

# Students' Performance in Chemistry in relation to their Logical Thinking Ability

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## Abstract

*Chemistry seems to be one of the difficult subject to study for many students. One of the probable reasons for their difficulties inherited in the nature of chemistry (Johnstone, 2000). Because some aspects of chemical phenomenon are observable while others are invisible to the learners. For example, a chemical reaction which takes place in a test-tube can be identified, by observing for evolution of gas, change in colour, change in energy etc., but description and prediction for such changes seemingly more difficult. This might be due to their inability for establishing relation between visible experiences and invisible changes that taking place at atomic or molecular level. Learning of abstract concepts requires abstract thinking and high level reasoning ability, probably best suited for formal operational thinker.*

*Logical thinking of formal-operational child involves deductive and inductive reasoning which they operate on operations. Hence, the investigator was intended to explore Grade 11 students' profile of logical thinking ability and to analyse a pattern of their performance in general chemistry, if any. The sample of the study comprised thirty students of science stream of Grade 11. Since, the sample is small it has little scope for generalisation. In spite of many limitations of the study, the findings have scope for further studies. Teachers, student-teachers and others in the field of education come under the ambit of this paper.*

**Keywords:** Chemistry; Logical thinking ability; TOLT

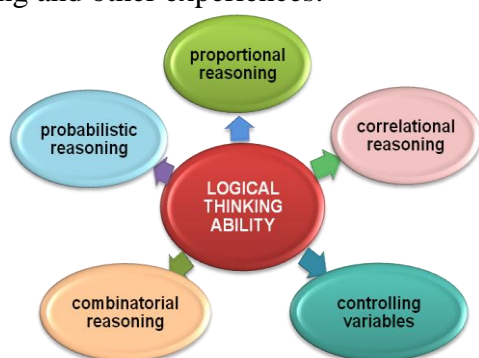
## 1. Introduction

The word 'thinking' is contextual, connotes various notions viz. remembering, solving problem, day dreaming and so on. Although thinking varies in nature yet no one can deny that it largely covers many aspects of the workings of one's intellect. All thinking can't be treated as logical thinking. The concept of logical thinking can be grasped from the work of Piaget, 'Logic of meaning'. In the words of Miller (2009) "Piaget emphasized that *logic* comes from the meanings of objects, developed from infants' actions. Specifically, infants learn that one action

on an object is related to other actions; the meaning of actions comes from 'what they lead to.' That is, one action can be inferred from another, in a sort of 'logic of meaning in actions,' a 'psycho-logic' on objects. This *action-based logic* later leads to *logic of operations....*" (p. 88). Piaget coherently described how an action-based logic grows into operational-based logic with the age in his cognitive development theory. His four stages of cognitive development are characterized by a certain level of logical ability that remains constant across different kinds of tasks. The two of the four stages of Piaget's

namely concrete operational stage and formal operational stage are special attention for teachers as well as curriculum developers, on account of the fact that these stages are directly linked with elementary and further higher school education.

The concrete operation child usually operates on reality and his or her thoughts are semi-logical. The object of logical thought remains concrete things. This logical thought of a child shifts from concrete world to ideal world when he or she reaches formal stage. A child of this stage is characterised by his/her well reasoned thought, i.e., the child can think logically about abstract propositions, he or she becomes concerned with the hypothetical and ideological problems, and can use both deductive reasoning and inductive reasoning. In other words, reaching at formal operational stage a child gets mature in terms of logical thinking. A formal operational child usually 'operates on operations'. Logical thinking is therefore, an ability that grows over period of time and influenced by maturation, learning and other experiences.



**Figure 1:** Components of logical thinking ability  
This ability constitutes of five kinds of reasoning namely, proportional reasoning, correlational reasoning, controlling variables, combinatorial reasoning and probabilistic reasoning.

### 1.1 Relevance of Logical Thinking Ability in Learning Chemistry

For many students chemistry seems to be a difficult subject (Johnstone, 2000). One of the possible reasons for difficulty lie abstract nature of many concepts in chemistry (BouJaoude, 1991). Some aspects of chemical phenomenon are observable while others are invisible to the learners. For example, a chemical reaction which takes place in a test-tube can identified by observing for evolution of gas, change in colour, change in energy etc., but description and prediction of the cause for such changes and formation product seems to be difficult for them. This might be due to their inability for establishing relation between visible experiences and invisible changes that taking place at atomic or molecular level. The changes which occur in the arrangement of atom, molecules or other subatomic particles are invisible and these changes are beyond students' direct sensory experience. In essence, learning of abstract concepts in chemistry demands abstract and formal thinking.

All five kinds of reasoning which comprise logical thinking ability are important for successful learning in science and chemistry (Bird, 2010; Bitner & Betty, 1991). Fah (2005) pointed out that logical thinking ability is crucial in the acquisition and understanding of science concepts. Bird (2010) found that logical reasoning skills are essential for student mastery of many of the concepts and more complex problem solving strategies are required to succeed in general chemistry. According to Sezen & Bulbul (2011), logical thinking constitutes one part of problem solving. One of the components of logical thinking ability is proportional reasoning.

McLaughlin (2003) found that student success in secondary science is highly dependent on proportional reasoning ability. Proportional reasoning seems to be essential in dealing with algorithmic or quantitative nature of problem in chemistry. This reasoning is used in solving algorithmic problems of mole concepts, stoichiometry, solid states, solution, Kinetic gas equations, chemical kinetics, chemical equilibrium and thermodynamics etc. Similarly, correlational reasoning explains an ability to relate two variables which is a very common task frequently required in chemistry. For doing experiment students should have ability to determine, discriminate and manipulate dependent and independent variables. Similarly, probabilistic reasoning allows students to understand the need for repeated trials in investigations as well as the use of averages of collected data from duplicated experiments.

The role of individual differences, for instance, logical thinking ability seems to be important factor which can influence performance of students in chemistry. Keeping in view the present investigation was conducted to explore the logical thinking ability profile of Grade 11 students of science stream. The investigator also intended to analyse a pattern of students' performance in general chemistry, if any, in relation to different levels of logical thinking ability.

### 1.2 Objectives of the Study

- 1 To study Grade 11 students' profile of logical thinking ability.
- 2 To categorise and study the students in terms of their logical thinking ability.
- 3 To study the performance of students on some basic-concepts in general chemistry.

- 4 To study the relationship between students' logical thinking ability and their performance on some basic-concepts in general chemistry.

### 1.3 Hypotheses of the Study

**Ho<sub>1</sub>:** There is no significant relationship between the students' logical thinking ability and their performance on some basic-concepts in general chemistry.

### 1.4 Delimitations

The study was confined to eleventh-class students of science stream following CBSE syllabus. The Test in Basic-concepts in Chemistry (TBC) was confined to cognitive aspect.

## 2. Methodology

### 2.1 Sample

The sample of the study comprised thirty students of Grade 11 enrolled in science stream. All students were taken from same class of one co-education school located in south Delhi.

### 2.2 Material and Procedure

The tools used in the study were:

**(i) The Test of Logical Thinking (TOLT):** To measure logical thinking ability of students standardized tool the TOLT was used. It was originally developed by Tobin & Capie (1981). The ten items of the TOLT measured five logical reasoning and the maximum possible score for each sub-scale is two.

**(ii) Test in basic-concepts in chemistry (TBC):** An achievement test consisted of 20 multiple-choice type items was developed by investigator. The test items were selected from two chapters of chemistry namely structure of atoms and chemical bonding of NCERT textbook of Grade 11.

### 2.3 Procedure

Before administering the tests, the necessary permission was sought from the Principal of sampled school. The TOLT was administered at in the beginning of the lessons taught and test

was conducted after completion of the required content.

### 2.4 Analysis of Data

Data was analyzed qualitatively and quantitatively keeping in view the objectives formulated for the study.

## 3. Results and Discussion

The forthcoming sections present interpretation of data, results and discussions.

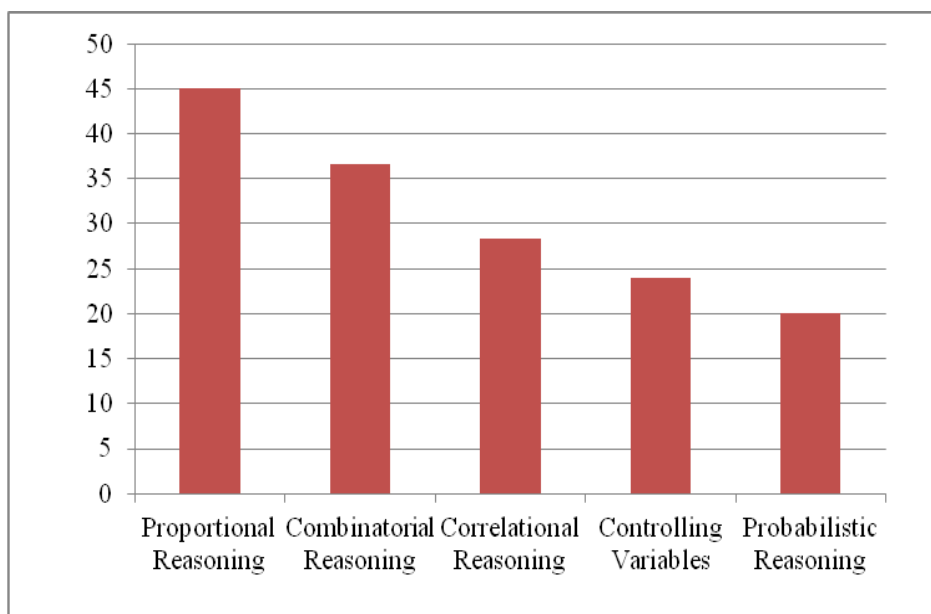
### 3.1 Logical Thinking Ability of Students

Students' logical thinking ability was gauged through the Test of Logical Thinking (TOLT). Performance of students on the five components of logical thinking ability is summarized in the Table 1. As it is revealed from the Table 1, students' score was highest (45%) in proportional reasoning and lowest (20%) in probabilistic reasoning. Students' highest difficulty in probabilistic reasoning was also supported by findings of earlier researches (Fah, 2010; Bitner & Betty, 1991).

**Table 1:** Students' Performance on Five Components of TOLT(N=30)

S. No.	Components of logical thinking ability	Scores Obtained	Max. possible score (N × 2)	Percentage
1	Proportional Reasoning	27	60	45.00
2	Controlling Variables	15	60	24.00
3	Probabilistic Reasoning	12	60	20.00
4	Correlational Reasoning	17	60	28.33
5	Combinatorial Reasoning	22	60	36.66
Overall				30.79

Their performance on the five components of logical thinking ability in decreasing order is depicted in Figure 2.



**Figure 2: Student's performance of components of logical thinking ability**

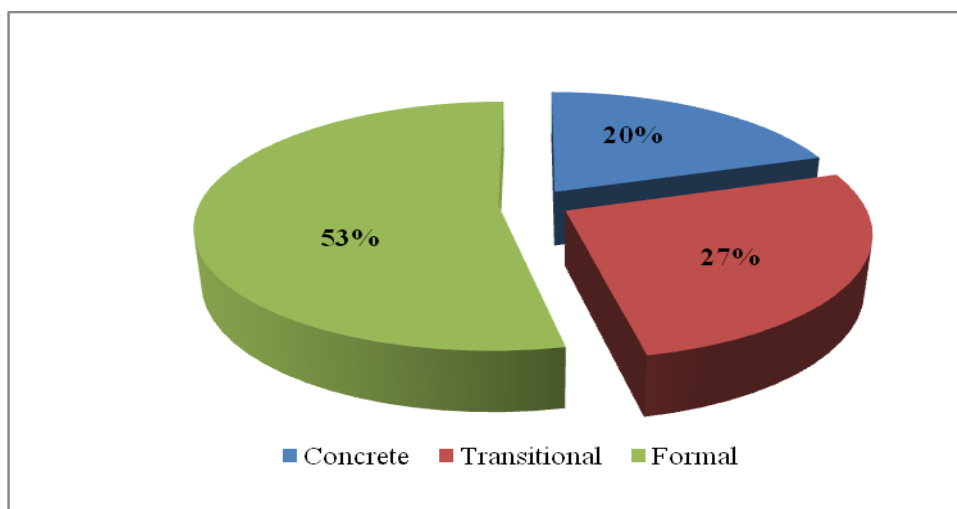
### 3.2. Categorisation of Students in terms of Logical Thinking Ability

Students' scores on the TOLT were used both as a measure of logical thinking ability and also as a means to categorise them into different levels. Valanides (1997) in his study cited Tobin & Capie as "Test scores from 0–1, 2–3 and 4–10 were used as a basis for classifying subjects as concrete, transitional, and formal reasoners, respectively" (p. 174). Piaget did not mention a transitional stage in between concrete and formal operational stage. The concept of transition stage: a sub-stage within concrete and formal operational stage was used by number of researchers (Fah, 2010; Bird, 2010; Valanides, 1997). Following the trend categorisation was done (Table 2).

**Table 2: Categorisation of Students Based on TOLT Score (N=30)**

Levels of Logical thinking ability	TOLT Score	Number of Students	Percentage
Concrete thinking	0-1	6	20
Transitional thinking	2-3	8	27
Formal thinking	4-10	16	53

The above Table 2 shows that 20% students were concrete thinker, 27% students were at transitional level and remaining 53% students reached formal thinking level. A pie diagram Figure 1 shows the distribution of students into three levels of logical thinking ability.



**Figure 2:** *Distribution of students by operational level*

The analysis revealed that about 53% students reaches formal level. These findings are somehow comparable to those obtained by Bird (2010) for students enrolled in general chemistry showed that 19% concrete, 40% transitional and 41% formal level although he used another instrument to measure logical thinking ability. Grade 11 student's profile of logical thinking ability highlights the inclusion of students with all three levels of logical thinking ability.

### 3.3 Performance of Students on the Test of Basic-concepts in Chemistry (TBC)

The mean and standard deviation of students were 13.53 (68%) and 3.75 respectively on the test of basic-concepts in general chemistry as shown in Table 3. Since the obtained mean was about seventy percent of maximum possible score of the test, it can be inferred that on an average, the students had a satisfactory performance on the Test in chemistry.

**Table 3:** *Students' Performance on TBC (Number of students N=30)*

Maximum possible score for each student = Total number of items	Minimum	Maximum	Sum	Mean	Mean percentage	SD
20	5.00	20.00	406.00	13.53	67.65	3.75

### 3.4 Performance of Students on Some Basic-Concepts in General Chemistry in terms of their Logical Thinking Ability

The mean and standard deviation on of performance scores on TBC for different levels of logical thinking ability are shown in Table 4.



**Table 4:** Mean and SD of TBC Scores with different levels of Logical Thinking Ability

Logical Thinking Ability	N	Mean	SD
Concrete Thinking	6	10.62	2.61
Transitional Thinking	8	11.83	4.40
Formal Thinking	16	15.62	2.68
Total	30	13.53	3.75

Analysis revealed expected trend in performance of students. Concrete thinker scored low ( $M = 10.62$ ,  $SD = 2.61$ ) compared to those of transitional ( $M = 11.83$ ,  $SD = 4.40$ ) and formal thinker ( $M = 15.62$ ,  $SD = 2.68$ ). It means that performance of formal thinker was better than transitional and concrete thinker. The finding shows that same instructional strategy for teaching basic-concepts in general chemistry cannot be equally effective for these all three groups.

### 3.5 Relationship between Students' Logical Thinking Ability and their Performance on TBC

The correlation between students' TBC scores and logical thinking ability was shown in Table 5.

**Table 5:** Correlation between TBC and Logical thinking ability

Variables	Correlation coefficient <i>r</i>	<i>p</i>
Students' understanding in basic concepts & logical thinking ability	.627**	.000

\* Correlation is significant at the 0.05 level

\*\* Correlation is significant at the 0.01 level

The correlation between logical thinking ability (the TOLT score) and students' performance on basic-concepts in general chemistry (the TBC score) was found to be significant and moderate ( $r = .627$ ,  $p \leq 0.01$ ). Thus, the null hypothesis stating that there is no significant relationship between logical thinking ability and students' performance on TBC was rejected. This finding was in line with many previous researches (Bird, 2010; Lewis & Lewis 2007) which showed a positive correlation between logical thinking ability and students' achievement in chemistry or sciences.

## 4. Major Findings of the Study

- Grade 11 students are of three levels of logical thinking ability.
- 20% students were concrete thinker, 27% students were at transitional level and remaining 53% students reached formal thinking level.
- Formal thinker performed better than transitional and concrete thinker.

- Students performance in probabilistic reasoning was low.
- Students' performance on basic-concepts in general chemistry and their logical thinking ability shows significant and moderate correlation ( $r = .627$ ,  $p \leq 0.01$ ).

## 5. Conclusion and Suggestions

Piaget's concrete and formal operational based logical thinking are a major concern of

educators. It is obvious because these two stages exercise logical operations. The findings of this study is in queue with earlier research findings (Bird, 2010; Adey and Shayer, 1990) showing that for a large proportion of secondary and higher secondary students are concrete and transitional thinker. Many of concepts in chemistry are related with microscopic phenomenon, such as structure of atom, organic reaction mechanism etc., which seem to require abstract and higher order logical thinking ability. The teacher should emphasise on the logical thinking ability of students. Striking a balance between operational level of students and instructional strategies followed can make teaching-learning of chemistry effective. The development of logical thinking ability in general can assist students in grasping many abstract concepts in chemistry. Effort of teachers in this direction will help students in learning advance concepts in chemistry. Use of computer assisted instruction or ICT in teaching-learning process can assist students in visualising abstract concepts. Similarly, providing more hands-on experiences and concrete problems to school-student can enhance their learning outcome.

This study was conducted on very small sample and hence it has little scope for generalization. Still, it can provide some direction for further studies to investigate many questions as, Does logical thinking ability true predictor for learning outcome in chemistry? Does logical thinking ability interact with computer-assisted instruction or any other instructional strategies used for teaching chemistry?

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