	2	4	2	3	3	14	3.46	3.20	2.0	13	26	29	3	52	70	360	470
37	240	3	3	2	3	3	14	3.64	2.51	2.21	47	104	46	4	59	54	520	440
38	240	2	4	4	4	3	17	3.13	2.0	2.50	6	15	36	3	43	52	530	370
39	244	2	4	4	4	4	18	3.12	3.25	2.79	27	75	46	2	61	66	560	460
40	245	2	3	3	3	4	15	3.84	2.85	2.52	23	58	30	4	57	45	490	480
41	243	2	3	2	2	4	13	3.22	2.68	2.61	13	34	10	3	63	62	320	380
42	238	2	4	3	3	3	15	3.50	3.0	2.60	20	52	33	3	48	50	500	410
43	236	2	3	4	3	3	15	3.39	2.89	2.83	18	51	49	3	61	60	520	470
44	360	2	3	3	3	1	12	3.28	2.68	3.0	18	54	30	2	50	52	420	350

and the ages of the subjects. This hypothesis was tested by regressing the Piagetian tasks scores on the corresponding ages (in months). An analysis of variance table (Table 4-2) was set up using the Statistical Interactive Programming System (SIPS) developed by the Department of Statistics, Oregon State University, Corvallis. Pearson-product moment correlation coefficient was also computed (See Table 4-12).

Table 4-2

REGRESSION ANALYSIS--PIAGETIAN SCORES ON AGE

Source	df	SS	MS	F
Total	43	276.9	6.44	
Regression	1	2.19	2.19	0.3358
Residual	42	274.7	6.5	

With an F-ratio of only 0.3358, hypothesis 1 was not rejected; there was no significant relationship between performance on Piagetian formal tasks and age among the subjects. The calculated Pearson product moment correlation coefficient (Table 4-12) was -.08, a low and negative relationship. The coefficient of determination (the weighted sum of correlations with the criterion variable) for the age was computed to be 0.008, in other words 0.008 or 0.8 percent of the variability in performance on the five Piagetian tasks was accounted for by the predictor variable, age. Studies such as those of Crowell, *et al*. (1957) and Guiliford (1967), which have investigated the relationships between age and psychometric measures in late adolescents and young adults have also reported low and negative correlations. It is possible that intellectual functioning reaches an asymptote among the subjects in the present study whose ages range from 19 to 30 years. Ausubel (1964) remarked "In any developmental process where experiential factors are crucial, age per se is generally less important than degree of relevant experience". Also, Piagetian theory stipulates that individuals of ages 19-30 years would be largely formal.

Hypothesis 2, in null form, states that there is no significant relationships between performance on the five Piagetian tasks and the subjects' attitudes toward science and science teaching. The correlation coefficients calculated for this hypothesis were very low, 0.09 for attitude toward science and 0.13 (Table 4-12) for attitude toward science teaching. The analysis of variance, Tables 4-3, 4-4, and 4-5 showed that the hypothesis could not be rejected--there was no significant relationship between performance on Piagetian tasks and attitudes toward science and science teaching among the group of prospective elementary school teachers. A coefficient of determination of only 1.63 percent (Table 4-3) indicated that both variables accounted for very little of the total variance in the criterion variable.

Table 4-3

REGRESSION ANALYSIS PTI SCORES ON ATS AND ATST

Source	df	SS	MS	F
Total	43	276.97	6.44	
Regression	2	4.51	2.25	0.3395
Residual	41	272.46	6.64	

$R^2 = .01629$

Table 4-4

REGRESSION ANALYSIS PTI SCORES ON ATS

Source	df	SS	MS	F
Total	43	276.97	6.44	
Regression	1	2.68	2.68	0.4112
Residual	42	274.29	6.53	

Table 4-5

REGRESSION ANALYSIS PTI SCORES ON ATST

Source	df	SS	MS	F
Total	43	276.97	6.44	
Regression	1	4.19	4.19	0.6461
Residual	42	272.78	6.49	

Hypothesis 3 states that no significant relationship exists between performance on Piagetian tasks and scores on the Sequential Test of Educational Progress (STEP Series II, Science Form IA).

The assumption in this hypothesis was that the STEP-SCI would measure the current science achievement of the subjects and that the ability to perform on the STEP-SCI test might be related to that required by the five Piagetian tasks, in other words, that both test and tasks were tapping the same psychological parameters. Table 4-6 shows the analysis of variance set up for testing this hypothesis.

Table 4-6

REGRESSION ANALYSIS PTI SCORES ON STEP-SCI

Source	df	SS	MS	F
Total	43	276.97	6.44	
Regression	1	51.29	51.29	9.546**
Residual	42	225.68	5.37	

** $p < 0.01$

An F-ratio of 9.54 was significant at the 0.01 level indicating that the null hypothesis should be rejected--there was a significant relationship between performance on the five Piagetian tasks and scores on the STEP-SCI. The coefficient of correlation was calculated to be .44 which was significant at the .01 level. About 19 percent of the variability in Piagetian performance was explained by the STEP-SCI variable (see Table 4-11 also).

Hypothesis 4 asserts that no significant relationship exists between performance on the five Piagetian tasks and the science product (SCI-PROD) achievement measures. The analysis of variance Table 4-7 shows the result on which this hypothesis was tested.

Table 4-7

REGRESSION ANALYSIS PTI SCORES ON SCI-PROD

Source	df	SS	MS	F
Total	43	276.97	6.44	
Regression	1	41.90	41.90	7.49**
Residual	42	235.06	5.59	

** $p < 0.01$

An F-ratio of 7.49 was significant at the 0.01 level, hypothesis 4 was therefore rejected--a significant relationship existed between SCI-PROD and Piagetian performance. The calculated coefficient of determination for this variable was 15.1 percent (Table 4-11), the SCI-PROD accounts significantly to the variability in performance on Piagetian tasks.

Success in the number of science courses experienced by a student presupposes fully equilibrated formal operational schemata. Many investigators Juraschek (1974), Lawson (1975) suggested that the difficulties prospective elementary teachers had in learning science and mathematics might be related to their inability to be formal operational. The present study using a unique variable (SCI-PROD) established a relationship between cognitive development and SCI-PROD among prospective elementary school teachers.

Hypothesis 5 states that there is no significant difference between scores on Piagetian tasks of students classified as high and those classified as low with respect to the SCI-PROD measures. The mean score of the SCI-PROD was calculated. Those subjects with

SCI-PROD score above the mean were classified as high; those below the mean were classified as low. The means and standard deviations for both groups were calculated, their means were then compared utilizing the t-test statistic. Table 4-8 shows the result obtained for this hypothesis.

Table 4-8

	N	$\bar{x}$	σ	t
High SCI-PROD Students	23	15.65	2.22	-1.76*
Low SCI-PROD Students	21	14.33	2.72	

* $p < 0.10$

The t-value of -1.76 was significant at the 0.10 level, the hypothesis was therefore rejected as there was a significant difference between the two groups.

One of the objectives of this study was to isolate those independent variables in the science background that correlate with and are significant in predicting performance on Piagetian formal operational tasks. When the Piagetian tasks scores were regressed on the ten predictor variables (Table 4-10) using the stepwise procedure, the STEP-SCI and SCI-PROD predictors, in that order, were found to be most significant in explaining the variability in performance on Piagetian formal operational tasks (See Tables 4-9 and 4-10).

An F-ratio of 2.184 was significant at the 0.05 level. The computed coefficient of determination of 40 percent (Table 4-10) indicated how much of the variability in the Piagetian task performance can be explained by all ten predictor variables. Of this, the STEP-SCI only accounted for about 19 percent of the variability (see Tables 4-10 and 4-11). About 60 percent (coefficeient of non-determination) of the variability in the criterion variable was not explained by all ten predictor variables. The significance of this finding is discussed in the next chapter.

Table 4-9

REGRESSION ANALYSIS, PTI SCORES ON 10 PREDICTOR VARIABLES

Source	df	SS	MS	F
Total	43	276.97	6.44	
Regression	10	110.32	11.03	2.184*
Residual	33	166.6	5.05	

* $p < 0.05$

Table 4-10

TEN PREDICTOR VARIABLES AND ASSOCIATED COEFFICIENTS OF DETERMINATION

No. of Entering Variable	Order of Var. Entering	Associated Coefficient of Determination
1	STEP-SCI	0.1852
2	SCI-PROD	0.2505
3	H. Schl. GPA	0.2782
4	AGE	0.2947
5	Coll. GPA	0.3103
6	ATS	0.3290
7	SAT-Q	0.3417
8	SAT-V	0.3852
9	ATST	0.3941
10	TOT. LOG. OPERA.	0.3983

Table 4-11

† CONTRIBUTION OF EACH VARIABLE INDEPENDENTLY TO THE VARIABILITY IN PERFORMANCE ON PIAGETIAN TASKS

Variable	R^2	% Contribution	F
Age	.0079	0.8	0.336
Sci-Tot	.0838	8.3	3.84
Sci-GPA	.1442	14.4	7.07*
Sci-Prod.	.1513	15.1	7.48**
Coll. GPA	.0044	0.4	0.187
Step-Sci.	.1852	18.5	9.54**
H. Schl. GPA	.1003	10.0	4.68*
ATST	.0151	1.51	0.646
ATS	.0096	1.00	0.411
SAT-Q	.1493	14.9	7.37**
SAT-V	.0281	2.8	1.216

* $p < 0.05$

** $p < 0.01$

† The criterion variable was regressed on each predictor variable to obtain the data in this table.

Table 4-12

Correlation Matrix, N = 44

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1) Elim. of Contradiction	1.00	.32	.52	.54	.39	.36	.03	.55	.20	.59	.14	.58	.31	-.17	-.11	.27	.37	.53
2) Oper. of Exclusion	..	1.00	.64	.59	.60	.69	-.04	.36	.31	.41	.06	.32	.04	.08	.15	.34	.13	.24
3) Recipro. Implication	..	..	1.00	.63	.52	.84	.18	.35	.20	.47	.02	.41	.17	.19	.09	.49	.08	.43
4) Comb. Logic	..	..	..	1.00	.62	.78	-.04	.39	.47	.49	.36	.54	.37	.07	.18	.56	.22	.40
5) Syllog. Reasoning	..	..	..	..	1.00	.79	-.37	.05	.36	.38	.05	.47	.26	.17	.13	.61	.07	.09
6) Piaget Total	..	..	..	..	..	1.00	-.08	.29*	.38**	.40**	.23	.44**	.32*	.13	.09	.03	.21	.40**
7) Age	..	..	..	..	..	..	1.00	.07	.06	.07	.29	-.02	.14	.02	.01	-.25	.01	.14
8) Science Courses	..	..	..	..	..	..	..	1.00	.05	.88	.18	.46	.15	-.04	-.18	.08	.29	.50
9) Science GPA	..	..	..	..	..	..	..	..	1.00	.52	.54	.47	.58	.03	.14	.04	.18	.49
10) SCI-PROD	..	..	..	..	..	..	..	..	..	1.00	.07	.56	.41	-.05	-.17	-.08	.32	.56
11) College GPA	..	..	..	..	..	..	..	..	..	..	1.00	.39	.53	.06	.26	.04	.18	.49
12) STEP-SCI	..	..	..	..	..	..	..	..	..	..	..	1.00	.32	.15	.02	.24	.34	.54
13) High Schl. GPA	..	..	..	..	..	..	..	..	..	..	..	..	1.00	-.03	.19	.15	.30	.44
14) ATST	..	..	..	..	..	..	..	..	..	..	..	..	..	1.00	.69	.17	.07	.16
15) ATS	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1.00	-.03	.00	-.16
16) LOG. OPER.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1.00	.07	.16
17) SAT-V	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1.00	.75
18) SAT-Q	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1.00

* $P < 0.05$

** $p < 0.01$

V. SUMMARY, CONCLUSION AND IMPLICATION

Summary

This study was designed to find answers to the following questions: What relationships exist between scores on Piagetian tasks (which reflect upon the intellectual level of the individual) and the following independent variables--age, attitude toward science and science teaching, STEP-science and Science-product? Is there a significant difference in the means of Piagetian task scores of subjects classified as high and those classified as low with respect to the variable Science-product? When the stepwise procedure is applied in analyzing the raw data, which variables, what percentage and in which order would the independent variables account for the total variance on the criterion variable? Intercorrelations among the variables were investigated and the proportion of the prospective elementary teachers performing at each of the two Piagetian operational level (concrete and formal) was also determined.

A review of the literature suggested that relatively few studies have investigated formal thought processes in relation to science background among prospective teachers. The results of available studies were inconclusive hence necessitating further empirical studies.

This study utilized five Piagetian formal operational tasks to assess and categorize the levels of intellectual development of 44 subjects. The tasks were administered and scored by the investigator in an attempt to eliminate experimenter variance. Records relevant to the science background of the subjects were collected in the Oregon State University Registrar's Office. Regression analysis, Pearson-product moment correlation coefficient, F-ratio, and t-test procedures were employed to analyse the data and to test the following null hypotheses:

There is no significant relationship between performance on the Piagetian tasks (level of cognitive development) and the age of the subjects. There is no significant relationship between levels of cognitive development and attitude toward science and science teaching. There is no significant relationship between performance on Piagetian tasks and scores on the Sequential Test of Educational Progress, Science: Form IA (STEP-SCI). There is no significant relationship between performance on Piaget Task Instrument (PTI) and science achievement measures (SCI-PROD). There is no significant difference in Piagetian task scores of the group of subjects classified as high and the group classified as low with respect to the SCI-PROD variable.

Hypotheses 1 and 2 were not rejected at the 0.05 level of significance, hypotheses 3 and 4 were rejected at the 0.01 significance level, and hypothesis 5 was rejected at the 0.10 level of significance. The coefficient of determination for the ten predictor variables was 40 percent. The STEP Science test score and the product of college science GPA and number of quarter hours of science completed accounted for 25 percent. Sixty-eight percent of the subjects were found to be formal operational, 32 percent concrete operational. No logical or defensible criteria could be established to identify subjects at the transitional level.

Conclusion

The study showed that the incidence of formal operations was not universal among the prospective elementary school teachers studied. However, this finding did not contradict Piagetian brand of holistic structuralism which stipulates universality in the hierarchical order in attaining the four psychogenetic levels but does not require that the highest level be attained by all Homo sapiens.

The low and negative correlation (r = -.08) between PTI scores and age was in agreement with most psychometric measures which have reported similar negative correlations with age, Guiliford (1967). The age range of the subjects in this study was between 19 to 30 years, this factor probably explained the low negative correlation. As the age range becomes smaller, correlations with performance are likely to decrease especially at the college level where measures of ability are generally supposed to be quite high. Another explanation would be to regard age as a threshold variable especially when it was used in predicting performance at the formal level (see Tables 4-10 and 4-11). After a certain age level is reached, age may no longer play a significant role in predicting performance on Piagetian formal tasks. A crystallization of performance on Piagetian formal operational tasks might be in operation among subjects within the age group studied.

Inherent in Piaget's constructivistic theorizing is the view that formal operational thought processes may be attained at different ages (presumably after 15 years) by different individuals depending on their progressive and qualitatively discriminating aptitudes and specific career specializations. This probably explains why significant correlations were found between performance on Piagetian tasks, STEP-SCI and SCI-PROD. Is it possible that formal thought processes are modeled along scientific fields for scientifically minded individuals?

The non-significant and low correlations between scores on Piagetian tasks and attitude toward science and science teaching was unexpected especially since there were significant correlations between measures of science achievements, aptitudes and performance on Piagetian tasks. This result seemed to indicate that for students enrolled in a professional program (curriculum), measures of attitudes were not related to performance. Enrollment in a teaching profession inherently presupposes a high dose of attitude in teaching. However, the findings of this study could also be attributed to the homogeneity of the prospective elementary teachers. One problem, however, involves the conceptual status of the attitude construct. Attitude is a multidimensional construct. Other variables may operate concurrently with attitudes or as mediating factors to suppress its correlation with performance on Piagetian tasks. The low and insignificant correlation reported in this study contradicted Lawson, _et al_. (1975) finding, which showed a significant correlation between scores on PTI and attitude toward science and science teaching. Curl (1975) found no significant correlation between cognitive development and attitude toward mathematics.

The stepwise regression procedure identified STEP-SCI as one most important independent (predictor) variable (Table 4-11) accounting for the largest variance in the criterion variable (Piagetian scores). STEP-SCI tested knowledge and understanding of the fundamental concepts and processes of science, the comprehension and application of this knowledge, and the mastery of science skills. Performance on these tests may therefore be used to predict performance on Piagetian formal tasks. The finding that a significant correlation existed between PTI scores and SAT (quantitative) was contrary to Schwebel's (1973) finding. In theory the SAT (quantitative) measures logical reasoning and perception of mathematical relations, which are also supposed to be tapped by Piagetian tasks. In several of his writing's Piaget has emphasized the role of verbal and logico-mathematical experiences in cognitive development, the moderate to high correlations between several of the independent variables and scores on Piagetian tasks would seem to confirm such an emphasis.

The results shown in Table 4-1 indicated that 68 percent of the prospective elementary school teachers were formal operational with respect to the tasks used in this study. This percentage is fairly high compared to McKinnon's (1970), Juraschek's (1974) and Chiappetta's (1974). McKinnon found that only 25 percent of college freshmen were formal operational, Juraschek found 48 percent of prospective teachers and Chiappetta 47 percent of female teachers to be formal operational. The differences might be due to the nature and number of tasks used to assess performance on (or rather incidence of) formal operations. This study included multiple-choice syllogistic reasoning format which was not included in any of the studies cited above. This study utilized five tasks (the same number as McKinnon's) but Juraschek used three tasks while Chiappetta used only one task. It was recognized, however, that many other confounding factors may account for the observed differences in the percentages of formal operational subjects.

Implications for Science Education

This study indicated that more prospective elementary school teachers were formal operational than previously assumed. However, the assumption that all subjects 15 years and above are formal operational should by now be discarded, also attempts by some science educators, e.g. McKinnon (1970), to transform students from concrete to formal operational level might not be necessary. This study, and others related to it, indicated that in reality we are always confronted in the classroom by a heterogenous group of concrete and formal operational students. To achieve the objectives of science education, to which we are committed, prescribing curricular activities in a developmental framework requires that the teaching and learning of content materials should simultaneously mirror and contribute to individual growth as well as recognizing the levels of cognitive development of the students.

Programs for prospective teachers should be designed to promote a balance between accommodation (conformity to the environment) and assimilation (transformation of the environment). Also, our instructional strategies should reflect forms of cognition that seek equilibrium between concrete reality--concrete operations (the way things _are_) and a rigorous adherence to the axiomatic, hypothetical and theoretical possibility--formal operations (the way things _could be_). The processes of codifications and operations in Piagetian paradigm are tightly interwoven. The differences between the concrete and formal operational subjects observed in this study probably reflected differences in the learning of new codes that could be used to modify operational strategies. If this was the case then it could be argued that the capacity to operate at the formal level may not solely be determined by the presense of abstract logical structures, the quantity and quality of the information and the codes (logical operators) by means of which the information is delivered may also be factors to be considered.

That not withstanding, it is suggested that meaningful instructional materials should be made available to prospective elementary teachers. These materials should be provided within the context of multiple concretisations (Dienes' 1963 perceptual variability) and multisensory approach. These approaches would encourage the student to cross-fertilize the concrete with the abstract materials, thus able to decontexualize the logico-mathematical structures inherent in a problem situation. Two questions which still loom in the air are: In what order should science concepts be taught in order that concrete and formal operations be as reliable and viable as possible? What proportion of concrete to abstract concepts should be included in the curriculum of prospective elementary school teachers? These questions become critical in the light of recent studies--Lawson (1973), Juraschek (1974), and this present one--which have shown that we are always confronted with a definite but variable proportion of concrete to abstract thinkers in our science classes.

This study failed to identify subjects whose total performance on the Piagetian tasks would indicate that they were operating between concrete and formal operational level. The available data, Table 4-1, suggest that subjects who exhibited concrete operational strategies were not necessarily incapable of the rigorous hypothetico-deductive approach. Within the age group of subjects studied, it would seem that in general both concrete and formal operations coexisted throughout the period the subjects were involved in solving the tasks. With respect to some of their professional responsibilities in the classroom, it would appear that concrete operations are applicable and adequate for prospective elementary school teachers. Highlighting the limitation of formal operations and the potentiality of concrete operations, Blasi and Hoeffel (1974) remarked:

> In simply attending to the label concrete, one may underestimate the power of adaptation to reality, in particular future reality, which is present in the concrete form of understanding possibility...Formal operations then, to the extent that they are necessarily derived from physics, would be limited to a special kind of possibility, namely the possibility of derivations from physical premises. (p. 351-352)

Concrete operations to be adaptive to everyday reality and practical classroom presupposes that past experiences and learning had been rich, varied and specifically relevant to reality. Meaningful concrete materials should therefore be highlighted in teacher education programs. These would eventually lead to a progressive extention and elaboration of their operational strategies to new, possibly, formal content areas if formal operations are a must to prospective teachers.

Recommendations

A study should be conducted to compare the use of concrete and formal operational strategies by prospective elementary school teachers in ordinary classroom situations. One of the aims of such a study would be to assess the desirability of formal and/or concrete operational approach(es) in practical classroom teaching situations.

Another study is suggested to investigate if the cognitive styles (field dependent or field independent) of formal operational subjects are different from those used by concrete operational subjects. Such study should also investigate the possible relationships between cognitive styles, science background and attitudes toward science and science teaching.

A study should be conducted to investigate the effect(s) of test-taking sophistication on performance on Piagetian formal tasks. It may be possible that many subjects obtained lower scores on Piaget-type tasks than their cognitive capabilities or aptitude demanded because they lacked the sophisticated approaches and techniques to tackling such tasks and not because of delayed cognitive capability.

The relationships between underlying competence and typical performance on Piagetian tasks should be investigated. Of recent some science educators, Chiappetta (1976) for example, have confused performance and competence, regarding the former to be synonymous to regression effect.

Research is needed to investigate the relationships between academic specialization, different segments of the range of ability and performance on Piagetian formal tasks.

Concluding Statement

This study has shown that the architectonic of formal operations was not possessed or rather was not exhibited by all prospective elementary teachers investigated. The stepwise regression technique used showed that all ten predictor variables (currently among the best in predicting academic success) accounted for less than half the variability in formal operational thought processes measured by five Piagetian tasks. The study provided empirical evidences to show that the level of cognitive development among prospective elementary school teachers is significantly related to experiences and success in college science. Multiple regression analysis and the stepwise procedure showed that the science achievement measures (STEP-SCI and SCI-PROD) in that order, together accounted for 25 percent of the variability in performance on Piagetian formal tasks. At the risk of violating Mills' (1930) canon of concomitant variation, these results suggested that the ability to be successful in science and related areas cannot be divorced from requirements to be formal operational and vice versa. This fact may account for some of the reported difficulties prospective elementary school teachers encounter in learning science.

After an analysis of several studies which used intellective factors to predict academic performance, Lavin (1965) concluded:

> In spite of the presence of these unfinished tasks, it is true that on those educational levels for which data are most reliable (high school and college), measures of ability on the average account for 35 to 45 percent of the variation in academic performance. While no other single type of factor accounts for this much variation, more than half still remains unexplained. (p. 59)

The present study has shown that only 40 percent of the variability in formal thought processes was accounted for by factors in the subjects academic experiences. In Piagetian paradigm, formal operations represent among other characteristics, the integration of several logico-mathematical experiences which approach a maximum degree of constancy and regularity under the influence of the equilibrium dynamics. Within the same context, performance at the formal level cannot be attributed solely to all the predictor variables utilized in this study. Such concourse factors as sex, socio-economic status, and culture, among others, which cross-fertilize to contribute to an individual's formal operational status, were not investigated in this study.

Caution should be exercised in interpreting the results of the present study. One of the objectives was to identify factors useful in predicting performance at the formal operational level, at only one point in time. Findings are tentative because science educators are still ignorant regarding the constancy and regularity of performance and the degree to which Piagetian formal thought processes are predictable over time.

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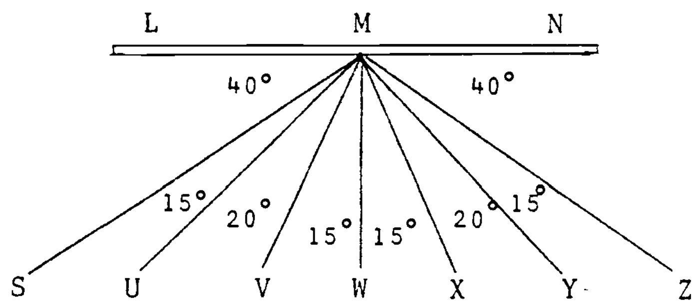
APPENDICES

APPENDIX A

TASK 1

Below are diagrams in which line LMN represents a projection wall with a rubber buffer such than when a ball is hit accurately to the wall, it always hits M and then rebounds.

Here is a diagram--study it and use it to answer questions 1 and 2:



1) If a ball is hit accurately from U to M on the projection wall LMN, it will bounce to:

   (a) S

   (b) X

   (c) Y

   (d) V

   (e) Z

2) If a ball bounces from M to S it must have been hit from:

(a) W

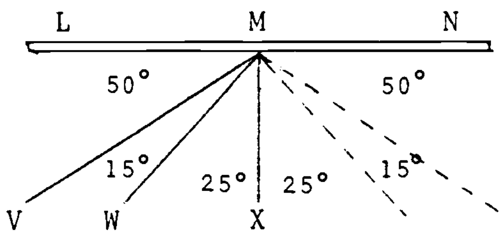
(b) X

(c) Y

(d) Z

(e) V

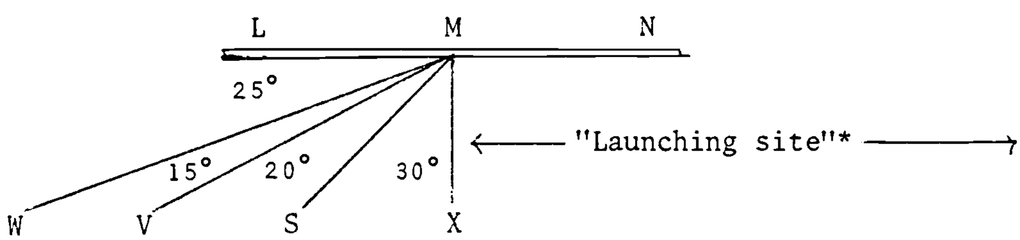
3) In the diagram below a ball is hit from V to a point M on the projection wall:



Mark on the diagram where the ball will go after leaving M.

Mark in the angle the new path the ball makes with line MX.

4) Suppose the ball is hit from somewhere in the section marked "launching site" in the diagram below. The ball hits the projection wall at M and bounces to V.



Indicate, by making on the answer sheet, the spot from which the ball was hit from the "launching site". Also mark in the size of the angle, from MX, at which the ball must have been hit.

APPENDIX B

It is the essence of formal reasoning that it includes potentially infinite sequence of categorical and hypothetical syllogisms which are deductively guaranteed and have capacities for induction. These criteria provided justification for the inclusion of the following syllogisms in the assessment of the subjects' performance at the formal operational level.

TASK 2

Read the following statements and choose the correct answer from the alternatives. Justify your choice. Your answers should be based on the information given in the premises. Personal opinions are not welcomed.

1. If all brilliant biologists make brilliant philosophers and Don is not a brilliant biologist, then:
   (a) Don is not a brilliant philospher.
   (b) Don's professor is a brilliant biologist.
   (c) We would not know whether or not Don is a brilliant philospher.
   (d) Don would not like to tell Joe about philosphizing.
   (e) Don knows very few physics concepts.

2. If all rich Oregon State University students oppress the poor and Jones is not a rich OSU student, then:

   (a) Jones does not oppress the poor.

   (b) Jones sister oppresses the poor.

   (c) Jones tells his friends about poor people in Oregon.

   (d) We would not know whether or not Jones oppresses the poor.

   (e) It is necessary that Jones becomes very rich in the future.

3. If all ladies with blond hair make successful Rose Bowl beauty queens and Linda does not have blond hair, then:

   (a) Linda would not make a successful Rose Bowl beauty queen.

   (b) Linda's hair was black.

   (c) Linda might still make a successful Rose Bowl beauty queen.

   (d) Linda would wish her hair were blond.

4. No one on a pepper-free diet ever sneezes. All ulcer-patients are on a pepper-free diet, hence:

   (a) Ulcer patients sneeze.

   (b) Ulcer patients are fat people.

   (c) Ulcer patients never sneeze.