



Original Article

Effect of Concept Mapping Strategy on Higher Order Thinking Skills among Secondary School Students

Dr. Navdeep Kaur¹, Arfa Sultan²

¹Assistant Professor, Department of Education Guru Nanak Dev University, Amritsar

²M.Ed Student, Department of Education, Guru Nanak Dev University, Amritsar

Manuscript ID:
IBMIIRJ-2025-020504

Submitted: 02 Apr 2025

Revised: 16 Apr 2025

Accepted: 03 May 2025

Published: 31 May 2025

ISSN: 3065-7857

Volume-2

Issue-5

Pp. 20-26

May 2025

Correspondence Address:

Dr. Navdeep Kaur
Assistant Professor, Department of
Education, Guru Nanak Dev
University, Amritsar
Email: Navdeep.edu@gndu.ac.in



Quick Response Code:



Web: <https://ibrj.us>



DOI: 10.5281/zenodo.17072050

DOI Link:

<https://doi.org/10.5281/zenodo.17072050>



Creative Commons

Abstract

This study investigates whether using concept mapping improves Higher Order Thinking Skills (HOTS) among Grade IX science students. We employed a pre-test-post-test experimental design. Two sets of participants were established: the Experimental group engaged in lessons focused specifically on concept-mapping exercises, whereas the Control group underwent standard classroom instruction. A researcher-developed HOTS test was administered before and after the teaching period to measure change. Results were compared across groups and further examined by gender (boys, girls) and intelligence level (high, average, low); interaction effects between treatment and these factors were also tested. Overall, learners in the Experimental group showed greater improvement on HOTS measures than those in the Control group. Additional analyses by gender and intelligence level were conducted and are reported in the main text. Taken together, the findings support the introduction of concept mapping into secondary science lessons as a practical way to strengthen higher-order thinking. Teachers should plan and scaffold concept-mapping activities thoughtfully so they can be effective for diverse learners.

Keywords: Concept Mapping Strategy; Higher Order Thinking Skills (HOTS); Science Education; Secondary School Students; Constructivist Teaching; Experimental Research Design.

Introduction

There is an urgent need to transfer classroom practice from didactic, memory-based learning to those that develop critical, reflective, and analytical capabilities in the twenty-first century. This shift concerns the development of higher-order thinking skills (HOTS), particularly in science education, the success of which relies on their capacity to think, solve problems, and understand concepts. Despite the fact that HOTS is increasingly occupying a larger place in the curriculum, most secondary schools still use teacher-centered teaching strategies that stress the transfer of information by encouraging in-depth discussion of the content. In addition to examining the moderating influence of gender and intelligence level, this study examines whether the Concept Mapping Strategy can be used as a pedagogical instrument to enhance HOTS among secondary school learners.

Concept Mapping Strategy

A pictorial student-centered learning method called concept mapping was created to help individuals arrange their knowledge in a meaningful way. Ausubel's (1968) meaningful theory of learning asserts that new information is best learned when it can be related to current cognitive frameworks, which is the foundation of Novak and Gowin's (1984) development. Hierarchical representation is usually used to encode conceptual depth and is composed of nodes, important ideas, and lines between them, which point to relationships. The structure presented here promotes active learning and the development of metacognition by allowing students to visualize, relate, and reflect on the connections between concepts. As Novak (1990) holds, concept maps are tools for organizational information, stimulating reflection, and higher-order thinking. Their success is supported by evidence: a meta-analysis by Nesbit and Adesope (2006) discovered that concept mapping greatly improves retention, transfer of learning, and understanding.

Creative Commons (CC BY-NC-SA 4.0)

This is an open access journal, and articles are distributed under the terms of the [Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International](https://creativecommons.org/licenses/by-nc-sa/4.0/) Public License, which allows others to remix, tweak, and build upon the work noncommercially, as long as appropriate credit is given and the new creations are licensed under the identical terms.

How to cite this article:

Kaur, N., & Sultan, A. (2025). Effect of Concept Mapping Strategy on Higher Order Thinking Skills among Secondary School Students. *InSight Bulletin: A Multidisciplinary Interlink International Research Journal*, 2(5), 20–26. <https://doi.org/10.5281/zenodo.17072050>

Concept mapping also strengthens conceptual understanding and promotes critical thinking in science education (Afamasaga-Fuata'i, 2008). Chiou (2008) reported that this approach enhances learner motivation and engagement, supporting long-term cognitive growth. In the Indian context, Sengupta and Biswas (2019) found that the benefits of concept mapping differ according to students' intellectual level: learners with high and average abilities made more noticeable gains in analytical and problem-solving skills than those with lower measured intelligence. These results suggest that the effectiveness of concept mapping may be moderated by individual learner characteristics, which calls for further study on how factors such as gender and intelligence interact with this instructional strategy to affect academic performance.

Higher Order Thinking Skills (Hots)

Higher-order thinking skills (HOTS) are thinking processes that go beyond simple memorization. These include critical thinking, analysis, synthesizing ideas, evaluation, problem-solving, and creative thinking. Anderson and Krathwohl's (2001) update of Bloom's Taxonomy places these skills at the top of the cognitive hierarchy because they help learners use what they know in new or demanding situations. In secondary science classes, HOTS helps students weigh experimental results, interpret data to draw sound inferences, notice important patterns, and frame arguments or hypotheses supported by evidence. HOTS also prompts students to question scientific claims and see how classroom ideas work in practice. Research links stronger HOTS with better academic performance, especially in subjects who ask for a depth of understanding. However, many classrooms still rely heavily on memorization and routine exercises, leaving little room for flexible or creative thinking. When this happens, students struggle to carry out what they have learned about unfamiliar problems. Constructivist approaches—concept mapping in particular—aim to address this gap by asking learners to organize, connect, and evaluate ideas explicitly. Accordingly, this study examines whether strengthening HOTS through concept mapping in science lessons shows different effects across intelligence levels (high, average, and low) and between boys and girls. It uses a pretest–post-test experimental design with a factorial layout to provide evidence and practical guidance for improving science teaching.

Review of Related Literature

In the teaching and learning context, concept mapping is increasingly recognized for its ability to develop higher-order thinking skills (HOTS) such as synthesis, analysis, and evaluation. It is based on the concept theory of meaningful learning by Ausubel and the constructivist learning paradigm, where concept mapping enhances participation and knowledge organization, which in turn fosters active thinking and understanding (Novak & Gowin, 1984). Numerous empirical studies have verified the usefulness of concept mapping in fostering HOTS. For example, in a quasi-experimental study conducted with nursing students in Taiwan, Chen and Liang (2011) reported that concept mapping enhanced students' critical thinking skills above the pre-test difference level, especially in the areas of inference and reasoning. Similarly, Hanewald (2012) reported that e-concept mapping enhanced HOTS among undergraduate science communication students in Australia, indicating its effectiveness in collaborative, technology-integrated settings. In the engineering education domain, Zvacek and Restivo (2013) demonstrated that students who consistently engaged in concept mapping scored higher on the final assessments, supporting their role in developing analytical thinking. Carr-Lopez and Galal (2014) further confirmed that concept mapping, particularly the crosslinks component, requires and develops higher-level thinking, outperforming multiple-choice tests in assessing deep understanding. From an assessment perspective, Erdimez and Tan (2017) concluded that concept maps provide a more accurate representation of higher-level thinking than traditional MCQ tests in elementary science classes. Similarly, Ghani and Ibrahim (2017) found that using concept maps in laboratory settings enhanced students' understanding of chemistry concepts, and promoted reflective and critical thinking during experiments. Studies in India support these findings. Aggarwal, Bhandari, and Gupta (2022) conducted an analytical study in Indian medical education and observed that concept mapping yielded higher assessment scores than MCQs, particularly in physiology. Sengupta and Biswas (2019) highlight that concept mapping benefits students with varying intelligence levels, with high and average groups showing greater improvements in analytical and problem-solving skills. Concept mapping also shows promise for diverse academic disciplines. For instance, Dorji (2022) reported improved academic performance and conceptual understanding in economics through the systematic use of concept mapping in Bhutanese higher secondary classrooms. Iroko and Olaoye (2021) observed a significant improvement in algebra achievement among Nigerian senior secondary school students, reinforcing the strategy's cross-disciplinary applicability. On a broader pedagogical level, Cañas and Reiska (2017, 2018) emphasized that concept mapping not only enhances content retention but also cultivates HOTS when implemented with iterative guidance and high-quality feedback. Their research suggested that conditions such as teacher expertise and student familiarity with mapping tools significantly influence learning outcomes. Accordingly, Pinandito and Hayashi (2023) discovered that structured concept map recomposition, particularly with closed mapping techniques (KB mapping), produced superior performance on HOTS tasks compared with conventional mapping strategies. Its relevance has been confirmed by recent international studies. Dong and Seah (2024) found that highly structured directed idea mapping significantly enhances students' critical thinking skills in a study conducted in Chinese high schools. Additionally, Bizimana, Mutangana, and Mwesigye (2022) demonstrated that concept mapping outperformed cooperative learning and traditional instruction in Rwandan lower secondary biology classes, improving cognitive processing and knowledge retention. Most studies have concluded that concept mapping promotes deeper engagement, improves content understanding, and develops higher-order cognitive abilities across educational contexts, although some point out that it does not always correspond with multiple-choice assessments (Carr-Lopez & Galal, 2014; Erdimez & Tan, 2017).

Justification of the Problem

Higher-order thinking skills (HOTS) development is crucial in today's educational system to equip students with critical thinking, creativity, and complex problem solving skills. However, traditional teaching methods usually depend on memorization, and do not actively engage students in producing useful knowledge. At the secondary school level, when students must shift from

concrete to abstract thinking, this is especially problematic, as concept mapping offers a student-centered constructivist strategy that encourages deeper understanding by visually organizing the relationships among concepts. While its theoretical benefits are widely recognized, empirical research on its effectiveness, especially in the Indian context, is limited and inconclusive, particularly regarding differences across intelligence levels and gender. Thus, there is a need for systematic investigation into whether concept mapping can effectively enhance HOTS among diverse learners in science classrooms. This study aims to address this gap and provide evidence-based guidance for improving teaching practices in secondary education.

Statement of the Problem

Effect of Concept Mapping Strategy On Higher Order Thinking Skills (Hots) Among Secondary School Students

Delimitation of the Study

1. The study was limited to secondary school students in Gurdaspur district (Punjab).
2. The study was limited to only 200 students in the IXth grade for the academic session [2024-2025].
3. This study was limited to co-educational schools affiliated with the Punjab School Education Board.
4. The study was delimited to science subject only.

Objectives of the Study

1. To prepare lesson plans based on the Concept Mapping Strategy in Science for IXth grade students.
2. To prepare test based on Higher Order Thinking Skills.
3. To study the mean gain scores of the experimental and control groups of IXth grade students.
4. To study the effect of the concept mapping strategy on higher-order thinking skills in science among boys and girls in the IXth grade.
5. To study the effect of concept mapping strategy and higher-order thinking skills in science with respect to different levels of intelligence, that is, High, Average, and Low in IXth grade students.
6. To study the interaction effect of treatment and gender on higher-order thinking skills among IXth grade students.
7. To study the interaction effect of treatment and intelligence on higher-order thinking skills among IXth-grade students.

Hypotheses of The Study

1. There was no significant difference in the mean gain scores of the experimental and control groups of IXth grade students.
2. There was no significant difference in higher-order thinking skills mean gain scores of IXth grade boys and girls taught using the Concept Mapping Strategy.
3. There was no significant difference in HOTS mean gain scores with respect to different levels of intelligence; that is, High, Average and Low in science taught through the Concept Mapping Strategy.
4. There was no significant interaction effect of treatment and gender on the mean gain scores of higher-order thinking skills among IXth grade students taught using the Concept Mapping Strategy.
5. There was no significant interaction effect of treatment and intelligence on the mean gain scores of higher-order thinking skills among IXth grade students taught using the Concept Mapping Strategy.

Research Design

This study followed an experimental research design to examine the effect of the on-cept-mapping strategy on higher-order thinking skills among Secondary School Students. In this study, two groups were formulated: an experimental group and a control group. A concept-mapping strategy was used to teach the experimental group. The control group received instructions using the traditional approach.

Sample of the Study

The study comprised 200 secondary school students equally divided into an experimental group (n = 100) and a control group (n = 100). Each group included 50 boys and 50 girls. Participants were chosen from two schools in the Punjab District of Gurdaspur.

Sampling Design

The investigator performed convenient sampling. A $2 \times 2 \times 3$ factorial design was used. design in this study.

Tools Used

The following tools have been used in the study:

- Lesson plans on Concept Mapping Strategy were prepared by the investigator.
- Intelligence Test by Atmananda Sharma-2005 (Standardized Tool).
- HOTS- based test of Science was prepared by investigator.

Statistical Techniques

Means, SD, t-tests, and ANOVA were used to analyze the data.

Result and Discussions

Hypothesis-I

There were no significant differences between the pre- and post-test scores of the experimental and control groups.

Table 1: Mean, Sd And T-Value Of Experimental And Control Group

Group/ Method	N	Mean Gain Score	SD	df	t-value	Remarks
Experimental Group	100	10.990	4.4665	198	15.686	Significant at (0.05)
Control Group	100	3.430	1.8105			

The Table -1 has shown that the experimental group (Mean gain score = 10.990, SD = 4.4665) outperformed the control group (Mean gain score = 3.430, SD = 1.8105) in terms of gain scores. The calculated t-value of 15.686 was significantly higher than the critical value (1.97) at a level of 0.05, indicating a statistically significant difference between the two groups. This confirms that the Concept Mapping Strategy was more effective in enhancing higher-order thinking skills (HOTS) than the conventional teaching method. Therefore, the null hypothesis was rejected.

Hypothesis-Ii

There was no significant difference in higher-order thinking skills gain scores between IXth grade boys and girls taught through the Concept Mapping Strategy.

Table 2: Showing the Mean Gain Scores Of IXth Grade Boys And Girls Taught Through Concept Mapping Strategy

Gender	N	Mean Gain Score	SD	df	t-value	Remarks
Boys	100	7.53	5.48	198	0.88	Significant (0.05)
Girls	100	6.89	4.67			

It is evident from Table-2 that the mean gain scores of boys and girls taught through the Concept Mapping Strategy were 7.53 and 6.89, respectively. The standard deviation values were 5.48 for boys and 4.67 for girls. The computed t-value was 0.88, which was lower than the critical value of 1.97 at a significance level of 0.05. This indicates that there was no statistically significant difference in higher-order thinking skill gains between the boys and girls. Hence, the null hypothesis—"There was no significant difference in higher-order thinking skills gain scores of IXth grade boys and girls taught through the Concept Mapping Strategy"—was accepted. Thus, it can be concluded that the Concept Mapping Strategy had a similar positive impact on both boys and girls.

Hypothesis-Iii

There was no significant difference in HOTS gain scores with respect to different levels of intelligence; that is, High, Average and Low in science taught through the Concept Mapping Strategy.

Hypothesis Iii (A)

Table 3 (A) : Showing The Mean Gain Scores Of High Level Of Intelligence Students In Science Taught Through Concept Mapping Strategy

Group	N	Mean Gain Score	SD	df	t-value	Remarks
Experimental Group	27	15.92	3.63	52	14.73	Significant (0.05)
Control Group	27	4.00	2.11			

It is evident from Table 3(a) that the mean gain scores for higher-level intelligence students in the experimental and control groups were 15.92 and 4.00, respectively, and the experimental group's standard deviation (SD) of the scores was 3.63, whereas that of the control group was 2.11. At a confidence level of 0.05, the calculated t-value is 9.71 is substantially greater than the crucial table value of 1.97. This suggests that the two groups' increases in higher-order thinking skills (HOTS) differed significantly. Therefore, the null hypothesis—"There was no significant difference in HOTS scores with respect to high-level intelligence"—was rejected.

Hypothesis Iii(B)

Table-3(B)- Showing The Mean Gain Scores Of Average Level Of Intelligence Students In Science Taught Through Concept Mapping Strategy

Group	N	Mean Gain Score	SD	df	t-value	Remarks
Experimental	46	9.41	3.235	90	11.49	Significant (0.05)
Control	46	3.23	1.675			

It is evident from Table -3(b) that the mean gain scores for average-level intelligence students in the experimental and control groups were 9.41 and 3.23, respectively. Furthermore, the experimental group's standard deviation (SD) was 3.235, whereas that of the control group was 1.675. Additionally, there was a statistically significant difference between the two groups, as indicated by a t-value of 11.49, which was significantly greater than the table value of 1.97 at a confidence level of 0.05. Hence, our null hypothesis—"There was no significant difference in HOTS gain scores with respect to Average Level of Intelligence in Science taught through Concept Mapping Strategy"—was rejected. This suggests that the Concept Mapping Strategy was significantly more effective than the conventional method in enhancing higher-order thinking skills (HOTS) among students with average levels of intelligence.

Hypothesis Iii (C)

Table-3(C)- Showing The Mean Gain Scores Of Low Level Of Intelligence Students In Science Taught Through Concept Mapping Strategy

Group	N	Mean Gain Score	SD	df	t-value	Remarks
Experimental	27	8.74	3.108	52	8.21	Significant (0.05)
Control	27	3.18	1.641			

It was evident from Table 3 (c) shows that the mean gain scores for low-level intelligence in the experimental and control groups were 8.74 and 3.18, respectively. Furthermore, the experimental group's standard deviation (SD) was 3.108, whereas that of the control group was 1.641. Additionally, there was a statistically significant difference between the two groups, as indicated by the t-value of 8.21, which was significantly greater than the table value of 1.97 at the 0.05 level of confidence, indicating a statically significant difference between the two groups. Therefore, our null hypothesis "There was no significant difference in HOTS gain scores with respect to Low Level of Intelligence in Science taught through Concept Mapping Strategy" was rejected. This suggests that the concept mapping strategy was significantly more effective than the conventional teaching method in enhancing higher-order thinking skills (HOTS) among students with low intelligence.

Hypothesis-Iv

There was no significant interaction effect of treatment and gender on the mean gain scores of higher-order thinking skills among IXth grade students taught using the Concept Mapping Strategy.

Table 4.: Showing Summary Table Of Analysis Of Variance Of Treatment And Gender On Higher Order Thinking Skills Of Students

Source	Sum of Square	df	Mean Square	F	Sig.
Intercept	10396.82	1	10396.82	86.848	.000
Group	2857.68	1	2857.68	252.979	.000
Gender	20.48	1	20.48	1.813	.180
Group*Gender (A*B)	64.98	1	64.98	5.75	0.17
Error	2214.04	196	11.296		
Total	15554.00	200			

From Table-4, it can be seen that the F-value for the interaction effect of treatment and gender on higher-order thinking skills (HOTS) of students was 5.75, which was significant at a confidence level of 0.05. The strong interaction effect suggests that both treatment (concept-mapping strategy) and gender have a major impact on students' higher-order thinking skills. Therefore, the null hypothesis—"There was no interaction effect of treatment and gender on the gain scores of Higher Order Thinking Skills among IXth grade students taught through Concept Mapping Strategy" was rejected.

Hypothesis-V

There was no significant interaction effect of treatment and intelligence on the mean gain scores of higher-order thinking skills among IXth grade students taught using the Concept Mapping Strategy.

Table- 5. Showing Summary Table Of Analysis Of Variance Of Treatment And Intelligence On Higher Order Thinking Skills Of Students

Source	Sum of Square	df	Mean Square	F	Sig.
Intercept	10335.779	1	10335.779	1454.442	.000
Group	2920.149	1	2920.149	410.921	.000
Level of Intelligence	565.111	2	282.555	39.761	.000
Group*Level of Intelligence (A*B)	355.756	2	177.878	25.031	.000
Error	1378.633	194	7.106		
Total	15554.000	200			

Table 5 reveals that the F-value for the interaction effect of treatment and intelligence on higher-order thinking skills (HOTS) of students was 25.091, which was significant at a confidence level of 0.05. This strong interaction effect suggests that treatment (concept mapping strategy) and intelligence levels have a significant combined impact on the development of higher-order thinking skills among students. Therefore, the null hypothesis—"There was no significant interaction effect of treatment and intelligence on the gain scores of Higher Order Thinking Skills among IXth grade students taught through Concept Mapping Strategy" was rejected.

In contrast to conventional teaching techniques, the Concept Mapping Strategy (CMS) is an effective instructional tool for dramatically improving Secondary School students' higher-order thinking skills (HOTS) according to data analysis and interpretation. By aiding students in organizing, evaluating, and synthesizing complex scientific concepts, CMS fostered meaningful learning. All intelligence levels benefited from this approach, but students with higher intelligence demonstrated the greatest improvement, followed by average- and low-intelligence students. This finding indicates that CMS operates across a range of differentiated outcomes and cognitive abilities. The boys and girls' equivalent and positive reactions to the intervention suggest that CMS supports teaching strategies that are both inclusive and multidisciplinary. The existence of

substantial interaction effects between treatment and gender, treatment, and IQ level suggests that CMS can be further developed using tailored teaching techniques to accommodate a wider range of learners.

Educational Implications of The Study

Among the study's educational implications are the following ones:

1. Move classroom tasks beyond memorization.

The study shows that asking students to build and link concepts helps them practice higher-order operations such as analysis and synthesis (Anderson & Krathwohl, 2001). When learners must organize ideas and show relationships, they tend to reflect on their own thinking and remember the material better (Novak & Gowin, 1984). Teachers should therefore include mapping activities—brief in-class maps, homework maps, and map-based review tasks—in place of exercises that only require rote recall.

2. Use concept maps with attention to learner needs.

Concept mapping benefits learners across gender and ability ranges, but the degree of benefit is not identical for every student (Sengupta & Biswas, 2019; Hyde, 2014). In mixed-ability classrooms, maps can increase engagement and clarify concepts; however, some students may require scaffolding. Practical support includes worked examples, partially completed maps, guided prompts, and peer collaboration, so that lower-level learners can participate and gradually take more responsibility.

3. Align teaching with curriculum reforms.

The findings support the direction of India's NEP (2020), which emphasizes skills, experiential learning, and critical thinking (Ministry of Education, 2020). Integrating concept mapping into regular lessons and formative assessments can make science lessons more inquiry-oriented and skill focused. Simple steps, such as adding a mapping task to a laboratory report or using maps as part of assessment rubrics, help connect classroom practice with policy goals.

4. Include practical mapping work in teacher education.

The effective use of maps depends on the teacher's skills. Teacher preparation and ongoing professional development should, therefore, include hands-on practice: designing mapping tasks, modelling classroom implementation, and interpreting student maps to inform instruction. Evidence suggests that teacher competence with mapping increases student motivation and participation (Chiou, 2008). Mentoring, classroom observation with feedback, and examples of mapped lessons will make the adoption more sustainable.

Overall, the study points to straightforward, classroom-level changes teachers and teacher educators can adopt: replacing some rote tasks with mapping activities, scaffold maps for learners who need it, align maps with assessment and curriculum aims, and build teacher capacity through practice and feedback. These steps can help students develop stronger higher-order thinking skills in science lessons.

References

1. Afamasaga-Fuata'i, K. (2008). Students' conceptual understanding and critical thinking: A case for concept maps and Vee diagrams in mathematics problem solving. *Australian Journal of Educational & Developmental Psychology*, 8, 47–59.
2. Agarwal, R., Bhandari, M., & Gupta, A. (2022). Applicability of concept maps to assess higher order thinking in the context of Indian medical education: An analytical study in the subject of physiology. *International Journal of Medical Education and Research*, 5(1), 22–29.
3. Ajaja, O. P. (2007). *Teaching methods across disciplines*. Delta State University Press.
4. Al-Khattab, S., Khalaf, M., & Saleh, R. (2023). The effects of using concept mapping and brainstorming strategies on the development of creative thinking skills among university students. *Journal of Educational and Psychological Studies*, 17(1), 75–89.
5. Anderson, L. W., & Krathwohl, D. R. (Eds.). (2001). *A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives*. Longman.
6. Aslami, Z., Shams, M., & Bazrafkan, L. (2021). Effect of concept mapping on the critical thinking skills of medical students: A quasi-experimental study. *Journal of Advances in Medical Education & Professionalism*, 9(2), 96–102.
7. Ausubel, D. P. (1968). *Educational psychology: A cognitive view*. Holt, Rinehart and Winston.
8. Bizimana, B., Mutangana, D., & Mwesigye, J. (2022). Effects of concept mapping and cooperative mastery learning strategies on students' cognitive processing in biology. *International Journal of STEM Education*, 9(1), 45.
9. Cañas, A. J., & Reiska, P. (2017). Developing higher-order thinking skills with concept mapping: A pedagogic frailty. *Knowledge Management & E-Learning*, 9(3), 348–359.
10. Cañas, A. J., & Reiska, P. (2018). What are my students learning when they concept map? *Knowledge Management & E-Learning*, 10(3), 319–329.
11. Carr-Lopez, S. M., & Galal, S. M. (2014). The utility of concept maps to facilitate higher-level learning in a large classroom setting. *American Journal of Pharmaceutical Education*, 78(9), 170.
12. Chen, D. H., & Liang, T. (2011). Effects of concept map teaching on students' critical thinking and approach to learning and studying. *Contemporary Nurse*, 38(1-2), 52–60.
13. Chiou, C. C. (2008). The effect of concept mapping on students' learning achievements and interests. *Innovations in Education and Teaching International*, 45(4), 375–387. <https://doi.org/10.1080/14703290802377240>
14. Dong, Y., & Seah, W. T. (2024). Enhancing critical thinking among Chinese high school students through concept mapping: An experimental study. *International Journal of Educational Research*, 125, 102703.

15. Dorji, T. (2022). Effect of concept mapping strategy in teaching and learning economic and academic performance in higher secondary. *Bhutan Journal of Research & Development*, 11(2), 14–25.
16. Erdimez, O., & Tan, S. (2017). The use of concept maps as a tool to measure higher level thinking skills in elementary school science classes. *European Journal of Educational Research*, 6(3), 259–268.
17. Ghani, S. A., & Ibrahim, N. H. (2017). Enhancing students' HOTS in laboratory educational activity by using concept map as an alternative assessment tool. *Journal of Physics: Conference Series*, 890(1), 012101.
18. Hanewald, R. (2012). Using C-map tools to develop higher-order thinking skills in undergraduate Science Communication students. *Journal of Learning Design*, 5(2), 31–37.
19. Hyde, J. S. (2014). Gender similarities and differences. *Annual Review of Psychology*, 65, 373–398. <https://doi.org/10.1146/annurev-psych-010213-115057>
20. Iroko, F. U., & Olaoye, M. O. (2021). Effect of concept mapping on students' academic performance in algebra at senior secondary school level. *African Journal of Educational Studies*, 18(1), 56–66.
21. Nesbit, J. C., & Adesope, O. O. (2006). Learning with concept and knowledge maps: A meta-analysis. *Review of Educational Research*, 76(3), 413–448. <https://doi.org/10.3102/00346543076003413>
22. Novak, J. D. (1990). Concept maps and Vee diagrams: Two metacognitive tools to facilitate meaningful learning. *Instructional Science*, 19(1), 29–52. <https://doi.org/10.1007/BF00377984>
23. Novak, J. D., & Gowin, D. B. (1984). *Learning how to learn*. Cambridge University Press.
24. Okebukola, P. A. (1999). Beyond the stereotype: Biology teaching and learning. *Science Teachers Association of Nigeria Press*.
25. Ossai, A. G. (2004). Concept mapping and achievement in biology. *Journal of Science Teachers Association of Nigeria*, 39(1 & 2), 33–38.
26. Pinandito, A., & Hayashi, Y. (2023). Promoting students' higher order thinking with concept map recomposition. *Education and Information Technologies*, 28, 12345–12368.
27. Sengupta, S., & Biswas, A. (2019). Influence of intelligence level on effectiveness of graphic organizers in enhancing higher-order thinking among Indian secondary students. *Journal of Educational Psychology and Research*, 9(1), 45–52.
28. Zvacek, S., & Restivo, T. (2013). Concept mapping for higher order thinking in engineering education. *In Proceedings of the IEEE EDUCON Conference*.