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Enhancing Educational Effectiveness in Physics through Cognitive Development Model: An Investigation in Formal Operational Stage

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---ABSTRACT---
A retrospective of objectives of Physics teaching during various decades reveal that they have undergone immense change. The goal of education is not to increase the amount of knowledge but to create the possibilities of a child to invest and discover.The present study is envisaged to find out the effectiveness of Cognitive Development Model on achievement in Physics at secondary level. It is expected that the findings of the study will help curriculum planners and those who are connected necessity of the application of these new techniques in the teaching of Physics. It also helps to provide a broad developmental perspective to the educator for building a curriculum for the secondary school students.It will help teachers to understand the effectiveness and necessity of the application of model approach in the teaching of Physics.

KEYWORDS: *Cognitive Development Model; Formal Operational Stage; Piagetian notion of stage.*

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I. INTRODUCTION

Education is a unique investment in the present and future. Education is a means of primarily enlarging and enlightening the mind to enable the individual to achieve a status, so that he may become an effectively functioning individual. But the aims objectives of education change from time to time with the philosophy of life, needs of society and the subject matter. A retrospective of objectives of Physics teaching during various decades reveal that they too have undergone immense change. The goal of education is not to increase the amount of knowledge but to create the possibilities of a child to invest and discover. “Teaching of science should be based on inquisitiveness, creativity, objectivity, and sensibility and questioning spirit of students” (Duck Worth, 1964). It should not be done in a lecturing and discussing method only but should be organized in a problem solving and decision making environment. Most of our children learn the concepts blindly, without knowing the meaning of it. The objectives of science teaching such as development scientific attitude, creative thinking, curiosity etc are not realized by the conventional practices of teaching, now following. Students are passive listeners in the classroom and they lack mental operations, which increases the meaning and internalization of new information”. The mental abilities which are required for scientific observation, classification conceptualization, problem solving etc. are more or less neglected. It is in this context that the investigator felt the need for an effective strategy that ensures more pupil participation. Teaching Models can provide outlines for generating the specific situations to achieve specific learning objectives.

According to Joyce and Weil (1992) “it is necessary that teaching should aim at improving strategies of learning and intellectual ability. Hence education and teachers are seeking for effective models or rather perfect Models of Teaching, which will unravel each child’s potential for learning. It add new creative dimension to childhood experience by the systematic application of sound learning principles to classroom organization and management”. Models of Teaching differ from general approaches of teaching in that they are designed to realize specific instructional objectives. General approaches of teaching are considered to be applicable to all teaching situations. Among the different families of models, Information Processing Models can provide effective means of knowledge and understanding to the students about new information and new facts. These models can create appropriate environment and stimuli for the students to solve problems.Hence the discussion reveals that the modern techniques of teaching or the development of new methods of teaching result in better learning outcomes in Physics. Of the very few modern techniques of teaching, the Information Processing

Models are assumed to be more useful in teaching Physics in the secondary schools. Hence a study is envisaged to find out the effectiveness of Cognitive Development Model on achievement in physics at secondary level.

II. COGNITIVE DEVELOPMENT MODEL

The Cognitive Development Model has emerged out of the contribution of Piaget, Siegler and Sullivan has gained wide acceptance in the theory and practice in educational circles. Their contribution to education is perceptible in the organization of the educational environment, curriculum sequencing, methodology of teaching and in testing and evaluation. Cognitive development is the development of the thinking and organizing systems of the brain. It involves language, mental imagery, thinking, reasoning, problem solving and memory development. Generally it is referred to the changes that occur to a person's cognitive structures, abilities and process. Cognitive development can be viewed as having three components: content, function and structure. Content is what children know about. It refers to observable behaviours (sensory motor and conceptual) that reflect intellectual activity. By its nature the content of intelligence varies considerably form age to age and from child to child. Function refers to those characteristics of intellectual activity (assimilation and accommodation) that are stable and continual throughout cognitive development. Structure refers to the inferred organizational properties (schemata) that explain the occurrence of particular behaviours. A study of cognitive development provides a major insight into the nature of human intelligence. Swiss psychologist Jean Piaget, who can be called as the father of cognitive studies studied and theorized about child development for over half a century.

III. PIAGET'S STUDY OF COGNITIVE DEVELOPMENT

Piaget (1955) produced a strict stage theory of development, in which the child actively constructs his or her knowledge of the world. Piaget's theory gives meaningful continuity to the development of human understanding. In it, cognition is a spontaneous biological process and the function and characteristics of thought are like those of digestion or respiration taking in, modifying and using whatever elements were needed. Piaget called his approach Genetic Epistemology. For Piaget all knowledge comes from action. The baby's knowledge grows neither from the objects themselves nor from the baby but from the interaction of the two and consequent link between action and objects. Schemes are mental categories that organize experience, based on actions infancy and progressing to abstract properties in adolescence. According to Piaget, children come to understand the world by using schemes, psychological structures that organize experience. As children develop their basis for creating schemes shift from physical activity to functional, conceptual and later, abstract properties of objects, events and ideas.

Intellectual adaption involves two processes working together, assimilation ad accommodation. Assimilation occurs when new experiences are readily incorporated into existing schemes. Accommodation occurs when schemes are modified based on experience. Assimilation and Accommodation are easy to understand if we remember Piaget's belief that infants, children and adolescents create theories to understand the word around them. Equilibration is the most general developmental principle in Piaget's theory. It states that the organism always tends towards biological and psychological balance and that development is a progressive approximation to an ideal state of equilibrium that it never fully achieves. In Piaget's theory, back-and-forth movement between cognitive equilibrium and disequilibria throughout development, this leads to more effective schemes. In Piaget's theory, the internal management and lining together of scheme so they form a strongly interconnected cognitive system.

IV. THE PIAGETIAN NOTION OF STAGE

Piaget found that a child enters the world lacking virtually all the basic cognitive competencies of the adult, and gradually develop these competencies by passing through a series of stages of development. They are

4.1Sensory Motor Stage

Piaget's first stage, during which infants "think" with their eyes, ears, hands and other sensory motor equipment spans the first two years of life. During this stage, behavior is primarily motor. This child does not yet internally represents events and 'think' conceptually though 'cognitive' development is seen as schemata are constructed.

- *Sub stage 1***:** Reflexive Schemes (Birth to 1 month) This sub stage is marked by sensory motor egocentrism, a form of ego-centrism that involves a merging of the self with surrounding world, an absence of the understanding that the self is an object in a world of objects.
- *Sub stage 2***:** Primary circular reactions (1-4 months) Infants start to gain voluntary control over actions by repeating chance behaviours that lead to satisfying results.

- *Sub stage 3*: Secondary circular reactions (4-8 months): Infants sit up and become skilled at reacting for grasping and manipulating objects. They try to repeat interesting sights and sounds that are caused by their own actions.
- *Sub stage 4*: Co-ordination of secondary circular reactions (8-12 months): Two land mark changes take place.

a) International or goal directed behavior: A sequence of actions in which schemes are deliberately combined to solve a problem.

b) Object permanence the understanding that objects continue to exist when they are out of sight.

- *Sub stage 5*: Tertiary circular reactions (12-18 months). Toddlers do not just repeat behaviours that lead to familiar results, they repeat with variation's provoking new outcomes.
- *Sub stage 6*: Mental representation (18-24 months). The child develops an ability to form an internal image of an absent object or a past event.

4.2 Pre-Operational Stage

Piaget's second stage, in which rapid development of representation takes place. However thought is not yet logical. Spans the years from 2 to 7. This stage is characterized by the development of language and other forms of representation and rapid conceptual development. Reasoning during this stage is pre-logical or semi logical. It consists of two stages

i. Pre-conceptual stage
ii. Intuitive stage

4.3 Concrete Operational Stages

Piaget's third stage, during which thought is logical, flexible and organized in its application to concrete information. However the capacity for abstract thinking is not yet present. Spans the years from 7 to 11. During these years, the child develops the ability to apply logical thought to concrete problems. Concrete operations are evident in the school age child's performance on a wide variety of Piagetian tasks.

4.4 Formal Operational Stage

Piaget's final stage, in which adolescents develop the capacity for abstract, scientific thinking, begins around age 11. During this stage, the child's cognitive structures reach their greatest level of development, and the child becomes able to apply logical reasoning to all classes of problems. At adolescence, young people first become capable of hypothetico-deductive reasoning. When faced with a problem they start with a general theory of all possible factors that might affect an outcome and deduce from its specific hypotheses about what might happen. Then they test these hypotheses in an orderly fashion to see which ones work in the real world. A second important characteristic of the formal operational stage is prepositional thought. The stage is also accompanied by formal operational egocentrism: the inability to distinguish the abstract perspectives of self and others.

The major characteristics of formal operational stage are:

i. *Hypothetic-Deductive Reasoning*: A formal operational problem solving strategy in which adolescents begin with a general theory of all possible factors that could affect an outcome in a problem and deduce specific hypotheses, which they test in an orderly fashion During the formal operational stage adolescents solve problems by thinking of all possible hypotheses that could occur in a situation. Then they test these predictions systematically to see which ones apply in the real world.

ii. *Proportional Thought*: A type of formal operational reasoning in which adolescents evaluate the logic of verbal statements without referring to real world circumstances.

iii. *Formal Operational Egocentrism*: A form of egocentrism present during the formal operational stage involving an inability to distinguish the abstract perspectives of self and other.

iv. *Imaginary audience*
Adolescent's belief that they are focus of everyone else's attention and concern. As a result, they become extremely self-conscious, often going to great length to avoid embarrassment.

v. *Personal Fable:* Adolescents' belief that they are special and unique leads them to conclude that others cannot possibly understand their thoughts and feelings and that they are invulnerable to danger.

V. DESCRIPTION OF THE MODEL

The Cognitive Development Model could be used for the dual purpose of teaching and testing for cognitive development. Teachers are required to prepare age-related tasks, and observe how students respond to them by probing their reasoning, seeking justification and furnishing cues where necessary.
This involves

a) Syntax
b) Social system
c) Principles of reaction
d) Support system
e) Instructional and Nurturant effect.

5.1Syntax
The syntax of Cognitive Development Model consists of three phases.
Phase I: Presentation of confronting situation;
Phase II: Promoting enquiry by the child;
Phase III: The transfer.

Table 2.6 Plan for the Cognitive Development Model

Phase	**Description**	**Activities (teacher and student)**
Phase I	Confrontation with stage relevant task	Establishes rapport with the child, presents a puzzling problem matched to the developmental stage of the child.
Phase II	Inquiry	Elicits student's responses, seeks reasoning and justification, offers counter suggestion, probes reasoning.
Phase III	Transfer	Presents a related task, poses a puzzling problem, Elicits responses, seeks justification, offers counter suggestions, probes reasoning.

5.2Social System
The teacher provides an activity-based environment where students are free to manipulate material to gain cognition of the underlying concepts. The teacher operates on a partially structured environment, initiates and guides inquiry, leading to logical conclusion.

5.3Principles of Reaction
Teacher may give cues while teaching, but avoids giving suggestions while testing. The teacher must probe into correct and incorrect reasoning. It would be beneficial to ask students to report similar situations (if any) encountered while performing a task.

5.4Support System
Teachers using the Cognitive Development Model should use a variety of objects as resources to construct tasks. Tasks may be devised from broad pedagogical areas, subject areas or real life situations. Materials must match the student's developmental stage. Teachers must equip themselves with relevant counter suggestions and related tasks. Low-cost resource materials, such as stones, plasticine, bottle caps etc may be used.

5.5 Instructional and Nurturant Effect
Cognitive Development Model is designed to instruct students in thinking, formal reasoning and higher order thinking. Its nurturants are the problem solving ability, intellectual development, abstract thought and deductive thought.

VI. OBJECTIVES OF THE STUDY

1. To find out the effectiveness of Cognitive Development Model
2. To compare the effect of instruction using the Cognitive Development Model and the conventional strategies of instruction on the achievement in physics of secondary school students.

VII. HYPOTHESES FORMULATED

It is assumed that pupil's achievement is based on method of teaching. On the basis of this assumption hypothesisis formulated.
When physics is taught among two groups of secondary school students, one using Cognitive Development Model and other using conventional strategies of instruction, then there will be significant difference between the mean scores of achievement.

VIII. METHODOLOGY

The major objective of the present study was to test the effectiveness of Cognitive Development Model in the teaching of physics at the secondary level. The method selected for the study was experimental method and the design used was pre-test post-test parallel group design.

The study was conducted on a final sample of 90 students of standard IX. Each division consisted of 45 students. One division was considered as the experimental group and the other control group. Pre-test was conducted before starting the experiment. The experimental group was taught with the lesson transcripts prepared on the basis of Cognitive Development Model and control groups was taught usingthe conventional strategies of instruction. After the treatment post-test were conducted. The data thus collected were computed and used for statistical analysis.

IX. ANALYSIS AND INTERPRETATION OF DATA

The data collected for the present study were analysed to throw light on the objectives of the study. The analysis and interpretation of the results have been presented under the following sections

The scores of 90 students of two groups with one group who learned using Cognitive Development Model and other using conventional strategies of instructionwere subjected to Analysis of Covariance (ANCOVA). This was done to determine the effectiveness of Cognitive Development Model over the conventional strategies of instructionon achievement in Physics. The scores obtained in the pre-test and post-test were analysed statistically using ANCOVA to compare the effectiveness of the Cognitive Development Model and the conventional strategy of instruction. The analysis done in this regard is given below.

Table 1 Summary of analysis of variance of the post-test scores for the experimental and control groups

Sources of variation	Df	SS_x	SS_y	$M S_x(V_x)$	$M S_y(V_y)$
Among means	**1**	**1.88**	**589.06**	**1.88**	**589.06**
Within groups	**88**	**235.29**	**1626.74**	**2.67**	**18.48**
Total	**89**	**237.17**	**2215.8**		

From table, for df = 1/88
F at 0.05 level = 3.96
F at 0.01 level = 6.96

The obtained value of F_x is 0.69. It is not significant whereasF_y (31.87) is significant at 0.01 level. It shows that there is no significant difference between pre-test scores of experimental and control groups. F_y value is significant indicating that the groups differ significantly in the post-test scores. The computations have to be carried out for the purpose of correcting the post-test (y) scores for the difference in the pre-test (x) score. So ANCOVA was adopted for further computation. The results of the analysis are presented in the table below.

Table 2 Summary of Analysis of Covariance for the Total Pre-test and Post-test Scores of Students in Experimental and Control Groups

Sources of variation	Df	SS_x	SS_y	SS_{xy}	SS_{yx}	MS_{yx}	D_{yx}
Among means	**1**	**1.88**	**589.06**	**33.25**	**586.2**	**589.06**	**4.323**
Within groups	**88**	**235.29**	**1626.74**	**6.498**	**1626.5**	**18.69**	
Total	**89**	**237.17**	**2215.8**	**39.74**	**2212.78**		

From table, for df = 1/88
F at 0.05 level = 3.96
F at 0.01 level = 6.96

Since F_{yx}ratio, 31.36 is greater than the table value 6.93, it is significant ($F_{y.x}$=31.36; p<0.01). The significant ratio for the adjusted post-test scores shows that the final mean scores of students in the experimental

and control group differ significantly after they were adjusted for the difference in the pre-test scores. The significantly F-ratio necessities proceeding to test the difference separately' test.
The data and results are shown in table below.

Table 3 Data for Adjusted Means of Post-test Scores of Pupil in the Experimental and Control Group

Groups	N	M_x	M_y	$M_{y.x}$ (Adjusted)	't'
Experimental	**45**	**4**	**18.29**	**18.286**	**5.609**
Control	**45**	**3.71**	**13.17**	**13.174**	
General means		**3.855**	**15.73**		

The difference in adjusted means for post-test scores of experimental and control group tested for significance for df 1/87. It significant at 0.01 level, since't' value from table is 1.99 and 2.64 at 0.05 and 0.01 levels respectively. This shows that the Cognitive Development Model is better than conventional strategies of instruction.

X. FINDINGS

The analysis of variance of pre-test and post-test scores of pupils in experimental and control groups showed that there was no significant difference between the means of pre-test scores of the two groups (F_x= 0.69, which is not significant even at 0.01 level of significance). But there was significant difference between the means of the post-test scores of the two groups (F_y= 31.87, which is significant at both level of significance) i.e. the experimental group was found to be superior to the control group in post-test achievement.The analysis of covariance of pre-test and post-test scores of pupils in experimental and control groups showed that there is significant difference between the means of post-test scores of the two groups (F_y= 31.36). The mean of the post-test scores of experimental group is 18.29 and that of control group is 13.17.

When the adjusted means of post-test scores of the pupils in the experimental and control groups were compared, the differences between them were found to be statistically significant. The experimental group was found to be superior to control group. The adjusted means of post-test scores of experimental group is 18.286 and that of control group is 13.144.

XI. SCOPE OF THE STUDY

The Model of Teaching selected for experiment as well as conventional method followed, aim at information processing, though in different ways. It is expected that the findings of the study will help curriculum planners and those who are connected necessity of the application of these new techniques in the teaching of Physics. It also helps to provide a broad developmental perspective to the educator for building a curriculum for the secondary school students. Also the description of developmental stage sand qualitative aspects of intellectual growth is very useful in providing suitable educational objectives. It will help teachers to understand the effectiveness and necessity of the application of model approach in the teaching of Physics. It may be useful for all those who are concerned with educational strategies and is hoped that the findings of the present study will help to find new frontiers to educational practice

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