DEVELOPING CONCEPT MAPPING MODEL AS AN EFFECTIVE TOOL TO TEACH SCIENCE

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I. INTRODUCTION

An exponential increase in knowledge has ushered in the age of science. To train our budding scientists in this new knowledge it is essential to develop in them the spirit of inquiry and divergent thinking abilities so that they get accustomed to the continuous process of knowledge acquisition through self-learning. Thinking in cognitive domain envisages abilities such as concept formation, reasoning, problem solving, creativity, etc. Of the above four, concept formation is the most fundamental cognitive process because while the others remain essential skills, concepts become relatively permanent cognitive structures that provide the basic bearing for further learning. Thus acquisition of the fundamental concepts lays a strong foundation for building of complex structures in any discipline. The need of concepts to develop a meaningful base has led to the emergence of numerous teaching methods and techniques. Based on this need various teaching strategies can broadly be classified into the deductive and the inductive categories. The origin of Concept Mapping, which is based on the deductive approach, lies in Ausubel's theory of meaningful verbal learning. Though Concept Mapping has been a favorite subject of research in the western world in the present decade, it is yet to attract the attention of researchers in India. The need to probe the potential of Concept Mapping in the Indian scenario motivated the investigator to study the effectiveness of this versatile technique in pedagogical processes. The investigator went a step further by comparing the effectiveness of Concept Mapping with an equally challenging General Inductive Model developed by Paul D.Eggen and Donald P.Kauchak. This Inductive Model differs from other inductive approach based models developed by Bruce Joyce and Marsha Weil in that while the former has an open structure and can be flexibly molded according to the needs of the learning process (though within the prescribed framework), the latter are highly objective models catering to a rigid syntax.

II. THE PROBLEM

The focus questions of the present study are:
(1) As compared to the Conventional Method, do Concept Mapping and Inductive Model foster better conceptual learning and retention?
(ii) Which of the two strategies, Concept Mapping or Inductive Model, lead to inculcation of concept comprehensibility and applicability in an effective manner?

III. DEFINITIONS OF KEY TERMS

The key terms inherent in the statement of the problem are defined in operational terms.

1. *Effectiveness*

Effectiveness is a relative, rather than an absolute, concept. It deals with the question: how effective a particular strategy is? Here effectiveness refers to the gain score ratios of the pupils on the criterion test (post-test I and post-test II) after they have been exposed to different instructional strategies.

2. *Teaching*

Teaching implies an act of helping someone to learn i.e. it is an act of helping someone to acquire knowledge, attitudes, ideas, habits or some other type of learning, which he did not posses previously. Teaching is a purposeful activity aimed at imparting knowledge or skill. Teaching is the stimulus and learning is the response.

3. *Teaching Strategies/Models*

These are thematically related techniques designed to help students accomplish pre-established objectives. Teaching strategies are characterised by a planned sequence of actions so as to perform the task of managing specific learning experiences. Models of teaching differ from general teaching strategies, as they are prescriptive in nature and designed to achieve specific goals. When a teacher identifies a goal and selects a particular strategy designed to reach that goal, it can be said that the teacher is using model approach. The teaching strategies/models used in the study are presented in the following section.

(i) Concept Mapping

Concept Mapping arranges the concepts in a deductive manner with the broader concepts placed at the top followed by the less inclusive concepts.

(ii) The Inductive Model

The Inductive Model developed by Paul D. Eggen and Donald P.Kauchak is considered appropriate for the present study. Based on the inductive approach, this model consists of four phases.

Phases Of Inductive Model

Phase I: The Open Ended Phase

(a) In this phase the students are shown an example of a concept or generalisation or a non example.
(b) The students are asked to observe and describe the example.
(c) The students are shown a second example or non example.
(d) Again the students are asked to observe and describe the example.

(e) The process is continued with as many examples and non-examples as have been prepared.

Phase II: The Convergent Phase
(1) Students are prompted to identify patterns in the examples.

Phase III: Closure
Patterns are explicitly stated in a definition.

Phase IV: The Application Phase
(h) Definitions are applied with additional examples.

4. *Concepts.*

A concept is an abstract notion that is based on a class of - ideas with common characteristics or generalisations arising from the common features of an observed class form the basis of features that describe the concept are called concept characteristics or a concept. Concepts are named by using labels or terms. The concept name is the label attached to the mental construct and that name is used for the purpose of communication.

5. *Science Education*

Science education is a vast area. In this study science education is delimited to the teaching learning processes which take place in the classroom. In the present context, science education operationally refers to Concept Learning .Concept learning refers to concept acquisition by pupils as a result of instructional treatment in the form of three different teaching methods viz. Concept Mapping, the Inductive Model and the Conventional Method. Concept learning outcome is measured in terms of comprehension and application of concepts.

IV. OBJECTIVES

1. BROAD OBJECTIVES

(i) To develop various phases of Concept Mapping as a model.

(ii) To compare the effectiveness of the three methods in teaching concepts in Chemistry. The effectiveness of concept
learning is to be measured in terms of comprehension and application of concepts.

2. SPECIFIC OBJECTIVES

(i) To develop instructional material based on the Concept Mapping Model.

(ii) To develop instructional material based on the Inductive Model.

(ii) To study the effectiveness of the Concept Mapping Model in terms of meaningful acquisition of concepts.

(iv) To study the effectiveness of the Inductive Model in meaningful acquisition of concepts.

(v)To study the relative effectiveness of the Concept Mapping Model and the Inductive Model in comparison to the Conventional Method in meaningful acquisition of concepts.

(vi) To assess the relative extent of concept retention over a period of time after the termination of instructional treatment.

V. HYPOTHESES

The findings of the related studies enabled the researcher to formulate the following research hypotheses.
H1: The pupils taught through the Concept Mapping Model show significantly better concept learning in terms of comprehension and application of concepts than the pupils taught through the Conventional Method.
H2: The pupils taught through the Inductive Model show significantly better concept learning in terms of comprehension and application of concepts than the pupils taught through the Conventional Method.

H3: The pupils taught through the Concept Mapping Model show significantly better concept learning in terms of comprehension and application of concepts than the pupils taught through the Inductive Model.

H4: The pupils taught through the Concept Mapping Model show significantly better concept retention of concepts than the pupils taught through the Conventional Method.

H5: The pupils taught through the Inductive Model show significantly better retention than the pupils taught through the conventional Method.

H6: The pupils taught through the Concept Mapping Model show significantly better retention of concepts than the pupils taught through the Inductive

VI. DELIMITATION OF THE STUDY

Keeping in view the nature of the problem and the research design along with the constraints of time and resources the present study has been delimited in the following ways:

1. Only three teaching strategies were chosen.

2. Only the General Inductive Model propounded by Paul. D. Eggen and Donald. P. Kauchak was selected for the study.

3. The study was confined to only three government aided girls schools situated in urban Delhi so as to have better accessibility and economy of time.

4. The sample was limited to class IX only

5. To do justice to the expertise of the investigator the study was limited to selected concepts in Chemistry prescribed by the C.B.S.E. syllabus.

6. Only comprehension and application aspects pertaining to the cognitive domain objectives of Bloom's taxonomy were considered.
7. Teaching treatment based on the three teaching strategies was given by the investigator herself so as to control the teacher variable in the study.

8. Only short-term retention (lasting over a period of six weeks) has been taken into account so as to maximise control over the intervening variables.

VII. EVOLVING CONCEPT MAPPING AS A MODEL

As this study compares the relative effectiveness of Concept Mapping and the Inductive Model, there is need to evolve Concept Mapping as a model with well defined phases, so as to bring it to the same functional and operational level as the Inductive Model. Four well-defined phases of Concept Mapping were evolved after rigorous discussions with experts in the subject and technique of drawing concept maps. Once at the same structural and functional level, the two strategies can be compared for their effectiveness.

Phases of Concept Mapping Model
Phase I: Presentation of Abstraction

(a) The students are presented with a definition or generalisation, which is linked to the learners' existing cognitive structure.
(b) The students are asked to identify various concepts and sub-concepts and to enlist them.
(c) The students' understanding of these concepts is assessed by asking them to provide new and unique examples.

Phase II: Propositional Phase

(d) The teacher uses prompts and cues to guide the learners to arrange the concepts hierarchically, with the broader/general concepts to be placed at the top and the less inclusive concepts at the bottom, thus giving the whole structure the look of a pyramid.

(e) The various concepts are inter-linked logically by using lines. These lines are supplemented by word/words/phrases which define them and elicit meaningful relationship among the various concepts.

(f) The whole concept map is viewed as a network of concepts.

Phase III: Application
(g) The students apply their knowledge to generate new examples at each level of hierarchy and reflect on the existing ones.

Phase IV: Closure
(h) The students summarise the major ideas evolved during the discussion.

VIII. REVIEW OF RELATED LITERATURE

Review and analysis of available literature related to Concept Mapping and inductive/deductive methods revealed the following:

1. Almost all the studies conducted on Concept Mapping showed a positive effect of the technique on concept learning and retention, irrespective of the discipline, age and sex of the learner. This could be attributed to the conceptual hierarchical framework involving propositional linkages inherent in concept maps. None of the reviewed studies involving Concept Mapping were done in India.

2. Concept maps have been proved to be equally effective with all the age groups. Boys and girls achieved equally on the concept map studies, though the anxiety level of girls was reported to be higher than that of boys while working with concept maps.

3. Most of the studies comparing inductive models/methods with the conventional method in teaching-learning situations reported superiority of the former over the latter. This could be attributed to the sequential processing of information required for the inductive approach. Most of these studies were done in India.

4. Studies comparing the inductive models/methods with the deductive models/methods revealed that approximately equal number of studies favoured either the inductive or the deductive approach or both. Hence no equivocal decision regarding superiority of any one instructional approach could be made for teaching science. However, recent studies provide evidence that the deductive approach when effectively implemented in designed instruction can be more effective than the inductive strategies.

5. The researcher did not come across any study, which compared the effectiveness of Concept Mapping with the Inductive Model. In fact, the effectiveness of Concept Mapping with the conventional method and co-operative learning has been studied but its comparison with any of the methods based on inductive approach is yet to be explored. Hence a need was felt, by the investigator, to compare the relative effectiveness of Concept Mapping with the General Inductive Model for learning and retention of concepts.

IX. DESIGN OF THE STUDY

As has already been mentioned that the present study involves comparison of teaching strategies in Chemistry based on the Concept Mapping Model, the General Inductive Model and the Conventional Method, hence an experimental research design was considered suitable for the above purpose. The experiment had to be conducted in a school setting without disturbing the school schedule, thus randomisation of subjects into groups was not feasible. Hence the three groups (two experimental and one control) were naturally assembled groups as intact classes. Therefore a quasi-experimental research design was selected. The subjects were not matched on their previous achievement in science, but were equated (in mean and standard deviation) with respect to intelligence. As the experiment involves administration of a pre-test and a post-test.

X. SAMPLE

A purposive sample comprising of 111 girl students belonging to three government aided girls senior secondary schools of Delhi and affiliated to CBSE was selected for the study. The sections from the first two schools were randomly assigned the experimental treatments I & II respectively and the section from the third school was treated as the control. After equating the groups in mean and standard deviation with respect to intelligence, 37 students from each group were considered for the experiment. The students of these schools were randomly assigned to different sections and there was no ability grouping. The three groups were as similar as availability permitted. They were comparable with respect to size, cultural and socio-economic status, age and past achievement in science. Thus it can be concluded that the pre-experimental measures were highly comparable for the three groups.

XI. VARIABLES

In the present study the independent variable which was manipulated by the investigator was the method of instruction (treatment variable). The dependent variable was the achievement of the pupils on the criterion test, measured in terms of mean gain score ratio. The dependent variable was measured for concept learning and retention with respect to comprehension and application of concepts. Situational variables like sex, teacher, conditions for teaching, duration of teaching, rewards & punishment and apparatus & audio- visual aids were controlled by the experimenter during the treatment. The variable under statistical control was Intelligence.

XII. TOOLS

1. Intelligence Test: Standard progressive matrices developed by J.C. Raven and J. H. Court (1996 edition) was used to measure intelligence of the subjects.

2. Concept Maps: After careful analysis of the technique involved in drawing concept maps, eleven concept maps were developed by the investigator based on selected class 1X Chemistry topics. The validity of these maps was established after rigorous discussions with experts in the subject and technique of Concept Mapping. These concept maps formed the basis of instruction imparted to the first experimental group.

3. Criterion Referenced Test: A try out test comprising of 105 objective type test items was administered to the students of the same age group but belonging to a different school than those selected for the actual experiment. Item analysis enabled selection of items for the final form of the test. The criterion referenced test comprised of 40 objective type and short answer questions and was designed to measure concept comprehension and application in Chemistry

XIII. THE EXPERIMENT

The Experiment consists of -

i. Administration of post-test I to measure comprehension and application of concepts.

ii. Administration of post-test II to measure comprehension and application of concepts after a gap of six weeks from the treatment.

iii. Delayed Post-treatment

XIV. INSTRUCTIONAL TREATMENT

The same number of concepts drawn from four Chemistry chapters were taught by the investigator for the same duration (approximately 36 hrs.) to the three groups belonging to class IX of the selected schools.

Chapter 1. The Nature of matter

a) Structure of atom
b) Atoms and molecules
c) Elements
d) Compounds
e) Mixtures
f) Types of mixtures
g) Atomic number and atomic mass
h) Electronic configuration
i) Isotopes and Isobars
.

Chapter 2. Chemical Bonding

a) Octet and Valency
b) Inertness of noble gases
c) Cause of chemical combination
d) Formation of ions
e) Electron dot representation
f) Electrovalent bonds
g) Covalent Bonds
h) Types of covalent bonds
i) Polarity in covalent compounds
j) Shapes of covalent molecules

Chapter 3. Chemical Reaction

a) Types of change
b) Writing chemical equation
c) Types of Reactions
i) Combination Reaction
ii) Displacement reaction
iii) Decomposition reaction
iv) Dissociation reaction
v) Double displacement reaction
vi) Rearrangement reaction
d) Comparing and classifying reactions

Chapter 4. Chemical Equations
a)Balancing chemical equations (Using hit & trial method)
b) Making equations informative
(i) Qualitatively
(ii)Quantitatively
c) Mole concept

The various concepts were categorised into eleven key concepts for inducing simplicity and objectivity while drawing concept maps. The key concepts were- Atom, Matter, Bonding, Electrovalent bonding, Covalent bonding, Change, Qualitative and Quantitative information imparted by equations and Mole concept.

XV. ANALYSIS OF DATA

In the present study ANOVA and t-tests were used to test the significance of difference between means of the three groups. The skewness value of 0.3 satisfies to some extent the first assumption of normally essential to apply ANOVA.The Fx ratio of 0.77 obtained during ANOVA satisfies the second assumption of a random sample, essential for ANOVA. The third assumption i.e. test for homoscedasticity was satisfied when the data collected was tested for its nature of distribution and for homogeneity of variance by the Bartlett's test which gave a non-significant F at 0.01 level, indicating that the groups under investigation had the same variability. Having satisfied the assumptions, a one way analysis of variance was applied. The data was analysed under two heads viz::

(i) Analysis of concept learning: Concept learning is measured as gain score ratio % I (post-test I score – pre-test score) / (maximum marks - pre-test score) x 100

(ii) Analysis of concept retention: Concept retention is measured as gain score ratio % II [|(post-test II score – post-test I score) / (maximum marks - post-test I score)] x 100
The coefficient of correlation between intelligence test score and gain scores was computed and found to be 0.72 being significant at 0.01 and 0.05 levels. Since a high degree of correlation exists between intelligence and achievement, it becomes essential to partial out the effect of intelligence from the dependent variable,

otherwise the experimental results would have been confounded. For this purpose groups were equated (in mean and standard deviation) with respect to intelligence. Further ANOVA was applied to the gain score ratios. In the analysis of variance the significance of F was tested for main effects.

XVI. RESULTS FROM STATISTICAL ANALYSIS

Since analysis was done under two heads viz. concept learning and concept retention, the results are described and interpreted as under

1. CONCEPT LEARNING : RESULTS
ANOVA shows Fx = 0.77
Fy= 11.13
(Here X denotes the intelligence score and Y denotes the gain score ratio percentage).
From the data df 2/108, F0.05 = 3.09 and F0.01 = 4.82 Fx falls short of the required values at both 0.01 and 0.05 levels of significant hence Fx is not significant. This implies that X means do not differ significantly and that the samples are random in the true The F test applied to the final Y scores (Fy =11.13), is significant at both levels of significance. This implies that the
difference between the means of Y's of the three groups is significant and that at least one of the three groups differ from the other two on concept learning outcome. The differential effects of teaching strategies were analysed by means of t-test. The difference between Y means of any two groups, D, and the difference between means, calculated for df =108 using t 0.05 = 1.98
and t 0.01 = 2.63

Following conclusions about the groups can be drawn:
Group E1 and C- Comparison of the differences between means of the two groups reveals that the difference between means of groups E1and C is higher than both D0.05 and D0.01. Thus the difference between means of groups E, and C is significant at both levels. This implies
that the mean of group E1 (taught through the Concept Mapping Model) differs significantly from the mean of control group (taught through the Conventional Method).
Group E2 and C- Comparison of differences between means reveals that the difference between means of groups E2 and C is higher than both D0.05 and D0.01.Thus the difference between means of groups E2 and C is significant at both levels of significance. The mean of group E2 (31.65) being higher than that of group C (20.25), it can be concluded that group E2 has performed better than group C.

Group E1and E2-Comparison of differences between means reveals that the difference between the means of E, and E2 is less than both D0.05 and D0.01. Thus the difference between means of E1 and E2 groups is not significant at either 0.05 or 0.01 level. This implies that the
group E1 is the same as the performance of group E2 on the dependent variable.

FINDINGS AND INTERPRETATION

Finding I- After the data is analysed for its variance the calculated F ratio for intelligence scores ofthe three groups is reported to be 0.77 which is far less than F at 0.05 and 0.01 as observed from the table (F0.05= 3.09 & F0.01= 4.82).

Interpretation I- The three intelligence test score means do not differ significantly and that the samples are random in the true sense.

Finding II- While performing ANOVA, the calculated F ratio for the means of gain score ratios of the three groups is 11.13 which is higher thanF0.05 (3.09) and F0.01 (4.82)

Interpretation II- The means of gain score ratios of the three groups differ significantly, further implying that the three teaching techniques have a significantly different effect on the concept learning outcome.

Finding III- The difference between the gain score ratio means of E1 and C groups is 16.83 which is higher than the difference calculated by using to.05=1.98 and t0.01=2.63 . The D0.05 and D0.01 values are 7.13 and 9.47 respectively.
Interpretation III- The difference between the means of E1and C groups is significant, implying that the Concept Mapping Model and the Conventional Method have varying effect on
the learning outcome. The mean of the former being higher (37.08) than that of the latter
(20.25), the former (i.e. the Concept Mapping Model) is more effective for concept learning
as compared to the latter (i.e. the Conventional Method).

Finding IV- The difference between the gain score ratio means of E2 and C groups is 11.40 which is higher than the difference calculated by using to.05 = 1.98 (D0.05 = 7.31) and t 0.05=2.63 (D 0.01 = 9.47).
Interpretation IV- The finding F4 reveals that the difference between the means of the groups significant at 0.05 and 0.01 levels of significance, implying that the Inductive
Model and the Conventional Method differ significantly the concept learning outcome.
The mean of the former being higher (31.65) than that of the latter (20.25), the former (i.e. the Inductive Model) is more effective for concept learning as compared to the latter (i.e. the Conventional Method).

Finding V- The difference between the gain score ratio means of Ej and E2 groups is 5.43 which isless than the difference calculated by using 10.05=1.98 (D 0.05=7.13) and t 0.05=2.63
(D0.01 =9.47).
Interpretation V- The difference between the means of E1 and E2 groups is not significant, implying that the Concept Mapping Model and the Inductive Model do not differ significantly on the concept learning outcome. Thus the Concept Mapping Model is as effective as the
be Inductive Model in learning concepts in Chemistry

XVII. CONCLUSIONS

On the basis of the above discussion it can be concluded that Concept Mapping Model and the Inductive Model are equally effective in fostering concept learning in Chemistry though the former has an edge over the latter in terms of understanding and application in chemistry.
The conclusions drawn from this study have direct implications for students in developing their cognitive faculties, for teachers and teacher educators in making learning meaningful, and for curriculum developers in designing instructional material according to the needs of the learners and teachers.