CHAPTER VIII

SUMMARY, CONCLUSIONS AND EDUCATIONAL IMPLICATIONS
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INTRODUCTION

The present study entitled 'The Relationship of Proportionality, Propositional Logic and Combinatorial Analysis to High School Science Achievement' was designed to study the attainment of cognitive abilities - Proportionality, Propositional Logic and Combinatorial analysis among high school students; find out the relationship of achievement in science with the development of cognitive abilities, determine the predictive efficiency of the three cognitive abilities both individually and conjointly for science achievement as also to identify the factorial structure underlying cognitive abilities and achievement in science.

Science students exhibit large differences in their ability to understand science concepts. Some students are extremely capable, while others demonstrate peculiar and inappropriate reasoning strategies to the extent that even after the best efforts these students are not able to grasp ideas. Also, quite often students follow solutions of difficult problems but fail miserably when they are required to apply the same solution strategies to slightly different problems. Among many factors which can account for these phenomena, the differences in behavior of students can be
attributed to stage-wise differences in their intellectual development. The thought processes required in science have been linked with those defined by Piaget's formal level of operations. (Vandenberg 1979).

The science concepts may be classified on the basis of reasoning patterns needed to understand them. The concrete concepts require concrete reasoning patterns for their understanding while formal concepts require formal reasoning patterns. Since a large number of concepts in science at the high school stage are abstract, the comprehension of these requires a student to operate at the formal stage of intellectual development. The students at the concrete operational stage have difficulty in understanding formal level concepts. Thus, it becomes imperative to know the level of cognitive development of high school students, i.e. what proportion of high school students are at concrete-operational and formal-operational stages. Such information helps to adapt course contents, goals and teaching methods to match the level of cognitive development of the students as also to find out ways and means to encourage and stimulate intellectual processes towards the transformations from concrete to formal operations.

In Jean Piaget's developmental theory, cognitive development has been described in four stages. These stages
are the periods when a person's reasoning and behavior show certain distinctive features that are used for understanding a particular concept. All persons progress through the four stages in the same order though not necessarily at the same rate. These stages are: (1) Sensory-motor stage (from birth to 2 years) (2) Pre-operational stage (from 2 to 7 years) (3) Concrete-operational stage (from 7 to 11 years) (4) Formal-operational stage (from 11 to 15 years).

Concrete-operational and formal-operational stages are relevant to secondary school students. The cognitive stages emerge and develop if nurtured by appropriate experiences in and out of school. There are certain concepts that are understandable to only those students who have reached the formal operational stage. But it has been found that a majority of high school students do not reach formal stage. This mismatch between the level of students' thinking and intellectual demand of the subject matter is a major cause of learning difficulties in science. According to Cantu and Herron (1978), there is reason to believe that part of this learning difficulty is associated with the students level of intellectual development as described by Piaget and Inhelder (1969).

Formal-operational reasoning such as combinatorial reasoning, propositional logic and proportional reasoning denote thinking that scientists find valuable. The

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relationship between Piaget's theory and scientific inquiry is so close that many have referred to Piaget's formal-operations as 'scientific-reasoning' (Greenbowe, 1981). Further, Greenbowe et al. (1981) maintained that few theoretical constructs from psychology or education have captured the imagination of science educators more than Piaget's theory of intellectual development and the concept of formal-operational reasoning during the past decade. As a result, much research has been generated on Piagetian theory of Cognitive Development. However, the realm of the attainment of formal operations in Indian setting and their relationship with achievement particularly science achievement yet needs to be explored further before the theory could be applied in the field of education with sufficient degree of certainty. Hence, it was thought worthwhile to explore as to what percentage of high school students are at the concrete-operational and formal-operational stages; whether or not there are significant differences in the ability for formal reasoning due to urban/rural background difference; what is the nature and extent of relationship between different formal-operational abilities and science achievement; to what extent formal operations, important components of cognitive ability, when taken singularly and conjointly can predict science achievement; and what type of factorial structure is
revealed underlying various formal-operations when taken along with the measures of subject-wise and total science achievement. The present study is addressed to these issues.

STATEMENT OF THE PROBLEM

THE RELATIONSHIP OF PROPORTIONALITY, PROPOSITIONAL LOGIC AND COMBINATORIAL ANALYSIS TO HIGH SCHOOL SCIENCE ACHIEVEMENT.

OBJECTIVES OF THE STUDY

The study was undertaken with the following objectives:-

1. To identify the percentage of high school students who have attained formal operation abilities of (a) Proportionality, (b) Propositional logic and (c) Combinatorial analysis.

2. To ascertain the differences in the development of abilities of (a) Proportionality, (b) Propositional logic and (c) Combinatorial analysis abilities across sex.

3. To study the differences in the development of abilities of (a) Proportionality, (b) Propositional logic and (c) Combinatorial analysis among high school urban and rural students.

4. To examine the nature and extent of relationship of (a) Proportionality, (b) Propositional Logic and
To determine the predictive efficiency of (a) Proportionality, (b) Propositional Logic and (c) Combinatorial analysis both individually and conjointly for science achievement of high school students.

6. To identify the factorial structure underlying Proportionality, Propositional Logic and Combinatorial analysis and achievement in science in terms of general and group factor/s.

DELIMITATIONS OF THE STUDY
1. The present study was delimited to only tenth class students.

2. The sample was restricted to those high schools which are affiliated to Punjab School Education Board.

HYPOTHESES OF THE STUDY
The study was designed to test the following hypotheses:

1. Majority of the high school students do not attain the formal operational abilities - Proportionality, Propositional logic and Combinatorial analysis.

2. There are significant differences in the development of (a) Proportionality, (b) Propositional logic and (c) Combinatorial analysis abilities between high school boys and girls.
There are significant differences in the development of (a) Proportionality, (b) Propositional logic and (c) Combinatorial analysis abilities between urban and rural high school students.

(a) The formal operational ability of Proportionality is significantly related to academic achievement in science.

(b) Propositional logic has a significant relationship with academic achievement in science.

(c) There is a significant relationship between Combinatorial analysis and science achievement.

(a) Formal operational abilities namely - Proportionality, Propositional logic and Combinatorial analysis are significant predictors of science achievement of high school students.

(b) The conjoint contribution of Proportionality, Propositional logic and Combinatorial analysis towards science achievement is greater than their separate predictive efficiency.

6. The variables of Proportionality, Propositional logic and Combinatorial analysis cluster together in general/group factor/s with science achievement at formal operational stage.
DESIGN OF THE STUDY

Descriptive Survey Method has been employed to assess the percentage of high school students who attain the formal operativity level of cognitive development and also to examine the relationship of formal operational abilities with achievement in science. The attainment of cognitive abilities has been seen in terms of percentages who reach a specific mean value, along with significance of difference between means across sex and urban-rural areas. The relationship of each of three cognitive abilities with achievement in science has been assessed through product-moment correlations.

Further, the predictability of three cognitive abilities taken individually and then conjointly in various combinations has been examined by the use of Multiple Regression Equations. In order to identify the clusters (groups) of variables (under study) going together, factor analysis was employed along with rotation of factors.

SAMPLE

The sample for the present study consisting of 409 students (Boys = 206 and Girls = 203) of grade X was drawn on the basis of Multi-stage Stratified Random Sampling Technique from various high schools in the State of Punjab. For reasons of practical difficulties of handling the complexities involved in the study requiring administration
of six individually administered Piagetian Tasks and the inclusion of rural and urban students of both sexes, only one zone i.e. Ferozepur was selected randomly out of the three educational zones of Punjab, namely - Ferozepur, Patiala and Jalandhar. From this zone, two districts, namely, Bhatinda and Faridkot were randomly drawn (out of three districts - Bhatinda, Faridkot and Ferozepur). Following this, a list of schools separately for urban (119) and rural (313) areas falling within these districts was prepared. Selection of four urban and six rural schools was done randomly and separately. As the number of students studying in grade tenth in urban and rural schools was found to be approximately equal, so equal number of urban and rural students was randomly drawn from the schools selected for the study. The sample can be taken as a representative one as students of these schools represent various strata of socio-economic status.

TOOLS USED

The following tools were employed in the study:

A. Six Piagetian Tasks adapted from Inhelder and Piaget's (1958) tasks included in 'The Growth of Logical Thinking from Childhood to Adolescence' were administered to measure the cognitive abilities - Proportionality, Propositional logic and Combinatorial analysis. These tasks are as follows:
I. **Proportionality** was measured through two tasks as given below:
(a) Equilibrium in the Balance
(b) The Projection of Shadows

II. Following two tasks were used in order to measure **Propositional logic**:
(a) Law of Floating Bodies and Elimination of Contradictions.
(b) The Oscillation of Pendulum and the Operation of Exclusion.

III. The ability of **Combinatorial Analysis** was tested with the help of two tasks namely:
(a) Combination of Coloured and Colourless Chemical Bodies.
(b) Combination of Coloured and Colourless Tokens (taken from cups).

B. Subject-wise achievement in Physics, Biology and Chemistry was measured through the science achievement test which was developed and standardized by the investigator herself. The addition of subject-wise scores led to obtaining a total science achievement score.

**DATA COLLECTION**

Data collection was done in a separate room in each school. The facility of a separate room was sought after by
approaching the Heads/Principals of the schools and seeking their co-operation.

Science Achievement Test was given in groups of about 40 students, followed by individual administration of Piagetian Tasks to one student at a time. As the test-items of science achievement test are of multiple-choice type, subjects were required to tick (✓) mark the correct answer in the test-booklet.

The individual administration of each Piagetian task is in the form of an interview - the investigator asking questions according to the response omitted by the subject. Sets of experimental apparatus are presented in interviews and the child verbally communicates his ideas while checking his/her working hypothesis in the manipulation of the apparatus. Verbal results thus obtained are evaluated qualitatively as to the type of thinking revealed by involvement in the problem situations. The same approach was followed by the investigator in the present study in administering Piagetian tasks. All the six tasks were administered in the same order to each student. Further, each subject had to finish all the six tests in one sitting. The inter-task time was kept as ten minutes to avoid the factor of fatigue.

**STATISTICAL TECHNIQUES**

1. Mean, standard deviation, skewness and kurtosis were calculated for examining the nature of distribution.
of various sets of scores. Also values of means and percentages were respectively used to compare subjects across various groups on three abilities and to identify formal-operations.

2. t-ratios were worked out between means of different cognitive abilities across rural-urban areas as also across sex.

3. Pearson's Product Moment Correlations were computerized to find out the relationship between different cognitive abilities and achievement in science.

4. Multiple Regression Equations were used to determine the predictive efficiency of various cognitive abilities in different combinations towards science achievement.

5. Factor Analysis along with Rotation of factors was employed for the purpose of identification of common factors underlying formal operations and science achievement.

RESULTS

I. PERCENTAGE OF STUDENTS REACHING FORMAL OPERATIONAL LEVEL

From the values of percentages, it is observed that:

(a) All the tenth class students included in the sample do not reach the formal-operational stage in all the three cognitive abilities, namely,
Proportionality, Propositional logic and Combinatorial analysis. Only 62% of the subjects attain this stage in Proportionality as against 38% who remained at concrete-operational stage; in case of Propositional logic, only 15% and on Combinatorial analysis only 16% obtain formal operational stage as against 85% and 84% respectively who still remain at the concrete operational stage of their cognitive development. Further, the concept of Proportionality is attained by a greater number of high school students as compared to concepts of Propositional logic and Combinatorial analysis. In other words percentage of tenth class students reaching formal level in Proportionality (62%) is greater than percentage of subjects reaching formal level in Propositional logic and Combinatorial analysis (15% and 16% respectively). Thus the first hypothesis 'majority of the High school students do not attain the formal operational abilities - Proportionality, Propositional logic and Combinatorial analysis' stands accepted in respect of Propositional logic and Combinatorial analysis. As far as Proportionality is concerned majority of the subjects (62%) in the
present sample could operate this ability at formal operational level.

(b) From the results of means and t-ratios, it is evident that with regard to the concept of Proportionality boys outperform girls. On the other hand on the concept of Propositional logic, girls outperform boys. In both these abilities differences between boys and girls are significant. As far as the ability of Combinatorial analysis is concerned, though the mean value for girls is greater than the mean value for boys, but the difference between the two are not significant. Thus the second hypothesis that 'there are significant differences in the development of (a) Proportionality, (b) Propositional logic and (c) Combinatorial analysis abilities between high school boys and girls' stands accepted only in respect of two of the three abilities that is Proportionality and Propositional logic.

(c) The values of mean for each of the three abilities namely - Proportionality, Propositional logic and Combinatorial analysis indicate that urban students have an edge over rural group. Results are strengthened by the t-ratios, all of which were observed as
significant at 0.01 level. Thus, the third hypothesis that 'there are significant differences in the development of (a) Proportionality, (b) Propositional logic and (c) Combinatorial analysis abilities between urban and rural high school students' stands accepted.

II. RELATIONSHIP BETWEEN DIFFERENT COGNITIVE ABILITIES AND SCIENCE ACHIEVEMENT

From the values of product moment correlations, it is observed that all the values of 'r' between achievement in science and the cognitive abilities (Proportionality, Propositional logic and Combinatorial analysis) exhibit significant positive correlation at 0.01 level indicating thereby that cognitive abilities are closely associated with features that characterize achievement in science. Proportionality exhibited significant correlations with subject-wise achievement in Physics, Biology and Chemistry as also with total science achievement at 0.01 level. The values of 'r' ranged from .433 to .494. The measure of Propositional logic was found to be significantly correlated with subject-wise achievement in Physics, Biology and Chemistry and with total science achievement (r=.414, .463, .467 and .482 respectively; all significant at 0.01 level). Combinatorial analysis, too, yielded significant correlation with total science achievement (r = .430) and was also found to relate
positively and significantly with subject-wise science achievement with values of $r = .344, .450,$ and $.409$ respectively in Physics, Biology and Chemistry. Results lead to the acceptance of hypothesis 4(a) 'The formal-operational ability of Proportionality is significantly related to academic achievement in science, 4(b) Propositional logic has a significant relationship with academic achievement in science and 4(c) there is a significant relationship between combinatorial analysis and science achievement'.

III.(a) PREDICTIVE EFFICIENCY OF PROPORTIONALITY, PROPOSITIONAL LOGIC AND COMBINATORIAL ANALYSIS TOWARDS SCIENCE ACHIEVEMENT

With regard to the testing of fifth hypothesis 'Formal operational abilities namely, 'Proportionality, Propositional logic and Combinatorial analysis are significant predictors of science achievement of high school students', the values of $R^2$ were computerized. When Proportionality is taken as independent variable, the values of $R^2=0.2325, 0.1961, 0.1876, 0.2440,$ all of which are significant at 0.01 level, for achievement in Physics, Biology, Chemistry and total science achievement respectively indicate that in 99 out of 100 cases, Proportionality predicts significantly the achievement in Physics, Biology, Chemistry and total science achievement.
The values of $R^2$ due to Propositional logic for achievement in Physics (0.1716), Biology (0.2140), Chemistry (0.2184), and total science achievement (0.2324) are too significant at 0.01 level.

The contribution of Combinatorial analysis towards achievement is 11.84% ($R^2=0.1184$) for Physics, 20.25% ($R^2=0.2025$) for Biology, 16.73% ($R^2=0.1673$) for Chemistry and 18.49% ($R^2=0.1849$) for total science achievement.

The significant values indicate that Proportionality, Propositional logic and Combinatorial analysis are significant predictors of the subject-wise achievement in science which leads to the acceptance of fifth hypothesis.

III.(b) CONJOINT PREDICTION OF PROPORTIONALITY, PROPOSITIONAL LOGIC AND COMBINATORIAL ANALYSIS.

In all, five models were prepared with a view to examining the conjoint contribution of three Piagetian abilities under study towards science achievement. Model I was taken for assessing separate effect of all the three abilities, namely Proportionality, Propositional logic and Combinatorial analysis; in Model IIA Proportionality and Propositional logic were combined, in Model IIB Proportionality and Combinatorial analysis were taken conjointly, and in Model IIC Propositional logic and Combinatorial analysis were included. All the three abilities of Proportionality, Propositional logic and
Combinatorial analysis were combined in Model III. Results show that:

(i) Subject-wise achievement in two science subjects namely Physics, Biology as also total science achievement is best predicted by conjoint effect of Proportionality, Propositional logic and Combinatorial analysis; followed by conjoint effect of Proportionality and Propositional logic. The prediction of Propositional logic conjointly with Combinatorial analysis is the minimum for achievement in Physics, Biology and total science achievement.

In case of achievement in Chemistry, it is best predicted by the conjoint effect of Proportionality, Propositional logic and Combinatorial analysis, followed by conjoint effect of Proportionality and Propositional logic. The prediction of Proportionality conjointly with Combinatorial analysis is the least for achievement in Chemistry.

(ii) The conjoint effect of three predictor variables that is Proportionality, Propositional logic and Combinatorial analysis is higher as compared to their singular effect or the effect of any two
of the three variables taken together at a time for the prediction of subject-wise achievement in Physics, Biology and Chemistry as also total science achievement.

Thus the sixth hypothesis, 'The conjoint contribution of Proportionality, Propositional logic and Combinatorial analysis towards science achievement is greater than their separate predictive efficiency' stands accepted.

IV. FACTOR-STRUCTURE UNDERLYING THE MEASURES OF ACHIEVEMENT IN SCIENCE AND FORMAL OPERATIONAL ABILITIES

(i) The significant factor-loadings on all the measures of cognitive abilities and achievement in science on original factor I clearly show the predominance of an underlying element of cognition in them. This original factor I has been named as General factor of Cognition which contributed a total variance of 61.63%. Varimax factor I has significant positive loadings only on four measures of achievement and has been named as group factor of Science Achievement. It may be recalled here that examination marks (based on essay type test) as a measure of science achievement had been taken only for a
limited purpose of examining the validity of the test of science achievement developed in the present study. Hence, loadings shared by this variable for the purpose of naming and interpreting do not fall within the scope of the present study.

(ii) Original factor II indicates bi-polarity wherein cognitive abilities - Propositional logic, Combinatorial analysis and total of cognitive abilities cluster together on the positive pole and the measures of achievement in science on the negative pole. This factor has been named as group factor of Formal Operational abilities, contributing 15.61% of total variance and suggest that although cognitive abilities and science achievement fall in the same domain of cognition (original Factor I) yet both are distinguishable from each other on account of their respective unique features. Varimax factor II, a group factor of Cognitive ability to use equal fractions at formal level shows significant loadings only on the measures of Proportionality and total of cognitive ability measures with loadings equal to .908 and .554 respectively.
Disregarding the variable of science achievement as measured by essay type test which was included only for the purpose of validating the locally developed objective type science achievement test, the examination of remaining loadings suggests that original factor III is a specific factor. Only one variable that is measure of Proportionality appears with significant loadings (-.564). Thus in view of the significant loading on the measure of Proportionality, original factor III may be termed as specific factor of Proportionality. Varimax factor III was also a specific factor of Combinatorial analysis (loadings = 0.316).

Original and varimax factors III respectively accounted for 8.2% and 12.18% of the total variance which is 9.01% and 13.19% of the common variance accounted for by all the four original factors.

Original factor IV, contributing 5.52% of the total variance, which is 6.07% of the common variance, like the original factor III, is a specific factor of Propositional logic (loading = 0.425).

However, varimax factor IV appeared as a group factor with significant positive loadings
on the measures of Propositional logic, Combinatorial analysis and totals of Cognitive abilities (0.878, 0.756, 0.751 respectively) and was identified as a group factor of Cognitive ability to use logic of all possible combinations. It contributed 25.01% of total variance which is 27.5% of common variance contributed by all four rotated factors.

CONCLUSIONS

1. While more than fifty per cent (62%) high school students reach formal operational level in attaining the concept of Proportionality, in the remaining two abilities the picture is at variance. Only 15% and 16% of the subjects attain concepts of Propositional logic and Combinatorial analysis respectively at formal level.

2. The concept of Proportionality at formal level is attained by greater number of high school boys than girls; on the other hand high school girls outperform boys in the development of concept of Propositional logic at formal level. No significant sex differences are found as far as attainment of the ability of Combinatorial analysis at formal level is concerned.

3. The development/attainment of all the three formal operational abilities under study, namely,
Proportionality, Propositional logic and Combinatorial analysis is higher among urban students than rurals.

4. The three cognitive abilities namely- Proportionality, Propositional logic and Combinatorial analysis are significantly and positively related with achievement in science thereby implying that in their functioning, thought processes of Piagetian formal operational abilities are quite similar, if not identical, to abilities required for achievement in science at the high school level.

5a. Formal operational abilities namely- Proportionality, Propositional logic and Combinatorial analysis are significant predictors of the subject-wise achievement in Physics, Biology, Chemistry as also of total science achievement.

b. The predictive efficiency of the three abilities for achievement in science (subject-wise and totals) is not significantly different from each other except, in the case of Proportionality and Combinatorial analysis for prediction of achievement in Physics in which case the differences are significant and in favour of Proportionality.

6a. The conjoint predictability of three variables - Proportionality, Propositional logic and
Combinatorial analysis is higher as compared to their singular contribution or the contribution of any two of the three variables taken together at a time for the prediction of subject-wise achievement in Physics, Biology and Chemistry as also total science achievement.

b. The conjoint effect of three predictor variables is maximum for the criterion measure of total science achievement, and minimum for the measure of achievement in Physics.

7. In factor analysis, original factor I shows the predominance of an underlying element of cognition (General Factor of Cognition) whereas varimax factor I is only a group factor (Group factor of science achievement).

The original and varimax factor II are group factors of formal operational abilities (sharing common variance with subject-wise and total measure of science achievement on the negative pole) and cognitive ability to use equal fractions at formal level respectively.

Both original and varimax factors III emerge to be specific factors namely Proportionality and Combinatorial analysis.

Original factor IV too is a specific factor of Propositional logic, whereas varimax factor IV
is a group factor of Cognitive ability to use logic of all possible combinations. The Factor structure underlying the measures of Proportionality, Propositional logic & Combinatorial analysis and subject-wise & total science achievement indicates that although both the formal operational abilities and science achievement have an underlying predominance of Cognition and may be said to belong to same Cognitive Domain yet both are distinguishable from each other in respect of group factors on account of their unique specific features.

EDUCATIONAL IMPLICATIONS

The findings of the present study that the two formal operational abilities, namely, Propositional logic and Combinatorial analysis are not attained by majority of tenth grade students suggest the necessity of alternative learning strategies in science. A large number of science concepts require students to operate at formal operational level of intellectual development. Students at the concrete level can understand formal concepts effectively by sequencing of instruction so as to begin with exploratory experiences and concrete concepts and involving the use of concrete materials before switching over to abstraction. In other words, there is need of concretisation of concepts which require students to operate at formal operational level
particularly for those high school students who have not reached formal level. Either formal operational abilities should be stimulated and strengthened by way of provision of sufficient practice with concrete experiences in curricular and co-curricular activities through appropriate instructional strategies or the topics of science which require students to operate at formal operational level should be included in the syllabus only at a later stage.

In order to make science curriculum functional and worthwhile it needs to be developed in accordance with the developmental tasks of children, i.e. it must provide learning activities in accordance with the developmental level of children. Even if the content is kept as such, the learning experiences provided therein, their systematization, processing, sequencing in presentation of concepts, experimentation and motivation of subject needs to be adapted to child's intellectual growth as well as learning requirements of the subject-matter.

As far as the sex differences are concerned, the differences are not significant in Combinatorial analysis ability, in the remaining two abilities their is mixed picture of boys outperforming girls in the Proportionality and girls outperforming boys in Propositional logic. The differences seem to be more on account of cultural - conditioned activities to which both sexes are exposed differentially and thus suggest a need to keep curricular
content and activities free from gender bias.

Findings that greater number of urban high school students attain the formal operational abilities than the rural ones suggest that there is need to adapt the teaching methods to match the level of cognitive development of the rural students by way of examples from within the social-milieu of the students. Mass media can provide learning experiences to stimulate thought processes by orienting their programmes to include examples, from rural areas. Some sort of remedial measures through structuring of educational environments can also profitably be used to facilitate cognitive development at formal level among tenth grade students in the rural schools.

As the intellectual development is closely and positively related to the science achievement of the students, it is suggested that teaching and learning materials and learning strategies be planned in congruence with the cognitive development of individuals and if the need arises this could be made differential for the extremely talented and the developmentally delayed students. Likewise, results in terms of positive relationship between cognitive abilities and science achievement necessitate the conditions and procedures which facilitate the positive attitudes and modify the negative ones into positive towards science so that students having suitable cognitive abilities acquire liking for science subjects.
The findings of formal operational abilities as significant predictors of science achievement can be utilized to some extent by the guidance workers in guiding the choice of science courses in the light of development of students abilities.

SUGGESTIONS FOR FURTHER RESEARCH

Based on the findings and discussions in this study, it is suggested that further researches be carried out using variations form this study. It is suggested that following problems may be undertaken:

1. Similar studies may be undertaken at +2 stage of the higher secondary stage.

2. Studies may be undertaken to trace the development of Proportionality, Propositional logic and Combinatorial analysis abilities linearly during adolescence.

3. Studies may be undertaken to develop science curriculum in accordance with cognitive development of students at the tenth class, compare it with traditional curriculum and to evaluate it in respect of attainment of educational goals.

4. Attempt to develop instructional strategy and test its efficacy for teaching formal concepts in science through concrete instructional experiences may also be taken up by researchers.