CHAPTER II

REVIEW OF RELATED LITERATURE
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Related literature is the base or foundation on which the structure of further studies is laid. Along with many other purposes which the survey of related study serves, it enables the investigator to gain familiarity with the knowledge of past achievements and developments in the concerned areas. Hence, a survey of the related literature was made so as to identify the trends of results of previous researches and formulate relevant hypotheses for the conduct of the present study.

The relevant studies have been reviewed and presented under the following headings:

(1) Formal operational abilities (Proportionality, Propositional logic and Combinatorial analysis) their development.

(2) Sex differences and formal operational abilities - Proportionality, Propositional logic and Combinatorial analysis.

(3) Urban-rural differences and formal operational abilities - Proportionality, Propositional logic and Combinatorial analysis.

(4) Formal operational abilities and science achievement.
2.1 **Formal operational abilities (Proportionality, Propositional logic and Combinatorial analysis) their development.**

According to Piaget's theory, the formal stage of intellectual development starts at 11-12 years of age and the individual becomes fully formal at the age of 15-16 years. This led to the belief that most individuals by 15 or 16 years of age were formal operational thinkers. As far as empirical evidence in this regard is concerned, Lovell (1961), who performed many studies using Piagetian tasks with English students, discovered that some of the subjects in his studies were not formal-operational by the age of 15 years. This, he suspected, might be due to better potentialities of students in Piaget's studies. Later in 1972, even Piaget himself realized that his subjects were drawn from better schools in Geneva.

Somewhat earlier, Keats (1955), tested Piaget's hypothesis that concrete-operations necessarily precede formal ones in cognitive development, that the ability to solve problems on the plane of formal operations presupposes their mastery on the plane of concrete operations but not the converse. This prediction was strongly confirmed in the case of arithmetic and probability items but not for inequalities. In the latter case, Keats felt that an artifact may have contributed to the negative side.
According to Inhelder and Piaget (1958), the use of systematic approach is necessary but not a sufficient condition for formal operations. A person at the formal operational level must be able to investigate the variables and then explain how they interact. The proportion of subjects using formal operations is influenced by the task used and the subject's previous experience. Vaidya discovered that adolescent pupils of two schools were in a position to state hypotheses but most of them were not in a position to test them.

In a study with American subject, Higgings-Trenk and Gaite (1971), reported that 'normal adolescents are unlikely to reach the level of formal thinking until their late teens or early twenties if they reach it at all.' Kholberg and Gillgen (1971), stated that all normal children reach the concrete level but do not necessarily reach the formal level. Only one study could be traced wherein Mecke and Mecke (1971), found all in a sample of 15 year old using formal operations. However, they determined that a subject used formal operations if he simply used a systematic approach to eliminate the irrelevant variables in Piaget's pendulum problem. Mishra (1973), investigated the role of hypotheses in problem-solving among 10th grade science students and found that many adolescent pupils experienced difficulty in testing hypotheses.
Lawson (1974), using six Piagetian type tasks examined the percentages of science students attaining formal-operational level. Cognitive developmental stages of 52 Biology, 50 Chemistry and 33 Physics students from a high school were assessed. His results showed that 64.8% of the Biology, 22% of the Chemistry and 36.3% of Physics subjects were at the concrete-operational level, while 35.2% of the Biology, 78% of the Chemistry and 63.7% of the Physics students were at the formal-operational level.

Later in 1976, results of the study of Lawson and Blake on 68 high school Biology students (age range 14 years 7 months to 17 years 10 months) indicated that 47% students were concrete-operational and 53% formal-operational.

Lawson and Nordland (1977), reported that a majority of high school Biology students performed below the formal-operational level on weight and volume conservation tasks. High school Biology students, college freshmen from Introductory Physics and college seniors majoring in science were administered two Piagetian tasks (Chemical liquids and Inclined plane) by Kolodiy (1977). The researcher reported that scores for high school and college freshmen were nearly equal (35% and 32% formal; 50% and 60% transitional; and 15% and 8% concrete) and significantly different from the college senior sample (64% formal, 28% transitional and 8% concrete).
Wheeler and Kass (1977), investigated the proportional reasoning ability among tenth grade Chemistry students and found that 22% of the students were late formal, 27% early formal and 29% concrete. Stolper (1979), used five Piagetian tasks in order to assess the cognitive level of 9th grade students. Out of a sample of 129, only 10% were found fully formal-operational 66% were concrete-operational and the rest were transitional.

Sandhu (1980), investigated the development of formal thought in relation to age by taking 11+ to 15+ age groups. The dimensions of formal thought had shown a trend of linear growth during the period of 11+ to 15+ years. The findings also revealed that these dimensions did not reach the state of full development up to the age of 15 years. A majority of the students in the age range 10+ to 14+ operated at the concrete level when 200 students (100 boys and 100 girls) of Mysore city were studied by Padmini (1981). Alport’s (1983), study on 100 high school and college students (using two concrete and three formal tasks) showed that no task was passed by more than 43% of the high school and college students, and the most difficult task was passed by only 18% of the sample.

In examining the performance of 6th, 9th and 12th grade students on five logical and spatial tasks, Wavering et al (1983), observed that only 9% or less scored at the
formal level on Proportional reasoning tasks. Almost similar findings were reported with students of grades 6, 9 and 12 (Wavering et al, 1986) wherein zero, six and sixty per cent respectively performing at the highest level on flexible rods task. Similarly, a considerable number of students were at the transitional level, when Wilson and Wilson (1984), made a population survey of high school students in Papua, New Guinea.

Murphy (1985), selected the entire population of college preparatory Chemistry students in an urban high school for the assessment of formal operational thoughts but none of the population studied was formal operational when the task scores were averaged. Cognitive growth of 110, 9th grade urban high school students was tested by Blackwelder (1986), and the results indicated that fewer than half of the sample reached the highest level of cognitive growth, known as formal reasoning.

Hudzik (1989), assessed the level of thinking ability among general Chemistry college students, using the (i) Longeot test of formal operational reasoning and (ii) the classroom test of formal operations by Anton, E. Lawson. Results of Longet and Lawson tests indicated that 54% of the students were at concrete-operational level and 71% of the students were at the transitional level of cognitive development.
Khalil (1989), investigated the performance of (N=502) subjects of age 11, 13 and 15 on science conceptualization. Results revealed that a small proportion of children attained the late concrete and formal operational stages. Shannon (1990), used two Piagetian tasks, in order to delineate the developmental progression outlined by Inhelder and Piaget (1958). In analysis of the test findings, it emerged that neither the lack of a developmental trend on the individual principles of logic nor their differential difficulty was predicted by Piagetian Theory.

In a slightly differently planned study Webb (1974), examined concrete and formal operations high IQ (160 and above) subjects including 25 very bright 6 years and 2 months to 11 years and 4 months old. The results indicated that all subjects were operational on all the concrete-operations problems. However, only four of the oldest boys were operational on the formal operational tasks. The author interpreted the results as substantiating 'the reality of Piaget's stage structures but suggest that the speed with which tasks within a stage are mastered is a function of intelligence in the psychometric sense.'

Ten Piagetian tasks were used by Nordland et al (1974), to study the reasoning ability of 96 randomly selected 7th grade students (age range 11.7 years to 12.6
years) from a predominantly Black and Spanish-American urban junior high school. Eighty three point four per cent of the students were found to be at the formal-operational level. Chapman (1975), studied the development of children's understanding of proportions, just at the beginning of formal operations and found that a majority of 5th grade subjects lacked a full understanding of proportion. These results are consistent with Inhelder and Piaget's contention that the comprehension of abstract relations requires formal operations.

Dulit (1972), found that only 25.33% of normal adolescents, aged 14-17, and 60% of the gifted 16 and 17 years old exhibited formal operations when they tried to solve some of the Piaget's experiments. Renner and Stafford (1972), assessed the developmental level of 298 junior high school students (grades 7, 8 and 9) and 290 senior high school students (grades 10, 11 and 12) living in various parts of Oklahoma, by using six Piagetian tasks. Their results showed that among junior high school students, 77% were concrete-operational, 14% post concrete-operational and 6% formal-operational. Among senior high school students, 66% were at the concrete-operational stage, 17% at the post-concrete operational stage and 14% at the formal-operational stage.
Chiappetta (1976), reviewed the studies which employed at least three (and usually more) Piagetian type tasks which were presented in a personal interview format to subjects. He concluded 'that most adolescents and young adults (over 85% of this population) in U.S.A. do not appear to be at the formal-operational level of intellectual development'. Five Piagetian formal tasks were used by Ehindero (1977), to assess the cognitive levels of 44 prospective elementary school teachers. The findings showed that only 68% of the subjects were formal-operational. Thornton and Fuller (1981), reported that only 60% to 78% of the college students showed formal thought on proportional tasks.

Jain (1982), administered four Piagetian tasks - metal cylinders, bending rods, balance and pendulum, to 180, 11th grade science students selected from higher secondary schools in Azmer city; 65 students were at the formal level, 32 were at the concrete-operational stage and rest at the post-concrete level. Twelve Piagetian formal-operational tasks were used by Hale (1983), with a view to describing the formal logical characteristics of 59 second year medical students, in terms of their abilities to solve problems in four logical schema: Combinatorial logic, Probabilistic reasoning, Propositional logic and Proportional reasoning and concluded that none of the sample was fully formal, and
approximately 96% of the sample functioned at the transitional stage of formal-operations on all tasks. Similarly, a majority of the students were functioning between the concrete and formal levels of cognitive development when the level of cognitive development of 55 education majors (19-22 years old) were assessed by Wyatt (1983).

Four Piagetian tasks - conservation of volume, separation of variables, equilibrium in the balance and combination of colourless chemical liquids were used by DeHernandez et al (1984), to assess the cognitive developmental level of 16-17 years old students. They found the following distribution of cognitive levels: 35% concrete-operational, 45% transitional and 20% formal-operational. Twelfth grade male science students in Saudi Arabia were tested by Maiman (1984), of which 67.5% were non-formal thinkers. A considerable number of students was at the transitional level, when Wilson and Wilson (1984), made a population survey of high school students in Papua, New Guinea.

On the basis of the results of studies as reviewed in this Section, it may be concluded that (a) most adolescents and young adults do not appear to have attained the formal-operational stage of Piagetian Cognitive development, (b) a large proportion of individuals in the various age groups
operate at the concrete-operational or transitional stage, and (c) the development of formal-operations relate to the level of IQ, that is percentage of subjects reaching the attainment of formal operations is very high (almost 100%) as compared to the normal population.

### 2.2 SEX DIFFERENCES AND FORMAL-OPERATIONAL ABILITIES - PROPORTIONALITY, PROPOSITIONAL LOGIC AND COMBINATORIAL ANALYSIS.

Studies related to sex difference in cognitive development at the formal operational stage reveal conflicting results. Lewis (1972), in a study on students from 7th to 12th grades reported sex differences favouring males. In a study of relationship between gender, field-dependence and formal thought, with samples drawn from junior high schools, high schools and colleges, Piburn (1977), found that males were more successful on two of the four proportionality tasks, and thus the total for that schema, and subsequently for the overall tasks. However, no significant differences were found between sexes on the performance of five combinatorial tasks or three correlational/probability tasks. Piburn (1977) concluded, 'sex differences are restricted to very specific abilities, and cannot be explained away as the result of some other factor'. In another study, Piburn (1980), on the basis of clinical interviews of grade eleven students from suburban
New Zealand schools, concluded that males achieved significantly better scores than females on the shadows task. Ninth grade science boys did better than girls in the ability to use Proportionality concepts (Brown, 1979).

Sandhu (1980), in a study, of students in the age group 11+ to 15+, found that boys performed either equal to or better than girls on the Piaget type tasks at the respective age levels. Cognitive developmental level of men was observed as higher than that of women (Marek, 1981). In 1984, DeHernandez, Marek and Renner’s concluded that: (i) males demonstrate a higher level of intellectual development than females, (ii) males mature intellectually earlier than females, and (iii) there appear to be factors other than age and gender that are related to development of formal-operational reasoning. High school Israeli boys performed significantly better than girls on displaced volume, probability, proportional reasoning and combinatorial reasoning when Hofstein and Mandler (1985), examined using Lawson’s Test. Significant gender difference in favour of male students was reported by Farrell & Farmer (1985), in first order direct proportional reasoning but no difference could be located in multiple proportional reasoning. The logical thinking ability of 10th grade students was measured with The Group Assessment of Logical Thinking (GALT) test by Hsiung (1989). The results indicated that male students
outperform females and the differences are significant. The above-mentioned studies indicate that sex difference in formal operational abilities exists, favouring males.

Saarni (1973) and Maccoby and Jacklin (1974), found no significant gender differences in their investigations. Rajput (1974), studied the schema of proportionality among adolescent pupils and reported that boys and girls perform equally well. Waite’s (1975), study indicated no significant relationships between ability to perform on the Piagetian type tasks and sex. No gender related difference was found in cognitive development by DeLuca (1979), and Mali (1979), for elementary school students. Kishta (1979) and Ehindero (1982), studied Jordanian and Nigerian high school students respectively; and did not reveal any sex difference in cognitive development. Junior high school, science students were tested by Hayes (1979), to test the ability to conserve and to reason by propositions. No correlation was observed between sex and conservation or sex and propositional reasoning. Padmini (1980), and Shukla (1980), reported that sex differences were not significant in respect of gains in cognitive development. No sex difference on Piagetian tasks, requiring conservation of volume, logic, separation and control of variables, proportional reasoning and exclusion of irrelevant variables was found by Jain (1982), for 11th grade science students.
In a study of the development of logical structures among second grades, Cohen (1984), reported that gender had no effect on the development of reasoning. Shepherd (1984), investigated, 11th grade, 77 students and there was no significant correlation between both the sexes, for the development of formal concepts. In a study, Murphy (1985), assessed the formal operational thought of 27 female and 36 male students of urban high school but no significant difference between the male and female students was observed. Non-significant gender difference was traced for cognitive operativity by Blackwelder (1986), among the 9th grade students. Golbeck (1986), using a sample of 64 college students, reported that college male and female students generally did not differ significantly on Piagetian spatial tasks, though they may be differentially influenced by task content.

Except ratio and proportion girls performed better than boys on all other types of Piagetian tasks. Only one study by Raizada (1982), could be traced by the investigator in which girls outperformed boys on all types of Piagetian tasks except ratios and proportions.

2.3 URBAN-RURAL DIFFERENCES AND FORMAL OPERATIONAL ABILITIES - PROPORTIONALITY, PROPOSITIONAL LOGIC AND COMBINATORIAL ANALYSIS.

Piaget (1964), stated that the average ages at which different cognitive stages appear varied to a great extent.
from one society to another, although the ordering of these stages was constant and had been found in all societies. In terms of empirical evidence, however, the investigator could not trace out many studies related to effect of urban-rural background on cognitive development.

Cognitive abilities of both rural and urban Nepalese school children of ages 8, 10 and 12 were investigated through the administration of six Piagetian tasks, all for concrete operations, by Mali (1979). The results showed that rural and urban students were similar in performance on most tasks. Similarly, Sutradhar (1982), found that urban and rural population did not differ in their cognitive development. On the other hand, Sandeep (1979), ascertained that cognitive operativity was based on the child's background like sex, religion, caste, income, parents' education, occupation and leisure activity. Padmini (1980), related cognitive development to socio-economic status positively but not to pre-school education. A sample of 1020 students of 6th, 7th and 8th classes was tested by Shukla (1980), on conservation and scientific creativity. The findings were that the score on the conservation in mass and liquid of the tribal students was invariably lower than that of urban, rural and refugee Bengali students.

Pichardo (1985), conducted a study on 100 Dominican adolescents (60 urban and 40 rural) between the ages 11 to
15 years to study the development of formal operational thought and its relationship to self-concept, across different eco-cultural environments. The results showed that a higher number of subjects from the urban group acquired formal operations than those from rural group. Bagdady (1991), administered SR test and Maze test on a sample of (N=235) 8th grade urban and rural students of Makkah, Saudi Arabia and found that urban students scored significantly higher than rural ones on the spatial ability.

Blackwelder (1986), tested a sample of 110 (9th grade) from two urban high schools and found that less than half of the sample was at the formal reasoning level. Khalil (1989), selected a sample (N=891) from two countries (Egypt & England) to investigate cross-culturally the performance on science conceptualization in the light of Piaget’s theory of cognitive development. The results revealed that there were very slight variations between Egyptian and English children’s attainment of the late formal stage.

Tiwari (1990), conducted a study to investigate the effect of environmental characteristics on cognitive development. 2 x 2 x 3 factorial design with two levels of ecological background (rural/urban), two types of school (superior/ordinary) and three grade level (3rd, 4th and 5th) was applied to study the relationship. The findings
indicated that broad environmental variables provide varying inputs and make differential demands for different cognitive skills. These results implied that structuring of environments can profitably be used to facilitate cognitive development among young children.

2.4 FORMAL OPERATIONAL ABILITIES AND SCIENCE ACHIEVEMENT

There continues to be much interest in documenting the magnitude and the nature of the relationship between student performance and level of cognitive development, particularly, the association between cognitive development and academic achievement.

Field & Cropley (1969), in an attempt to clarify the relationship between science achievement and four cognitive style variables - mental operations, originality, flexibility and category width found the existence of significant relationship between formal-operations and science achievement. Sheehan (1970), studied the effectiveness of concrete and formal instructional procedures with concrete and formal-operational students between the ages 12 years 6 months and 13 years 5 months. Formal-operational students achieved significantly higher scores as a result of concrete instruction than from formal instruction. Sheyer (1973), emphasized the formal-operational nature of Chemistry and suggested that conceptual demands of Chemistry should be considered higher
than those of Physics or Biology at similar school levels. Raven (1974), after seven years of participating and co-
ordinating many research studies concerned with the facilitation of logical operations in elementary and junior high school students, concluded ‘that the level of reasoning used for inquiry and concept acquisition by every individual is substantially below his capacity’.

Ross (1974), conducted a study on formal thinking, paired associate learning and creativity in adolescents taking 78, 6th and 10th grade students. He found that formal operational thinking improved significantly across grade levels, with only the high achievers showing a degree of formal thinking at the 6th grade level. Lawson and Renner (1975), examined the relationship between developmental level and acquisition of concepts classified as concrete and formal. Developmental level was assessed by six individual interview tasks and understanding of concepts was tested by multiple-choice test. Analysis of variance showed significant differences in the relationship between developmental level and proportion of correct responses for the concrete and formal questions, respectively.

Waite (1975), conducted a study comparing science students’ performance on Piagetian type tasks taking 193 university students and found that students with science majors were likely to be formal than were non-science majors.
Wheeler and Kass (1977), correlated subjects' proportional reasoning ability to achievement in introductory Chemistry; using 10th grade Chemistry students. Correlation between Piagetian reasoning ability and Chemistry achievement was moderate ($r=0.48$).

Basmajian (1978), assessed, the relationship between Piagetian cognitive maturity and scholastic success of junior college students enrolled in an Audio-tutorial Biology programme and concluded that formal operational students achieved a significantly higher level than did non-formal operational students.

Greer (1979), assessed the performance of 277 students in grades 6, 8, 10 and 12 using formal-operational instruments and a modest relationship was observed between formal-operational abilities and overall recall performance.

Hayes (1979), investigated the relationship between Propositional Reasoning to Science Achievement on the Junior High School level (i.e. in grades 7, 8 and 9); which was in the positive direction. Similarly, Stephenson (1979), used correlation statistics to analyse the relationship between the intellectual level of the learner and score in Chemistry, which came to be significant.

Stolper (1979), conducted a study, with a purpose to examine cognitive development and other variables as predictors of academic achievement on a sample of 129, 9th grade students. The results indicated that 41% of the
variance in academic achievement, was due to cognitive
development.

In a study by Ward (1979), formal students (1) showed
higher achievement on test-items requiring concrete thought
than those at concrete level, (2) out-performed concrete
students on test-questions requiring formal thought.

Nussbaum (1979), in his study on the impact of
Science Curriculum Improvement Study’s ‘Relativity’ unit on
students level of cognitive development, found that students
who were closer to transitional stages had higher
achievement. The cognitive developmental levels of the
students were closely associated with achievement, was also
reported by Padilla and Smith (1979). Cobern (1979),
Ehindero (1979), Holden (1979), and Lybeck (1979), too
reported that formal students studying in high schools
outperform concrete-operational students in science
achievement. Brown (1979), studied 6th to 9th grade science
students with a purpose to investigate the proportionality
schema. A significant positive correlation between
performance on the proportional reasoning measure and on
problems derived from the science curriculum was observed.

Tobin (1986), focused his research on, how is
variation in student formal reasoning ability related to
variation in process skill achievement. The results
indicated that students formal reasoning ability was
positively related to student generalizing rates. Students
with higher formal reasoning ability obtained higher achievement scores than those with lower formal reasoning ability. Similarly, Padmini (1980), ascertained that significant relationship existed between the cognitive development status and the academic achievement. The same results were reported by Contessa (1980), Sheyer and Wylam (1981), Miller (1981), Thronton and Fuller (1981), Viravaidhaya (1981) and Za’rour and Gholam (1981). Formal cognitive skills are essential for successful understanding (Glass, 1981). Formal operational students significantly out-performed concrete-operational students (Crenshaw, 1983). Song (1982), studied the relationship between Piagetian cognitive developmental level and scholastic variables on a sample of prospective secondary school teachers. Cognitive and perceptual factors made significant contribution to the academic achievement of the children when Sutradhar (1982), had taken the sample irrespective of settings and also when rural and urban population were considered separately.

Cho, Hee-Hyung (1983), studied the learning of biological concepts at different cognitive levels by high school students. The findings of the study revealed that achievement levels are related to cognitive levels. Harper, Howard and David (1984), suggested that levels of cognitive development may be used as valid predictors of academic achievement. Maiman, Solainan and Ibrahim (1985), assessed
the Piagetian cognitive abilities required for the 12th grade Chemistry students enrolled in 10 public schools in Saudi Arabia. The findings revealed that most of the concepts tested required formal thinkers in order to understand the concepts, the way they are represented.

In a study of high school Chemistry students, Durr (1984), found that students' cognitive level was significantly and positively correlated with overall (unit) test scores and with per cent success on test-items. Work (1984), conducted a study on 7th grade life science students (N=122) from a sub-urban junior high school and reported that developmental level and problem-solving ability were significantly related. He further added that the best problem-solvers were field-independent and formal-operational or transitional.

Hofstein and Mandler (1985), in a study on Israeli high school students, reported that formal thinkers scored significantly higher than non-formal thinkers in Mathematics, Physics, Chemistry and Biology which was later supported by the findings of Abraham and Renner (1986). A high positive correlation (r = 0.60, p < 0.001) was reported by Tobin (1986), between formal reasoning ability and science achievement.

Dozier (1986), used Burney's test to measure general logical reasoning abilities such as Propositional logic, Proportional reasoning, Syllogistic reasoning and Analogical
reasoning of 7th to 9th grade science students. Values of coefficient of correlation between general logical abilities and science achievement were significant.

Chikara (1987), investigated the relationship of reasoning abilities with achievement of concepts in life science of 200 (10th Class) urban area students and concluded that there was a definite positive relationship between conceptual achievement in life science and reasoning abilities. Regression analysis indicated the possibility to predict conceptual achievement in life science on the basis of reasoning ability tests.

The role of developmental level in undergraduate science course students’ (N=25) ability to balance chemical equations was investigated by Niaz and Lawson (1985). Investigators reported significant correlations between developmental level and equation balancing ability for both simple and complex equations.

Wirt (1987), conducted a study on 101 high school Chemistry students, multiple-regression analysis showed that formal-operational students consistently out-performed concrete-operational students. The relationship among integrated science process skill achievement, logical thinking abilities and science achievement of 10th grade public school students (N=635) in Taipei, Taiwan, Republic of China was studied by Hsiung (1989). A significant but moderate correlation coefficient (r = 0.37, p < 0.001)
between integrated science process skills and logical thinking abilities was observed. Urban high school Biology students (N=500) was the sample of correlational study by Elias (1989). Results of Pearson-Product Moment Correlations indicated that variables cognitive development and achievement in Biology are correlated significantly (level of significance = 0.05). The relationship of cognitive style and academic achievement of university students (N=75) was investigated by Witten (1990). Investigator reported significant correlation between cognitive style and academic achievement (level of significance = 0.05).

Rai and Prakash (1989), studied post-graduate students (N=216), in order to investigate the relationship between cognitive style variables on one hand and achievement on the other hand. It was concluded that the knowledge of students’ standing on cognitive styles may be useful in predicting choice of academic majors. Vernon (1991) and Moody (1991), reported high formal reasoning ability increased laboratory achievement.

Sutherland (1991), found that visualization ability a characteristic of formal operational ability was significantly and positively correlated with and was also a significant predictor of biology achievement. Patricia (1991), investigated that Group Assessment of Logical
Thinking along with sex at the formal operational stage can be used to predict achievement in Chemistry.

Some studies, however, do not reveal a significant relationship between cognitive development and achievement. Kishta (1979), in his study of 4th, 5th & 6th graders, found no evidence of a relationship between level of cognitive development and achievement as measured by a Standardized Achievement Test (Iowa Test of Basic Skills). Collins (1979), studied (N=100) 10th and 12th graders and no relationship evidenced between their cognitive development and achievement in Physics. Students of different cognitive development achieved similarly on a criterion test on problem-solving in a study conducted by Grant (1979). No significant relationship between cognitive development and achievement in science was found by Champagne et al (1979), Cole (1979), Dallen (1979), Filson (1979), Williams et al (1979) and Ackerman (1978).

From the above-quoted studies, it is observed that (a) achievement in science is related to cognitive level of thinking that is for the understanding of concepts in science formal-reasoning is required; and (b) cognitive level can be used as a valid predictor of science achievement.

**Hypotheses**

Emergent from the trends of the previous studies,
following hypotheses have been formulated in the present study:

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.

3. 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.

4. (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.

5. (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.