Concept Mapping: Unleashing the Power of Visual Learning in Science Education

Bishnu Kumar Dahal
Associate Professor, Department of Science Education, Mahendra Ratna Campus, Tribhuvan University, Nepal
Email: bishnume2@gmail.com

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Abstract: *Concept mapping is an effective approach for improving learning in science education by using visual representations of knowledge. The purpose of this quasi-experimental study is to determine the effectiveness of concept mapping as visual representations in increasing understanding of concepts and knowledge retention among secondary school students studying science. The students in the research are divided into two groups: the experimental group (N = 45), which gets instruction using concept mapping methods, and the control group (N = 50), which receives instruction using conventional methods of teaching. Participants in this study were chosen at random from two public secondary schools in Kathmandu and the Lalitpur district. To evaluate both groups' understanding and recall of scientific concepts, a pre-and post-test approach was used. The outcomes of this study will give important insights into the effectiveness of concept mapping as a method of instruction in science education. It is hypothesized that students in the experimental group who participate in concept mapping activities will show better conceptual understanding and retention than students in the control group.*

Keywords: *Concept mapping, Conceptual understanding, Knowledge retention, Science education, Quasi-experimental design, Visual learning*

Introduction

There has been growing recognition in recent years of the value of visual learning strategies in supporting effective instruction and learning in science education. Visual representations, such as concept maps, have long been recognized for their capacity to help students organize their information, understand concepts, and think critically (Novak & Canas, 2008; Safdar, Hussain, İqbal, & Rifat, 2012). Concept mapping, a technique for visualizing connecting concepts and their relationships, has emerged as a potent tool for creating meaningful learning experiences across a wide range of disciplines (Novak & Gowin, 1984)

According to Adey and Shayer (1994), learning is a deliberate, conscious, and intricate process. Environmental, social, motivational, emotional, and cognitive aspects are all connected to learning (Baron & Byrne, 2003; Huffman, 2004; Joyce, Weil, & Calhoun, 2004). Various teaching-learning strategies in science education have been developed to accelerate learning process of students. Learning strategies evolve from the learning theories defining the role of teacher, students and the contents (Iqbal, 2011). Concept mapping is one of the teaching-learning strategies under constructivism having its orientation in David Ausubel's Assimilation theory (1968) of cognitive learning, which aims at fostering meaningful learning by students. By visually capturing the relationships between scientific concepts, concept mapping encourages students to actively engage with the material, identify key ideas, and uncover conceptual hierarchies. This process not only aids in knowledge acquisition but also enhances students' ability to integrate and apply their understanding in problem-solving contexts (Kassab, 2016; Soika, Reiska, & Mikser, 2014). Result of these study revealed that Concept mapping method of teaching is more effective than the conventional method in fostering achievement of students in basic science.

Concept maps were developed in 1972 as part of Novak's research program at Cornell University, where he attempted to follow and explain changes in children's knowledge of science (Novak & Musonda, 1991). Concept mapping is a technique for visually depicting the structure of knowledge, concepts, and their relationships. According to research studies in the field of science education, concept mapping can be used as an effective teaching-learning method from primary school to college levels. Concept maps are used as a tool for meaningful learning, assessment, and instructional planning, as well as identifying alternate concepts or misconceptions held by learners (Enger, 1998; Nesbit & Adesope, 2006; Novak, 1980; Novak & Canas, 2006; Novak & Canas, 2008).

The future prospects of concept mapping in science education lie in its ability to go beyond the conventional linear presentation of information and instead provide a comprehensive and integrated picture of knowledge. Conventional instructions concentrate on strategies for learning designed to teach specific course content. The emphasis is currently on learner-centered strategies and methods that teach learners how to learn. Small group discussions, peer training, computer simulations and games, interactive lecture demonstrations, case studies, concept mapping, and instructional worksheets are examples of these strategies, according to Sealfon (2012).

According to currently recorded data from a myriad of investigations at various levels, students in science education study as a school subject/course in high school have poor academic achievements (Hoffmann, 2002). Several decades of research have revealed that conventional methods of teaching have an adverse effect on the ability of the majority of students to learn physics (Halloun, 1987; Van Heuvelen, 1991). This deterioration of poor performance has been reported to arise as early as lower high school (Hoffmann, 2002) and subsequently compromises enrollment in college (Tobias & Birrer, 1999). Recognizing the major hurdles, attempts have been made to improve students' performance in science.

In the context of Nepal, the researcher witnessed different challenges in the teaching and learning of science in schools as a teacher. The majority of students in schools are uninterested in learning science, which results in low final exams The researcher observed a mismatch between the teacher's teaching style and the student's learning strategies in the classroom. final examination. In this context, a number of issues have been identified as contributing to students' low achievement in science in general, and in physics in particular. Concept mapping, according to Novak and Gowin (1984), can boost the capacity for meaningful learning.

Theoretical Foundation for the Study

Concept mapping is based on the constructivist theory of learning, which holds that knowledge is generated by the learner and allows learners to interrelate isolated concepts through visual representations of what they comprehend (Conceicao & Taylor, 2007). As a theoretical framework, constructivism encourages the creation of meaning and knowledge (Fosnot & Perry, 1996; Phillips, 1995). According to Fosnot and Perry (1996), knowledge is temporary, subjective, internally formed, progressive, and impacted by social and cultural forces. It is believed that people develop their meanings and understandings through a balancing act between previous knowledge and beliefs and newly acquired information and experiences (Virginia Richardson, 1997; Virginia Richardson, 2003; Schunk, 2012). Constructivist knowledge, according to this viewpoint, is a structured framework comprised of concepts that are meaningfully connected. Second, teachers support behaviors that contribute to conceptual growth and meaning-making. Teachers can promote discussion, reflection, and active involvement as learning activities to promote cooperation and meaningful learning. Third, when learners are encouraged by an environment that encourages conceptual change and idea integration, they are perceived as autonomous, which allows them to restructure knowledge by making new links between ideas (Daley, Durning, & Torre, 2016).

As a result, according to constructivism theory, teaching and learning are processes in which students actively participate in the construction of their own knowledge in an environment in which students interact with peers and other members of the learning community (Gredler, 2001). As a consequence, students take an active part in recognizing and clearing their misconceptions, resulting in increasingly accepted knowledge.

In constructivist learning settings, concept maps provide customizable and efficient support systems for varied learners (Melrose, 2013). The use of a constructivist method is also essential in concept mapping practice. Concept maps are teaching tools that allow students to demonstrate their understanding of the concepts covered in a particular domain of knowledge (Marchand, d'Ivernois, Assal, Slama, & Hivon, 2002).

The main objective of the study was to examine the effectiveness of the concept mapping method in selected science classes to the conventional method. The following research questions were examined in this study: What is the achievement score of students in science by teaching concept mapping strategy and conventional method? Does concept mapping strategy improve students' achievement in Science Education?

Hypothesis

The study hypothesized that was a substantial difference in mean achievement between students taught using concept mapping and students taught using conventional methods.

Methods

Research Design

The present study adopted a quasi-experimental research strategy, which included two intact non-equivalent groups with pre-test and post-test. The dependent variable in this study was student achievement, while the independent variable was the instructional technique used.

Population and Sample

The population of the research was selected from Kathmandu Valley's secondary public schools and secondary-level students. The study made use of purposive sampling technique.

Instrument for Intervention

Concept Map was used as an intervention tool for 15 teaching episodes regarding heat and light based on the secondary-level science curriculum for tenth-grade students.

Reliability and Validity of Instrument

The reliability of the teaching episodes was established by allocating some of the aforesaid teaching episodes to different teachers. Expert judgment was used to determine the validity of the instructional episodes.

Data Collection Methods, Tools and Techniques

As a data collection method, the researcher used achievement tests. Two parallel types of achievement test items containing 40 science-related items concentrating on the areas of Heat and Light were produced. These questions were designed to evaluate cognitive domains at many levels, including knowledge, understanding, application, and higher-order thinking (analysis, synthesis, and evaluation).

Reliability and validity of Tools

A pilot test was carried out at another public school that was not sampled in this study to assess the tool's validity and reliability. The pilot test consisted of 40 multiple-choice questions from secondary-level science related to heat and light to be taught. *Techniques for Data Analysis*

The researcher analyzed quantitative data on a computer using the Statistical Package for the Social Sciences (SPSS) version 20 software. The features and patterns of the acquired scores for both groups were examined using descriptive analysis.

Data Analysis and Interpretation

To address the research questions and investigate the effectiveness of concept mapping in the field of science, the data obtained for this study were examined using rigorous statistical approaches. To provide accurate and reliable results, the analytical procedure included numerous phases. The results were interpreted in light of the study objectives and hypotheses. The data were assessed to see if there were any statistically significant differences between the experimental and control groups in conceptual comprehension and knowledge retention.

Research Question 1*: What is the achievement score of students in science by teaching concept mapping strategy and conventional method?*

The answer to the first research question was examined using descriptive statistics as well as an independent sample t-test from software comparing the experimental and control groups of students.

Table 1. *Analysis of Achievement Score Obtained by Experimental and Control Groups in Pre-test*

Group	N	Mean	S.D.	Variance	t-value	p-value	df	Remarks
Control	50	20.80	1.99	3.96				
Experimental	45	20.93	1.78	3.16	0.35	0.73	93	0.35 > 0.05

Table 1 shows an analysis of the experimental and control groups' pretest achievement results. An independent sample t-test and SPSS software were used to analyze this. The mean pre-test scores for the experimental and control student groups were 20.80 and 20.93, respectively. The calculated standard deviation and variance in the control groups were 1.99 and 3.96, respectively. The computed variance and standard deviation for experimental groups were 1.78 and 3.16, respectively. The t-value was determined to be 0.35, while the p-value was found to be 0.73. The two-tailed test with a degree of freedom 93 was declared significant at the 0.05 p-value level since the computed p-value exceeded the standard deviation.

Conclusion: The null hypothesis was supported by the findings of this study. The results indicate that there were no significant differences in the science achievement of students between the control and experimental groups. These findings lead to the conclusion that the experimental group and control group were comparable and homogeneous prior to the test.

Research Question 2*: Does concept mapping strategy improve students' achievement in Science Education?*

The response to the second research question was examined using descriptive statistics as well as an independent sample t-test from software comparing the experimental and control groups of students.

Table 2. *Analysis of Achievement Score Obtained by Experimental and Control Groups in Post-Test*

Group	N	Mean	S.D.	Variance	t-value	p-value	df	Remarks
Control	50	20.94	1.878	3.527	10.667	.000	93	0.00< 0.05
Experimental	45	26.09	2.704	7.310				

Significant at 0.05 levels

Table 2 compared the achievement scores attained by students taught using the concept mapping teaching approach with the conventional method in the post-test. This was examined using the SPSS software's independent sample t-test. The mean pre-test scores of the control and experimental groups of students were 20.94 and 26.09, respectively. In control groups, the computed standard deviation and variance were 1.88 and 3.53, respectively. While the computed standard deviations and variances for the experimental groups were 2.70 and 7.31, respectively. The calculated t-value was 10.67 and the p-value was 0.00. Since the calculated p-value was less than the standard deviation p-value of 0.05 level of significance employing two-tailed tests with a degree of freedom was 93. Conclusion: Hence, the null hypothesis was rejected in favor of the alternative hypothesis. The findings suggest a significant difference in the achievement scores between students taught using the concept mapping teaching method and those taught using the conventional method in the context of science education. Specifically, the results indicate that the achievement scores of students who received instruction through the concept mapping teaching method were superior to those of students who received instruction through the conventional method.

Discussion and Results

This study investigated the effectiveness of concept mapping as a method of instruction in science education and how it affected students' conceptual understanding and knowledge retention. The findings showed that concept mapping considerably increased students' post-test scores when compared with conventional methods of instruction that were without concept mapping. The difference in means (Table 2) of the control group and experimental group student achievement was found to be significant after intervention with concept mapping to the experimental group. As a result, the null hypothesis was rejected, whereas the alternative hypothesis was accepted. Therefore, it may be concluded that concept mapping is more effective than conventional methods of teaching in improving student achievement in science.

The findings of this research line up with prior studies highlighting the benefits of concept mapping in fostering meaningful learning experiences (Ainsworth & VanLabeke, 2004; Jena, 2021). Furthermore, the findings are consistent with those of Horton, McConney, Gallo, Woods, Senn, & Hathelin (1993), who conducted a meta-analysis of research on the use of concept mapping as an instructional tool to determine its effectiveness in terms of student overall achievement. In addition, Yunus (2010) discovered that drawing concept maps was more effective than conventional methods in increasing the science achievement of participating students. Concept mapping helps students identify key ideas and relationships by providing a visual representation of scientific topics. Educators can improve students' learning and integration of scientific knowledge by actively engaging students in the development of concept maps (Novak & Canas, 2008).

In addition, the findings of the current study also support those of Mesrabadi, Hosseini Nasab, and Fathi Azar (2009), Sakiyo and Waziri (2015), Malekzadeh, Ghasemizad, Taheri, and Mashayekh (2020), and Kardan, Hatami, and Fathi Azar (2016) on the effect of concept maps on academic achievement.

The results of this study support the use of concept mapping aligning with the principle of constructivist theory as a successful method of instruction in science education. Concept mapping improves meaningful learning experiences by utilizing visual representations and encourages active interaction with the subject matter (Ainsworth & VanLabeke, 2004). The findings add to the present body of information on visual learning strategies, emphasizing the potential of concept mapping in enhancing conceptual understanding and better knowledge retention.

Conclusion

In conclusion, this study illustrates the effectiveness of concept mapping in science teaching. The results show that concept mapping improves students' conceptual understanding and knowledge retention. Educators can create interesting and effective learning environments that develop students' scientific literacy and knowledge by unleashing the potential of visual learning through concept mapping.

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