Effect of Concept Mapping Strategy on Cognitive Processes in Mathematics Achievement at Secondary Level

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Abstract- **The present study explored the effect of the concept mapping strategy on the cognitive processes in secondary mathematics achievement. The researcher used a quasi-experimental pretest-posttest equivalent group design. The subjects were the students of Class-IX comprising both boys and girls. The sample had 100 students divided into two groups: a control group of 50 students and an experimental group of 50 students on the basis of matching by Raven's Progressive Matrices intelligence test. The teaching learning process was carried out over three months by the researcher utilising both traditional and concept mapping strategies. As a tool, the researcher made achievement test covering the Class-IX mathematics textbook of the West Bengal Board of Secondary Education in India was employed. According to the findings of the study, students who were exposed to the concept mapping strategy performed much better than those who were studied by traditional method. The current study demonstrates that the concept mapping technique has a considerable influence on cognitive processes (applying, analysing, evaluating and creating) as well as higher order thinking in mathematics achievement. It is recommended that teachers may use the concept mapping technique when teaching mathematics.**

Keywords: **Concept Map, Cognitive Processes, Mathematics Achievement, Higher Order Thinking**

1. Introduction

One of the main strands of human intellectual activity across all countries is learning mathematics. The development of students' individual learning capacities is placed at the forefront of new curricula, which also work to assist students learn how to learn by fostering their keen interest in active inquiry-based constructivist instructional environments and genetic aptitudes for learning (Olarewaju & Awofola, 2011). The constructivist paradigm places more emphasis on the learner than the teacher in order for them to comprehend its components, create their own conceptualizations, and resolve issues. According to NCF (2005), improving conceptual comprehension in science and mathematics training requires a paradigm transformation from behaviourism to constructivism. By identifying the conceptual essence of fundamental concepts from a culture-historical framework, educators must substantially engage the subjects they teach in order to foster the development of mathematical mindfulness. The skilful application of Concept Mapping can strengthen this important aspect of the pedagogical effort. One of the constructivist teaching methods for promoting meaningful learning in classrooms is concept mapping, this is based on David Asubel's Assimilation theory of cognitive learning (Asubel et al., 1978). Concept mapping is a meta-cognitive learning technique used to assess a person's knowledge organization and structure in a particular field of knowledge. According to Novak & Gowin (1984), concept maps are two-dimensional graphics that describe a person's knowledge base. A concept map represents a group of concepts that are linked together and shows the particular connections between concepts upon the links that connect them. Concept maps are organized in a hierarchy. It also forces one to think from many angles as well as various levels of abstraction, which typically leads to a deeper understanding of the subject and the dispelling of misunderstandings (Sukanya, & Shekhar, 2019). Therefore, when properly executed, concept mapping is a simple approach to obtaining very high standards of cognitive performance (Novak & Canas, 2006). The process of learning through our ideas, circumstances, and perceptions is known as cognition. Cognitive processes cover issues like memory, language production and comprehension, problem-solving, and decision-making. Therefore, cognitive processes are the source mix of cognitive skills in action. Factual, conceptual, procedural, and metacognitive knowledge are only a few of the different kinds and degrees of knowledge that taxonomy affects (Anderson & Krathwohl, 2001). This blending can be demonstrated by showing how one is instructing both cognitive processes and knowledge levels. The concept mapping strategy addresses higher-order thinking processes (such as analyzing, evaluating, and creating) among the categories of cognitive processes, whereas traditional methods access lower-level processes (such as remembering, understanding, and applying) (Anderson & Krathwohl, 2001). Students begin a cognitive process of meaning construction and sense building as they become exposed to the new mathematical concepts, either consciously or unconsciously combining these new ideas with prior knowledge.

2. Conceptual Framework of the Study

The use of concept maps as teaching aids has led to fruitful classroom outcomes (Novak et al., 1983). The crucial distinction between rote learning and purposeful learning was highlighted by Asubel et al., 1978. It has been necessary to assist instructors and students in developing a well-organized knowledge base in a particular field (Pankratius, 1990). The reviewed literature demonstrates the positive impact of concept mapping on cognitive processes and students' achievement in mathematics at the secondary level. Concept mapping enhances conceptual understanding, critical thinking, problem-solving skills, and metacognitive abilities (Bera & Mohalik, 2016). Educators can effectively integrate concept mapping as a pedagogical strategy to promote meaningful learning and enhance mathematical proficiency among secondary level students. The use of concept mapping strategy in mathematics instruction at the secondary level positively impacts cognitive processes and mathematics achievement (Sukanya & Shekhar, 2019; Kaur, 2012). It enhances comprehension, critical thinking skills, meta-cognitive awareness, long-term retention and overall mathematical concepts. The findings support the integration of concept mapping as an effective instructional tool for promoting deeper understanding and improved performance in secondary mathematics education (Kumar & Singh, 2017). However, further research is needed to explore the specific conditions and best practices for implementing concept mapping in diverse classroom contexts. The present study is an effort to investigate at the **"Effect of Concept Mapping Strategy on Cognitive Processes in Mathematics of Students' Achievement at Secondary Level"**.

3. Objectives of the Study

1. To find out the effectiveness of concept mapping strategy over the traditional method on cognitive processes (applying, analyzing, evaluating and creating) in mathematics achievement at secondary level.
2. To ascertain the gain scores between experimental and control groups on cognitive processes (applying, analyzing, evaluating and creating) in mathematics students' achievement.

4. Hypotheses of the Study

1. There is no statistically significant difference between the experimental and control groups in the cognitive processes (applying, analyzing, evaluating and creating).
2. There is no statistically significant difference between the experimental and control groups in the gain score of cognitive processes (applying, analyzing, evaluating and creating).

5. Delimitation of the Study

1. The present study is delimited in class IX students on mathematics subject only.
2. The study conducted in Netaji Vidyapith High School (Bengali Medium) of South 24 Parganas District, Basanti sub-division, which is affiliated to West Bengal Board of Secondary Education.

6. Methodology

6.1. Design of the study

The study used a quasi-experimental pre-test-post-test equivalent control group design. The independent variables are concept mapping strategy, traditional teaching strategy and the dependent variables are students' achievement of cognitive processes in mathematics. The tabular representation of the design is as follows-

Table-1. Experimental design of the present study.

Group	Pre-test	Treatment	Post-test
Experimental group	✓	Teaching by concept mapping strategy	✓
Control group	✓	Traditional teaching strategy	✓

6.2. Population ad Sample

The researcher conducted the present study at Netaji Vidyapith High School (Bengali Medium), considering secondary school in Basanti sub division, South 24 Parganas district under the West Bengal Board of Secondary Education as the target population. In present study the researcher used the purposive sampling technique to select the secondary school. The subjects were the students of Class-IX comprising both boys and girls. The sample had 100 students divided into two groups: a control group of 50 and an experimental group of 50.

6.3. Tools

6.3.1. Ravens Progressive Matrices for IQ Measurement: Raven's Progressive Matrices (2000 Edition: updated 2004) is a well-known non verbal intelligence test developed by John C. Raven. It is designed to measure abstract reasoning and problem solving abilities. The test consists of a series of visual patterns presented in a matrix format, with one piece missing. The task is to identify the missing piece from a set of options. The researcher used this tool to measure the IQ of sample students.

6.3.2. **Lesson Plan based on Concept Mapping:** The researcher constructed concept maps on the particular mathematical topics from class-IX mathematics book. The researcher prepared concept maps for each topic based on concepts and sub-concepts from the chosen topics.

6.3.3. **Achievement test on cognitive Processes:** The researcher developed the achievement test on cognitive processes based on mathematics of class-IX. The test included True/False, Matching, Fill in the Blanks, Find the Odd One, Comparison and Short Answer questions. The test was designed with a focus on application, analysis, evaluation, and creation categories. By considering the opinions of experts, the test's content was validated, and the test's reliability was examined using the test-retest approach.

6.4. Procedure of data collection

The researcher visited the target institute and received approval from the head of the institution to conduct the present study. First, the researcher made a good relationship with the students of Class-IX. Then the researcher applied the Ravens Progressive Matrices test to measure the IQ scores of the sample students. Individuals were separated into two groups based on IQ scores: a control group that received instruction using a conventional teaching technique, and an experimental group that received instruction using a concept mapping strategy. The researcher pre-tested both groups by giving them an accomplishment test. The experimental group was instructed using the concept mapping method. The delivery of each topic to each group was done in the same order. The teaching and learning activities were carried out over a three months period for both groups as post-test.

7. Data Analysis

The collected data were stored in excel file and analyzed by IBM SPSS. The researcher used the mean, standard deviation, t-test, and analysis of variance to demonstrate the results after analysis. The post-test and the cognitive processes of applying, analysing, assessing, and constructing components were compared using the independent samples t-test.

Table.2. Comparison of means of variables between control and experimental group in pre-test

Variables	Group	N	Mean	SD	SEM	Mean Diff.	df	t-value	Sig.
Applying	**Cont.**	50	3.92	0.665	0.094	0.040	49	0.330	0.743
	Expt.	50	3.88	1.538	0.084				
Analysing	**Cont.**	50	3.88	0.521	0.074	0.080	49	0.893	0.376
	Expt.	50	3.96	1.488	0.049				
Evaluating	**Cont.**	50	3.84	0.370	0.052	0.040	49	0.444	0.659
	Expt.	50	3.80	1.502	0.070				
Creating	**Cont.**	50	2.86	0.756	0.107	0.100	49	0.962	0.341
	Expt.	50	2.76	1.383	0.101				
Achievement	**Cont.**	50	14.40	0.948	0.134	0.120	49	0.735	0.456
	Expt.	50	14.28	5.032	0.134				

From the above findings, it has been found that the mean difference in applying, analyzing, evaluating, and creating between control and experimental group is insignificant at pre-test ($P>0.05$). The achievement result is insignificant between control and experimental group ($P>0.05$). Additionally, it can be mentioned that there was no treatment administered in the control and experimental group.

Table.3. Comparison of means of variables between control and experimental group in post-test

Variables	Group	N	Mean	SD	SEM	Mean Diff.	df	t-value	Sig.
Applying	**Cont.**	50	7.96	1.538	0.218	1.800	49	9.607	0.000
	Expt.	50	9.76	1.393	0.197				
Analysing	**Cont.**	50	7.90	1.488	0.210	1.580	49	9.335	0.000
	Expt.	50	9.48	1.389	0.196				
Evaluating	**Cont.**	50	7.70	1.502	0.212	2.060	49	10.699	0.000
	Expt.	50	9.76	1.506	0.213				
Creating	**Cont.**	50	7.38	1.383	0.196	2.060	49	11.342	0.000
	Expt.	50	9.44	1.500	0.212				
Achievement	**Cont.**	50	31.05	5.032	0.712	7.440	49	18.984	0.000
	Expt.	50	38.50	4.958	0.701				

From the above table it has been found the mean value is higher in the experimental group than the control group in post-test. The control group students were taught the lesson through traditional teaching strategy, whereas the experimental group students studied the lessons through concept mapping teaching strategy. Therefore, this type of result may be attributed due to the concept mapping teaching strategy. Additionally, the above table reveals that the mean difference in applying, analysing, evaluating and creating between the control and experimental group is statistically significant in post-test at $P<0.05$. The achievement is also supports these findings ($P<0.05$).

Table.4. Analysis of Variance (ANOVA) of Post Test of Experimental Group

Variables	Sum of Square		df	Mean Square	F	Sig.
Applying	Between Groups Within Groups Total	52.156 42.964 95.120	2 47 49	26.078 0.914	28.527	0.000
Analysing	Between Groups Within Groups Total	53.778 40.702 94.480	2 47 49	26.889 0.866	31.050	0.000

Evaluating	Between Groups Within Groups Total	81.463 29.657 111.120	2 47 49	40.731 0.631	64.550	0.000
Creating	Between Groups Within Groups Total	81.168 29.152 110.320	2 47 49	40.584 0.620	65.432	0.000
Achievement	Between Groups Within Groups Total	1047.098 157.402 1204.500	2 47 49	523.549 3.349	156.331	0.000

From the above findings, it has been noted that the F value is 28.527, which is significant at P<0.01level, indicating a relationship between applying and the level of intelligence (high, average and low). Similarly, in case of analyzing, the calculated F value is 31.05, which is significant at P<0.01 level concerning the level of intelligence. Furthermore, the calculated F values are 64.550 and 65.432 in evaluating and creating respectively n relation to the level of intelligence and statistically significant (P<0.01). Lastly, the above table reveals that the F value is 156.331which is statistically significant at P<0.01 indicating a relationship between achievement and the factors being studied.

Table.5. Comparison of gain score between control and experimental group.

Variables	Group	N	Mean	SD	SEM	Mean Diff.	df	t-value	Sig.
Applying	**Cont.**	50	4.01	1.490	0.211	1.98	49	6.747	0.000
	Expt.	50	5.99	1.299	0.183				
Analysing	**Cont.**	50	4.07	1.381	0.195	1.47	49	5.208	0.000
	Expt.	50	5.54	1.410	0.199				
Evaluating	**Cont.**	50	4.04	1.541	0.218	2.07	49	5.881	0.000
	Expt.	50	6.11	1.485	0.210				
Creating	**Cont.**	50	4.56	1.497	0.211	2.05	49	5.518	0.000
	Expt.	50	6.61	1.569	0.222				
Achievement	**Cont.**	50	16.69	4.912	0.695	7.15	49	6.332	0.000
	Expt.	50	23.84	4.513	0.638				

In terms of gain scores, the above table compares the mean of cognitive characteristics between the control and experimental groups. It is noted that each of the experimental and control groups has 50 samples. The table indicates that the calculated t-value for the comparison of applying between the control and experimental group is 6.747, which is significant at P<0.05. The calculated t-value in gain scores are 5.208 and 5.881 in analyzing and evaluating respectively between control and experimental group, significant at P<0.01. Furthermore, the table demonstrates that the t-value found 5.518 and 6.332 in creating and achievement respectively in gain scores. All are statistically significant at P<0.01.

Table.6. Analysis of Variance of Gain scores of Experimental Group

Variables	Sum of Square		df	Mean Square	F	Sig.
Applying	Between Groups Within Groups Total	6.132 76.613 82.745	2 47 49	3.066 1.630	1.881	0.164
Analysing	Between Groups Within Groups Total	3.241 94.179 97.420	2 47 49	1.621 2.004	0.809	0.451
Evaluating	Between Groups Within Groups Total	12.470 95.675 108.145	2 47 49	6.235 2.036	3.063	0.005
Creating	Between Groups Within Groups Total	23.541 97.104 120.645	2 47 49	11.771 2.066	5.697	0.001
Achievement	Between Groups Within Groups Total	163.920 834.300 998.220	2 47 49	81.960 17.751	4.617	0.000

The above table reveals the analysis of variance of different categories of gain scores in experimental group. In case of gain scores of applying and analyzing, there is no statistical significance difference found (P>0.05). There is a statistical significance (P<0.05) has been noted in the gain scores of evaluating and creating categories of cognitive processes. Similarly, in terms of achievement, there is a statistically significance (P<0.01) observed in gain scores.

8. Discussion

The focus of the present study intended to find out how well the concept mapping approach affected secondary school students' ability to think mathematically. According to the findings o the present study, students in the experimental group significantly outperformed those in the control group on the post-test mean score for higher-order thinking. The findings examine students' higher-order thinking abilities, including applying, analysing, evaluating, and producing (Novak et al., 1983). They are consistent with concept mapping. Both of these skills and structural knowledge, which facilitates the transformation of declarative knowledge into procedural knowledge, have some degree of transferability (Bii, 2019; Liu & Hinchey, 1996). Olarewaju & Awofola (2011) state that concept mapping enabled students to clarify linkages between complicated concepts by breaking them down into their component sub concepts and then combining these sub concepts with linking terms to create a cohesive, meaningful whole. Along with these skills, pupils have the ability to assess the relevance of the linking words and pass judgements on the conceptual arrangement. All of these could have contributed to the concept mapping group's improved performance (Bera &Mohalik, 2013). Another reason is that idea mapping gives students the chance to actively participate in their education, which improves their ability to think critically when finding solutions (Cheema & Mirza, 2013). They gain more conceptual clarity when they present the ideas to their fellow classmates (Freeman, 2004). Students discover their misconceptions as a result of the peer conversation. Cognitive conflict is caused by illogical reasoning. The instructor may be able to identify misconceptions in everyday conversation by comparing concept maps created by the students with those that have been approved by science (Hammad et al., 2021), or by seeing how the students respond to questions. According to the study, concept mapping has a discernible impact on students' academic performance. This effect could be attributed to the qualities of concept mapping itself. Students in this study were able to understand definitions of concepts, arrange concepts in a hierarchy, and draw significant relationships between concepts in order to develop a consistent, interconnected network of the information they acquired (Bii, 2019). According to research, when knowledge is conveyed and learnt verbally and graphically, kids are more likely to remember it. Visual learning is the process of learning using pictures, diagrams, graphs, symbols, icons, and other visual representations (Kumar & Singh, 2017; Asan, 2007). Concept mapping blends spatial representation of data with visual learning to encourage meaningful conceptual learning.

9. Conclusion

The current study shows that the concept mapping strategy significantly influences cognitive processes in mathematics achievement. The results of the current study confirm that the concept mapping strategy is a useful tool for fostering the development of higher-order cognitive processes. The achievement result supports this view to a greater extent. Students in the experimental group were given instruction utilizing concept mapping strategy, whereas those who were in the control group were given instruction by traditional teaching strategy. Adopting concept mapping necessitates that the mathematics instructor understands constructivist learning and how concept mapping may be utilised to develop students' thinking. As a result, it is recommended that teachers employ the concept mapping technique when teaching mathematics. Additionally, teachers must be trained on how to make and employ such maps.

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