

## CHAPTER VI

## SUMMARY AND CONCLUSIONS

## 6.0 Introduction

In this concluding chapter of this report a brief summary of the study is presented. A short description of the theoretical basis is given followed by the presentation of the problem and the objectives of the study. A brief description of the procedure adopted for the realisation of the objectives is presented next. This is followed by a short description of the analysis and the major findings of the study. The chapter concludes with a discussion on the implications that can be derived from the present study for future research in the field of Science Education.

## 6.1 Theoretical Background

At a given point of time in the history of the evolution of human knowledge the understanding of various phenomena and their interrelationships exists in the form of a well connected structure. The structure is internally consistent and that it accounts for almost all observations made during that time. When contradictory observations are made, they are either rejected as invalid or modified to fit into the structure. When an observation or a set of

observations, does not fit into the structure there arises a need from within the structure to undergo modifications; thus evolving into a new stage. Human knowledge has evolved through several such stages. 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. His construction of cognitive structures also undergo similar stages of evolution like the human knowledge structure. Such an idea of an isomorphism between the knowledge generated by mankind over generations and how an individual constructs his cognitive structures is implicit in the theory of cognitive development propounded by Jean Piaget, a Swiss psychologist. Piaget's theory of cognitive development suggests four major stages in the mental development of a child. They are: sensorimotor, pre-operational, concrete operational and formal operational. These stages are characterised by the mental operations a child is capable of manifesting at a point of time. Major changes in the logical reasoning patterns occur when a child transits from one stage to another. The need for the transition comes from within the cognitive structure of the child. The structures grow as a child moves up from one stage to another. Older structures are not replaced by newer ones but are integrated with. The order of the stages is consistent and sequential.

The cognitive development of a child is influenced by two factors viz., 1) certain organisers inherent in the system determined by genetic factors and 2) environment. The environment comprises mainly of casual experiences and organised social experiences. One of the main forms of organised social experiences is formal education. Since the development of logical reasoning is dependent on social environment and experiences in general, designing instruction suitably should influence the cognitive development. In the natural development the need for restructuring ones cognitive structure comes from the failure to explain certain observations with the existing reasoning patterns. These reasoning patterns form a part of ones cognitive structure by means of which an individual explains an observation or a set of observations. When one fails to explain an observation, he feels the need to modify the reasoning patterns and thus effecting a change in his cognitive structure. So, it may be possible to induce the need for changing ones cognitive structure through constantly posing challenges to his knowledge structure or data that would contradict with his reasoning and help him resolve the contradiction. Normally the tendency of an individual would be to explain the observations with his existing reasoning patterns of his cognitive structure. But, the instructor may have to constantly point out the internal contradictions when such explanations are

made and if the individual realises it as a contradiction, the need for changing the cognitive structure would come from within.

## 6.2 Attempts at Accelerating Logical Reasoning

Earlier attempts on accelerating the logical reasoning patterns in laboratory and quasi-laboratory conditions indicate that transitional students are more prone to acceleration rather than those who are in an early stage of development. Rigid structuring of experiences does not show much of an influence on improving the logical reasoning. Attempts at influencing the reasoning patterns of students after taking into consideration their previous knowledge and existing cognitive structures, and framing experiences based on these have shown positive results. An inquiry approach to teaching is found to accelerate reasoning when compared to expository or didactic mode of teaching. Previous attempts at accelerating the logical reasoning patterns also indicate that creating 'cognitive conflict' as a strategy has been successful in developing cognitive structures and also the reasoning patterns. Acceleration studies conducted on Indian students are mainly confined to laboratory type of conditions where no attempt is made to reorganise the curriculum frame or relate the treatment to instructional activities

prescribed for the grade. Here, arises the need for conducting field studies attempting at accelerating the logical reasoning in the actual classrooms given all its constraints. Also, there is a need to relate the classroom experiences to the curriculum frame prescribed for the grade. Taking this research need into consideration, the present study makes an attempt at influencing the reasoning of students through actual classroom teaching based on the prescribed curriculum frame.

### 6.3 The Bases of the Present Problem

Among the school subjects 'science' is the most appropriate one to attempt at accelerating the reasoning. This is because of the reason that 'science' gives a lot of scope for the students to act upon with the physical environment and through these actions they construct mental structures and concomitantly develop their reasoning patterns. A review of the field conditions in India indicates that the science curriculum frame is outdated and disorganised. The curriculum framing is not based on any theoretical frame. The curriculum demands a lot of hardwork from the students in rote memorising the facts, principles, etc. There is hardly any provision for the students to act upon objects and ideas and discover the laws and principles

of natural phenomena. The curriculum experiences are rather prescriptive and curb the students from thinking in an original manner. The present study attempts at answering the question whether it is possible to influence the reasoning patterns of the learners' under the field conditions.

A total reorganisation of the curriculum frame may have to be done in the light of 1) the previous concept structure of the learners and 2) the logical reasoning patterns they are capable of manifesting, for an attempt at accelerating the reasoning patterns. The need for reorganisation becomes all the more meaningful in the Indian context because the students of a particular grade have undergone through the static and ill-prepared curriculum during the previous years of learning. Also, the reorganisation should be done in consideration to the conceptual structure of the discipline. Such a reorganisation of the curriculum frame should make it highly flexible and dynamic. The dynamism and flexibility of the curriculum frame may be seen in terms of its adaptability to the various cognitive demands of the learners, so that their reasoning patterns are accelerated. This calls for the use of an instructional model of science which is also dynamic in nature. The model of instruction should include the ingredient of an inquiry approach. A guided inquiry approach

where the teacher acts as a facilitator to the process is more appropriate than a pure inquiry approach. Earlier attempts clearly support this view. The facilitator may continually assess the knowledge structure of the learners and provide data in such a way as to cause cognitive conflicts in their mind. This would stimulate the students to come out with several hypotheses. The facilitator may then help the students in testing these hypotheses by recalling day to day experiences or by supplying appropriate data (pre-fabricated or from the history of science). These tested hypotheses get integrated to the cognitive structures of the learner. By such a cyclic process the learners construct their cognitive structures and improve their reasoning (mental operations).

In the intellectual development model propounded by Piaget the mental operations appear during the concrete operational stage. An early concrete operational child may need a long term interaction with the environment to transform to the formal operational stage. The instruction of formal concepts may not be beneficial to such a student as he is not equipped to assimilate such concepts. Therefore, it may be worthwhile to attempt at influencing the reasoning patterns of students when they are in a transitional state from concrete to formal. Preliminary investigations

conducted by the investigator indicate that among the secondary classes, grade IX and X students show transition from concrete to formal operational thought. Among these two grades, grade IX is chosen for the present study.

A few examples of reasoning patterns that can differentiate between the concrete and formal operational student are 1) combinatorial reasoning 2) controlling of variables 3) proportional reasoning and 4) deduction. These reasoning patterns are inter related - some closely and others remotely. Some of these reasoning patterns evolve to a higher level faster when compared to others. This is termed as 'horizontal décalage' in the Piagetian theoretical framework. From the point of view of assessing the reasoning patterns and attempting at accelerating these patterns, it would be better to choose closely related reasoning patterns. Also, the choice of reasoning patterns should be based on the possibilities the science curriculum offer for its acceleration. Based on these criteria the reasoning patterns 'combinatorial reasoning' and 'controlling of variables' are chosen in the present study. Therefore, the research question of the present study boils down to whether the reorganising of the prescribed curriculum frame of grade IX to suit the level of reasoning of students would aid the development of the same reasoning pattern in an actual

classroom situation given all its natural constraints. There is a basic assumption behind this question: That is, an active participation by the students on the curriculum material presented to them would aid cognitive development.

#### 6.4 The Problem of the Study

##### 7 STUDY OF THE EFFECT OF REORGANISING THE PRESCRIBED CURRICULUM FRAMEWORK ON THE COMBINATORIAL REASONING AND CONTROLLING OF VARIABLES OF GRADE IX STUDENTS.

The study is aimed at accelerating the logical reasoning of students with the aid of curricular experiences in a real classroom setting, with all its natural interferences. The two logical reasoning patterns that are accelerated are 1) combinatorial reasoning and 2) controlling of variables. The chemistry portion of the science curriculum prescribed for the grade is selected for reorganising. The reorganising is carried out based on three criteria viz., 1) the background knowledge of the students, 2) the reasoning patterns manifested by the students and 3) the structure of the discipline.

#### 6.4.1 Objectives of the study

The major objectives of the study can be stated as follows:

1. To assess the level of reasoning of students of grade IX in the following reasoning patterns  
(a) combinatorial reasoning and (b) controlling of variables.
2. To analyse the chemistry portion of the science curriculum of grade IX with a view to reorganising it to suit the level of reasoning of students.
3. To study the effect of reorganising the curriculum frame on the following reasoning patterns  
(a) combinatorial reasoning and (b) controlling of variables in comparison to the existing curriculum frame.

The assessment of the level of reasoning (objective No. 1) demands the use of problems or tasks to be presented to the students and observing the way they go about solving it. The exposure to such problems or tasks might interfere with studying the effect of the treatment (objective No. 3). There arises the need to study the effect of the pre-assessment and its influence on the treatment. Therefore, the following two objectives are added alongwith the above three.

4. To study the effect of assessment of the reasoning patterns (a) combinatorial reasoning and (b) controlling of variables on the development of the same.
5. To study the interaction between the pre-assessment and treatment on the two reasoning patterns (a) combinatorial reasoning and (b) controlling of variables.

#### 6.4.2 Hypotheses of the study

The following hypotheses are tested in the present investigation.

1. The reorganisation of the chemistry portion of the science curriculum for grade IX may positively influence the combinatorial reasoning of students who undergo the classroom instruction with reorganising the prescribed curriculum when compared to those students who undergo the normal classroom teaching based on the existing curriculum frame.
2. The reorganising of the chemistry portion of the science curriculum for grade IX may positively influence the 'controlling of variables' of students who undergo the classroom instruction with the reorganising of the prescribed curriculum when compared to those students who undergo the normal classroom teaching based on the existing curriculum frame.

The above hypotheses have been framed in the directional form since earlier attempts show that acceleration is possible under laboratory conditions and field conditions other than Indian.

The objective No. 1 demands the assessment of the reasoning patterns of the students before attempting at reorganising the curriculum frame. This is done by posing problems to the students which demand them to manifest the reasoning patterns. This assessment may affect the

the development of these reasoning patterns because the students who are exposed to those tasks may be triggered to mentally operate in a similar fashion. Since there are two possible sources of influence on the reasoning patterns, i.e., the treatment and the pre-assessment, there could be a possible joint effect of the two influences. The following four hypotheses are added alongwith the above two.

3. There is no difference in the combinatorial reasoning of students, who have been assessed through tasks which demand the use of such a reasoning pattern, and those who have not been assessed through such tasks.
4. There is no difference in the 'controlling of variables' of students, who have been assessed through tasks which demand the use of such a reasoning pattern, and those who have not been assessed through such tasks.
5. There is no difference in the 'combinatorial reasoning' of students, who have been pre-assessed on the same reasoning pattern and who have undergone the treatment, and who have not been pre-assessed and not undergone the treatment; and those who have not been pre-assessed and who have undergone treatment, and those who have been pre-assessed but not undergone the treatment.
6. There is no difference in the 'controlling of variables' of students, who have been pre-assessed on the same reasoning and who have undergone the treatment, and who have not been pre-assessed and not undergone the treatment; and those who have not been

pre-assessed and who have undergone treatment, and those who have been pre-assessed but not undergone the treatment.

#### 6.5 The Design of the Study

The design should be able to accommodate the study of the following: 1) the effect of reorganising the prescribed curriculum frame on the reasoning patterns in comparison to the existing curriculum frame, 2) the effect of pre-assessment on the development of these reasoning patterns and 3) the interaction between the treatment and the pre-assessment. This problem may be examined through what is called a Solomon Four Group Design. The design is as follows:

Group 1	R	$O_1$	X	$O_2$
Group 2	R	$O_3$	.	$O_4$
Group 3	R		X	$O_5$
Group 4	R			$O_6$

where R is random assignment, X is experimental treatment and  $O_1$  to  $O_6$  are observations. Randomisation in the present study is not carried out by pooling all the units of the sample and allotting them to the four groups; but, four clusters (belonging to two different academic years) are taken from an institution which does not have any specific criterion for the allotment of students into each division.

## 6.6 Sample

The sample of the study comprises of four groups of students of grade IX of an English medium school in Baroda. The total number of students in the four groups is 204. The number of students in the four groups are as follows: Group 1 ( $N_1 = 50$ ), Group 2 ( $N_2 = 52$ ), Group 3 ( $N_3 = 52$ ) and Group 4 ( $N_4 = 50$ ). Two of these groups belong to the academic year 1981-'82 and the other two of the academic year 1982-'83. Only 6% of the sample speak English with peers and at home. The rest of the sample speak Gujarati, Marati or Hindi with peers and at home. The parental occupation of 61% of the sample is business and the rest are doing office jobs. The average age of the sample is fourteen years and eight months. The four groups are matched on two external criteria viz., 1) age and 2) intelligence as measured through Ravens Standard Progressive Matrices.

## 6.7 Tools and Techniques of Data Collection

The tools and techniques used in the present study are 1) clinical interview 2) an observation schedule for science instruction called System of Observation of Cognitive Processes in Science Instruction (SOCOPSI) and 3) unstructured interviews. In order to assess the level of reasoning of students the clinical interview technique gives more valid

information when compared to testing or pure observation. In a clinical interview the interviewer asks questions to a child, listens, observes, makes a hypothesis about the interviewees conceptual ability, and proceeds to ask more questions based on the hypothesis he has formed. The interviewer uses probing questions to get at underlying reasoning, encourages the child to test predictions and verify answers. In order to assess the level of reasoning of children with the above mentioned technique needs carefully planned tasks or problems. The study demands the assessment of two reasoning patterns viz., 'combinatorial reasoning' and 'controlling of variables'. Four tasks to assess each reasoning pattern is developed. Two of these tasks are used for pre-assessment and the other two for post-assessment. The four tasks used to assess the combinatorial reasoning are 1) Fun house puzzle, 2) Coloured chemicals, 3) Hockey player puzzle, and 4) Electrical switching system. The tasks used to assess the 'controlling of variables' are 1) Photosynthesis problem, 2) Pendulum, 3) Growth rate of plants, and 4) Falling bodies on an inclined plane. All these eight tasks were tried out on twentyfour IX grade students to establish the reliability of the scoring procedures and to establish the equivalence of the four tasks assessing one reasoning pattern.

The observation schedule used in this study is called

the "System of Observation of Cognitive Processes in Science Instruction" (SOCOPSI). The SOCOPSI gives a qualitative description of a classroom instructional process. It has two major dimensions viz., the behavioural dimension and the process dimension. Teacher and pupil initiated activities are coded separately into instructional events. Several such instructional events put together form an instructional episode based on the content point being discussed. The episodes can be categorised into different instructional patterns depending on the level of cognitive processes involved in the instruction.

Unstructured interview was used in the present investigation for three purposes. One, to probe into the reasons behind the non participation of students in the classroom activities. Two, to collect data regarding the planning of activities by the regular teacher of the school who was teaching the control groups. Three, to collect data regarding the admission procedure adopted by the school from the Principal. The main difference between the unstructured interview and the clinical interview is that in the former the investigator does not frame any hypothesis on the responses of the interviewee whereas in the latter the investigator (interviewer) frames a certain set of hypotheses on the responses of the interviewee and test against the actual responses.

## 6.8 The Experiment

Among the four groups mentioned in the design of the study group 1 and group 2 are pre-assessed using four tasks (two each for assessing two reasoning patterns). The assessment was made using clinical interview technique. The tasks used to assess the combinatorial reasoning are 1) fun house puzzle and 2) coloured chemicals, and for controlling of variables the tasks used are 1) photosynthesis puzzle and 2) pendulum task. The pre-assessment shows that none of the students operate at the formal level (III B). A vast majority of the students (67% in the combinatorial reasoning and 77% in the controlling of variables) operate at the concrete operational level (II A). Only 2 to 6% of the students show early formal reasoning. Objective No. 1 of the study is realised through this assessment procedure.

The curriculum analysis and reframing demand concretising of the formal concepts since the students are operating at the concrete level. The analysis of the prescribed curriculum indicate that most of the concepts dealt with demand formal operational structures on the part of the learners to assimilate. Also, dealing with the chemical and physical properties of elements as separate units leave a lot of gaps in the curriculum structure. The students should be able to interlink the relationship

between the preparation of one element with the property of another. The curriculum frame should be able to highlight such interrelationships among the elements. Based on these lines the whole curriculum is reorganised, thus realising objective No. 2 of the study. The dynamism of the curriculum frame lies on the instructional model through which it is presented to the learners. A model of instruction which incorporates a guided inquiry approach. The experimental group students (group 1 and group 3 of the design) were taught through such an instructional model for a semester (six months). The number of sessions engaged in these two groups were forty seven and forty eight respectively. The students of the control groups (group 2 and group 4 of the design) were taught by the regular teacher of the school. The teaching was based on the prescribed curriculum frame. The number of sessions engaged by the teacher were fifty and fifty two respectively to these two sections. Six sample lessons of both the experimental and control groups are observed using the SOCOPSI.

The levels of reasoning (combinatorial reasoning and controlling of variables) of all the students, belonging to both the control and experimental groups, were assessed at the end of the respective semesters. The assessment was made using the clinical interview technique. The tasks used to

assess the combinatorial reasoning are 1) hockey player puzzle and 2) electrical switching system, and the tasks used to assess controlling of variables are 1) rate of growth of plants and 2) falling bodies on an inclined plane.

### 6.9 Analysis of Data

The data gathered through the experiment are subjected to qualitative and quantitative analyses. The improvement in the reasoning patterns (combinatorial reasoning and controlling of variables) in the control and experimental groups are compared. This comparison is made on the differences between the pre and post-assessments of group 1 and group 2. For a statistical analysis, the levels of reasoning are converted into scores; concrete operational reasoning (II A) is given a score of 1, transitional state (II B) is given a score of 2, early formal reasoning (III A) is given a score of 3, and formal operational reasoning (III B) is given a score of 4. The scale thus formed is assumed to be of interval scale. The 't' test is applied on the following four pairs of observations i.e.,  $O_2$  and  $O_1$ ,  $O_2$  and  $O_4$ ,  $O_5$  and  $O_6$ , and  $O_5$  and  $O_3$  to test the effect of the experimental treatment. Two way analysis of variance is applied on the post-assessment observations  $O_2$ ,  $O_4$ ,  $O_5$  and  $O_6$  to test the effect of the experimental treatment,

pre-assessment and the interaction between the treatment and pre-assessment.

#### 6.10 Major Findings of the Study

The major findings of the study can be summarised as follows:

1. The reorganising of the prescribed curriculum frame and executing it through a dynamic model of instruction has positively influenced the 'combinatorial reasoning' of students when compared to those students who have undergone the normal classroom teaching based on the prescribed curriculum frame.
2. The pre-assessment of the 'combinatorial reasoning' of students through tasks have no significant effect on the same reasoning pattern.
3. There is no significant interaction between the experimental treatment and the pre-assessment on the 'combinatorial reasoning' of students.
4. The reorganising of the prescribed curriculum frame and executing it through a dynamic model of instruction has positively influenced the 'controlling of variables' of students when compared to those students who have undergone the normal classroom

teaching based on the prescribed curriculum frame.

5. The pre-assessment of the 'controlling of variables' of students through tasks have no significant effect on the same reasoning pattern.
6. There is no significant interaction between the experimental treatment and the pre-assessment on the 'controlling of variables' of students.
7. History and maturation have no significant effect on both the reasoning patterns viz., 'combinatorial reasoning' and 'controlling of variables'.

#### 6.11 Suggestions for Further Research

The present study attempted at accelerating the reasoning patterns viz., 'combinatorial reasoning' and 'controlling of variables', through actual classroom instruction by reorganising the chemistry portion of the prescribed science curriculum. The reorganisation is based on 1) the prior conceptual structure of the learners, 2) the logical reasoning patterns the learners are capable of manifesting based on their logico-mathematical structures, and 3) the conceptual structure of the discipline. Deriving implications from the present study the following suggestions are discussed for future research.

1. Though the present study suggests that acceleration is possible it cannot be taken as conclusive evidence from this single attempt. A similar reorganisation of the Physics and Biology portions of the prescribed curriculum frame; and teaching it through the model of instruction used in the present study and studying the effect on the reasoning patterns would give further evidence on the merit of the instructional model.
2. The results of the present study suggest that a guided inquiry approach is better than a didactic approach in accelerating the logical reasoning. This cannot be taken as conclusive evidence because both these approaches were based on two different curriculum frames, i.e., the reorganised one and the prescribed one. This calls for a comparative study of both the approaches to instruction based on the reorganised curriculum frame.
3. The initial assessments of the reasoning patterns of grade IX students reveal that more than 70% of the students operate at the concrete level. In such a situation one can hypothesise that individualised instruction may be more effective in accelerating the logical reasoning. Or it may also be hypothesised that individual instruction coupled with group instruction might accelerate the reasoning patterns than by either one mode of instruction. These hypotheses may be put to test under laboratory conditions and then under field conditions.
4. The analyses of the data obtained through the present investigation suggest that students in the transitional state have gained better than the concrete operational

students. The differential effect of concrete and abstract instructional experiences on the acceleration of the reasoning patterns is an unanswered question. It may be hypothesised that concrete learners may gain better from concrete experiences and formal learners may gain better from abstract learning experiences.

5. The formal operational stage is the most complex among the stages of development in the Piagetian theoretical framework. Among the reasoning patterns that constitute this complex structure only 'combinatorial reasoning' and 'controlling of variables' have been assessed and accelerated in the present study. The logical operations of multiple classification, seriation, logical multiplication, proportional thinking, probability and correlational thinking may be used for assessing the formal structure and depending on the content being taught in an instructional situation, the acceleration of suitable logical operations may be attempted.
6. The assessment of the two reasoning patterns viz., 'combinatorial reasoning' and 'controlling of variables' have shown differences in the levels of development. That is, all students who have shown early formal or formal operational reasoning in 'combinatorial reasoning' have not shown similar reasoning ability in 'controlling of variables'. Such a difference is termed as 'horizontal décalage' in the Piagetian theoretical framework. The assessment of other reasoning patterns that constitute the formal structure among the secondary students, and studying their interrelationship would aid the curriculum reorganisation at the secondary level. This is of

importance because the secondary school students are in a transitional state from concrete to formal operational stage and the development of formal structures are necessary for the assimilation of abstract concepts dealt with in the curriculum prescribed for the grades.

7. In the present study acceleration of formal reasoning patterns have been attempted at grade IX. Similar studies may be taken up at grades VII and VIII, where students show signs of transition. Attempts at accelerating the reasoning patterns at these grade levels may emphasise more on the manipulation of objects than the manipulation of ideas for the construction of cognitive structures.
8. The influence of language (medium of instruction and mother tongue) on the development of cognitive structures need further investigation. The experiences of the investigator during the clinical interviews in the present study, indicate that students think, comprehend and communicate better in the language they speak with peers than the medium of instruction, here, English. Whether teaching through an alien language would hinder the cognitive development is an unanswered question? Similarly, the relative merit of mother tongue and English in the development of cognitive structures need further investigation.
9. The relationship among other personality variables like affect attributes on the cognitive development has not been studied in the present investigation. The theory suggests that the affective and cognitive development are not only parallel, but influence each

other. There is, however, little empirical evidence on the interrelationship between emotional and cognitive development. Certain questions that can be taken up for further investigation in this field are:

a) whether the development in reasoning affects the attitude of students? and b) does scientific interest aids the development of cognitive structures?

10. The present study has attempted the acceleration of reasoning in a given urban context. Replication of similar studies under varied socio-cultural contexts would give further evidence on the hunch that the reorganising of the curriculum frame can influence the cognitive development of the students.

-----