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Effectiveness of Concept Mapping Strategy on Cognitive Processes in Science at Secondary Level

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Abstract:

The present study investigated the effectiveness of concept mapping strategy on cognitive processes in science at secondary level. For this pre-test post-test experimental and control group design is used, with 100 samples grouped as experimental group (50) and control group (50) on the basis of matching by intelligence test. The investigators conducted this experiment over twelve weeks by using both traditional and concept mapping strategy. The self-developed achievement test covering class IX text book of West Bengal Board of Secondary Education, India was used as tool. The study found that the students exposed to the concept mapping strategy significantly achieved better than those exposed to the traditional teaching method at their applying, analyzing, evaluating and creating level of cognitive processes. In addition, the students exposed to the concept mapping strategy significantly higher than those exposed to the traditional teaching method in respect to their gain scores at every levels of cognitive processes. The concept mapping strategy is capable of improving student's mastery of content at the higher order levels of cognition. It is therefore recommended that concept mapping should be used in science teaching for the development of student's higher order thinking level.

Key words: concept mapping, cognitive processes, higher order thinking, science, secondary level.

1.0. INTRODUCTION

Learning science is an intellectual search involving inquiry, rational thinking and generalization. The highly conceptual nature of science makes it particularly difficult for students and the strategies used in the classroom have not sufficiently eased the learning process. Learning is purposeful, conscious and complex process (Adey & Shayer, 1994). It is the act of acquiring new or modifying and reinforcing, existing knowledge, behaviours, skills, values or preferences and may involve synthesizing different types of information. Various teaching learning approaches have been developed to accelerate learning process of students in science. But in India, mostly behavioural practices going on in schools where students are passive and classroom are mostly dominated by the teacher. In science education in recent years, the increasing awareness of the importance of learner-centeredness in the teaching learning situation has generated a lot of attention in relation to understanding how learners learn and how to help them learn about concepts (Jegede et.al., 1990). National Curriculum Framework (2005) stresses for the paradigm shift from the behaviourism to constructivism to enhance conceptual learning in science education. To provide meaningful science education, where students' will construct knowledge and teacher will act as facilitators possible through concept mapping strategy.

Concept mapping is one of the teaching learning strategies under constructivism based on David Ausubel's Assimilation theory of cognitive learning for fostering meaningful learning in the classroom (Ausubel et. al., 1978). Concept maps are two dimensional graphical representation of one's knowledge of a domain (Novak & Gowin, 1984). A concept map is a diagram showing the relationship among concepts. It is a graphical tool for organizing and representing knowledge. It includes concepts, usually enclosed in circles or boxes and relationships between concepts indicated by a connecting line

linking two concepts. Words on the line referred to as linking words or linking phrases, specify the relationship between the two concepts (Dammani, 2012).Concept map is similar to a spider chart or a flow chart with interconnections. Another characteristic of concept map is hierarchical nature of the concept map, with more general concepts at the top and more inclusive specific concepts below. Thus a concept map depicts hierarchy and relationships among concepts, which bring clarity of meaning and integration of crucial details. It also makes one think in multiple directions and different levels of abstraction, resulting usually in acquiring deeper understanding of the topic and clarifying misconceptions. Hence concept mapping is an easy way to achieve very high levels of cognitive performance, when the process is done well (Novak and Canas, 2006).

Cognitive processes are processes that involve knowledge and how people use their knowledge. It includes matters such as attention, memory, producing and understanding language, solving problems and making decisions. So, cognitive processes are the performance of some composite cognitive activity. In 1950s Benjamin Bloom developed Taxonomy of cognitive objectives, means of expressing qualitatively different kinds of thinking. It provides way to organize thinking skills into six levels, from the most basic to the more complex levels of thinking (Bloom, 1981). In 1990s Lorin Anderson revisited the Taxonomy and made number of changes. Revised Bloom taxonomy creates understanding the student behaviour and learning outcomes. Taxonomy reflects different forms of thinking and thinking is an active process (Anderson and Krathwohl, 2001). There are six major categories in this taxonomy. These are as follows- Remembering, Understanding, Applying, Analysing, Evaluating and Creating. Among these six categories Analysing, Evaluating and Creating come under higher order thinking process and bottom two categories i.e., Remembering

and Understanding come under Applying category. As students are introduced to new science concepts, they embark on a cognitive process of constructing meaning and making sense by consciously or subconsciously integrating these new ideas with their existing knowledge. Concept maps provide a unique graphical view of how students organize, connect and synthesize information (Vandies et. al., 2005).

2.0. RATIONALE OF THE STUDY

In science education, concept mapping has been widely recommended and used in a variety of ways. Concept mapping has been used to promote positive self-concepts, positive attitudes toward science and increased responsibility for learning (Novak and Gowin, 1984). It has been used to help teachers and students to build an organised knowledge base in a given discipline (Pankratius, 1990, Kopec et.al., 1990).Different research studies indicate that the concept mapping is an effective tool in teaching learning process on academic performance at secondary level in the subject of physics (Bascon and Novak, 1985; Pankratius, 1990, Karakuyu, 2010, Akeju et.al., 2011), in mathematics (Olarewaju and Awofala, 2011, Kaur, 2012) and biology (Jegede et.al., 1990; Esiobu and Soyibo, 1995; Shailaja, 2011; Udeni and Okafor, 2012;Bera and Mohalik, 2013;Sakiyo and Waziri, 2015). On the other hand, concept mapping has been used as a diagnostic tool to assess students' conceptions (Ross and Munby, 1991;Wallace and Mintzes, 1990), for clarifying student's understandings and making connections between concepts explicit as an alternative science classroom achievement assessment (Stoddart et.al.,2000) and assessing for learning processes (Fleener and Marek, 1992).

The analysis of the above research studies found that different researches had conducted on concept mapping strategy but majority of researches were related to academic

achievement of students. There were few studies conducted on concept mapping strategy in India but most of the studies had conducted in English medium schools and urban area. There were no studies found in regional medium schools and the effect of concept mapping strategy on cognitive process as well as higher order thinking level. Therefore need was felt to conduct study on effectiveness of concept mapping strategy on cognitive process in science at secondary level.

3.0. STATEMENT OF THE PROBLEM

The present study is an attempt to investigate the **"Effectiveness of Concept Mapping Strategy on Cognitive Processes in Science at Secondary Level"**.

4.0. OPERATIONAL DEFINITION OF TERMS USED

Concept Mapping: A concept map is a graphic organizer which uses schematic representation to hierarchically organize a set of concepts, connected by means of order to build meaningful statements. After identification of concepts from a unit or sub-unit showing meaningful relationships between concepts in the shape of proposition, the concept map reveals each student's performance of some composite cognitive activity.

Cognitive Processes: In this study cognitive processes can be stated operationally as mental abilities mentioned by Revised Bloom's Taxonomy. It involves process such as Applying, Analyzing, Evaluating and Creating.

Secondary Level: Secondary level is a period of intense physical change and formation of identity. It is also the period of intense vibrancy and energy. Secondary level indicates the students of class IX and X of the school. It refers to the boys and girls individuals falling approximately 14-17 years.

5.0. OBJECTIVES OF THE STUDY

1. To study the effect of concept mapping strategy on cognitive process (applying, analysing, evaluating and creating) in science at secondary level in comparison to traditional teaching strategy.
2. To ascertain the significant difference in gain score of control and experimental group in cognitive process (applying, analysing, evaluating and creating).

6.0. HYPOTHESES OF THE STUDY

1. There will not be significant difference in the cognitive process of students taught by concept mapping strategy and traditional teaching strategy.
2. There will not be significant difference in the gain score of cognitive processes between the control group and experimental group.

7.0. METHODOLOGY

7.1. Research Design:

The present study is an experimental research. The independent variable is concept mapping teaching strategy and the dependent variables is cognitive processes in science. This study adopted a pre-test, post-test equivalent group design. The diagrammatic representation of the design is shown in the following figure-

Experimental group O_1X_1 O_2

Control group O_3 X_2O_4

Where, O_1, O_3 represent pre-test

O_2, O_4 represent post-test

X_1 represents treatment (concept mapping strategy)

X_2 represents treatment (traditional method)

7.2. Sample and Sampling Procedure:

The present study was conducted at Kendradangal High Madrasah (H.S.) in Birbhum district of West Bengal, India. The study was conducted on a sample of 100 students of class IX. These students belong to both the gender, i.e., boys and girls. Students of both control and experimental groups are assigned on the basis of their intelligence score. The students were divided into two groups, i.e., control group (50 students) and experimental group (50 students). The control group was taught through traditional method and experimental group was taught through concept mapping strategy. The effectiveness of concept mapping strategy on cognitive process in science was determined by administering the self developed test on cognitive processes of both the groups.

7.3. Tools

7.3.1. Intervention Tool:

Concept Mapping Lesson Plan: Concept maps were prepared on the selected topics of science and used by the investigators. At first researchers selected the second chapter of life science of class IX book biological process containing plant physiology, respiration, nutrition, circulation and excretion units. Researchers identified concepts and sub concepts from the selected topic and developed concept map against every topic. Researchers developed lesson plan for every class based on concept mapping. Each lesson plan contains major five points. Learning points and learning objectives were fixed for each lesson. Teaching learning process composed of introduction, presentation and summarization. At the end of teaching, researcher assessed the day's lesson through concept map. Home assignment was given by the researcher for the measuring students' understanding of concept map. During teaching learning process researcher explained every topic, concept map was also prepared and discussed in the class. They were also allowed to discuss with peers and also the

investigator helped them to clarify their doubts. After discussion investigator summarized the day's lesson through concept map with the help of students' opinion.

7.3.2. Measuring Tool:

i) **Intelligence Test:** Standard Progressive Matrices (SPM) (2000 Edition: updated 2004) was used for assessing intelligence of the students. There were sixty problems in the test divided into five sets as A, B, C, D and E. the problems are arranged from simple to difficult level. Scoring was done using the instruction given in manual. In the original work with SPM reliabilities range from 0.83-0.93, with the higher values being associated with younger respondents (under 30). From the analysis of the criterion oriented content validity, factorial construct validity and internal validity it has been found that the SPM is a good measure of general intellectual ability.

ii) **Test on Cognitive Processes:** This test was developed by the investigator. The maximum marks of the test were fifty. Test comprised of multiple choice questions, true/false, matching, fill in the blanks, find out odd one, comparison and short answer type questions. Test was constructed based on applying, analyzing, evaluating and creating categories. The test was content validated by taking experts comments and was tested for reliability using test-retest method. The reliability coefficient of 0.82 was obtained.

7.4. Procedure:

The permission of the head of the institution was obtained by the researcher. On the basis of Intelligence score groups were equated in control (traditional teaching) and experimental (concept mapping) group. The both groups were pre-tested using a researcher made achievement test. The experimental

group taught through concept mapping strategy. Researcher had prepared concept maps of all the selected units of biological process covered were plant physiology, nutrition, respiration, circulation and excretion. Concept map was also prepared and discussed in the class. Doubts of students were cleared. They were also allowed to discuss among themselves and with also researcher to clarify their doubts. The control group taught through traditional method. In case of traditional method researcher taught the control group through chalk and talk method and with the help of traditional teaching aids. All topics were taught in the same sequence to experimental as well as to control group. Both experimental and control groups were not aware that they were being involved in a study. The treatment was continuing over 12 weeks. At the end of the treatment the same test was administered in both the groups.

7.5. Data Analysis

The obtained data was analyzed by using mean, standard deviation and t-test. The independent samples t-test was used to compare means on the post test and on the applying, analysing, evaluating and creating components of the cognitive process. Significance level of 0.01 was used. All quantitative data were analysed by using IBM SPSS statistics 20.

8.0. RESULTS

The first objective of this study was to find out effect of concept mapping strategy on cognitive process (applying, analysing, evaluating and creating) in science at secondary level in comparison to traditional teaching strategy. For this investigators, calculated t value for both control and experimental group in post-test, which is given in table-1.

Table.1. Comparison of Means of Variables of Control and Experimental Group in Post Test

Variables	Group	N	Mean	SD	SEM	df	t-value	Significance
Applying	Control	50	8.20	1.565	0.221	49	7.584	0.000
	Experimental	50	9.46	1.432	0.202			
Analyzing	Control	50	8.18	1.587	0.224	49	6.960	0.000
	Experimental	50	9.24	1.302	0.184			
Evaluating	Control	50	8.02	1.450	0.205	49	8.566	0.000
	Experimental	50	9.72	1.565	0.221			
Creating	Control	50	7.62	1.524	0.216	49	7.737	0.000
	Experimental	50	9.20	1.498	0.212			
Cognitive Processes	Control	50	32.14	5.175	0.732	49	12.132	0.000
	Experimental	50	37.74	5.337	0.755			

Table.1. shows the means the means, standard deviations and standard error of mean of the students' post test scores in the applying, analyzing, evaluating and creating levels of cognitive process of the two groups. The results showed significant outcomes in the students' scores at applying level ($t=7.584$, $p<0.01$), analyzing level ($t=6.960$, $p<0.01$), evaluating ($t=8.566$, $p<0.01$) and creating ($t=7.737$, $p<0.01$) of cognitive processes. The overall result showed ($t=12.132$, $p<0.01$) significant outcomes in the students' scores at cognitive processes. Hence the null hypothesis there will not be significant difference 'There will not be significant difference in the cognitive process of students taught by concept mapping strategy and traditional teaching strategy.' is rejected at 0.01 levels. It can be concluded that the students exposed to the concept mapping strategy significantly achieved better than those exposed to the traditional teaching method at their applying, analyzing, evaluating and creating level of cognitive processes.

The investigators also to find out the gain scores of the students in the applying, analysing, evaluating and creating levels of cognitive process of the two groups. The investigators calculated t value for gain score of control and experimental group, which is given in table-2.

Table.2. Comparison of Gain Scores of Variables of Control and Experimental Group in Pre and Post Test

Variables	Group	N	Mean	SD	SEM	df	t-value	Significance
Applying	Control	50	4.34	1.451	0.205	49	5.581	0.000
	Experimental	50	5.68	1.518	0.215			
Analysing	Control	50	4.40	1.678	0.237	49	4.341	0.000
	Experimental	50	5.48	1.502	0.212			
Evaluating	Control	50	4.56	1.487	0.210	49	7.160	0.000
	Experimental	50	6.24	1.492	0.211			
Creating	Control	50	4.88	1.734	0.245	49	7.133	0.000
	Experimental	50	6.52	1.403	0.198			
Cognitive Processes	Control	50	18.25	4.685	0.662	49	11.165	0.000
	Experimental	50	24.01	4.554	0.644			

Table 2. revealed that the means, standard deviations and standard error of means of the students' gain scores in the applying, analysing, evaluating and creating levels of cognitive process of the two groups. The result showed significant outcomes in the students' gain scores at applying ($t=5.581$, $p<0.01$), analysing ($t=4.341$, $p<0.01$), evaluating ($t=7.160$, $p<0.01$) and creating ($t=7.133$, $p<0.01$) levels of cognitive process. The cognitive process showed significant outcomes in the students' gain score ($t=11.165$, $p<0.01$). Hence the null hypothesis there will not be significant difference 'There will not be significant difference in the gain score of cognitive processes between the students taught by concept mapping strategy and traditional teaching strategy.' is rejected at 0.01 levels. These outcomes showed that the students exposed to the concept mapping strategy significantly gain better than those exposed to the traditional teaching method at their applying, analyzing, evaluating and creating level of cognitive processes.

9.0. DISCUSSION

The results of the present study showed that the post-test mean score of the students in the experimental group was found to be significantly better from that of their counterparts in the control group at higher order thinking level. This findings consistent with concept mapping assesses students' structural knowledge which mediates the translation between declarative

knowledge and procedural knowledge (Jonassen et.al., 1993) and higher order abilities (applying, analysing, evaluating and creating) (Novak et al., 1983) which possess some degree of transferability (Liu and Hinchey., 1996). One likely explanation for this finding is that concept mapping enabled the students to break down complex concepts into component sub concepts to see relationships for clarity and at the same time putting together these sub concepts with linking words to form an integrated meaningful whole (Olarewaju and Awofola, 2011). Besides these skills, students were able to make value judgements about arrangement of the concepts and assess the appropriateness of the linking words. All these may have enhanced the better performance of the concept mapping group. Another reason is that concept mapping provides opportunity for active involvement of students in their learning process and hence enhances their thinking ability while cross questioning and thinking for seeking solution (Cheema and Mirza, 2013). Presentation of the concepts to the fellow students brings a greater conceptual clarity for themselves (Freeman, 2004). During the discussion among the peers, learners become aware of their misconceptions. Inconsistent reasoning leads to cognitive conflict. In normal discourse there is a chance that misconceptions can be traced very easily by the teacher or by comparing student made concept maps with the scientifically accepted concept maps (Cheema and Mirza, 2013).

The noticeable impact of concept mapping on students' achievement recorded in this study may be attributed to the characteristics inherent in the use of concept mapping. In this study students were able to comprehend concept meanings, organize concepts in hierarchy and form meaningful relationships between concepts to arrive at a coherent, integrate network of the material learned. Research evidence has indicated that pieces of information are better remembered by students when they are communicated and learned verbally and visually. Concept mapping combines visually learning with

spatial representation of information to promote meaningful conceptual learning. Visual learning according to (Asan, 2007) is absorbing information from illustrations, photos, diagrams, graphs, symbols, icons and other visual models.

10.0. EDUCATIONAL IMPLICATIONS

The present study was conducted on regional medium students to find out the effectiveness of concept mapping strategy on cognitive processes in science. The result of the study found that concept mapping strategy enhancing the cognitive process and higher order thinking level. So, it is useful for parents, teachers, curriculum planner, students, teacher educators, text book writers, researchers, corporate and government organization.

i) Teacher can use the concept map as a tool for teaching and learning science effectively for the development of cognitive process.

ii) Concept mapping strategy can be used as an effective tool to study the science at secondary level and student can be easily constructing their own knowledge with higher order thinking.

iii) The educational administrator can think for training teachers in using concept mapping in their class as it enhances students higher order thinking. The study would also helpful for teachers for creating concept maps for teaching science based on cognitive process.

iv) Curriculum planner may incorporate this strategy in curriculum guidelines for achievement of intended learning outcomes and content development for meaningful and higher order learning.

v) Text book writers may present and organize the content thoughtfully with the help of concept map to children.

11.0. CONCLUSION

The present study reveals that the concept mapping strategy has significantly better effect on cognitive processes in science. The results of the study support that concept map is an effective tool to engage students in higher order thinking level of cognitive process. Adopting concept mapping requires that science teacher have a good knowledge of constructivist learning and the ways in which concept mapping can be used to foster students' thinking. Hence it is suggested that teachers should use the technique of concept mapping while teaching science. Moreover the teachers should be trained to develop and use such maps. This study can be replicated with larger sample size and other subject disciplines. This would determine the most efficient means of using concept mapping for students' benefit.

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