

CHAPTER V

ANALYSIS AND INTERPRETATION

5.0 Introduction

The data gathered through the procedures detailed in the previous chapter is analysed and presented in this chapter alongwith the interpretations. The analysis of the data gathered through the SOCOPSI is presented, in the first section of this chapter, to highlight the nature of classroom interaction in the experimental and control groups. This is followed by the analyses and interpretation of the data obtained from the experiment described in the preceeding chapter, keeping in view the objectives of the present investigation (refer chapter III, section 3.9). It may be mentioned here that among the five objectives presented in chapter III the realisation of objectives 1 and 2 have already been discussed in chapter IV (refer sections 4.4.1 and 4.4.2). The realisation of objectives 3, 4 and 5 are discussed in this chapter. A process of hypotheses testing is implicit in the realisation of these three objectives. The hypotheses set in chapter III (refer section 3.10) are restated under each sub-section. This is followed by a qualitative analysis of the anecdotal records tracing out the major reasons for the lack of interest in classroom

activities among the students. The chapter concludes with a discussion on the results of the present investigation amidst other studies in the field.

5.1 Classroom Interactions

Six sessions each of the 'treatment' (reorganised curriculum frame) and the control (prescribed curriculum frame) were observed using the System of Observation of Cognitive Processes in Science Instruction (SOCOPSI). The 'instructional events' and the 'instructional episodes' recorded using the SOCOPSI are given in Appendix K. An analysis of the 'instructional episodes' (which contains several 'instructional events') show clearly that they differ in the experimental and control groups. All the six instructional sessions observed, among the treatment, show 'process of inquiry pattern' of instruction (see pattern IX in Appendix D). A closer examination of these episodes reveal that during these interaction sessions the students initiated hypotheses, challenged hypotheses initiated by the teacher, tested hypotheses, accepted or rejected hypotheses, and concluded through the process of testing. In contrast the analyses of the 'instructional episodes' of the control group reveal that they are of 'narration with recall type questions' type (refer pattern III of Appendix D). All the six lessons observed of the control group were of this type. A closer

examination of the instructional episodes reveal that the student initiated questions and hypotheses were given prescriptive answers or explanations by the teacher in the control group. There is no attempt made by the teacher to ignite the thought processes of the students. Here, the treatment of the content is at the information level.

5.2 Effect of Reorganising the Curriculum Frame on the Combinatorial Reasoning of Students

Studying the effect of reorganising the curriculum frame on the combinatorial reasoning of students form a part of the objective of the study (refer objective No. 3, chapter III, section 3.9). The effectiveness can be established in three ways viz., 1) by comparing the difference between the pre and post-assessments of group 1 and group 2 students, i.e., the experimental and control groups (refer chapter IV, section 4.1); 2) by the statistical analyses of the following four pairs of observations i.e., O_2 & O_1 , O_2 & O_4 , O_5 & O_6 , and O_5 & O_3 ; and 3) by subjecting the post-assessment data to a 2 X 2 analysis of variance as suggested in chapter IV.

5.2.1 Comparison of the gain scores of experimental and control groups

Group 1 and group 2 students have been subjected to pre and post-assessments. They are O_1 and O_2 , and O_3 and O_4 respectively as given in the design of the experiment. The

difference in the pre and post-assessments i.e., O_2 minus O_1 and O_4 minus O_3 are computed from the data given in Appendices F and J and presented in table 5.1.

Table 5.1

Improvement in the combinatorial reasoning of students in the experimental and control groups (groups 1 and 2).

Nature of the group	Task V and Task I		Task VI and Task II	
	Not improved	Improved	Not improved	Improved
Experimental N = 50	21	29	23	27
Control N = 52	38	14	38	14

The above table shows that among the students who have undergone the experimental treatment, 58% have improved their reasoning when assessed through a pair of tasks and 54% have improved their reasoning when assessed through a parallel pair of tasks. While, in the control group only 27% of the students show improvement when assessed through both the pairs of tasks. It may be mentioned here that in both the experimental and control groups there is not even a single case where there was a decrease in the level of reasoning. A further analysis of the data, where improvement in the levels of combinatorial reasoning is noted, reveal that the increment has been of only one unit in the case of all the fourteen students of the control group. In the experimental group out of the twentynine students who have shown

improvement, when assessed through the first pair of tasks, the increment is of one unit for twenty two of them and of two units for seven. Similarly, among the twentyseven students who have shown improvement, when assessed through a parallel pair of tasks, the increment is through a degree of one unit among nineteen of them, seven of them show an increment of two degrees and one shows an increment of three units. The increment of increases in the level of reasoning are further elaborated in table 5.2.

Table 5.2

The increment of improvement in the combinatorial reasoning of experimental and control group students

Group	Tasks	Improvement in the level of reasoning					
		II A to II B	II B to III A	III A to III B	II A to III A	II B to III B	III A to III B
Expt.	V & I	9	11	2	6	1	0
	VI & II	7	11	1	5	2	1
Cont.	V & I	8	5	1	0	0	0
	VI & II	0	5	0	0	0	0

It may be noted from table 5.2 that the improvements in the levels of reasoning from concrete (II A) to formal (III B) is shown only by the experimental group students whereas among the control group students there is not even a single case of such an improvement. The improvement in the level of reasoning from transitional (II B) to formal (III B)

is shown only by the experimental students. It may also be noted from the table that the number of students who have improved their level of reasoning from transitional (II B) to early formal (III A) is more when compared to the improvement from concrete (II A) to transitional (II B) in the case of the experimental group whereas in the control group the number of students who have improved from II A to II B is more when compared to the improvement from II B to III A. This shows that the treatment is effective in improving the reasoning of students to higher levels when compared to the control group. These evidences clearly indicate the effect of reorganising the prescribed curriculum frame on the combinatorial reasoning of students when compared to the improvement brought out by the existing curriculum frame.

5.2.2 Statistical analyses of the experimental data

In order to conduct a statistical analyses on the experimental data the four levels of reasoning are assigned scores. The scores assigned are as follows: 1 to the level of reasoning II A, 2 to II B, 3 to III A, and 4 to III B. The levels of reasoning from early concrete to formal are in hierarchical order and hence the scores are given in the increasing order from 1 to 4. The scale thus formed is assumed to be of interval scale. Based on the assigned values the means and standard deviations are computed on the six

observations made during the experiment. To test the significance of the difference between the means '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 following hypothesis:

There is no difference between the mean scores of the students, who undergo the classroom instruction with the reorganising of the prescribed curriculum and those who undergo the normal classroom instruction based on the existing curriculum frame, on the combinatorial reasoning as assessed through tasks.

The above hypothesis is restated from the hypothesis No. 1 given in chapter III, section 3.10. Here the hypothesis is stated in the null form.

Among the four pairs of observations to be subjected to statistical testing O_1 and O_2 are made on the same students and therefore the 't' test applied is for the significance of difference between two means for correlated samples (Ferguson, 1959). The 't' test applied, on the other three pairs of observations, is for the significance of difference between independent samples. The 't' value between the two observations O_2 and O_1 is 7.2 when the assessment is made through task I and task V. The mean score of these two observations O_1 and O_2 are 1.38 and 2.08 respectively. The 't' value is significant at 0.01 level rejecting the null

hypothesis. Observation O_2 has a significantly higher mean than O_1 showing that the experimental treatment has positively influenced the combinatorial reasoning. The 't' value of the difference between means when the assessment is made through task II and task VI is 6.74. This value is also significant at 0.01 level rejecting the null hypothesis in favour of O_2 (mean scores of $O_1 = 1.46$ and $O_2 = 2.2$).

The mean, standard deviation and the 't' values for the three pairs of observations O_2 and O_4 , O_5 and O_6 , and O_5 and O_3 are given in the tables 5.3, 5.4, and 5.5.

Table 5.3

The mean, standard deviation, and 't' values of O_2 and O_4 for two tasks assessing combinatorial reasoning

Task	Task V		Task VI	
	O_2	O_4	O_2	O_4
N	50	52	50	52
Mean	2.08	1.59	2.2	1.69
S.D.	0.97	0.68	1.02	0.77
't'	2.91**		2.89**	

** significant at 0.01 level

Table 5.4

The mean, standard deviation and 't' values of O₅ and O₆ on two tasks assessing combinatorial reasoning

Tasks	Task V		Task VI	
	O ₅	O ₆	O ₅	O ₆
Observations				
N	52	50	52	50
Mean	2.15	1.52	2.17	1.44
S.D.	1.02	0.64	1.03	0.60
't'	3.69**		4.15**	

** significant at 0.01 level

Table 5.5

The means, standard deviations, and 't' values of O₅ and O₃ on two tasks assessing combinatorial reasoning

Tasks	Task I and V		Task II and VI	
	O ₅	O ₃	O ₅	O ₃
Observations				
N	52	52	52	52
Mean	2.15	1.28	2.17	1.38
S.D.	1.02	0.49	1.03	0.56
't'	5.4**		4.64**	

** significant at 0.01 level

All the above six 't' values are significant at 0.01 level showing that the means of the scores after treatment on the 'combinatorial reasoning' are significantly different from the mean scores of those who were taught through the proscribed

curriculum frame. The strength of such an inference is high since all the experimental group mean scores are higher than those for the control groups.

The analysis of the post test data O_2 , O_4 , O_5 and O_6 is discussed alongwith the testing of the hypothesis concerning the interaction between pre-assessment and treatment.

5.3 Effect of Pre-assessment on the Combinatorial Reasoning

The need for studying the effect of pre-assessment on the combinatorial reasoning comes from a part of the objective number four of the study (refer chapter III, section 3.9). The hypothesis being tested is as follows:

There is no difference in the combinatorial reasoning of students, who have been assessed through tasks which demand the use of such reasoning patterns, and those who have not been assessed through such tasks.

The effect of pre-assessment on the combinatorial reasoning can be established by comparing the following two pairs of observations i.e., O_2 and O_5 , and O_4 and O_3 . The data on the four observations are converted into scores as mentioned in section 5.2.2 and 't' test is applied for testing the significance of the difference between two means for independant samples. The means, standard deviations, and the

't' values for these samples are given in tables 5.6 and 5.7.

Table 5.6

The means, standard deviations, and 't' values of O_2 & O_5 and O_4 & O_6 on task V assessing combinatorial reasoning.

Tasks	Task V		Task V	
	O_2	O_5	O_4	O_6
Observations				
N	50	52	52	50
Mean	2.08	2.15	1.59	1.52
S.D.	0.97	1.02	0.68	0.64
't'	0.35		0.52	

Table 5.7

The means, standard deviations, and 't' values of O_2 & O_5 and O_4 & O_6 on task VI assessing combinatorial reasoning

Tasks	Task VI		Task VI	
	O_2	O_5	O_4	O_6
Observations				
N	50	52	52	50
Mean	2.2	2.17	1.60	1.44
S.D.	1.02	1.03	0.77	0.60
't'	0.15		1.83	

All the 't' values shown in the tables 5.6 and 5.7 are not significant indicating that the combinatorial reasoning of students is not influenced by the pre-assessment with a task to assess the same reasoning.

5.4 Analysis of Variance of the Experimental Data

The data gathered through the observations O_2 , O_4 , O_5 and O_6 are arranged into a 2 X 2 analysis of variance table as shown in chapter IV section 4.1. In such an analysis the two factors taken into consideration are 1) treatment and 2) pre-assessment. The two levels in the treatment are the observations on the two treatment groups and the observations on the 'no treatment' groups. The two levels of assessment are the observations on the pre-assessed and the observations on the not pre-assessed students. Here again the data obtained from the four observations are converted into scores. The scores given are as follows. To the reasoning level II A score one is assigned, to II B score two, to III A score three and to III B score four is assigned. The data given in appendix J are assigned the values given above before applying the test of analysis of variance. The number of scores in the four cells are not equal. They are as given in table 5.8.

Table 5.8

The number of students in the four groups

	Treatment	No treatment	
Pre-assessed	N = 50 O_2	N = 52 O_4	102
Not pre-assessed	N = 52 O_5	N = 50 O_6	102
	102	102	204

In such a case when the cell frequencies are unequal the first step taken before applying the analysis of variance is to apply a χ^2 test on the cell frequencies to find out whether they depart very much from equality. The frequency in the cell corresponding to the r^{th} row and c^{th} column is denoted by n_{rc} . The expected equal frequency is then computed by adding all the n_{rc} and dividing by the number of rows multiplied by the number of columns i.e., N/RC . In the present experiment this value is $204/4 = 51$. This value is denoted by \bar{n} . The χ^2 is then computed using the formula
$$\chi^2 = \sum \sum \frac{n_{rc} - \bar{n}}{\bar{n}}^2$$
 with $RC-1$ degrees of freedom. The chi square value thus obtained is 0.0784. For degrees of freedom three the table value is 0.12 at 0.01 level. Therefore it can be inferred that the n in the four cells do not deviate significantly from equality. Following this a simple adjustment to the sum and sum of squares for each cell is made by multiplying the respective values by \bar{n}/n_{rc} . This adjustment estimates what the cell sum and sum of squares would be, were there an equal number of cases \bar{n} in each cell. The adjusted cell sums and sums of squares are used to obtain the row and column totals and the total sum of squares. Further analysis of variance is carried out employing computational formulas given by Ferguson (1959, p.254).

The above discussed procedure was adopted for the

analysis of variance on the four observations O_2 , O_4 , O_5 and O_6 made on the students using task V and task VI for assessing the combinatorial reasoning. The summary of these two analyses are given in tables 5.9 and 5.10. The hypotheses being tested through this 'F' test are as follows:

1. There is no difference between the mean scores of the students, who undergo the classroom instruction with the reorganising of the prescribed curriculum and those who undergo the normal classroom instruction based on the existing curriculum frame, on the combinatorial reasoning as assessed through tasks.
2. 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.
3. 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 (the reorganising of the science curriculum), and who have not been pre-assessed and not undergone the treatment; and those who have not been pre-assessed and who have undergone the treatment and those who have been pre-assessed but not undergone the treatment.

Among the three hypotheses stated above, the first one is restated from hypothesis No. 1 given in chapter III section 3.10. The second and third are from hypotheses No. 3 and 5 given in the same section.

Table 5.9

Summary of analysis of variance on the combinatorial reasoning scores assessed through task V

Source of variance	Sum of squares	Degrees of freedom	Variance estimate	F value
Rows (pre-ass.)	0.00013	1	0.00013	0.00017
Columns (treatm.)	15.91	1	15.91	20.94**
Interaction	0.2699	1	0.2699	0.3552
Within	151.93	200	0.7596	
Total	168.11	203		

for df of 1 and 200 the values at 0.05 = 3.89 and 0.01 = 6.76

** significant at 0.01 level

Table 5.10

Summary of analysis of variance on the combinatorial reasoning scores assessed through task VI

Source of variance	Sum of squares	df	Variance estimate	F value
Rows (pre-asses.)	0.99	1	0.99	1.26
Columns (treatment)	19.61	1	19.61	24.86**
Interaction	0.63	1	0.63	0.79
Within	157.8	200	0.78	
Total	179.03	203		

** significant at 0.01 level

The F values in tables 5.9 and 5.10 show that the null hypothesis number one is rejected and the other two

null hypotheses are not rejected. This indicates that the treatment has an influence on the combinatorial reasoning of students whereas the pre-assessment as well as the interaction, caused because of the treatment and pre-assessment, do not have any significant effect on the combinatorial reasoning.

The significant F value of 24.86 for the treatment effects calls for further analysis of the observations O_2 & O_4 and O_5 & O_6 by subjecting these observations to 't' tests. This has already been detailed in section 5.2.2.

5.5 Effect of Maturation and History on the Combinatorial Reasoning

A comparison of observation O_6 with O_1 and O_3 separately would indicate the combined effect of maturation and the effect due to the instruction through the prescribed curriculum frame on the combinatorial reasoning of students. Tables 4.5, 4.6 and 4.10 given in chapter IV present the data collected through observations O_1 , O_3 and O_6 respectively. These data are further subjected to statistical analysis. The mean, standard deviation and 't' values of O_6 with O_1 and O_6 with O_3 are given in table 5.11.

Among the four 't' values only the one between O_6 and O_3 when assessed through task I and V shows a significance

Table 5.11

The Means, standard deviations, and 't' values of O₆ with O₁ and O₆ with O₃ through two pairs of tasks assessing 'combinatorial reasoning'.

	Task I and Task V			Task II and Task VI		
	O ₁	O ₆	O ₃	O ₁	O ₆	O ₃
N	50	50	52	50	50	52
Mean	1.38	1.52	1.28	1.45	1.44	1.38
S.D.	0.59	0.64	0.49	0.60	0.60	0.56
't'	1.12		2.1*	0.18		0.55

* significant at 0.05 level

in the difference of the mean scores. All the other 't' values are not significant. This shows that the effect of maturation and history on the combinatorial reasoning is marginal. One 't' value being significant is insufficient evidence to conclude that there is a positive effect due to maturation and history within a period of six months.

5.6 Effect of Reorganising the Curriculum frame on the Controlling of Variables of Students

Studying the effect of reorganising the prescribed curriculum frame on the 'controlling of variables' of the students form part of the objective No. 3 of the present investigation (refer chapter III, section 3.9). The effectiveness can be established in three ways viz., 1) by comparing the difference between the pre and post-assessments

of group 1 and group 2 students i.e., the experimental and control groups (refer chapter IV, section 4.1), 2) by the statistical analyses of the following four pairs of observations i.e., O_2 & O_1 , O_2 & O_4 , O_5 & O_6 , and O_5 & O_3 , and 3) by subjecting the data obtained through O_2 , O_4 , O_5 and O_6 to a 2 X 2 analysis of variance as suggested in chapter IV, section 4.1.

5.6.1 Comparison of the gain scores of experimental and control groups

Group 1 and group 2 students have been subjected to pre and post-assessments. These are observations O_1 and O_2 on group 1 and O_3 and O_4 on group 2. The difference in the levels of reasoning as observed through the pre and post-assessments i.e., O_2 minus O_1 and O_4 minus O_3 are computed from the data given in Appendices F and J. These differences are presented in table 5.12

Table 5.12
Improvement in the 'controlling of variables' of students in the experimental and control groups

Nature of the group	Task III and VII		Task IV and VIII	
	Not improved	Improved	Not improved	Improved
Experimental N = 50	35	15	37	13
Control N = 52	42	10	46	6

Table 5.12 shows that among the students who have undergone the experimental treatment 30% have improved their reasoning when assessed through a pair of tasks (task III & task VII) and 26% have improved their reasoning when assessed through a parallel pair of tasks (task IV and task VIII). While, in the control group only 19.2% improved their reasoning when assessed through the tasks III and VII and 11.5% of the students improved their reasoning when assessed through the tasks IV and VIII. A further analysis of the data, where improvement in the reasoning is noted, reveal that the improvement has been of only one unit in all the sixteen cases (10+6) of the control group. In the experimental group out of the fifteen students who have shown improvement, when assessed through the first pair of tasks, the improvement in the levels of reasoning is of one unit among eleven of them and of two units in the rest four. Similarly, among the thirteen students who have shown improvement, when assessed through a second pair of tasks, the improvement is through a degree of one unit for nine of them, three show an increment of two units and one shows an increment of three units. The improvements in the level of reasoning are further detailed in table 5.13.

It may be noted from table 5.13 that in the control group the improvement in the level of reasoning is confined

Table 5.13

The improvements in the controlling of variables of experimental and control groups assessed through two pairs of tasks

Group	Tasks	Improvements in the level of reasoning					
		II A to II B	II B to III A	III A to III B	II A to III A	II B to III B	II A to III B
Expt.	III & VII	8	2	1	4	0	0
	IV & VIII	6	2	1	2	1	1
Cont.	III & VII	7	3	0	0	0	0
	IV & VIII	3	3	0	0	0	0

to the reasoning levels II A to II B and II B to III A. Among the experimental students there are higher level of improvement i.e., from III A to III B, II A to III A, and also II A to III B. Though the number of students who have improved by two and three increments are few, these increments are due to the treatment. All these indicate the positive influence of the reorganising of the prescribed curriculum on the reasoning (controlling of variables) of students when compared to the control group.

5.6.2 Statistical analysis of the data

Based on the experimental design there are six observations made i.e., O_1 , O_2 , O_3 , O_4 , O_5 and O_6

(see chapter IV, section 4.1). The data obtained through these observations are in the form of categories viz., II A. (early concrete), II B. (transitional), III A (early formal) and III B (formal). These four levels of reasoning are assigned scores 1, 2, 3 and 4 respectively as discussed earlier (refer section 5.2.2). With these assigned values the means and standard deviations are computed for the observations made. In order to establish the effectiveness of the treatment the following four pairs of observations are subjected to 't' test. The observations are: O_1 and O_2 , O_2 and O_4 , O_5 and O_6 , and O_5 and O_3 . The hypothesis being tested through these four 't' tests on the observations is as follows:

There is no significant difference between the mean scores of the groups of students, who undergo the classroom instruction with the reorganising of the prescribed curriculum and those who undergo the normal classroom instruction based on the existing curriculum frame, on the controlling of variables of students as assessed through tasks.

The above hypothesis is restated based on hypothesis No. 2 stated in chapter III, section 3.10. Here it is stated in the null form.

Among the four pairs of observations to be subjected to testing O_1 and O_2 are made on the same students and

therefore, the 't' test meant for testing the significance of difference between two means for correlated samples is applied (Ferguson, 1959 p.139). The 't' test applied on the other three pairs of observations, is the test of significance of difference between two means for independent samples (Ferguson, p.137). The 't' values between the two observations O_2 and O_1 is 4.0 when the assessment is made through task III and task VII. The mean scores of these two observations O_1 and O_2 are 1.26 and 1.62 respectively. The 't' value is significant at 0.01 level leading to the rejection of the null hypothesis. Observation O_2 has a significant mean difference with O_1 showing that the experimental treatment has positively influenced the reasoning (controlling of variables) of students. The 't' value of the difference between means when the assessment is made through task IV and task VIII is 3.67. This value is also significant at 0.01 level, rejecting the null hypothesis in favour of O_2 . The observations through the second pair of tasks also show that the treatment is effective.

The means, standard deviations, and 't' values for the three pairs of observations O_2 & O_4 , O_5 & O_6 , and O_5 & O_3 are given in tables 5.14, 5.15 and 5.16.

Table 5.14

The Means, Standard Deviations, and 't' values of O_2 and O_4 on two tasks assessing the 'controlling of variables'

Tasks	Task VII		Task VIII	
	O_2	O_4	O_2	O_4
Observations				
N	50	52	50	52
Mean	1.62	1.4	1.62	1.42
S.D.	0.79	0.63	0.87	0.63
't'	1.57		1.32	

Table 5.15

The Means, Standard Deviations, and 't' values of O_5 and O_6 on two tasks assessing 'controlling of variables'

Tasks	Task VII		Task VIII	
	O_5	O_6	O_5	O_6
Observations				
N	52	50	52	50
Mean	1.63	1.28	1.57	1.3
S.D.	0.92	0.49	0.82	0.53
't'	2.36*		1.94	

Table 5.14 shows that, though O_2 has higher mean compared to O_4 when assessed through tasks VII and VIII, the mean differences are not significant. Table 5.15 shows that the means of the experimental group observations O_5 are higher when assessed through the tasks VII and VIII. The mean difference is significant at 0.05 level when assessed

Table 5.16

The Means, Standard Deviations and 't' values of O_5 and O_3 on two tasks assessing 'controlling of variables'

Tasks	Task III and VII		Tasks IV and VIII	
Observations	O_5	O_3	O_5	O_3
N	52	52	52	52
Mean	1.63	1.23	1.57	1.28
S.D.	0.92	0.46	0.82	0.49
't'	2.77**		2.16*	

* significant at 0.05 level

** significant at 0.01 level

through task VII whereas when assessed through task VIII the 't' value falls short of the significantly different value, (the 't' value to be significant at 0.05 level is 1.98). Table 5.16 shows that the experimental group observation O_5 have significantly higher means when assessed through both the pairs of tasks (tasks III & VII and tasks IV & VIII). The strength of the inference is reduced since three out of the eight 't' values are not significant. From the five 't' values which are significant it may be inferred that the treatment is effective in improving the reasoning (controlling of variables) of the students. This inference may be further strengthened by subjecting the observations O_2 , O_4 , O_5 and O_6 to analysis of variance (see section 5.8).

5.7 Effect of Pre-assessment on the 'Controlling of Variables'

The need for studying the effect of pre-assessment on the 'controlling of variables' form a part of the objective number four (refer chapter III section 3.2). The hypothesis being tested is as follows:

There is no difference in the 'controlling of variables' of students, who have been assessed through tasks which demand the use of such reasoning pattern, and those who have not been assessed through such tasks.

The effect of pre-assessment on the 'controlling of variables' can be established by comparing the following two pairs of observations i.e., O_2 & O_5 and O_4 & O_6 . The data gathered through these four observations are converted into scores as mentioned in section 5.2.2 and 't' test is applied for the significance of difference between two means for independent samples. The means, standard deviations and the 't' values are given in tables 5.17 and 5.18.

Table 5.17

The Means, Standard Deviations and 't' values of O_2 & O_5 and O_4 & O_6 as assessed through task VII

	O_2	O_5	O_4	O_6
N	50	52	50	52
Mean	1.62	1.63	1.4	1.28
S.D.	0.79	0.92	0.63	0.49
't'	0.05		1.22	

Table 5.18

The Means, Standard Deviations, and 't' values of O₂ & O₅ and O₄ & O₆ when assessed through task VIII

	O ₂	O ₅	O ₄	O ₆
N	50	52	50	52
Mean	1.62	1.57	1.42	1.3
S.D.	0.87	0.82	0.63	0.53
't'	0.27		1.02	

The 't' values in both the tables 5.17 and 5.18 are not significant and therefore the null hypothesis is not rejected. It may be inferred that the pre-assessment does not influence the 'controlling of variables' of students.

5.8 Analysis of Variance on the Experimental Data

The data gathered through the experiment, O₂, O₄, O₅, and O₆ are arranged into a 2 X 2 analysis of variance table as shown in chapter IV section 4.1. The four sets of observational data are converted into scores as detailed in section 5.2.2. The number of units in each cell is not equal and therefore, before applying the analysis of variance, adjustments are made on the cell sums and sum of squares as detailed in section 5.4. The summary of the analysis of variance on the controlling of variables observational data are given in tables 5.19 and 5.20. The hypotheses being tested through this 'F' test are as follows:

1. There is no difference between the mean scores of the students, who undergo the classroom instruction with the reorganising of the prescribed curriculum and those who undergo the normal classroom instruction based on the existing curriculum frame, on the 'controlling of variables' as assessed through tasks.
2. 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.
3. There is no difference in the 'controlling of variables' of students, who have been pre-assessed on the same reasoning pattern and who have undergone the treatment (the reorganising of the science curriculum), and who have not been pre-assessed and not undergone the treatment; and those who have been pre-assessed and who have undergone the treatment, and those who have been pre-assessed but not undergone the treatment.

Among the three hypotheses stated, the first one is restated from hypothesis No. 2 given in chapter III, section 3.10. The second and third are the hypotheses numbered 4 and 6 in the same section.

The F values in tables 5.18 and 5.19 show that the null hypothesis; number one, stated in this section, is rejected and two and three are not rejected. This indicates that the treatment has an influence on the reasoning (controlling of variables) of students whereas

Table 5.19

Summary of Analysis of Variance on the 'Controlling of Variables' scores when assessed through task VII

Source of variance	Sum of squares	df	Variance estimate	F
Rows (pre-ass.)	0.15	1	0.15	0.27
Columns (treat.)	4.15	1	4.15	7.68**
Interaction	0.24	1	0.24	0.44
Within	108.20	200	0.54	
Total	112.74	203		

For df 1 & 200 the value at 0.05 = 3.89 and 0.01 = 6.76

** significant at 0.01 level

Table 5.20

Summary of Analysis of Variance on the 'Controlling of Variables' scores when assessed through task VIII

Source of variance	Sum of squares	df	Variance estimate	F
Rows (pre-ass.)	0.44	1	0.44	0.83
Columns (treat.)	3.11	1	3.11	5.86*
Interaction	0.04	1	0.04	0.07
Within	107.52	200	0.53	
Total	111.11	203		

* significant at 0.01 level

the pre-assessment and interaction caused because of treatment and pre-assessment do not have any significant effect on the 'controlling of variables of students.

The significant F values of 7.68 and 5.86 shown in tables 5.19 and 5.20 call for further analysis of the observations O_2 & O_4 and O_5 & O_6 by subjecting these observational scores to 't' tests. This has already been detailed in section 5.6.2.

5.9 Effect of Maturation and History on the Controlling of Variables

A comparison of observations O_6 with O_1 and O_3 would indicate the combined effect of maturation and the effect due to the instruction through the prescribed curriculum frame on the reasoning (controlling of variables) of the students. Tables 4.5, 4.6 and 4.10 given in chapter IV present the data collected through observations O_1 , O_3 and O_6 respectively. This data is further subjected to statistical analysis. The means, standard deviations, and 't' values of O_6 with O_1 and O_6 with O_3 are given in table 5.21.

All the four 't' values presented in table 5.21 are not significant. This clearly indicates that the effect of maturation and history on the controlling of variables is marginal. The mean is higher in case of O_6 when compared to O_1 and O_3 when assessed through both the pairs of tasks. This indicates that due to maturation and history there is improvement in the reasoning but, within six months the difference is not significant.

Table 5.21

Means, Standard Deviations, and 't' values of O_6 with O_1 and O_6 with O_3 through two pairs of tasks assessing controlling of variables

Tasks	Tasks III and VII			Tasks IV and VIII		
	O_1	O_6	O_3	O_1	O_6	O_3
Observations						
N	50	50	52	50	50	52
Means	1.25	1.28	1.23	1.26	1.3	1.28
S.D.	0.56	0.49	0.46	0.48	0.53	0.49
't'	0.23		0.53	0.41		0.21

5.10 Analyses of the Anecdotal Records

Though the acceleration or improvement in the reasoning patterns viz., 1) combinatorial reasoning and 2) controlling of variables are statistically significant all the students in the experimental group have not shown improvements. It may be observed here that the assumption of the experiment is that students will actively participate in the classroom interaction so that their reasoning patterns would develop (refer chapter I, section 3.8). The analyses of the anecdotal records maintained by the investigator indicates a general lack of interest in the instructional activities by many students. The lack of interest originate from different basic reasons for different students. A few of them who have been informally interviewed indicate that one of the main reasons is because of the security they foresee

in their future prospects. They know that the formal education is not going to help them much with their future plans. Their parents and guardians are involved in business and they are sure that they would enter the same as soon as they are mature to take over. The above point may be further elaborated with an example from the anecdotal records.

DES (age 15 years, 6 months) belong to group 1 of the design. That is, the pre-tested experimental group. He was one among the many who did not participate in the classroom discussion even when information seeking questions are directed to him. During the interview he indicated that his father owns three sweet meat shops in the city. Two of these shops are managed by his elder brothers and the third shop presently run by his father would be handed over to him as soon as he is mature. On the investigators suggestion that formal education can help him better with his business, he replied that, what is possible has already been acquired, i.e., basic mathematics, and to read and write in English and Gujarati. The above illustration is only one among similar instances where students have expressed their reasons for the lack of interest in the classroom interactions. It may also be mentioned here that the pre and post-assessments of the boy indicates that he has not shown any improvement in the 'combinatorial reasoning' and 'controlling of variables'.

Another major reason for the lack of interest among the students in instructional activities is the over anxiety to score high in the examination. The students show a general tendency to show interest in only those activities which would directly help them in getting more marks in the examinations and a lack of interest in actively participating in the classroom interactions through which they would discover the laws and principles of nature. Such a tendency of 'examination orientation' is shown even by those who actively participate in the classroom discussions. An illustration from the anecdotal records may further explain this point. Two students of the pretested experimental group on approaching the investigator with a content clarification in Physics, were suggested to do the experiments in the laboratory so that they may discover the law. The investigator offered to help. The immediate response of the students was that they have a 'test' the next day and just needed only an explanation of the experiment and expressed their disinterest in doing the actual experiment. The above illustration clearly indicates how the natural curiosity of the students is curbed by the overemphasis on 'test' or examination oriented teaching.

From the analyses of the anecdotal records a third major reason that has emerged is the medium of instruction.

It may be recalled here that only 6% of the total sample speak English at home and with peers (refer chapter IV, section 4.2). The rest of the sample speak Indian languages (Hindi, Gujarati Marathi, etc.). During the clinical interview settings the investigator had to explain the problem situation using Hindi/Gujarati words in place of English since the students showed a lack of understanding of the problem. An example of such a usage is the word 'choola' in place of a pendulum. Also, during instructional situations, where day to day experiences are recalled, students showed a lack of understanding of the problem situation. For a proper understanding of the problem situation needed the use of Hindi or Gujarati words. All these indicate a lack of understanding on the part of the students through the medium of instruction viz., English. Therefore, the medium of instruction, being different from the language the students speak with peers, poses a hinderance to the proper understanding. This may be mainly due to the reason that the medium (language), through which experiences are assimilated by the student, is different from the medium of instruction.

The above illustrations are a few among many indicating a general lack of interest in instructional activities among students. The present investigation indicates that given such constraints of lack of interest in instructional activities

of normal classroom students the reorganising of the prescribed curriculum can initiate cognitive dissonance in students and thus improve their reasoning patterns.

5.11 Discussion

The analyses of the experimental data clearly indicates that the experimental treatment is effective in accelerating the 'combinatorial reasoning' and 'controlling of variables' of students. But, the improvement in the 'controlling of variables' is to a lesser extent when compared to the 'combinatorial reasoning'. This is based on two observations. One, the number of students who have improved their reasoning (controlling of variables) is less when compared to the number of improvements in 'combinatorial reasoning'. Two, the improvements in the reasoning indicated through the pre and post-assessments indicate that those who have shown improvements in the 'controlling of variables' have also improved their 'combinatorial reasoning'; but, the reverse is not true. That is, all those who have shown improvements in the 'combinatorial reasoning' have not improved their reasoning in 'controlling of variables'. It may be mentioned here that both the reasoning patterns 'combinatorial reasoning' and 'controlling of variables' form parts of the formal reasoning structure. Such a difference in the reasoning patterns exhibited by the students, i.e.,

manifesting formal reasoning when assessed through one task, and not when assessed through a related task, is termed as horizontal décalage in the Piagetian theoretical framework (refer chapter III, section 3.6). This finding, of a horizontal décalage in the closely related reasoning patterns, is contradictory to the findings of the earlier studies (Kerplus, 1979; Follman & Chen, 1982; and Lawson et. al. 1975). But, there is a psychological link between the 'combinatorial reasoning' and 'controlling of variables'. That is, the generation of all possible combination of variables in a given situation is required for an individual to 'isolate' and 'control' variables. Such a psychological link has been already suggested by Lawson (1979), and the findings of the present study also indicate the same.

The acceleration of the reasoning patterns viz., 'combinatorial reasoning' and 'controlling of variables' is in agreement with studies conducted under different field conditions. The strategy used for acceleration in the present investigation has common characteristics with those studies (studies conducted under field conditions different from that of the present investigation). For example, Bredderman (1973) used a cognitive conflict strategy to accelerate the ability to control variables among young adolescents. This strategy has the common characteristic of inducing cognitive conflict

in the learners with the instructional model used in this study. The main difference is that Bredderman used an individual focused mode of instruction whereas the present study has used a group instructional model. A similar group instructional model, called 'learning cycles', is used by McKinnon & Renner (1971) and Smith & Von Egerene (1977) to accelerate 'combinatorial reasoning' and 'controlling of variables'. The strategy used by these researchers focused more on the manipulation of objects when compared to the model used in the present study. The field conditions in the present investigation did not permit such a possibility, of manipulation of objects by each student, because of the non-availability of adequate facilities in the school where the experiment was conducted.

Among the various strategies used by researchers for accelerating the formal reasoning patterns there are two strategies which resemble the instructional model used in the present study. They are: 1) the peer interaction model used by Ward (1979) and 2) the social interaction model used by Wollman and Chen (1982). The main characteristic which is common to these two instructional strategies and the one used in this study is the element of group interaction. The findings of the present investigation are in agreement with those where group interaction strategies have been used.

The feature which differentiates the instructional model used in the present study from those referred above, is the epistemic characteristic of instruction. That is, the curriculum reorganisation has been carried out based on the historical development of the concepts, principles and laws. This characteristic makes the model of instruction used in the present study, more suitable for concrete operational learners, than the ones used by other researchers referred in chapter II.

The mode of instruction in the control groups of the present investigation was not based on any specific theoretical grounds. The lack of acceleration in these groups may be attributed to such a lacuna in the instructional mode. This mode of instruction may be taken as one that goes on in a 'normal' classroom. Sandeep (1979) after surveying the relationship between the classroom interaction pattern and cognitive development on Indian sample reports that the classroom interaction adversely affects the cognitive skills. The 'steady state' of the reasoning patterns in the control groups may be because of such an adverse effect.

The guided inquiry approach to instruction used in the experimental group of the present study is found successful in accelerating the reasoning patterns whereas the didactic presentation of content matter was not successful. The acceleration of the reasoning patterns may be seen similar to

the improvement in problem solving abilities. That is, the students who have improved their reasoning patterns will be able to perceive the different variables in a problem situation and isolate and control variables effectively in finding a solution. This finding of the present study is in agreement with the one conducted by Ajwani (1979) where he tried to accelerate the problem solving ability by guided discovery, through learning puzzles and by giving specific directions. He found that guided discovery is better than the other two approaches in accelerating the reasoning. Also, the study conducted by Yadav (1982) shows the superiority of guided discovery over lecture method in accelerating concepts. It may be mentioned here that, in the studies conducted by Ajwani and Yadav the experimental inputs are not directly related to the prescribed curriculum of the grades, whereas the present investigation focused on the reframing of the prescribed curriculum frame for the grade.

Though the present investigation has shown that acceleration of logical reasoning is possible through the reorganised curriculum frame, it cannot be taken as conclusive evidence. Further research in this area under varied field conditions is required to conclude on the possibility of accelerating logical reasoning patterns under field conditions. Also, the model of instruction used in this study has to be

compared with other models of instruction before concluding on its merits. Based on these lines a few studies are suggested for further research in the concluding chapter of this report alongwith the summary.

REFERENCES

All references that appear in this chapter have already appeared in chapter II of this report (see references given at the end of chapter II), except for the one given below.

FERGUSON, G.A. Statistical Analysis in Psychology and Education. New York: McGraw Hill, 1959.