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EFFECT OF CONCEPT MAP ON LEARNERS' INHIBITORY CONTROL, WORKING MEMORY, AND COGNITIVE FLEXIBILITY IN SECONDARY SCHOOL STUDENTS

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ABSTRACT

Concept mapping is an effective instructional strategy widely used in teaching–learning processes; however, limited research has examined its impact on learners' executive function. The present study aimed to investigate the effect of concept mapping on inhibitory control, working memory, and cognitive flexibility among secondary school students.

A purposive sample of 150 Class IX students was selected and divided into three groups: two experimental groups (Spider Map and Hierarchical Map approaches) and one control group (traditional method), each comprising 50 students. The study employed a pre-test–post-test non-equivalent quasi-experimental design (Jena, 2011). Pre-tests and post-tests were administered to assess executive function components.

Data were analyzed using t-tests and ANOVA. The results showed that the experimental groups achieved higher post-test mean scores than the control group, indicating that concept mapping strategies are more effective than traditional methods in enhancing learners' executive function.

KEYWORDS: *Concept Map, Spider Map, Hierarchical Map, Inhibitory Control, Working Memory, Cognitive Flexibility, Executive Function*

AN INTRODUCTION

Over the past four decades, perspectives on the development of executive function have undergone significant revision. Earlier research suggested that the cognitive processes underlying executive function—such as thinking and goal-directed mental activity—emerged primarily during early adolescence, coinciding with the maturation of the frontal lobes necessary for higher-order cognition (Golden, 1981). However, subsequent empirical evidence has challenged this assumption, demonstrating that executive function begins to develop much earlier. Foundational components, including inhibitory control and working memory, have been observed even during infancy (Diamond, 1985; Diamond & Doar, 1989; Diamond & Goldman-Rakic, 1989). Research in the 1980s, particularly within developmental psychology and neuroscience, highlighted purposeful behaviors in infants and toddlers, thereby initiating extensive inquiry into the early development of executive function. Contemporary understanding now recognizes executive function as a gradually evolving set of cognitive processes that continue to develop across childhood and adolescence. In this context, the present study seeks to assess key components of executive function—namely working memory, inhibitory control, and cognitive flexibility—among secondary school students.

Concept mapping represents a pedagogical strategy with considerable potential to enhance learners' executive functioning. The construction of concept maps requires students to systematically plan and organize information, engaging core executive processes such as working memory, cognitive flexibility, and inhibitory control. Learners must identify essential concepts, determine relationships among them, and represent these connections in a coherent visual format. This process also demands selective attention, as students are required to focus on relevant information while disregarding extraneous details. Furthermore, the iterative refinement of concept maps encourages learners to evaluate and reorganize their understanding, thereby strengthening planning and organizational skills. Through these processes, concept mapping offers meaningful opportunities for learners to actively practice and develop executive function abilities, ultimately supporting improved academic performance and adaptability in diverse learning contexts.

Concept Mapping: Concept mapping is a visual technique used to organize, structure, and represent knowledge, ideas, and relationships among concepts. It involves the graphical depiction of concepts, typically enclosed within nodes such as boxes or circles, with connections between them illustrated through lines or arrows to indicate relationships. This structured representation facilitates the understanding of complex information by making conceptual linkages explicit.

Concept maps serve multiple purposes, including supporting the generation of new ideas, enhancing problem-solving, and promoting deeper comprehension of intricate subject matter. They can be constructed manually or through various digital tools and are widely applied across diverse contexts such as education, business, and research. As a cognitive and instructional strategy, concept mapping is particularly valuable for organizing information systematically, fostering creativity, and clarifying complex concepts in a coherent and accessible manner.

Executive function: Executive function comprises a set of higher-order cognitive processes responsible for the regulation and coordination of thoughts, emotions, and actions. These processes include attention, working memory, cognitive flexibility, inhibitory control, as well as planning and organization. Attention enables individuals to focus on relevant stimuli while filtering out distractions. Working memory supports the temporary storage and manipulation of information necessary for task completion. Cognitive flexibility allows individuals to shift between tasks or mental frameworks and adapt to changing demands. Inhibitory control facilitates the suppression of impulsive responses and resistance to distractions or temptations. Planning and organizational skills enable individuals to set goals, devise strategies, and effectively execute complex tasks.

Executive function plays a critical role in a wide range of everyday activities, including problem-solving, decision-making, planning, and goal-directed behavior. Impairments in these processes can result in challenges across academic, social, and occupational domains. However, executive function is malleable and can be enhanced through targeted cognitive training, supportive environmental conditions, and appropriate lifestyle practices, thereby improving overall functioning and adaptability.

Working Memory: Working memory (WM) is a core component of executive function that involves the temporary storage and active manipulation of information, particularly information that is no longer directly available in the immediate environment (Baddeley & Hitch, 1994). It is commonly categorized into two domains based on the nature of the information processed: verbal working memory and nonverbal (visuospatial) working memory.

Working memory plays a fundamental role in comprehension and learning, as it enables individuals to retain previously encountered information and integrate it with incoming input. This capacity is especially important for understanding concepts that unfold over time, where continuous updating and integration of information are required. Consequently, working memory is crucial for learning in domains such as science, where the assimilation of sequential and interrelated concepts is essential for meaningful understanding.

Inhibition Control: Inhibitory control refers to the capacity to regulate one's attention, behavior, thoughts, and emotions in order to suppress dominant or automatic responses, whether internally driven or externally triggered, and to engage in more appropriate, goal-directed actions. This executive function enables individuals to resist impulses, override habitual patterns of thinking or behavior, and manage the influence of distracting environmental stimuli.

The ability to exercise inhibitory control is essential for adaptive functioning, as it allows individuals to act in a deliberate and flexible manner rather than responding automatically to impulses or learned routines. By supporting self-regulation and intentional behavior, inhibitory control facilitates thoughtful decision-making and the adjustment of responses in accordance with situational demands.

Cognitive Flexibility: Cognitive flexibility encompasses several interrelated processes, including the ability to update or modify information in working memory, shift attention, and transition between different response sets. These components are particularly important in the assessment of young children's cognitive development. One widely used measure of working memory in early childhood is the Delayed Alternation task (Espy et al., 1999). In this task, a child searches for a reward hidden under one of two locations, such as wells or cups. When the child successfully identifies the correct location, the reward is subsequently relocated to the alternate position; if the response is incorrect, the reward remains in the same place (Espy et al., 1999). Successful performance on this task not only reflects working memory capacity but also requires the ability to adjust search strategies and, in older children, to recognize and apply an alternating pattern.

For older children, particularly at the elementary level, self-ordered search tasks are commonly employed to assess working memory. These tasks typically involve maintaining and continuously updating information—often of a visuospatial nature—within short-term memory. Together, such tasks provide valuable insights into the development of working memory and cognitive flexibility during early and middle childhood.

SIGNIFICANCE OF THE STUDY

Concept mapping is an effective instructional strategy that enhances academic performance by promoting meaningful learning. It helps learners understand complex information by organizing it into structured, interconnected units, thereby facilitating the integration of new knowledge with prior understanding. Its visual format also improves retention by combining verbal and graphical representations, strengthening memory processes.

In addition, concept mapping fosters critical thinking by requiring learners to analyze, organize, and synthesize information. It supports better organization of ideas, leading to more coherent academic work, and increases learner engagement and motivation. The process also promotes metacognitive skills, as students reflect on their understanding and regulate their learning.
Executive function, particularly inhibitory control, plays a crucial role in long-term academic and life outcomes. Working memory involves both storing and manipulating information, while cognitive flexibility enables individuals to adapt their thinking to changing situations. These components are interrelated yet distinct, with strong links to higher-order cognitive processes.

Within this framework, concept mapping can enhance executive function by engaging working memory through information organization, strengthening inhibitory control by focusing attention on relevant concepts, and promoting cognitive flexibility through the restructuring of knowledge. Therefore, examining the impact of concept mapping on these executive function components is essential.

OBJECTIVES

1. To study the effects of Concept Mapping strategies on learner's inhibition control of secondary school students.
2. To study the effects of Concept Mapping strategies on learner's working memory of secondary school students.
3. To study the effects of Concept Mapping strategies on learner's cognitive flexibility of secondary school students.

HYPOTHESIS

H1 There is no effects of concept mapping strategies on learner's inhibition control of secondary school students.
H2 There is no effects of concept mapping strategies on learner's working memory of secondary school students.
H3 There is no effects of concept mapping strategies on learner's cognitive flexibility of secondary school students.

METHODOLOGY OF THE STUDY

Participants: Approximately 150 students aged 14–16 years were selected through purposive sampling from three schools in the Cachar district of Assam, India. The study employed a three-group design, comprising two experimental groups and one control group. The experimental groups were taught using the Spider Map and Hierarchical Map approaches, while the control group received traditional instruction. The study aimed to examine the effect of concept mapping strategies on students' academic achievement, with specific focus on executive function components—working memory, cognitive flexibility, and inhibitory control.

Design of the study: The study employed a pre-test–post-test non-equivalent quasi-experimental design, with two experimental groups and one control group selected purposively (Jena, 2011). All groups were assessed on executive function components—working memory, cognitive flexibility, and inhibitory control—before and after a three-month intervention. This design allowed for the evaluation of changes in executive function resulting from the applied instructional strategies.

Tools to be used

Instructional tools: In this study researcher had developed three instructional tools like teaching through Traditional method approach as an instructional tool for control group only. And teaching through Spider map and Hierarchical approach as an instructional tool for both experimental groups.

Measuring tools: Researcher had developed an achievement test before and after the experiment to measure student's academic performance on life science learning on class IX, followed by standardized test construction steps like planning, preparation, try out, and evaluation.

Procedure of conducting experiment

For this experimental study the main objective of the study to find out the effect of concept mapping technique on student's executive function for that reason researcher had selected five chapter on class IX Life science book, and prepared concept map of all five chapter. Researcher had taught one experimental group through Spider map approach, another experimental group through Hierarchical map approach, and another control group through Traditional approach.

ANALYSIS AND RESULTS

Between-Subjects Factors			
		Value Label	N
Group	1.00	Control Goup	50
	2.00	Experimental Group (Higherarchial concept Map)	50
	3.00	Experimental Group (Spider Concept Map)	50

Descriptive Statistics			
Dependent Variable: Difference			
Group	**Mean**	**Std. Deviation**	**N**
Control Goup	.3400	.62629	50
Experimental Group (Higherarchial concept Map)	5.6800	2.07453	50
Experimental Group (Spider Concept Map)	9.4000	2.08982	50
Total	5.1400	4.11093	150

Levene's Test of Equality of Error Variances[a]			
Dependent Variable: Difference			
F	df1	df2	Sig.
15.623	2	147	.000
Tests the null hypothesis that the error variance of the dependent variable is equal across groups.			
a. Design: Intercept + Group			

Tests of Between-Subjects Effects

Dependent Variable: Difference

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[b]
Corrected Model	2073.960[a]	2	1036.980	343.247	.000	.824	686.494	1.000
Intercept	3962.940	1	3962.940	1311.759	.000	.899	1311.759	1.000
Group	2073.960	2	1036.980	343.247	.000	.824	686.494	1.000
Error	444.100	147	3.021					
Total	6481.000	150						
Corrected Total	2518.060	149						

a. R Squared = .824 (Adjusted R Squared = .821)

b. Computed using alpha = .05

FINDINGS AND DISCUSSION

The findings of the present study indicate that, at the level of higher-order thinking, the post-test mean scores of students in the experimental groups were significantly higher than those of the control group. These results are consistent with the theoretical foundations of concept mapping, which emphasize the development of higher-order cognitive skills such as application, analysis, evaluation, and creation. Concept mapping also facilitates the development of structural knowledge, which serves as a bridge between declarative and procedural knowledge (Jonassen et al., 1993; Novak et al., 1983; Liu & Hinchey, 1996).

One possible explanation for these findings is that concept mapping enables students to deconstruct complex ideas into smaller, more manageable components, thereby making it easier to identify relationships among concepts. Through the use of linking words, learners can integrate these elements into a coherent and meaningful structure (Awofola, 2011). Additionally, the process requires students to evaluate the appropriateness of conceptual links and to make judgments regarding the hierarchical organization of ideas, further strengthening their analytical and evaluative abilities.

Another contributing factor may be the active engagement promoted by concept mapping. This strategy encourages learners to participate actively in the learning process, enhancing their critical thinking and problem-solving skills through activities such as cross-referencing and collaborative discussion (Cheema & Mirza, 2013). Interaction among peers can also promote awareness of underlying assumptions, leading to cognitive conflict when inconsistencies arise. Such conflicts provide opportunities for the identification and correction of misconceptions, either through teacher guidance or by comparing student-generated maps with established conceptual frameworks.

The effectiveness of concept mapping may also be attributed to its capacity to support meaningful learning through both verbal and visual representation. By organizing concepts hierarchically and illustrating their interrelationships, students develop an integrated understanding of the subject matter. Research suggests that information presented through both textual and graphical formats is more effectively retained. In this regard, concept mapping aligns with principles of visual learning, which involve the processing of information through images, diagrams, symbols, and other visual representations (Asan, 2007). Consequently, the combined cognitive and visual features of concept mapping contribute to its positive impact on students' academic performance.

Educational implications

The present study, conducted among students studying in a regional medium, sought to examine the impact of the concept mapping approach on the executive functions—namely cognitive flexibility, working memory, and inhibitory control—of Class IX students in life science. The findings revealed that the use of concept mapping significantly enhanced these components of executive function, as well as students' higher-order thinking abilities.

The implications of the study are relevant for a wide range of stakeholders, including researchers, educators, policymakers, curriculum developers, students, teacher educators, textbook authors, and parents. First, teachers can effectively utilize concept mapping as a pedagogical tool to facilitate the teaching and learning of life science, thereby promoting students' cognitive development. Second, students can actively construct their own understanding through the use of concept mapping, which supports higher-order thinking and meaningful learning at the secondary school level.

Third, educational administrators are encouraged to provide professional training for teachers in the use of concept mapping, given its potential to foster advanced cognitive skills among learners. Teachers may also integrate concept maps into their instructional practices to support concept-based learning aligned with cognitive processes. Fourth, curriculum planners can incorporate concept mapping strategies into curriculum design to achieve intended learning outcomes and promote deeper, more meaningful engagement with subject content. Finally, textbook authors can employ concept maps as an organizational and representational tool to present subject matter in a structured and learner-friendly manner, thereby enhancing students' comprehension and retention.

CONCLUSION

The findings of the present study indicate that the concept mapping approach exerts a significantly positive influence on key components of executive function, including inhibitory control, working memory, and cognitive flexibility, within the context of life science education. The results further suggest that concept mapping serves as an effective instructional strategy for promoting higher-order thinking by actively engaging learners in executive processes.

For effective implementation, life science teachers should possess a sound understanding of constructivist learning principles and the role of concept mapping in facilitating critical thinking and meaningful knowledge construction. Accordingly, it is recommended that teachers incorporate concept mapping techniques into their instructional practices. In addition, systematic training should be provided to educators to enhance their competence in designing and utilizing concept maps effectively in the classroom.

Future research may extend this study by including larger and more diverse samples, as well as by exploring its applicability across different subject domains. Such investigations would contribute to identifying optimal strategies for implementing concept mapping to maximize its benefits for learners' cognitive development.

REFERENCE

1. *Alloway, T. P., Gathercole, S. E., Willis, C. & Adams. A. (2004). A structural analysis of working memory and related cognitive skills in early childhood. Journal of Experimental Child Psychology. 87 (2):85-106. doi:10.1016/j.jecp.2003.10.002.*
2. *Awofala,A.O.A. (2011). Effect of Concept Mapping Strategy on Students' Achievement in Junior Secondary School Mathematics. International Journal of Mathematics Trends and Technology. 2(3).*
3. *Baddeley, A. D., & Hitch, G. J. (1994). Developments in the concept of working*
4. *Cheema, A.B., & Mirza, M.S. (2013). Effect of Concept Mapping On Students' Academic Achievement. Journal of Research and Reflections in Education, 7(2), 125 -132. http://www.ue.edu.pk/jrre*
5. *D'Esposito, M., Postle, B. R., Ballard, D., & Lease, J. (1999). Maintenance versus*
6. *Diamond, A. (1985). Development of the ability to use recall to guide action, as ndicated by infants' performance on AB. Child Development, 56(4), 868 883.*
7. *Diamond, A., & Goldman-Rakic, P. S. (1989). Comparison of human infants and rhesus monkeys on piaget's AB task: evidence for dependence on dorsolateral prefrontal cortex. Experimental Brain Research, 74(1), 24–40.*
8. *Diamond, A., &Doar, B. (1989). The performance of human infants on a measure of frontal cortex function, the delayed response task. Developmental Psychobiology, 22(3), 271–294.*
9. *Espy, K. A., Kaufmann, P. M. McDiamid, M. D.,&kGtisky, M.L. (1999). Executive*
10. *Evidencefor multiple manipulation processes in prefrontal cortex. Brain Research, 1123, 145–156.*
11. *G.Hynd & J. Obrzut (Eds.), Neuropsychological assessment of the school-aged child, (pp.277–302). New York: Grune& Stratton.*
12. *Golden, C. (1981). The Luria-Nebraska children's battery: Theory and formulation. In hctioninginpreschool children: Perfcwtnancc on A-not-B and other delayed response fonnattasks. Bruin and Copition.41. 178-199.*
13. *Jena. A.K. (2012). Does constructivist approach applicable through concept maps to achieve meaningful learning in Science?. Asia-Pacific Forum on Science Learning and Teaching, 13(1).*
14. *Jonassen, D., Mayes, T., & McAleese, R. (1993). A manifesto for a constructivist approach to uses of technology in higher education. In Designing environments for constructive learning (pp. 231-247). Berlin, Heidelberg: Springer Berlin Heidelberg.*
15. *Liu, Q., Zhu, X., Ziegler, A. & Shi, J. (2015). The effects of inhibitory control training for pre-schoolers on reasoning ability and neural activity. 4. doi:10.1038/srep14200.*
16. *Liu, X., & Hinchey, M. (1996). The internal consistency of a concept mapping scoring scheme and its effect on prediction validity. International journal of science education, 18(8), 921-937.*
17. *Novak, J.D., Gowin, D.B., & Johansen, G.T. (1983). The use of concept mapping and knowledge vee mapping with junior high school science students. Science Education, 67(5), 625-645.*
18. *Spiro, R.J. &Jehng, J. (1990). Cognitive flexibility and hypertext: Theory and technology for the non-linear and multidimensional traversal of complex subject matter. D. Nix & R.*