CHAPTER I

INTRODUCTION
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RATIONALE AND NEED OF THE STUDY

Human resource development, both a cause and a consequence of every development in the ultimate analysis, is of crucial importance for educators. The optimum and integrated development of physical resources is possible only with fully functioning personalities behind it. In order to ensure that physical and human resources are fully developed to keep pace with the advancements and demands of the day, there is need to inculcate objectively discrimination ability, innovativeness and originality through the educational system. For this purpose, a change is in order regarding objectives, content, teaching methods and evaluation procedure involved in the educational process. For making these changes effective, the knowledge of learner’s intellectual development assumes a great significance so as to gear the changes congruent with learner’s growth characteristics and development tasks in order to maximize learning.

With the explosion of knowledge taking place in exponential terms due to the invention of computers and other modern scientific gadgets, facts of today may not be the facts of tomorrow, and theories may also undergo a change. Under such circumstances, there can be no going
away from the development of qualities of scientific temper which can best be fostered through the teaching of science. Science also helps in reducing general obscuresness and prejudices based on caste, religion, language or region, by emphasising a rational approach—which in their own turn facilitate democratic outlook, tolerance and harmonious development of personality. The approach paper on curriculum for the ten-year school prepared by the National Council of Educational Research and Training (N.C.E.R.T., 1977), states that: 'There is hardly any need to justify the place of science in a scheme of general education for school children. Science is all pervasive. In the present situation, anyone in any walk of life must be aware of some quantum of science and technology.'

It is not merely the introduction of science at various stages of education that will be enough. The teaching of science, will have to be revamped. Instead of remaining merely theoretical, it must include a predominantly practical bias in terms of its teaching objectives with a view to inculcating scientific attitude, originality, creative and improvisional abilities and stimulating innovative thinking among students needed in a society increasingly becoming more and more technologically oriented. Further, the assessment of these objectives must find a place in the academic achievement of the students.
While laying stress on science education and science achievement, the National Policy on Education - 1986, envisages, 'Science education will be strengthened so as to develop in the child well-defined abilities and values such as spirit of inquiry, creativity, objectivity, the courage to question and aesthetic sensibility. Science education programmes will be designed to enable the learner to acquire problem-solving and decision-making skills and to discover the relationship of science with health, agriculture, industry and other aspects of daily life.' (p.23)

Researches claim that there can be a high degree of relevance between Piaget’s theory of cognitive development, and materials and teaching methods of science subjects. These researches stress two points mainly: (a) that there are certain ascertainable developmental differences among students when Piaget’s measures are employed, and (b) that such differences warrant new approaches to curriculum, teaching methods and evaluation in the line of Piaget’s theory (Cohen 1978).

A large proportion of science concepts require students to operate at the formal operational level of intellectual development. But it has been found that a majority of science students exhibit large differences in their ability to understand science concepts and to solve specific problems. An understanding of concepts needs to be
matched with the hierarchy of concept formation. 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 the concrete-operational and formal-operational stages. This will help to assess with what effectiveness different science concepts can be taught to them. Herron (1975), has suggested that 'formal concepts of Chemistry can be taught in terms of concrete exemplars, which model the abstract concept.' Such information helps to adapt course contents, goals and teaching methods to fit the level of cognitive development of the students, and hence justifies the need for the taking up the present investigation.
Science is considered to be a difficult subject as it demands keen observation of phenomena, correct measurements, wide experimentation and appropriate predictions. Many of the science concepts taught in schools, cannot be comprehended readily by high school students (Cantu and Herron, 1978; Clement, 1982). Arons (1979, 1980) and Karplus (1981), reported that many secondary school and college students have difficulties while learning fundamental concepts and principles in science, such as abstractness of concepts, reasoning, required mathematical skill etc.

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). The research of Inhelder and Piaget has shown that there is a progression in the use of logical operations in the solution of science tasks. In the early part of concrete operational stage, pupils may categorize and separate variables. In the later part, the pupils use logical multiplication operations and compensation operations on the same phenomena. As they enter the formal operations stage, adolescents begin to use proportions, probability ratios and correlational relationships.

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 has stimulated considerable interest in science during the past decade. Formal-operational reasoning such as Combinatorial reasoning, Propositional logic and Proportional reasoning denote thinking that scientists find valuable. The 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).

Piaget believes that all societies have certain unique characteristics, that all individuals in their cognitive development have certain universal characteristics (Evans, 1973) and variations may exist in the ability for formal reasoning in all situations like (a) the influence of social environment to reach that level, (b) formal reasoning involves a special aptitude that not all individuals may possess, and (c) though all individuals will eventually develop formal operations, the type of formal reasoning developed may not be capable of solving all of problems.

In as much as the degree and direction of the process of development of formal operational reasoning is influenced by and in turn influences the educational stimulus and content, its development becomes a major priority in science education (McKinnon and Renner, 1971; Lawson, 1982a).
A sizeable number of studies is available at concrete stage of cognitive development in Indian condition, but the number of studies (Vaidya; Sandhu, 1979; Jacob, 1982; Jain, 1982 and Mathur, 1982) at the formal-operational stage is scarce and inadequate in order to arrive at sound generalizations. However, there is a need for further research on the issues such as: what percentage of high school students reach formal operational level; whether or not there are significant differences in the ability for formal reasoning due to urban/rural background differences; 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 alongwith the measures of subject-wise and total science achievement. The present study is addressed to these issues.

COGNITIVE DEVELOPMENT

Cognitive development of the students is one of the main important factors that determines their academic achievement in a subject, especially in science. The study of cognitive process has now become an important field of psychological and educational investigations. In the
opinion of Murray (1985), there is a consensus among psychologists that changes introduced by the cognitive process are relatively stable and continue for a long period.

Two major categories of theories in respect of cognitive development can be classified into - continuous and discontinuous approaches. Cognitive development occurs linearly (continuously) and follows a smooth progression according to the continuous approach. The fundamental nature of the facet of mental function remains unchanged and the growth is quantitative (Emmerich, 1964; Wholwill, 1973). This approach does not take into account the active participation of children in their interaction with the environment.

On the other hand, discontinuous theories of development visualize development as going through a series of stages of development. The abilities gained in each subsequent stage are not simply "more of the same"; at each stage qualitatively different understandings, abilities and beliefs develop. Piaget (1950), Erikson (1950, 1959) and Kohlberg (1963, 1964), are all stage-related theorists. Although their theories focus on different aspects of development and each theory describes development in terms of different stages, all share the belief that distinct stages of development can be identified and described. They
view development as an organismic phenomenon, with various core conceptual issues of development, while emphasising on nature and nurture factors up to different degrees. Piaget (1958), puts greater emphasis on the interaction between nature and nurture factors than do Freud and Erikson (1963) who place greater emphasis on nature variables and view the nurture variables as either facilitators or inhibitors of intrinsic emergences.

Erikson’s (1950, 1959) psycho-social theory of personal and social development, is an adaptation of the developmental theory of Sigmund Freud who proposed a stage theory of psychosexual development pertaining to the development of emotions. Erikson’s theory relates principles of psychological and social development that an individual passes through in terms of eight psycho-social stages, namely - (i) trust versus mistrust; (ii) autonomy versus doubt; (iii) initiative versus guilt; (iv) industry versus inferiority; (v) identity versus role confusion; (vi) intimacy versus isolation; (vii) generativity versus self-absorption; and (viii) integrity versus despair. The theory besides focusing on different aspects of behaviour also sees development as more automatic.

Kohlberg’s (1963, 1969), stage theory of moral reasoning is an elaboration and refinement of Piaget’s theory which will be discussed in detail in the subsequent
paragraphs. Like Piaget, Kohlberg is not so much concerned with the direction of the child’s answer as with reasoning behind it. He theorizes that an individual progresses through three levels, namely - (i) Pre-conventional level; (ii) Conventional level and (iii) Post-conventional level. These levels of moral development are roughly parallel to Piaget’s stages of cognitive development. Reaching Piaget’s stages of cognitive development is necessary but not sufficient for reaching Kohlberg’s stages of moral development.

PIAGET’S THEORY OF COGNITIVE DEVELOPMENT

Jean Piaget’s theory is considered as the most unique and mature one both from the perspective of specificity and completeness of the theoretical mechanics as well as from the richness of empirical findings it has generated. It was original and comprehensive and many of the most important ideas in it are simple and flexible. He was not as interested in individual differences as in the constancy of modes of conceptualization irrespective of outside variables like intelligence, socio-economic status, rural-urban differences, personality traits and motivation. He said that all children must go through certain stages of intellectual development in the same order; but he described these not so much in terms of age changes (as does Gesell, 1954) as in terms of stages, although he indicated the ages
at which he noticed the various stages appearing. While for
Furth and Wach (1974) stages of development, 'imply inborn
maturational processes that come about according to a rigid
internal time-table, regardless of life experience'. To
Piaget, stage denotes a change in structure of knowing based
on the assumption of organism - environment interaction.

The significance of Piaget's work, in this
resurgence, stems from the fact that he has provided a
comprehensive stage-dependent conceptual frame-work within
which cognitive functioning has been intensively studied.
The frame-work differs from that of other investigators like
Darwin, Spearman, Binet and Weschler in so much as in
Piaget's system structure of intellectual development is
stressed while others have placed emphasis on content and
function. While reorganising the necessity of content and
functions, he interposes cognitive structure as an
additional element which is necessary in explaining
intelligence. Content pertains to that amorphous mass of
behaviour which is available to the individual and which
varies with environment. Function on the other hand, refers
to the unchanging aspects of intelligence - organisation and
adaptation. Adaptation involves both the process of
assimilation of new material into the old; and the process
of accommodation which occurs when the individual is
required to reorganise his behaviour to cope with the
demands of a novel situation. Between these two-function and content - he inserted structure, which is described in terms of stages.

In Inhelder's (1970) words, 'Each stage involves a period of formation (genesis) and a period of attainment, characterised by the progressive organisation of a composite structures of mental operation; each structure constitutes at the same time - the attainment of one stage and the starting point of the next stage, of a new evolutionary process; the order of succession of the stages is constant, ages of attainment can vary within certain limits as a function of factors of motivation, exercise, cultural milieu and so forth; and the transition from an earlier to a later stage follows a law of implication analogous to the process of integration, preceding structures becoming a part of later structures'.

Stages imply qualitative differences in the mode of solving the same problem at different ages. Different stages of development form an invariant sequence and are hierarchial integrations; though some factors may speed up, slow down or stop development, but the sequence does not change. Only the higher stages reintegrate the structures found at lower stages.

Piaget visualised that development from sensory-motor neonate to an abstract thinking adult passes through four
stages of development, each stage defined in respect of the
type of behaviour and potential capacity. These stages are
(i) Sensory-motor stage (from birth to 2 years); (ii) Pre-
operational stage (from 2 years to 7 years); (iii) Concrete-
operational stage (from 7 years to 11 years) and
(iv) Formal-operational stage (from 11 years to 15 years).
In the following pages, the first three stages have been
given only very briefly highlighting the essential
characteristics so as to arrive at the correct understanding
of the fourth i.e. formal-operational stage which, as main
concern of the present study, has been described more
comprehensively.

(i) **Sensory-motor stage** Originally defined by Piaget
(1953a, 1954b), this is the stage in which sensory-
motor performance becomes progressively structured
into functional systems which form the building
blocks of successive cognitive activity. The
sensory-motor child's behaviour, while organised, is
not cognitive since it depends on responding to the
stimuli as presented, rather than as represented or
interpreted by cognitive activity. Thus, sensory-
motor behaviour lacks the representational component
of true cognition (Piaget, 1947). But the concept of
object permanence is formed and there is a gradual
progression from reflective behaviour to goal-
directed behaviour.
(ii) **Pre-operational Stage** During this period, children acquire the internalization of thought process which they lacked as infants. But the internalization of actions, in which the children can make use of a system of operations does not take place at this stage. Their thinking is mostly dominated by their perceptions. Due to failure at conserving-number, length, weight, area, volume and related tasks, it is difficult for them to understand the effect of different points of view on the same event and in the integration of information. The development during this period can be conceived of as preparing the way for the achievement of operations through increasing co-ordination of assimilation and accommodation in the child’s symbolic activities.

(iii) **Concrete-operational stage** Piaget and Inhelder (1969), maintain that entry into this stage is the turning point in the entire course of cognitive development, as the thought process becomes more logical; losing its intuitive character. At this stage, children bear marked resemblance to adults than the children of the first two stages, though the mental operation is limited to concrete and tangible information. Newly developed abilities include the use of operations that are reversible and understanding of the laws of conservation,
classification and seriation. But abstract thinking is not possible, as the concrete-operational can imagine of an object that is perceived by the senses e.g. block, ball etc.; and is unable to aggregate the ideas acquired as symbols e.g. square, circle etc.

(iv) **Formal-operational stage** This stage, approximately from 11 to 15 years, is usually conceived as that of emotional instability which may cause adjustment difficulties (Erikson, 1963, 1968). But for Piaget, it is the most exhilarating and productive period during which the adolescent demonstrates commendable thinking and reasoning potentialities (Brainerd, 1978).

Formal-operations is the crowning achievement of intellectual development, the final equilibrium state towards which intellectual evolution has been moving since infancy. It is characterised by the development of formal, abstract thought operations enabling one to reason not only on the basis of objects but also on the basis of hypothesis as also to perform 'operations on operations' in a systematic manner. The formation of hypotheses and of deducing possible consequences from them leads to a 'hypothetico-deductive' level of thought which expresses itself in linguistic formation of propositions and logical constructions.
The adolescent at this stage develops the capacity to engage in Propositional logic restricted neither by what he directly sees or hears, nor by the problem he immediately encounters. The highest level in the development of mental structure is the imagination of various dimensions of a problem of past, present or future, and devise hypotheses about what logically may occur under different combinations of factors. Formal thinkers are capable of reasoning verbally even in the absence of concrete objects (Piaget, 1973). The reasoning may even surpass everyday experience as it is not tied up with perception and memory. The adult begins to imagine the situation under certain hypothetical sets and can set up a hypothesis in a given situation, conclude what would happen if it is true, check and verify if the facts in front of him are consistent with his deductions from hypothesis. If they are not, then another hypothesis is formulated. Thus, hypothetico-deductive thought is achieved, along with the ability of reversal of direction between possibility and reality (UNESCO-UNICEF Report, 1974). Ability to manipulate symbols and deal with ideas verbally without the necessity for an intervening arrangement of physical objects, capability of thinking systematically and at the purely abstract level are the characteristics of the stage.

Understanding is analytical rather than intuitive at the formal-operational level. During later stages of formal
thought, ability to 'hold other things equal' while investigating one variable at a time is achieved. Direct and inverse proportionality is readily available for perceiving and formulating relationships. Such an individual '----- thinks beyond the present and forms theories about everything, delighting especially in considerations of that which is not'. (Piaget, 1966; p.148).

Different abilities developed at formal-operational level can be listed as below:

First, and the most important ability is to think about possibilities versus empirical reality. The adolescent begins his consideration, by trying to envisage all possible relations and to find out which of these possible relations in fact do hold true.

Second ability developed at formal level is the thinking through hypotheses or using hypothetico-deductive reasoning. Formal reasoners are not tied to testing the facts, as the concrete ones; they can think about impossible, the opposite or the 'contrary-to fact'.

Propositional thinking is the third characteristic of formal reasoners. The concrete reasoners think with operations (intra-propositional) and the formal reasoners think about operations (inter-propositional). Formal operations are performed on propositions rather than directly on reality.
Combinatorial analysis, the ability to systematically isolate all the individual variables plus all combinations of these variables, is the fourth ability.

Proportions is the ability to construct fractions or numerical ratios (e.g. equality of two ratios \( \frac{x}{y} = \frac{x'}{y'} \)). Proportionality has two aspects - one logical, and the other mathematical. The acquisition of the operational schema of numerical or metrical proportions presupposes qualitative expectations in the form of compensations by equivalence and in the form of logical proportions.

Out of these Propositional thinking, Combinatorial analysis and Proportions as pre-requisite for the understanding of science concepts have been selected for the present study.

**SCIENCE ACHIEVEMENT**

Achievement refers to accomplishment or proficiency of performance in a given skill or body of knowledge. The social acknowledgment of a person's skill, the range and depth of his knowledge or his proficiency in a designed area of learning or behaviour indicates the extent of his achievement. In the words of Pressey, Robinson and Horrock (1941), 'An achievement is the status or level of a person's learning and his ability to apply what he has learnt.' For Crow and Crow (1956), 'Achievement means the extent to which a learner is profiting from instructions in a given area of learning.' In other words, achievement is
reflected by the extent to which skill or knowledge has been acquired by a person from the training imparted to him. It is the outcome of general and specific learning experience.

According to Stephens (1956), 'Not that other aspects of educational objectives are to be ignored but the fact remains that academic achievement is the unique responsibility of all educational institutions established by the society to promote a wholesome scholastic development of the pupil.'

Good (1959, 1973) in his Dictionary of Education defines academic achievement as, 'knowledge attained or skills developed in the school subjects, usually designated by test scores or by marks assigned by teachers or by both'.

Academic achievement as viewed by Trow (1960) is 'the attained ability or degree of competence in school tasks usually measured by standardized tasks and expressed in age or grade units based on norms derived from a wider sampling of pupils' performance'. In other words, achievement may be defined as the competence they actually show in the school subjects in which they have received instructions.

Page and Thomas (1979), in the International Dictionary of Education define achievement as, 'performance in school or college in a standardized series of educational tests. The term is used more generally to describe performance in the subjects of the curriculum'.
According to Christian (1980), the word performance indicates the learning outcome of students. As a result of learning different subjects, the behaviour pattern of students changes. Learning affects three major areas of behaviour of students - (1) cognitive, (2) affective and (3) psychomotor. All these three levels are not affected in equal measure at a time, a student may be at a higher level in one domain and lower in another. Cognitive area is primarily concerned with intellectual growth of the individual. It involves acquisition of basic intellectual skills such as reading, ability to add and subtract, learning of facts etc. Cognitive domain includes all those objectives which deal with recall or recognition of knowledge and development of intellectual abilities (Bloom, 1956). Affective area deals with the self-concept, personal growth and emotional development of the students. The psychomotor domain is primarily concerned with the development of muscular skills and coordination.

Academic achievement is only a part of wider term-educational growth, which includes growth in all aspects. It refers to the pupils' knowledge attainment and skills developed in the school subjects which are assessed by the authorities with the help of achievement tests in the form of university examination. It is considered the primary goal of education.
Academic records are the most widely used index of its worth and success. ‘Whatever the socio-economic background of the children, they get opportunity to achieve success of a level which approximates to the level of children from comparatively better-off sections of society’ (Programme of Action, p.11). ‘Evaluation is, an integral part of any process of learning and teaching’ states the National Policy on Education (1986).

Even the most efficient programmes of improving the effectiveness and efficiency of teaching-learning process can yield best result only when these are judiciously used and suitably matched with the ability of students to master the task. In other words, level of attainment of objectives of teaching science and academic achievement of students depend as much as on the inherent strength of innovative teaching techniques as on the suitability of these techniques to the level of development of students' basic cognitive abilities.

Piaget’s work provides much of the theoretical basis for the way teaching units be organised and sequenced in terms of the child’s intellectual maturity level. His concept of operations closely fits the idea of process skills, how children acquire and manipulate information. Acquisition of formal-operational schemata is of considerable importance to science students e.g. Combinatorial analysis is required for comprehension of
Mendalian Genetics. Proportions are the most important mathematical tools of any science course. Indeed, many Physics concepts such as - density, gravitational force etc. are but naming the proportional relationships. Research work of scientists and educationists can be described through different types of correlations so that the teaching is meaningful. Because a large number of science concepts are abstract and require formal thought for their understanding, it becomes essential to know the level of cognitive development of the school students i.e. what proportion of students is at the concrete-operational and formal-operational stages. This will help to assess, with what effectiveness different science concepts can be taught to them. Such information helps to adapt course contents, goals and teaching methods to fit the level of cognitive development of the students. It is reasonable to believe that formal-operational students, capable of hypothetical thought, will attain science concepts better than concrete-operational students and achievement in science will be related to students operational reasoning ability (Sheehan, 1970; Lawson and Renner, 1975; Cantu and Herron, 1978; Barber, 1980; Bass and Maddux, 1982; Mckenzie, 1984; Abraham and Renner, 1986).
STATEMENT OF THE PROBLEM

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

OBJECTIVES

1. To identify the percentage of high school students who have attained formal operational 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 (c) Combinatorial analysis with academic achievement in science.

5. 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.

OPERATIONAL DEFINITIONS

Formal Operations: In the present study the Piagetian concept of formal operations-Proportionality, Propositional logic and Combinatorial analysis has been used as such.

Science Achievement: In the present study science achievement refers to the students knowledge attained and understanding of science concepts, as measured with the help of Standardized Science Achievement Test.

ORGANISATION OF RESEARCH REPORT

After having presented the rationale and need for studying the present study along with objectives in the Introductory Chapter I, Review of Related Literature and Hypotheses have been given in Chapter II. The IIIrd Chapter deals with Method and Procedure and Statistical Techniques used. In the IVth Chapter detailed account of the steps in Developing Achievement Test in Science have been given. Chapters V, VI and VII deal with nature of score
distributions, analysis and discussion of results simultaneously. Summary, Conclusions and Educational Implications form the content of Chapter VIII. Bibliography and Appendices have been given at the end of the Research Report as usual. Analysis of Data was done by using the 'Uni Comp PC/XT' Computer.