CHAPTER V

RESULTS AND DISCUSSION - I
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ATTAINMENT OF COGNITIVE ABILITIES (PROPORTIONALITY, PROPOSITIONAL LOGIC AND COMBINATORIAL ANALYSIS) ACROSS SEX AND URBAN-RURAL AREA.
A. DESCRIPTION OF DATA

Before proceeding with the statistical analysis of data, it was considered appropriate to examine the nature of distribution of scores related to the measures of Proportionality, Propositional logic, and Combinatorial Analysis in respect of normality of distribution of scores. In the present investigation, distribution of scores pertaining to the above mentioned variables for a sample of 409 high school students was examined with a view to justifying the application of various statistical techniques such as correlations, factor analysis and regression analysis employed for testing different hypotheses. In order to test the normality of distribution, the values of mean, median, mode, standard deviation, skewness and kurtosis were calculated*, which have been entered in Table 5.1.

This table of codes for various variables is given at the end of Chapter III. (Method & Procedure).

* Various analyses were obtained through computerized results at the 'Uni Comp PC/XT,' Computer Centre, Panjab University, Chandigarh.
<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Cognitive Ability</th>
<th>Mean</th>
<th>Median</th>
<th>Mode</th>
<th>SD</th>
<th>Sk</th>
<th>Ku</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>T&lt;sub&gt;I+II&lt;/sub&gt;</td>
<td>6.866</td>
<td>6.740</td>
<td>6.488</td>
<td>1.589</td>
<td>1.001**</td>
<td>0.304</td>
</tr>
<tr>
<td>2.</td>
<td>T&lt;sub&gt;III+IV&lt;/sub&gt;</td>
<td>5.179</td>
<td>4.860</td>
<td>4.222</td>
<td>1.040</td>
<td>1.217**</td>
<td>0.249</td>
</tr>
<tr>
<td>3.</td>
<td>T&lt;sub&gt;V+VI&lt;/sub&gt;</td>
<td>5.600</td>
<td>5.320</td>
<td>4.760</td>
<td>1.320</td>
<td>0.929**</td>
<td>0.166</td>
</tr>
<tr>
<td>4.</td>
<td>T&lt;sub&gt;P&lt;/sub&gt;</td>
<td>17.840</td>
<td>17.650</td>
<td>17.270</td>
<td>3.970</td>
<td>0.704**</td>
<td>0.224</td>
</tr>
</tbody>
</table>

Sk ± 0.237 significant at 0.05 level
± 0.312 significant at 0.01 level

Ku ± 0.475 significant at 0.05 level
± 0.627 significant at 0.01 level
Table 5.1 shows values of Mean (6.866), Median (6.74) and Mode (6.488) for the Proportionality (Tj+II) - a measure of cognitive ability, and their differences are further reflected by the numerical determinants of skewness (1.001). The value of skewness is in the positive direction and above the value of 0.312, the value significant at 0.01 level of significance. With regard to Kurtosis (Ku = 0.304), the value does not show significant departure from normality.

For the remaining cognitive abilities, that is Propositional logic and Combinatorial analysis (TIII+IV and TV+VI) respectively, the differences between the values of Mean and Median for both the variables are small but the values of Mode (4.222 and 4.76 respectively) are much lower than Mean and Median. Values of Skewness equal to 1.217 and 0.929 respectively are in the positive direction and significant at .01 level. With regards to Kurtosis the measures of Propositional logic (Ku = 0.249) and Combinatorial analysis (Ku = 0.166) do not show significant departure from normality.

For the measures of Total scores on Piagetian cognitive abilities (TpT), Table 5.1 shows that the value of skewness (Sk = 0.704), similar to the three abilities when taken separately, is in the positive direction. The distribution is significantly and positively skewed. However, the value of kurtosis (Ku = 0.224) does not show a significant departure from normality.
An overview of the above results suggests that the score distribution of different cognitive abilities although positively skewed are mesokurtic and hence may be taken as proximating the normal distribution.

B. PERCENTAGE OF STUDENTS REACHING FORMAL OPERATIONAL LEVEL

In order to examine the level of development of abilities namely (a) Proportionality, (b) Propositional Logic and (c) Combinatorial analysis among high school students, the relevant data for the total sample (N=409) was subjected to calculations of percentages. The number of students who reached the formal operational level were calculated for each of the three cognitive abilities on the basis of which further percentages were worked out. The results are shown in Table 5.2 and Fig. 5.1 (a). Similarly, the number of students reaching at concrete operational level and their percentages were calculated for each of the three abilities. These results have also been entered in Table 5.2 and Fig.5.1(a). The reporting of results and their discussion has been taken together.

Values entered in Table 5.2 show that for Proportionality 62% of the total sample reached the formal operational level, a percentage which is greater as compared to those (38%) reaching concrete operational level. For the
Table 5.2
PERCENTAGE OF STUDENTS REACHING FORMAL-OPERATIONAL LEVEL AND CONCRETE-OPERATIONAL LEVEL

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Cognitive Ability</th>
<th>%age of students reaching Formal level.</th>
<th>%age of students reaching Concrete level</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Proportionality</td>
<td>62</td>
<td>38</td>
</tr>
<tr>
<td>2</td>
<td>Propositional Logic</td>
<td>15</td>
<td>85</td>
</tr>
<tr>
<td>3</td>
<td>Combinatorial Analysis</td>
<td>16</td>
<td>84</td>
</tr>
<tr>
<td>4</td>
<td>Total of Piagetian tasks</td>
<td>46</td>
<td>54</td>
</tr>
</tbody>
</table>
PERCENTAGE OF STUDENTS REACHING FORMAL-OPERATIONAL LEVEL AND CONCRETE-OPERATIONAL LEVEL ON DIFFERENT COGNITIVE ABILITIES

Figure 5.1 (a)
remaining two cognitive abilities namely Propositional logic and Combinatorial analysis the percentages of subjects reaching formal level are only 15% and 16% respectively as compared to the percentage of those who still functioned at the concrete operational level (85%; 84% respectively).

Proportionality - the ability to manipulate propositions has been identified with Piaget's stage of formal operational reasoning which theoretically emerges at the ages 12 to 13 years (Inhelder and Piaget, 1958). A study of the development of Proportional reasoning, therefore, has theoretical implications. This means that an understanding of Proportionality can be used to diagnose how well children reason abstractly. Piaget investigated the child's acquisition of Proportionality by examining children's reactions to situations such as Equilibrium on a Balance and Shadow Size. He found that younger children (7 to 12 years) dealt with these problems by using arithmetic solutions whereas adolescents (13 to 17 years old) demonstrated understanding of proportional increase and decrease and reciprocity between various relations. Piaget also found that children demonstrated an intuitive understanding of proportionality before they could deal with it quantitatively. In the present study majority of 15+ years (62%) were observed to have already obtained the ability to manipulate propositions, that is proportionality.
During the formal stage, individuals also begin to reason with propositions and with hypotheses. In other words, formal operations are ways of transforming propositions about reality so that the relevant variables can be isolated and relations between them deduced. Propositional logic is a type of thinking wherein verbal statements are substituted for objects. According to Piaget’s view, at the concrete-operational stage, the form of reasoning is termed as intra-propositional and at the formal-operational stage, the form of reasoning is termed as inter-propositional thinking.

Intra-propositional thinking means thinking within the confines of a single proposition. Inter-propositional thinking means that the individual at this stage reasons about the logical relations that hold among two or more propositions, a more subtle and abstract form of reasoning. Although Piaget had previously stressed a stage of development beginning at 11 to 12 years, Inhelder’s data indicated a period of new structuring leading to another level of equilibrium at about 14 to 15 years for propositional logic, a formal mode of thought.

Trend, similar to Inhelder’s observations, is visible in case of sample of the present study the results of which make it amply clear that only a small number of subjects that is fifteen per cent have reached the stage of using the
ability of propositional logic. Other are still operating at concrete level.

While propositions or propositional logic equip the individual to combine propositions mentally and to isolate those which confirm his hypotheses on the different determinants, the combinatorial system enables the individual to make combinations of facts for isolating the relevant variables and deducing relations between them.

Combinatorial operations are second degree operations, permutations are serial orders of serial orders and combinations are multiplications of multiplications, and do not in fact appear until the formal level (Inhelder & Piaget, 1958).

The mathematical operation of combinations and permutations is the ability to construct a systematic, efficient method for generating all possible combinations and permutations of a set of elements. Piaget believed that the ability to generate all possible combinations in particular is especially important in solving scientific, control-of-variables type problems wherein the solver has to determine exactly which combinations of physical variables when isolated produced exactly what results (Inhelder & Piaget, 1958). These combinations are regarded as hypotheses, some of which are confirmed and reformulated by subsequent investigation. According to Piaget, 'Even at 11
or 12 years, unambiguous experiments were not spontaneously devised; although adolescents were able to realize the inadequacy, when questioned. Only at the age of 13 or 14 were adolescents able to, spontaneously, adopt the strategy of deliberately varying each of factors in turn, holding all others constant'. This is supportive of the results of the present study which show that even at the age of 15+, only 16% were able to use the ability of Combinatorial analysis while solving the tasks of combination of coloured and colourless liquids and combinations of tokens.

As regards to totals of all the three cognitive abilities Proportionality, Propositional logic and Combinatorial analysis, the percentage of high school students reaching formal level which is equal to 46%; 54% students still operate at the concrete level.

Studies, investigating the cognitive developmental level of children of different age groups, on different tasks and under different circumstances have shown that concrete thought dominates the adolescent years, in other words majority of adolescents do not reach formal level (Dulit, 1972; Lawson, 1974; Lawson and Blake, 1976; Nordland, 1974; Stolper, 1979; Sandhu, 1980; Padmini, 1981; Vaidya, 1982; Alport, 1983; Maiman, 1984; Wilson and Wilson, 1984; Wavering et al, 1986 and Hudzik, 1989). The percentage of subjects as reported by various studies ranges from 1.6% to 60%.
In the present study Equilibrium in the Balance, Combination of colours and Oscillation of Pendulum tasks were used to measure Proportionality, Propositional logic and Combinatorial analysis. These tasks were also employed by Koloidy (1977); Jain (1982); De Hernandez et al (1984) and Murphy (1985) in determining the level of cognitive development. Their results showed a variation of percentage from 1.6 to 36.

The results of the present study are in agreement with the findings noted above and in particular with studies of Koloidy (1977), Jain (1982), DeHernanadez et al (1984) and Murphy (1985) using similar tasks, that all the high school students do not reach formal-operational level but are not in consonance with the expectation of theoretical formulation that appearance of formal operations takes place between 12 and 15 years, which is the fourth and final stage, preparatory to adult thinking. Thus the first hypothesis 'majority of the high school students do not attain the formal operational abilities - Proportionality, Propositional logic and Combinatorial analysis ' stands accepted, in respect of Propositional logic and Combinatorial analysis. As far as Proportionality is concerned majority of the subjects (62%) in the present sample obtained this ability.
C. SEX DIFFERENCES IN THE DEVELOPMENT OF FORMAL OPERATIONAL ABILITIES

Means and t-ratios were worked out in order to examine significance of differences in the development of (a) Proportionality, (b) Propositional logic and (c) Combinatorial analysis between boys and girls as also between subjects belonging to urban and rural areas. Results are entered in tables 5.3 and 5.4 and Fig. 5.2 (a) & 5.3 (a) respectively.

The value of mean = 7.80 for the concept of Proportionality attained by boys is higher than that of girls (mean = 6.79). However, for the concepts of Propositional logic and Combinatorial analysis the mean values equal to 5.23 and 5.67 respectively attained by boys are lower than those of girls which have scored means = 5.56 and 5.96 respectively. These results indicate that while high school boys have an edge over high school girls for the development of Proportionality; in contrast to this, Propositional logic and Combinatorial analysis are attained by higher number of tenth class girls than boys. Whether these differences are significant or not has been examined by way of t-ratios.

**Proportionality**: Proportionality was measured by two Piagetian tasks namely - (a) Equilibrium in the Balance and (b) Projection of Shadows. The differences in the mean
<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Cognitive Ability</th>
<th>Sex</th>
<th>Mean</th>
<th>SD</th>
<th>N</th>
<th>t-ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Proportionality</td>
<td>Boys</td>
<td>7.80</td>
<td>1.675</td>
<td>206</td>
<td>6.201**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Girls</td>
<td>6.79</td>
<td>1.594</td>
<td>203</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Propositional Logic</td>
<td>Boys</td>
<td>5.23</td>
<td>1.122</td>
<td>206</td>
<td>-2.550*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Girls</td>
<td>5.56</td>
<td>1.463</td>
<td>203</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Combinatorial Analysis</td>
<td>Boys</td>
<td>5.67</td>
<td>1.433</td>
<td>206</td>
<td>-1.806</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Girls</td>
<td>5.96</td>
<td>1.754</td>
<td>203</td>
<td></td>
</tr>
</tbody>
</table>

** t-ratio significant at 0.01 level
* t-ratio significant at 0.05 level
DIFFERENCE IN THE DEVELOPMENT OF COGNITIVE ABILITIES ACROSS SEX

Figure 5.2 (a)
scores obtained in the cognitive ability of Proportionality between boys and girls groups as indicated by $t = 6.201$ is significant at 0.01 level of significance. It leads to infer that the development of Proportionality is greater in boys than girls.

Studies investigating the developmental acquisition of Proportionality, have compared subject’s performance across several tasks to determine under what circumstances and at what age level an understanding of Proportionality becomes operational.

Piburn (1977), found that males were more successful on two of the four proportionality tasks. In another study Piburn (1980), on the basis of clinical interviews of grade eleven students, concluded that males achieved significantly better scores than females on shadows task. Performance on the proportional reasoning measure was significant and positively correlated with male gender (Brown, 1979). Significant gender difference in favour of male students was reported by Farrell and Farmer (1985) in first order direct proportional reasoning. The result of present study also favour males over females in the attainment of Proportionality.

**Propositional Logic:** Difference between means of boys and girls on propositional logic as measured by two Piagetian tasks namely - (a) The Oscillation of Pendulum and (b) The
Law of Floating Bodies and the Elimination of Contradictions is significant at 0.05 level (t = -2.55). The values of means indicate that the development of Propositional logic is greater among high school girls than boys.

The results of present study are in agreement with Raizada’s (1982) study which led to the conclusion that except ‘ratio and proportion’ girls performed better than boys on all types of Piagetian tasks. Sandhu (1979) found that performance of boys on Piaget type tasks was superior to that of girls. A study by Khalil (1989) revealed that there was a relationship between gender and attainment of formal operational stage.

**Combinatorial Analysis:** The mean difference between boys and girls as depicted by t = -1.806 in ability of Combinatorial analysis as measured by Combination of Coloured and Colourless Chemical Bodies and Combination of Tokens, is not significant. The value of mean attained by girls (M = 5.96) is however greater than the mean value (M = 5.67) for boys.

In Hofstein and Mandler’s (1985) study boys performed significantly better than girls on combinatorial reasoning whereas no significant gender differences were found on the performance of five combinatorial tasks by Piburn (1977).

As in Propositional logic, the results related to sex differences on combinatorial analysis in the present study
fall in line with those obtained in Raizada’s study that except ‘ratio and proportion’ girls performed better than boys on all other types of Piagetian tasks. Thus the second hypothesis that ‘there are significant differences in the development of (a) Proportionality, (b) Propositional logic and (c) Combinatorial analysis abilities between high school boys and girls’ stands accepted only in respect of two of the three abilities that is Proportionality and Propositional logic.

D. URBAN-RURAL DIFFERENCES IN THE ATTAINMENT OF FORMAL OPERATIONAL ABILITIES

Proportionality: The differences in the mean scores on Proportionality between urban and rural groups as indicated by t = 2.614 are significant at 0.01 level. The values of mean for urban (m=7.52) and rural (m = 7.08) areas lead to infer that urban students outperform rural ones.

Propositional Logic: Differences between means of urban (m=5.82) and rural (m=4.87) groups on Propositional logic are also significant at 0.01 level (t=6.912) indicating thereby that urban students outperform rural ones.

Combinatorial Analysis: As in other two abilities, the difference between urban (m=6.31) and rural (m=5.32) groups in the development of Combinatorial analysis is significant at 0.01 level (t = 6.575) in favour of urban
Table 5.4

t - RATIOS BETWEEN URBAN AND RURAL GROUPS ON DIFFERENT COGNITIVE ABILITIES

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Cognitive ability</th>
<th>Urban/ Rural Mean</th>
<th>SD</th>
<th>N</th>
<th>t-ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Proportionality</td>
<td>Urban 7.52</td>
<td>1.784</td>
<td>205</td>
<td>2.614**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rural 7.08</td>
<td>1.605</td>
<td>204</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Propositional logic</td>
<td>Urban 5.82</td>
<td>1.433</td>
<td>205</td>
<td>6.912**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rural 4.87</td>
<td>1.014</td>
<td>204</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Combinatorial analysis</td>
<td>Urban 6.31</td>
<td>1.706</td>
<td>205</td>
<td>6.575**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rural 5.32</td>
<td>1.325</td>
<td>204</td>
<td></td>
</tr>
</tbody>
</table>

** t-ratio significant at 0.01 level
* t-ratio significant at 0.05 level
DIFFERENCE IN THE DEVELOPMENT OF COGNITIVE ABILITIES BETWEEN URBAN-RURAL AREA

Figure 5.3 (a)
Studies investigating the cognitive developmental level of children of urban and rural groups on different tasks have shown that greater number of urban high school students reach formal level than that of rural students (Nordland et al, 1974; Wheeler and Kass, 1977; Murphy, 1985; Pichardo, 1985; and Bagdady, 1991).

Findings of present study thus lead to infer that the abilities-Proportionality, Propositional logic and Combinatorial analysis are developed more among urban students than rural. While explaining such a phenomenon Tiwari (1990) opines that broad environmental variables provide varying inputs and make differential demands for different cognitive skills. Results of the present study too imply that structuring of environments can profitably be used to facilitate cognitive development among young children.

Thus, the third hypothesis that 'there are significant differences in the development of (a) Proportionality, (b) Propositional logic and (c) Combinatorial analysis abilities between urban and rural high school students' stands accepted.