CHAPTER I

THEORETICAL FRAMEWORK

1.0 Evolution of Scientific Knowledge

Throught history men have observed various phenomena of nature and then attempted to explain them. Man's knowledge of such phenomena, observed and explained at different points of time, has gone through a number of stages (Robinson, 1968, p.15). At a given stage the knowledge of the various phenomena and their interrelationships exists in the form of a well connected structure. This structure is internally consistent in that it accounts for almost all observations made during that time. If any contradictory obsrvation is made during this time, it is either rejected as invalid or modified to fit into the structure. When many such observations are made and the existing structure fails to explain or account for these observations, there is created a disequilibrium and thus arises a need for the structure to undergo modifications in order to accommodate the new observations. Therefore, such an observation or a set of observations may trigger several changes in the knowledge structure thereby evolving into a new stage in the evolution of human knowledge. This is what Kuhn (1962) calls as normal and revolutionary phases of science. The new stage is relatively stabler in that it can assimilate many more observations than the previous stage.

So, the structure of knowledge is not to be taken as a static one, instead it is dynamic, and the evolution may be seen in terms of its change from a less stable equilibrium to that of a stabler one through an active interaction of the human mind with the environment[1]. This stage wise development of the knowledge structure may be further explained using a couple of illustrations from the history of science. During the period of Ptolemy (c. 140 A.D.) and for another 1300 years, it was believed that the celestial objects revolved round the earth in uniform motion. There was difficulty when some observations regarding the motion of planets conflicted with the existing knowledge structure. The structure was extended and not modified in an effort to assimilate the contradictory observations. When many such observations could not fit into this structure of knowledge, the then philosophers claimed that the observations must be wrong (Koestler, 1959,p.69). The sixteenth century Polish astronomer Copernicus set up a milestone in restructuring the understanding of the universe. His view of the universe (that the sun, not the earth, is at the centre of the system) could accommodate those unaccounted observations and also many more which were made later by others (Feldman and Ford, 1979,p.20). Thus, the structure of knowledge evolved from a lower stage to a higher one which could accommodate the previous observations as well as observations made during that period. Another major structural change that took place in the human understanding of his

environment is the development of quantum mechanics which led to the breakdown of the Newtonian mechanics. The work of Heisenberg, Dirac, Einstein, etc., forced the scientists to give up the classical explanations (Robinson, 1968,p.18).

Such a step wise evolution is also true in the case of the development of concepts which form part of the total knowledge structure. For example, the concept of the unit of matter and its constitution has undergone several such stages of evolution in history. The discovery of the fundamental particle 'electron' by J.J. Thomson in the year 1897 made a major change in the understanding of the unit of matter i.e., atom. It was then believed that positive and negative particles are embedded in a hard sphere called the atom. This concept of the atom could explain several observations regarding the constitution of matter and its transformations. But, when Rutherford in 1909 bombarded a collection of atoms with positive particles, they passed through. The then existing concept of the atom failed to explain this observation. There arouse a need for the conceptual structure to undergo transformation to accommodate the new observation. This led to the discovery of the Rutherford model of the atom with a heavy nucleus at the centre and the electrons moving around it.

The above examples are a few among the umpteen examples which show the stage wise evolution of concepts as well as the total knowledge structure through a process of

assimilation-accommodation-equilibration. This process is further elaborated in the coming sections.

1.1 An Individual's Understanding of his Environment

An individual, right from his childhood, interacts with his environment and adapts cognitively. He progressively constructs his cognitive structure through active interaction with his surroundings[2]. This includes elementary sensorymotor actions of a child to the most sophisticated intellectual operations of an adult. Such a construction of reality by an individual does not seem to proceed in a gradual and continuous fashion; rather it evolves in a stagewise fashion. An early example of such an evolution is the construction of the notion of the permanence of objects by a child by about the age of 9-12 months[3]. During the first few months of existence, the child is not aware of permanent objects, but only of pictures which appear, dissolve and then reappear. At this stage the child believes that objects depend on his action of looking for them. For the object to become permanent the child has to construct a new structure. This he does when the child discovers from repeated failures to recover an object from the initial position and later by successfully following it around an obstacle. At this point the child's body instead of being considered the centre of the world becomes an object like any other. Piaget (1976,p.14), describes it as a 'Copernican revolution', babies accomplish in

twelve to eighteen months. Such a stagewise evolution in an individual's construction of cognitive structures can be seen in his understanding of the environment[4].

1.2.0 Piaget's Theory

Piaget's theory of development, which is particularly concerned with the development of cognitive functions, is impossible to understand if one does not begin by analysing in detail the biological presuppositions from which it stems and the epistemological consequences in which it ends. Piaget (1976) says that he finds the same problems and same types of explanation to three processes viz., 1) the adaptation of an organism during its growth, 2) the adaptation of intelligence in the course of the construction of its own structures, and 3) the establishment of cognitive structures progressively constructed by continuous interaction between the subject and the external world. In the common view, the external world is entirely separate from the subject and an objective knowledge then appears to be simply the result of a set of perceptive recordings, motor associations, verbal descriptions and the like. But this passive interpretation of the act of knowledge is in fact contradicted at all levels of development. Actually, inorder 'to know' objects, the subject must act upon them, and therefore transform them; he must displace, connect, combine, take apart, and reassemble them. From the most elementary sensorimotor actions to the most sophisticated intellectual

operations, which are interiorised actions carried out mentally, knowledge is constantly linked with actions or operations, that is, with transformations (Piaget, 1976,p.12). The result of these transformations is the progressive construction of knowledge structures. But these structures are the result of construction and are not given in the objects, since they are dependant on action, nor in the subject, since the subject must learn how to coordinate his actions. The origin of knowledge lies in an inextricable interaction between both subject and object, such that what is given physically is integrated in a logicomathematical structure involving the coordination of the subject's actions (Piaget, 1976,p.16).

The above discussion on construction of structures seem to overemphasise the importance of experience. This is not true. According to Piaget the genesis of the mechanism of knowledge cannot be explained by any of the classical factors of developmental theory; it is not solely due to maturation, it does not result solely from learning on the basis of experience, and it does not result solely from social transmission. Piaget advances the hypothesis that another factor must be identified alongwith those of the above. This is the factor of equilibration (Inhelder, 1970; Thomas, 1977).

1.2.1 Equilibration

Piaget postulates that each organism is an open, active,

self-regulating system. Mental development would be then characterised by progressive changes in the process of active adaptation. Elkind (1967) paraphrases that 'at each level of development there are two poles of activity: change in the structure of the organism in response to environmental intrusions (accommodation) and changes in the intruding stimuli due to the existing structure (assimilation). Any action on the part of a subject gives rise to 'schemes' of assimilation[5]. That is, an object can be taken into certain schemes through the actions that are carried out on it; each of these schemes of assimilation goes hand in hand and with an aspect of accommodation of the schemes to the situation. Thus, when a subject takes cognisance of or relates to an object, there is a pair of processes going on. It is not just straight association. There is a bipolarity, in which the subject is assimilating the object into his schemes and at the same time accommodating his schemes to the special characteristic of the object. And in this bipolarity and sharing of processes, there is already a factor of equilibration between assimilation and accommodation. Piaget (1977,p.11), speaks of three kinds of equilibrium. The first one is in the relationship between assimilation and accommodation, discussed above. The second kind of equilibrium is an equilibrium among the subsystems of the subject's schemes. In reality, the schemes of assimilation are coordinated into partial systems,

referred to as subsystems in relation to the totality of the subject's knowledge. These subsystems can present conflicts among themselves and as they evolve, there is a constant need for coordination of the two, that is, an equilibration of subsystems. The third kind of equilibrium in cognitive development appears to be fundamental. Little by little, there has to be a constant equilibrium established between the parts of the subject's knowledge and the totality of his knowledge at any given moment. Pascual-Leone and Goodman (1979,p.304) explicate the notion of equilibration as follows: 'it is an active disposition of the psychological organism to spontaneously undergo reconstructions or structural changes in order to (a) maximise the internal consistency among its functional parts, (b) maximise adaptation in its dealings with the environment, and (c) minimise internal complexity in its organisation.

1.2.2 Stages in cognitive development.

The intellectual development model of Piaget has suggested four major stages. First is a sensorymotor stage which extends from birth to about two years and which occurs before the advent of language. This period is characterised by what Piaget(1971) calls 'sensorimotor intelligence', which is a type of intelligence resulting in a certain number of performances, such as the organisation of spatial relationships,

the organisation of objects and a notion of their permanence, the organisation of causal relationships, etc. After the sensorimotor period around the age of two years, comes another period which starts with the symbolic function. This is called the 'preoperational stage' since the child is capable of having representational thought by means of the symbolic function. The third period starts at around the age of seven or eight years and is characterised by the inception of operations. The term operation is obviously quite important on this intellectual development model. As Piaget (1964a, p.17) has stated 'to know an object is to act on it'. Eventually a child reaches a point where he learns from the actions rather than just from the objects. When learners discover the properties of their actions, they have begun to perform mental operations. An operation obviously is reversible and is an interiorised action (discussed in detail in the next section). Piaget describes the third stage i.e., 'concrete operational' stage as follows: 'the first operations appear, but I call this concrete operations because they operate on objects and not yet on verbally expressed hypotheses'. He describes the concrete operational thinker thus: 'in order to think children in the concrete stage need to have objects in front of them that are easy to handle or else be able to visualise objects that have been handled and that are easily imagined without any real effort'. In the last stage of the Piagetian model, formal operational thought, individuals

think with verbally expressed hypotheses. A learner who has acquired formal operational thought will be able to visualise Newton's second law of motion, relate the law of supply and demand to the movements of the stock exchange, appreciate the symbolism in a poem, succeed in Euclidean geometry, and construct the model of the atom from available data. This type of thought is 'the stock in trade of the logistitian, the scientist or the abstract thinker' says Bruner (1977,p.37).

1.2.3 Mental operations.

According to Piaget (Piaget, 1950; 1954a; 1954b; 1955; 1957) and Inhelder (Piaget and Inhelder,1956; Inhelder and Piaget, 1958) actions performed by the subject constitute the substance or raw material of all intellectual and perceptual adaptation. In infancy, the actions in question are relatively overt, sensorimotor ones. With development, intelligent actions become progressively internalised and covert (Flavell, 1963, p.182). As internalisation proceeds, cognitive actions become more and more schematic and abstract, broader in range, more, what Piaget calls reversible, and organised into systems which are structurally isomorphic to logico-mathematical systems[6]. Thus the overt, slow paced actions of the neonate eventually get transformed into lightning-quick, highly organised systems of internal operations. However, despite the enormous differences between simple sensorimotor adjustments

and the abstract operations which characterise mature, logical thought, the latter are as truly actions as are the former.

During the first few weeks of life the child depends largely on reflexes, the most important of which is the sucking reflex. Experience in using the sucking reflex causes modifications of this inherited schema so that it becomes more sophisticated[7]. After the first few weeks, the infant develops behaviour patterns that go beyond the primary reflex actions. Motor coordination develops that allows the child to place objects in the mouth and the first signs of curiosity in surrounding objects are observed. During the second year of life, the child searches for new things merely for the sake of finding out about new situations. Nearer the end of second year the child begins to show evidence that it can mentally represent objects that are no longer present. This symbolic function signals the beginning of representational thought. The thought is still very egocentric and 'other' points of view are not within the child's frame of reference. The child during this stage is unable to reverse the order of events in thought and arrive once again at the beginning point. This feature of thinking from two to seven years of age is perhaps emphasised most by Piaget as the major obstacle to real operational thinking (Good,1977 p.152). The first operations appear at the concrete operational stage (refer section 1.2.1). Piaget has divided operations during the concrete operational

period into two main groups: logical and infra-logical. The logical operations such as establishing one to one correspondence, adding and subtracting are not tied to any specific quantities, space, time, or the like as are the infra-logical operations (Good, 1977, p.153). Concrete operations require objects that can be grouped or ordered. The concrete groupings involve reversibility by either inversion or reciprocity but not by a synthesis of the two as in the 'formal' operations. The groupings are only simple or multiple classifications rather than a complete combinatorial system. When the adolescent accomplishes a complete combinatorial system, problems of a concrete as well as an abstract nature can be solved. Propositional thought is characterised by a complete combinatorial system that allows for separation and control of variables and a generalised hypothetico-deductive approach to solving problems. For a concrete operational thinker propositional thought is limited by an incomplete combinatorial system. Inhelder and Piaget (1958) have noted that one to one class multiplication is involved in such an approach and the subject discovers the combinations in a concrete manner. Sometimes, the twelve year old child will also include two by two class multiplication, but all combinations are not exhausted. Propositional thought presupposes the ability to make all possible combinations even though it may not be possible to actually verify each one experimentally (Good, 1977 p.132).

Piaget does not have arithmatical operations in mind so much as logical operations, of which the most common example are such things as conjunction, disjunction, implications and the like (Halford, 1978 p.12). The conjunction of two things, A and B, is anything which includes A and B, and is written as A•B. Thus the conjunction of things which are 'red' and 'triangular' is all the things which are red triangles. The disjunction of A and B (AvB) is all the things which are either A or B. Thus the disjunction of red and triangle is all triangles, all red things, and all things which are both red and triangular. The implication, A implies B (A⊃B), means that whenever A occurs B occurs also. Halford (1978 p.12) says that logical operations of this kind is a particular set of contingencies between events, which can be summarised in a form which is called a truth table. Below given is such a 'truth table' for conjunction (A•B), disjunction (AvB), and implication (A⊃B).

Table 1.1

Truth table for conjunction, disjunction, and implication.

A	B	Conjunction A•B	Disjunction AvB	Implication A⊃B
1	1	1	1	1
1	0	0	1	0
0	1	0	1	1
0	0	0	0	1

On the left are shown the two variables, A and B. They are variables because they have two possible values, present or absent (corresponding to true or false). Presence of a variable is signified by 1, absence by 0. All the four combinations of presence and absence of A and B are shown. The next column shows whether each combination of values of A and B is consistent with the concept of conjunction. For instance, the first row shows that when A and B are both present, A and B (A•B) is true, as also are AvB and A⊃B. In the second row, when A is present but B is not, then A•B is not true, but A or B (AvB) is true. In the same case, A B is not true, because if A is present but not B, then it cannot be true that A implies B. Consider now the last row, when A and B are both absent, both conjunction and disjunction are false, but implication is true because this case is consistent with the proposition that A implies B. Each concept in the truth table is a binary operation in that values of two variables are mapped into a value of another variable. Thus table 1.1 defines three distinct operations (Halford, 1978 p.13). Actually sixteen such operations can be defined by taking all possible assignments of this kind; these are the sixteen binary operations of propositional logic, which Piaget makes the basic building blocks of formal operations. The above discussion on the concrete operational thought (four binary operations), and the formal operational thought (sixteen binary operations), can be

brought out clearly with a couple of illustrations. Hunt (1961) describes the limitations of the concrete phase in dealing with these operations with the following example. He assumes that the propositions concern the class of animals which are divided into invertibrates (I) and vertibrates (V). The class of animals is also divided into those which live on land and are terrestrial (T) and those which live in water and are aquatic (A). If a child in the concrete operational stage is given the task of describing the population of animals on a newly discovered planet, he would be limited to the empirical task of searching for animals and assessing them to the four classes based on a two-way classification with the following entries in the 2x2 contingency table:

VT	VA
IT	IA

But if an adolescent or adult in the stage of formal operations were given the same task he would be capable, theoretically, of generating all the various combinations of classes of animals which were possible, and would be able to set out these possibilities without the benefit of empirical support as given in table 1.2 (Seggie, 1978 pp.350-351).

Table 1.2

Possible combinations of classes of animals.

1.	No animals at all
2.	Only VA
3.	Only VT
4.	Only IA
5.	Only IT
6.	VA and VT but no IA or IT
7.	VA and IA but no VT or IT
8.	VT and IT but no VA or IA
9.	IA and IT but no VA or VT
10.	VA and IT but no VT or IA
11.	VT and IA but no VA or IT
12.	VA, VT, and IA but no IT
13.	VA, VT, and IT but no IA
14.	VA, IA, and IT but no VT
15.	VT, IA, and IT but no VA
16.	All four classes

The sixteen binary operations, detailed in the above table, is constructed by taking each of the binary operations, shown in table 1.1, and negating or inverting it, or by performing other transformations on it. These are operations on the four binary operations. One such transformation is called identity or null transformation (I) which preserves the original operation. The next possible transformation is called the inverse (N), which negates each operation; e.g., it turns A and B into not A or not B. The reciprocal transformation (R) reverses the operation in a different way, by inverting the individual terms, so that R (A·B) becomes $\overline{A}\cdot\overline{B}$. The fourth transformation is actually the inverse of the reciprocal, and converts A·B into AvB, etc. Actually there is a simple rule for each transformation: for the inverse, replace

all the 1s in the truth table with 0s, and vice versa; the pattern of 1s and 0s for the reciprocal is a mirror image of the pattern for the original operation, and the correlate can be found by simply taking the inverse of the reciprocal. These rules hold for all the sixteen binary operation given in table 1.2. This group of transformations on logical operations is what Piaget calls the INRC group. Mathematically it is called the Klein group (Halford, 1978 p.15).

1.2.4 Transitions

According to Piaget, there occurs major changes in the logical reasoning patterns, when the child transits from one stage to another. About the transition from one stage to another he says as follows: 'a phenomenon which was noted empirically or else had been felt to be simply probable, all of a sudden became logically necessary for the child from his point of view. This necessity comes from a closure or completion of a structure' (Piaget, 1971 p.5). He continues to say that the feeling of necessity is neither a subjective illusion nor an innate or a priori idea. It is an idea which is constructed at the same time as the overall structures. As soon as a structure is sufficiently complete for closure to occur or, in other words, once the internal compositions of the structure become independent and independent of external elements and are sufficiently numerous to allow for all types

of arrangements, then the feeling of necessity manifests itself. 'Thus stages are characterised by overall structures which become necessary but which are not so initially. Formal structures become necessary when the structures of identity, of functions, etc., are complete; and those in turn become necessary when the sensorimotor functions are complete. But nothing is given in an a priori or innate fashion; nothing is performed or predetermined in the activity of the baby. For instance, we would search far and wide in the behaviour of the baby without finding even the rudiments of the group of four transformations, or of the combinatorial. These are all constructed and the construction - this I find to be the great mystery of the stages - become more and more necessary with time. The necessity is the end of development, not at the point of departure. This then, is the model upon which we are trying to base our work and our experiments' (Piaget, 1971 p.9). Kuhn (1979), says about transition as follows: 'what is initially a disturbance from the outside gives rise to simple regulations and then to more complex compensatory reactions. These compensations eventually reach a form having complete symmetry, and what are initial disturbances become systematic transforming agents within the system. In other words, they lead to an enriched, more highly differentiated structure.

1.3 Logic and Content of an Individual's Cognitive Structure

The development of an individual's cognitive structure depends on the growth and development of his logical reasoning and the development of conceptual structure[8]. In other words, the cognitive structure of an individual has a grammar and a content part. The grammar is the logical reasoning and the content is the conceptual frame. A minimum of grammar is required for the development of the content (assimilation) and it is through the construction of content structures that the logic developed from a qualitatively lower level to that of a higher level. Also, the conceptual structures undergo modifications as the logic develops[9]. The truth of the above proposition can be brought out clearly by the following illustrations. An individual who has not yet developed the formal operational logic and who operate at the concrete level, will not be able to visualise Newton's laws of motion or the relationship between electronic configuration of atoms and their physical and chemical characteristics. Such an individual needs objects in front of him that are easy to handle, or else be able to visualise objects that have been handled and that are easily imagined without any effort, in order to think (Piaget, 1971 p.4). Development of the logic does not ensure the development of the cognitive structure unless the individual comes across such questions in his interaction with the external world. An adult who has

developed the formal reasoning may not be able to discriminate between a planet and a star by looking up in the night sky or give reasons for the cyclic changes of the phases of the moon, if he had not asked himself questions concerning them and made relevant observations. He might not have noticed the planets and the stars as his cognitive structure had not integrated such a concept, though he is capable of doing so since he has the equipment (logic) to do it.

Piaget (1977), offers three interpretations for such anamolies. 'The slowness in development would be due to the quality and frequency of intellectual stimulation received from adults or obtained from the possibilities available to children for spontaneous activity in their environment. In the case of poor stimulation and activity, it goes without saying that the development of the first three of the four periods will be slowed down. When it comes to formal thought, there will be even greater retardation in its formation; or that perhaps in extremely disadvantageous conditions, such a type of thought will never really take shape or will only develop in those individuals who change their environment while development is still possible' (p.7). The interpretation would suggest that all normal individuals are capable of reaching the level of formal structures 'on the condition that the social environment and acquired experience provide the subject with the cognitive nourishment and intellectual

stimulation necessary for such a construction' (p.8). The second interpretation deals with the diversification of aptitudes with age and that the aptitudes of individuals differentiate progressively with age. Some adolescents are more talented for physics or problems dealing with causality than for logic or mathematics, while others demonstrate the opposite aptitude. The third most probable interpretation would be that 'all normal subjects attain the formal operations stage if not between 11 to 12 and 14 to 15 years, such would be true between 15 to 20 years. However, this would be dependent on their aptitudes and their professional specialisations and the manner in which formal structures are employed may not necessarily be the same in all cases' (p.9).

1.4 Environment as a Major Influence on Cognitive Development

The above discussion on the development of conceptual structures and the explanation by Piaget (1972) indicates the importance of social environment and acquired experiences on the construction of structures in an individual. In the case of an environment which provides poor stimulation and activity the development is retarded, whereas an environment which can provide cognitive nourishment and intellectual stimulation will aid development. The social environment would comprise of casual experiences and organised experiences. Casual experiences include those experiences which the individual

derives from his interaction with other members of the society viz., his parents, siblings, peers, etc.; and with objects around him like books, magazines, play objects, etc. Such interactions though important in influencing one's cognitive development are less amenable to manipulation by external sources. The organised environment comprises of formal and non-formal educational settings. Such organised environments should provide cognitively nourishing and intellectually stimulating experiences for an individual to interact and construct his cognitive structures.

1.5 Formal Education as a Potential Medium of an Individual's Interaction with the Environment

One of the main forms of organised social environment is provided by the formal educational system. Formal education aims at developing the personality of an individual which includes physical as well as mental development. Construction of cognitive structures forms a major portion of the development which includes the construction of logical reasoning and the development of conceptual structures. Kuhn (1979) and Kamii (1978) say that the promotion of formal operational reasoning should be the goal of education. Piaget's own views on educational objectives in modern society are probably shared by most educators today. According to him, 'the principal goal of education is to create men who are capable of doing new things, not simply of repeating what

other generations have done - men who are creative, inventive and discoverers. The second goal of education is to form minds which can be critical, can verify, and not accept every thing they are offered. The great danger today is of slogans, collective opinions, ready made trends of thought. We have to be able to resist individually, to criticise, to distinguish between what is proven and what is not. So we need pupils who are active, who learn early to find out by themselves, partly by their own spontaneous activity and partly through material we set up for them; who learn early to tell what is verifiable and what is simply the first idea to come to them' (Piaget, 1964a p.5).

If the formal education has to aid the construction of cognitive structures by the learner the curriculum frame should be a well connected network of theories, laws, principles, etc., and it has to take into consideration the level of abstraction the children of different grades are capable of. Overloading the curriculum with abstract concepts, especially to those grades where the children are incapable of showing formal reasoning, may aid neither the development of conceptual schemes nor the construction of logical structures. Also, the type of classroom interaction should be able to provide a congenial atmosphere for the active interaction of the learner with the environment. Piaget opines: 'the question comes up whether to teach the structure,

or to present the child with situations where he is active and creates the structure himself. The goal of education is not to increase the amount of knowledge, but to create the possibilities for a child to invent and discover. When we teach too fast, we keep the child from inventing or discovering himself. Teaching means creating situations where structures can be discovered; it does not mean transmitting structures which may be assimilated at nothing other than a verbal level' (Duckworth, 1964).

Engelmann (1971,p.120), says that there are five primary principles derived from Piagetian theory that describe development: 1) learning is subordinated to development and not vice versa, 2) learning is associated with developmental stages and these stages occur in an invariant succession, 3) the logical structure is not the result of physical experience, it cannot be obtained by external reinforcement. The logical structure is reached only through internal equilibration, by self-regulation, 4) it follows that the only way to 'teach' logical structure is through the process of internal equilibration and self-regulation. Conversely, if one observes a child who has acquired 'logical' structure in connection with a specific test, one could conclude that the child had acquired his skills through an internal process of self-regulation, and 5) the structures that are induced through equilibration last a life time.

A great deal of implications can be derived from the above principles for the assessment of a child's development and for curriculum development. The curriculum has to be highly flexible and dynamic. It has to take into account the logical structures of the learner and provide conflicting data or objects, through the manipulation of which cognitive conflicts are created or demonstrate phenomena which would induce cognitive conflicts, so that the self-regulatory mechanism of the learner is activated. In short, the basic principle of curriculum development, which includes the mode of classroom instruction, would be to provide an environment for the learner so that he undergoes the process of scientific inquiry and constructs cognitive structures through the self-regulatory mechanism.

Hooper(1968), stresses accurate assessment of the child's cognitive structure at a given point of time or development. The curriculum sequence should be designed in accordance with the child's changing cognitive status. The task of a teacher becomes one of relating the measures of cognitive function and structure to classroom requirements and schedules and the Piagetian tasks are viewed as diagnostic tools for educational assessment. Piaget(1962), criticises the school system for inhibiting the child's spontaneous development. 'Piaget's tasks could be valuable adjuncts to those measures designed to determine grade or level

placements, subject matter readiness, and corrective or remedial instructional programmes. These considerations apply to such topics as quantity-number readiness, scientific concepts, and causality relationships which have a rather direct connection with their respective curriculum areas (Hooper, 1968 p.424). The particular stage specification indicates when to intervene and what to present for the content area in question. While many topic areas are directly inferable from the content specific areas mentioned earlier, Piaget's system also includes a more general curriculum directive. 'The great power of Piaget's model lies in its inherent generality and potential application to a broad range of achievement areas subordinate to logical thought processes or reasoning' (p.425). The above statement may be further explained with an illustration. A concrete operational student is capable of certain functional capabilities including multiple classification and the ability to perceive and utilise reversible transformations. Training in these particular functional skills through content oriented problems should aid the assimilation of conventional scholastic areas into the learner's cognitive structure. In short, concretisation of content structures should help the learner assimilate these into his cognitive structure. But, a mere didactic presentation of a perfectly organised content sequence would not aid development. Piaget (1964b), is quite clear regarding the

value of straight forward didactic presentations. 'Experience is always necessary for intellectual development ..... but I fear that we may fall into the illusion that being submitted to an experience (a demonstration) is sufficient for a subject to disengage the structure involved. But more than this is required. The subject must be active, must transform things, and find the structure of his own actions on the objects' (Piaget 1964a p.4). It is this cognitive reorganisation by 'self discovery' in the classroom which Piaget stresses as a crucial element. The above contention may be further elaborated with an example. For the concrete operational child, an actual concrete manipulation of the objects or task material is required for his self-discovery. This, in the case of number training, addition-subtraction and multiplication-division experiences should be provided such that the child can actually perform them and reverse their activities. Similarly, multiple classification experiences could be ordered in terms of increasing complexity with the children actually constructing and reconstructing matrices on the basis of single-dimension attributes. Formulation of such tasks would demand considerable ingenuity on the part of the teacher to analyse the content to be learned in terms of the operations implicit upon it. Having done this, the teacher will have to arrange the learning materials so that these operations can actually be carried out by the student himself (Flavell, 1963 p.368).

1.6 Can Mental Operations be Induced?

This is a highly controversial question in the Piagetian theoretical framework. Piaget himself is silent on the question. This may be because his theory of cognitive development could not accommodate the factors which stimulate cognitive development. This observation is based on Piaget's reaction to the question of how transition from one stage to another occurs. Piaget (1971 p.9) says that the necessity for construction of structures from within the individual and he admits that this is 'the great mystery of stages'. Inhelder and her collaborators have later refined the Piagetian theoretical framework and the question of the acceleration of reasoning patterns seems to find a place in the reformed theory. Cellérier (1976), says that recent studies on transition seem to show a common process behind the construction of new rules and concepts by an individual. He says that new rules and concepts arise from recombination of the ones that are present. This recombination relies heavily on the existence of a general purpose representation system that can code both actions and situations, and a pattern recognition device that acts on these representations to produce rules and concepts - that is, higher order entities such as prescriptions and descriptions. This means the representation system must have some capacity to accommodate new types of input: it must itself be adaptive. Finally,

there must exist a decomposition and recombination device that acts on these descriptions and prescriptions to generate new ones. The actual choice as to which combination should be generated would have to be based on the construction of a succession of partial, reorganised representations (structured models) of the relationship between prescriptions and descriptions. The selection of the adapted combination would depend on an evaluation of their effects on the (external) problem environment, this evaluation being used to update the internal model and start a new recombination sequence. This cyclic chaining of external observations and internal coordinations is emphasised in Piaget's recent reformulation of the equilibration model. This type of analysis gave rise to a picture of cognitive development as a parallel evolution of cognitive categories, each composed of a neat filiation of progressively stronger structures. It has been recently complicated by the discovery that many different schemes and concepts may be applied by the child to the same problem, and that the different cognitive categories seem to evolve at slightly different rates. The net result is that lateral interaction between precursors appear at the decomposition and recombination level. These interactions take place between elements that are heterogeneous in two ways: 1) they originate from different categories; and 2) their degree of completion are not necessarily the same. Thus, Piaget's

picture of development now incorporates vertical relations (intracategory filiations) horizontal ones (intercategory filiations), and oblique ones (interactions between elements of different operatory levels)' (Cellérier, 1976 Pp.41-42).

The question of inducing the construction of logical operations seem to have more relevance in the reformed Piagetian theoretical framework described above. The decomposition and recombination model seems to accommodate this question. Also, the cyclic chaining of external observations and internal coordinations seems to accommodate the same question better than the classical equilibration model. The above observations are based on two reasons: 1) the decomposition-recombination model offers the possibility of the breaking down of the internal contradictions in the constructed cognitive structures of an individual on the basis of a dialectical feedback-evaluation relationship between the external problem environment and the internal model, 2) the idea of filiations which strengthens the structures, gives room for secondary construction on the cognitive structures which at a later point of time may be decomposed and recombined. Such a concept gives scope for learners constructing augmentations to a structure at that point of time when he is confronted with a problem.

A subsequent question that arises to the question of 'inducing' is how far one can induce. Is it infinitely

possible to induce the construction of logical operations? In other words, can formal operations be induced at a very early stage of development of the child. Perhaps the answer is that infinitely one may not be able to induce the construction of logical operations. At least the theory does not permit this. So, within certain limits one may be able to induce cognitive development if the learners are provided with the right type of environment, and their cognitive equipment is ready for transformations. Duckworth(1979 p.302), discussing on the dilemma of 'applying Piaget' asks a similar question: 'Is it possible for a child's understanding ..... of necessary relationship to evolve in especially devised situations more than it would spontaneously?' and she says that it is not the pressure of data that gives rise to the understanding. It is, on the contrary, the child's own struggle to make sense of the data. Talking about accleration she says: 'in every case where acceleration takes place, it results from a conflict arising in the child's own mind. It is the child's own effort to resolve a conflict that takes him or her on to another level'. Piaget questions the effect of stimulation on the child's initiative. He asks 'when some notions are facilitated by learning experts, whether they can serve as points of departure for new, spontaneous constructions, or whether the child will then tend to depend upon outside provocation rather than his or her own initiative

in pursuing the relationships among ideas'. Duckworth (1979 p.311), concludes the discussion by saying that 'learning in school need not and should not be different from children's natural forms of learning about the world. We need only broaden and deepen their scope by opening up parts of the world that children may not, on their own, have thought of thinking about'. She does not mention about any specific ways of deepening the children's scope of 'opening up parts of the world'. However, specific ways and means of inducing the construction of cognitive structures are discussed in the following chapter in the form of empirical evidences.

Notes

1. Here, the 'human mind' is not to be taken as an individual's mind, but, the mind of the human species.

2. Here, 'cognitive structures' refer to an individual's construction of logico-mathematical structures and the construction of physical reality by actively interacting with the environment.

3. Here, the period 9-12 months is not to be taken as refering to an individual child's development. Rather, it is the norm for that population.

4. The use of the term 'stage' should not be taken to imply that the development in question is a sudden affair. The term refers primarily to a similarity in the underlying process of the reasoning (structure) and presumably, to an organisation of nervous process that is common to all and only secondary to a relative synchronicity of development.

5. Here the term 'scheme' refers to a systematic or orderly arrangement of the elements of a body of knowledge.

6. The logico-mathematical system or logico-mathematical structures are progressively constructed by an individual through his cognitive action with the environment.

7. Here the term 'schema' refers to Piaget's term for the sensory motor coordinations present within the child at birth.

8. Here the term 'logical reasoning' or 'logical operations' refer to any computational operation such as addition or subtraction, or non computational operation such as, comparing, selecting, and extracting.

9. Here the 'conceptual structure' refers to the idea of hierarchical nature of concepts of David Ausubel.

REFERENCES

BRUNER, J.S. The Process of Education. Cambridge: Harward University Press, 1977.

CELLÉRIER, G. "Information processing tendencies in recent experiments in cognitive learning - Theoretical implications." In B. INHELDER and H.H. CHIPMAN (Eds.). Piaget and His School, New York: Springer Verlag, 1976. pp. 36-44.

DUCKWORTH, E. "Piaget Rediscovered", Journal of Research in Science Teaching, 2, 172-175, 1964.

DUCKWORTH, E. "Either We're Too Early and They Cant Learn it or We're Too Late and They Know it Already: The Dilemma of 'Applying Piaget'." Harward Educational Review, 49, 297-312, 1979.

ELKIND, D. "Editor's Introduction." In Six Psychological Studies, New York: Random House, 1967.

ENGELMANN, S.E. "Does the Piagetian Approach Imply Instruction"? In D.R. GREEN (Ed.) Measurement and Piaget, New York: McGraw Hill, 1971.

FELDMAN, A. & P. FORD. Scientists and Inventors. London: Aldus Books, 1979.

FLAVELL, J.H. The Developmental Psychology of Jean Piaget, New Jersey: Van Nostrand, 1963.

GOOD, R.G. How Children Learn Science. New York:MacMillan, 1977.

HALFORD, G.S. "The Structural Approach to Cognitive Development." In J.A. KEATS., K.F. COLLIS, & G.S. HALFORD. (Eds.). Cognitive Development, New York: John Wiley, 1978.

HOOPER, F.H. "Piagetian Research and Education." In I.E. SIEGEL and F.H. HOOPER (Eds.) Logical Thinking in Children, New York: Holt Rinehart and Winston, 1968.

HUNT, J. Intellegence and Experience. New York: Ronald Press, 1961.

INHELDER, B. "Some aspects of Piaget's genetic approach to cognition." In Cognitive Development in Children - Five Monographs of the Society for Research in Child Development, Chicago: The University of Chicago Press, 1970. p.26.

INHELDER, B. & J. PIAGET. The Growth of Logical Thinking from Childhood to Adolescence, New York: Basic Books, 1958.

KAMII, C. & R. DeVRIES. Physical Knowledge in Preschool Education: Implications of Piaget's Theory: Prentice Hall, 1978.

KOESTLER, A. The Sleepwalkers: A History of Man's Changing Vision of the Universe. London: Penguin Books, 1959.

KUHN, D. "The Application of Piaget's Theory of Cognitive Development to Education." Harward Educational Review, 49, 340-360, 1979.

KUHN, T.S. The Structure of Scientific Revolutions. Chicago: Chicago University Press, 1962.

PASCUAL-LEONE, J. & D. GOODMAN. "Intellegence and Experience: A Neopiagetian Approach." Instructional Science,8,1979.

PIAGET, J. The Psychology of Intelligence. New York: Hardcourt, Brace, 1950.

PIAGET, J. The Construction of Reality in the Child. New York: Basic Books, 1954a.

PIAGET, J. "Perceptual and Cognitive (or operational) Structures in the Development of the Concept of Space in the Child." Proceedings of the Fourteenth International Congress of Psychologists, 1954b, pp. 41-46.

PIAGET, J. "The Development of Time Concepts in the Child." In P.H. HOCH & J.ZUBIN. (Eds.). Psychopathology of Childhood, New York: Grune & Stratton, 1955. pp. 34-44.

PIAGET, J. Logic and Psychology. New York: Basic Books, 1957.

PIAGET, J. Comments on Vygotsky's critical remark concerning 'The Language and Thought of the Child'. In L.S. VYGOTSKY. Thought and Language, Massacheutes: MIT Press, 1962.

PIAGET, J. "Development and Learning." In R.E. RIPPLE & V.N. ROCKCASTLE (Eds.). Piaget Rediscovered, New York: Ithaca, Cornell University, 1964a.

PIAGET, J. "Development and Learning." Journal of Research in Science Teaching, 2, 176-186, 1964b.

PIAGET, J. "The theory of Stages in Cognitive Development." In D.R. GREEN. (Ed.). Piaget and Measurement, New York: McGraw Hill, 1971.

PIAGET, J. "Intellectual Evolution from Adolescence to Adulthood." Human Development, 15, 1-12, 1972.

PIAGET, J. "Piaget's Theory." In B. INHELDER & H.H. CHIPMAN (Eds.). Piaget and His School - A reader in Developmental Psychology. New York: Springer-Verlag, 1976.

PIAGET, J. "Problems of Equilibration." In M.H. APPEL & L.S. GOLDBERG (Eds.). Topics in Cognitive Development, Vol.1, New York: Plenum Press, 1977.

PIAGET, J. & B. INHELDER. The Child's Conception of Space, London: Routledge and Kegan Paul, 1956.

ROBINSON, J.T. The Nature of Science and Science Teaching, California: Wadsworth Publishing Co., 1968.

SEGGIE, J.L. "Formal Operational Thought." In J.A. KEATS, K.F. COLLIS., & G.S. HALFORD (Eds.). Cognitive Development. New York: John Wiley, 1978.

THOMAS, F.J. Piaget and Lamark. Science Education, 61, 279-286, 1977.