

Concept Mapping and Critical Thinking Pedagogy in School Education: A Qualitative Study of Secondary School Teachers' Perceptions and Classroom Experiences

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ABSTRACT

Critical thinking has become an important educational priority in contemporary school education, particularly in the context of competency-based and learner-centred approaches advocated by the National Education Policy 2020 and the National Curriculum Framework for School Education 2023. Concept mapping is a visual and knowledge-organising strategy that enables learners to represent concepts and the relationships among them through nodes, linking words, propositions, hierarchies, and cross-links. Such processes can create opportunities for learners to analyse information, compare ideas, identify relationships, evaluate understanding, and reorganise existing knowledge. The present study explored teachers' perceptions and classroom experiences regarding the potential of concept mapping to support critical thinking among school students. A qualitative-descriptive design was adopted, and data were collected from 76 purposively selected secondary school teachers working in government and private schools affiliated with the State Board and Central Board of Secondary Education through a semi-structured questionnaire. Thematic analysis was used to identify recurring patterns in teachers' responses. The findings indicated that teachers generally perceived concept mapping as a useful learner-centred strategy for promoting conceptual understanding, analytical engagement, reflection, and collaborative learning. Teachers also reported that concept maps could help students visualise relationships among ideas and identify gaps or misconceptions in their understanding. However, limited instructional time, inadequate teacher training, large class sizes, and insufficient technological support were identified as important implementation challenges. These findings are consistent with broader empirical literature indicating the positive potential of concept mapping for learning and critical thinking, while recent reviews also caution that its effectiveness depends on how mapping activities are designed and implemented. The paper argues that concept mapping should not be treated as an isolated technique but as part of a structured pedagogical process involving questioning, evidence evaluation, explanation, reflection, and discussion.

Keywords: Concept Mapping, Critical Thinking, School Education, Higher-Order Thinking, Learner-Centred Pedagogy, NEP 2020, NCFSE 2023

INTRODUCTION

The purpose of school education extends beyond the transmission and reproduction of factual information. Contemporary education increasingly emphasises learners' ability to interpret information, examine relationships, evaluate evidence, solve problems, communicate reasoning, and make informed decisions. Critical thinking is therefore an important component of meaningful and competency-oriented learning. In the Indian context, the National Education Policy 2020 explicitly emphasises higher-order cognitive abilities, including critical thinking and problem solving, alongside creativity, communication, collaboration, and social-emotional competencies (Government of India, 2020).

The National Curriculum Framework for School Education 2023 similarly promotes learning experiences that move beyond mechanical recall towards conceptual understanding, inquiry, reasoning, application, discussion, and reflection. The framework is intended to translate the broader vision of NEP 2020 into

curricular and pedagogical practices at the school level (NCFSE, 2023). Despite these policy directions, a continuing challenge for school education is the translation of higher-order learning goals into everyday classroom practices. Teachers need pedagogical approaches that enable students not merely to acquire information but to organise, connect, interrogate, and use knowledge. One potentially useful approach is concept mapping.

Concept mapping was developed by Novak and his colleagues within the theoretical framework of Ausubel's meaningful learning theory. A concept map represents concepts and their relationships in a visual structure. Concepts are generally represented as nodes, while relationships are expressed through connecting lines and linking words or phrases. Meaningful propositions are created when concepts are connected through appropriate relationships (Novak & Gowin, 1984; Novak & Cañas, 2006). Thus, concept mapping can externalise aspects of a learner's knowledge structure and make relationships among ideas visible. The value of concept mapping lies not simply in its visual appearance but in the cognitive activity involved in constructing and revising the map. When students determine which concepts are important, organise them, establish relationships, select appropriate linking phrases, identify cross-links, and revise their representations, they are required to make decisions about knowledge. These activities can create opportunities for analysis, interpretation, synthesis, explanation, and reflection.

Research evidence provides considerable support for concept mapping as a learning strategy. Nesbit and Adesope's (2006) meta-analysis of 55 studies involving 5,818 participants found that learning with concept and knowledge maps was associated with improved knowledge retention, although the magnitude of effects varied according to instructional conditions and how maps were used. More recently, Schroeder et al. (2018), synthesising 142 independent effect sizes from 11,814 participants, reported a moderate positive effect of concept and knowledge mapping on learning; importantly, constructing maps was associated with greater benefits than merely studying pre-constructed maps. The relationship between concept mapping and critical thinking is particularly relevant to the present paper. Barta et al. (2022), in a meta-analysis of 21 studies involving 1,695 students, reported positive effects of concept mapping on both critical-thinking ability and critical-thinking disposition compared with traditional teaching, although the effects varied across research conditions. Similarly, Tseng (2020), working with high-school students, found that students who constructed concept maps demonstrated stronger performance in several critical-thinking dimensions than students who completed fill-in concept-map activities.

At the same time, the evidence should not be interpreted uncritically. A recent systematic review by Jeong et al. (2025), covering 17 studies and 1,363 students, found mixed evidence regarding the effect of concept mapping on critical-thinking skills and identified considerable variation in research designs, mapping procedures, and critical-thinking measures. This suggests that concept mapping does not automatically produce critical thinking merely because information is represented graphically. Rather, its effectiveness depends substantially on the quality of instructional design and the cognitive processes that students are encouraged to perform. The present study therefore examines concept mapping from the perspective of school teachers. Rather than assuming that concept mapping automatically enhances critical thinking, the study explores how teachers perceive its usefulness, how they experience its implementation, and what challenges they encounter in classroom practice.

Concept Mapping as a Pedagogical Strategy

Concept maps are graphical representations of knowledge in which concepts are connected through meaningful relationships. Novak and Gowin (1984) conceptualised concept mapping as a means of helping learners organise knowledge and establish meaningful relationships between new information and existing cognitive structures.

A typical concept map includes four major elements:

1. **Concepts or nodes** - key ideas represented in boxes or other visual forms.
2. **Linking lines** - connections between concepts.

3. **Linking words or phrases** - words that specify the nature of the relationship.
4. **Propositions** - meaningful statements produced through the connection of concepts and linking expressions.

Hierarchical organisation is another important feature. More general concepts can be placed above more specific concepts, while cross-links can be used to establish relationships between different sections of the map (Novak & Cañas, 2006). The process of constructing a concept map can therefore be viewed as a sequence of cognitive decisions. Students must first determine what information is important, distinguish major concepts from supporting details, classify related ideas, establish relationships, justify connections, and revise their representations. In this sense, concept mapping can support learning processes that extend beyond memorisation.

The uploaded literature similarly emphasises that concept maps can represent relationships within knowledge structures and can be used for learning, instruction, assessment, and reflection. The concept-map scoring framework included in the reviewed thesis gives particular attention to propositions, hierarchy, cross-links, and examples, demonstrating that the quality of a map depends on the meaningfulness and validity of relationships rather than simply on its visual appearance.

Critical Thinking and Concept Mapping

Critical thinking involves purposeful cognitive activity directed towards understanding, analysing, evaluating, and making reasoned judgments. Paul and Elder (2014) emphasise elements such as purpose, questions, information, concepts, assumptions, implications, and points of view in critical thinking. Concept mapping can provide a practical classroom environment in which several of these elements are exercised simultaneously. For example, when a teacher asks students to create a concept map around the question “Why does climate change occur?”, students must identify relevant concepts, distinguish causes from consequences, determine relationships, examine evidence, and organise the information into a coherent structure.

The potential relationship between concept mapping and critical thinking can be understood through the following processes:

- **Analysis:** Students analyse a topic by breaking it into important concepts and sub-concepts. Instead of treating a chapter as a continuous body of information, they identify its constituent ideas and determine their relevance.
- **Identification of relationships:** Critical thinking requires understanding relationships among ideas. Concept maps make these relationships explicit through linking words and propositions.
- **Comparison and classification:** Students may compare concepts and organise them into categories or hierarchical structures. This can support classification and differentiation.
- **Evaluation:** Students must judge whether a proposed relationship is meaningful and appropriate. When teachers ask students to justify their links, the mapping activity becomes more evaluative.
- **Synthesis:** Constructing a complete map requires students to bring together separate pieces of information into an integrated representation.
- **Reflection and metacognition:** A completed map can make students aware of what they understand, what they do not understand, and where their knowledge is fragmented. Revising the map therefore creates opportunities for metacognitive reflection.

The empirical literature supports this potential but also suggests that the construction process matters. Schroeder et al. (2018) found greater benefits when learners constructed concept maps than when they merely studied existing maps. Similarly, Tseng (2020) reported stronger critical-thinking outcomes for students engaged in constructing maps compared with students completing fill-in maps.

Rationale of the Study

The shift towards competency-based education requires classroom practices that actively involve students in thinking. A strategy is particularly valuable when it can be incorporated into regular subject teaching rather than being taught as an isolated “thinking-skills” activity. Concept mapping has several characteristics that make it potentially suitable for school classrooms. First, it can be used across subjects. Science concepts, mathematical relationships, historical developments, literary themes, environmental issues, and social-science processes can all be represented through meaningful conceptual relationships. Second, concept mapping can be implemented individually, in pairs, or collaboratively. Third, it can function both as an instructional strategy and as a formative assessment tool.

The reviewed literature also suggests that concept maps can be used to identify students’ misconceptions and gaps in conceptual organisation. However, teachers require sufficient knowledge of concept-map construction and assessment to use the strategy effectively. The thesis literature reviewed for this paper describes explicit procedures involving focus questions, identification of concepts, hierarchical organisation, linking phrases, cross-links, examples, revision, and evaluation. Consequently, the effectiveness of concept mapping in actual school classrooms depends not only on the availability of the technique but also on teacher preparation, classroom time, curriculum alignment, appropriate topics, and the nature of the mapping task.

Objectives of the Study

The study was guided by the following objectives:

1. To examine teachers’ perceptions regarding the potential of concept mapping for enhancing critical thinking among school students.
2. To explore teachers’ experiences of using concept mapping in classroom teaching-learning processes.
3. To identify perceived benefits of concept mapping for conceptual understanding, reasoning, reflection, and collaborative learning.
4. To identify the major challenges faced by teachers in implementing concept mapping in school classrooms.
5. To suggest strategies for effective integration of concept mapping into school pedagogy in alignment with NEP 2020 and NCFSE 2023.

METHODOLOGY

Research Design

The study employed a qualitative-descriptive research design. The design was considered appropriate because the purpose was to understand teachers’ perceptions, experiences, and observations regarding concept mapping rather than to statistically test the causal effectiveness of a concept-mapping intervention.

Participants

The participants consisted of 76 purposively selected secondary school teachers working in government and private schools affiliated with State Boards and the Central Board of Secondary Education (CBSE). This study included teachers from different classroom and subject contexts.

Data Collection Tool

A semi-structured questionnaire was used to collect teachers’ responses. The questionnaire included open-ended questions concerning:

- teachers' understanding of concept mapping;
- their experiences of using concept maps;
- perceived benefits for student learning;
- potential contribution to higher-order thinking;
- areas and topics in which concept mapping appeared useful; and
- challenges associated with classroom implementation.

Data Analysis

The qualitative responses were analysed thematically. Responses were examined for recurring patterns and grouped into broader themes related to teachers' perceptions, critical-thinking processes, classroom engagement, implementation barriers, and policy alignment. Because the study was qualitative and descriptive, the findings are interpreted as teachers' reported perceptions and experiences rather than as experimental evidence of a statistically significant causal effect.

FINDINGS

The thematic analysis resulted in five major themes.

Positive Teacher Perceptions of Concept Mapping

Most teachers expressed favourable views regarding concept mapping as an instructional strategy. Teachers described it as a learner-centred approach that could help students move beyond the simple reproduction of information. Teachers particularly valued the capacity of concept maps to represent relationships among concepts. According to the responses, visual representation made complex information more accessible and encouraged students to organise knowledge rather than simply memorise isolated facts. This perception is consistent with the theoretical foundation of concept mapping, in which meaningful learning occurs through the integration of new knowledge with existing cognitive structures (Novak & Gowin, 1984).

Perceived Contribution to Critical Thinking

Teachers reported that concept mapping could encourage students to analyse, interpret, compare, connect, and reorganise information. They perceived that students had to make decisions about the importance and relationship of concepts while constructing maps. These observations are consistent with experimental and meta-analytic evidence. Barta et al. (2022) found positive effects of concept mapping on critical-thinking ability and disposition across the studies included in their meta-analysis. However, the current study itself does not establish such an effect statistically; it demonstrates that teachers perceived these cognitive benefits. This distinction is important because recent evidence indicates that the relationship between concept mapping and critical thinking is not uniform. Jeong et al. (2025) found mixed findings across 17 studies and highlighted methodological differences in how concept mapping and critical thinking were implemented and measured.

Active and Collaborative Learning

Teachers reported that concept mapping was particularly useful when students worked collaboratively. Group mapping required students to discuss the meaning of concepts, negotiate relationships, explain their reasoning, and modify the shared map. Such activities can transform concept mapping from an individual note-making exercise into a dialogic learning process. Students are required not only to produce a visual structure but also to explain and defend the relationships they establish. This is important because critical thinking is strengthened when students are encouraged to articulate reasons and respond to alternative interpretations rather than merely produce a correct answer.

Identification of Learning Gaps and Misconceptions

Several teachers indicated that concept maps could help identify gaps in students' understanding. A student may know individual concepts but fail to establish appropriate relationships among them. A concept map makes these gaps visible to both the student and teacher. This feature also supports formative assessment. The teacher can examine whether concepts have been appropriately selected, whether relationships are valid, whether important concepts are missing, and whether students have established meaningful cross-links. The reviewed thesis literature provides a structured scoring framework based on propositions, hierarchy, cross-links, and examples, demonstrating how concept maps can be used to examine the structure of students' knowledge.

Challenges in Classroom Implementation

Teachers also reported several challenges:

- limited classroom time;
- insufficient training in concept-map construction;
- difficulties in assessing students' maps;
- large class sizes;
- limited access to digital resources;
- uncertainty regarding which topics are most suitable for mapping

These findings indicate that simply recommending concept mapping is insufficient. Teachers need professional development that addresses both technical knowledge and pedagogical knowledge. Training should therefore cover not only "how to draw a concept map" but also how to formulate focus questions, select appropriate concepts, design meaningful mapping tasks, facilitate discussion, assess propositions and cross-links, and provide feedback.

DISCUSSION

The findings suggest that teachers generally view concept mapping as a promising strategy for supporting critical-thinking-oriented classroom practices. However, the findings should be interpreted alongside the broader research literature.

From Knowledge Recall to Knowledge Organisation

Traditional instruction can sometimes position students primarily as recipients of information. Concept mapping changes the nature of the learning task by requiring students to organise and represent knowledge. Novak and Gowin (1984) argued that meaningful learning depends on establishing relationships between new knowledge and relevant prior knowledge. Concept mapping provides a visible representation of these relationships. The meta-analysis by Nesbit and Adesope (2006) provides broader support for the value of concept and knowledge maps, reporting positive effects on knowledge retention across studies involving learners from Grade 4 through postsecondary education.

Why Construction Is More Important Than Mere Viewing

An important implication of the literature is that teachers should not restrict concept mapping to showing students a completed diagram. Schroeder et al. (2018) found that constructing concept maps produced greater benefits than simply studying pre-constructed maps. Therefore, if the objective is critical thinking, students should be given opportunities to construct, explain, critique, compare, and revise maps.

For example, rather than showing students a completed concept map on “Photosynthesis,” the teacher could ask: “How are sunlight, chlorophyll, carbon dioxide, water, glucose, and oxygen related?”

Students could initially construct individual maps, compare them in pairs, identify differences, justify their links, and revise their maps after discussion.

Such an activity transforms concept mapping into a thinking process.

Concept Mapping and Different Dimensions of Critical Thinking

The relationship between concept mapping and critical thinking is multidimensional.

Critical-thinking process	Potential role of concept mapping
Analysis	Identifying and separating major and supporting concepts
Interpretation	Representing the meaning of relationships
Comparison	Examining similarities and differences
Inference	Connecting information to derive relationships
Evaluation	Judging the validity of propositions
Explanation	Explaining why concepts are connected
Synthesis	Integrating multiple ideas into a coherent structure
Reflection	Revising the map after identifying gaps or errors

This interpretation is supported by the meta-analysis of Barta et al. (2022), which reported positive effects of concept mapping on critical-thinking ability and disposition. Nevertheless, Jeong et al. (2025) caution against assuming that every concept-mapping activity will produce the same cognitive outcomes. Their systematic review found considerable methodological variation and mixed results, highlighting the importance of specifying which critical-thinking skills are being targeted and how students are expected to use them.

Thus, critical thinking should be deliberately embedded into the mapping task.

Concept Mapping Across School Subjects

Concept mapping can be adapted across different curricular areas.

- **Science:** Students can represent relationships among causes, processes, variables, and outcomes. For example, a map on ecosystems can connect producers, consumers, decomposers, food chains, energy flow, and environmental factors.
- **Mathematics:** Concept maps can help students connect mathematical concepts, procedures, properties, representations, and applications. For example, students can map relationships among fractions, decimals, percentages, ratios, and proportional reasoning.
- **Social Science:** Historical events can be mapped through causes, events, consequences, individuals, institutions, and social conditions. Geography concepts can similarly be represented through relationships among environment, resources, population, and human activity.
- **Language:** Students can map characters, themes, settings, conflicts, literary devices, and events in a text. Such maps can help learners analyse relationships rather than simply recall narrative details.
- **Environmental Education:** Concept maps can represent interconnected relationships among human activity, natural resources, pollution, biodiversity, climate, and sustainability.

Therefore, the value of concept mapping lies partly in its cross-curricular adaptability.

Implications for Classroom Practice

Based on the findings and supporting literature, concept mapping should be implemented as a structured instructional process.

Step 1: Begin with a focus question

The teacher should formulate a question that requires students to think about relationships rather than simply recall information.

Step 2: Identify important concepts

Students generate concepts relevant to the question.

Step 3: Organise concepts

Students distinguish more general concepts from more specific concepts.

Step 4: Establish relationships

Students connect concepts using meaningful linking words or phrases.

Step 5: Explain propositions

Students should be required to explain why two concepts are connected.

Step 6: Search for cross-links

Students should examine whether concepts in different sections of the map are related.

Step 7: Peer discussion

Students compare their maps and explain differences in their reasoning.

Step 8: Revision

Students revise their maps based on discussion, evidence, teacher feedback, or newly acquired knowledge.

Step 9: Reflection

Students identify what they understood, what they misunderstood, and which relationships require further investigation.

This process is more likely to promote critical thinking than simply asking students to reproduce a teacher-prepared map.

Educational Implications

The findings have implications for several stakeholders.

- **Teachers:** Teachers should be trained to use concept mapping as a thinking strategy, not merely as a visual presentation technique. Professional development should include construction, facilitation, assessment, feedback, and subject-specific applications.
- **Teacher Education Institutions:** Teacher education programmes can introduce prospective teachers to concept mapping as part of pedagogical courses, lesson planning, assessment, and reflective practice.

- **Curriculum Developers:** Concept-mapping activities can be incorporated into textbooks and supplementary learning materials, particularly where conceptual relationships and higher-order thinking are important.
- **Assessment:** Concept maps can complement conventional assessment by providing evidence of how students organise and connect knowledge. Assessment rubrics can include propositions, hierarchy, cross-links, conceptual accuracy, and explanation.
- **School Leadership:** School leaders should provide time, resources, and professional support for teachers experimenting with innovative pedagogies. Digital tools may be useful, but concept mapping should not be dependent on technology; paper-and-pencil mapping can also be effective.

Challenges and Ways Forward

The study indicates that teachers' positive perceptions coexist with practical constraints. These challenges should be addressed systematically.

Challenge	Possible strategy
Limited instructional time	Use short mapping activities within regular lessons
Lack of teacher training	Provide continuous professional development
Large classes	Use pair and group mapping
Difficulty assessing maps	Develop simple analytic rubrics
Limited technology	Use paper, cards, board work, or low-tech resources
Students unfamiliar with mapping	Begin with guided or partially completed maps
Poor-quality maps	Provide examples, modelling, and feedback
Focus on appearance rather than reasoning	Assess relationships and propositions rather than artistic quality

A particularly important issue is teacher training. The reviewed thesis literature describes explicit procedures for constructing concept maps, including focus questions, concept identification, hierarchical organisation, linking phrases, cross-links, examples, and revision. Such procedures can be incorporated into teacher professional-development programmes.

LIMITATIONS OF THE STUDY

The study has several limitations.

1. The findings are based on the perceptions and experiences of 76 teachers rather than direct measurements of students' critical-thinking performance. Therefore, the findings should not be interpreted as experimental evidence that concept mapping causes improvement in critical thinking.
2. The study used a qualitative-descriptive design. The thematic findings identify patterns in teacher responses but do not provide statistical estimates of the magnitude of concept mapping's effects.
3. The study relied on teachers' self-reported experiences. Such responses may be influenced by teachers' familiarity with concept mapping and their broader attitudes towards innovative pedagogy.
4. The study did not experimentally compare different types of mapping activities. This is important because recent research indicates that the design of mapping tasks may influence learning and critical-thinking outcomes. For example, Tseng (2020) found differences between constructing maps and completing fill-in maps.

Future research should therefore combine teacher perspectives with direct measures of students' critical-thinking skills, concept-map quality, academic achievement, and classroom observations.

CONCLUSION

Concept mapping represents a promising pedagogical approach for creating classroom conditions that support critical-thinking-oriented learning. The present study found that teachers generally perceive concept mapping as useful for helping students organise knowledge, establish relationships among concepts, engage in discussion, identify gaps in understanding, and reflect upon their learning. The broader research literature provides additional support for the educational value of concept mapping. Meta-analytic evidence indicates positive effects on learning and, more specifically, on critical-thinking ability and disposition (Barta et al., 2022; Nesbit & Adesope, 2006; Schroeder et al., 2018). Evidence from high-school research also indicates that constructing concept maps can be particularly valuable for critical-thinking development (Tseng, 2020). At the same time, recent systematic evidence demonstrates that the effects of concept mapping on critical thinking are not automatic or uniform. The effectiveness of the strategy depends on the purpose of the activity, the degree of student involvement, the nature of the mapping task, teacher guidance, assessment procedures, and the specific critical-thinking skills being targeted (Jeong et al., 2025). Concept mapping should not be viewed simply as a colourful diagram or an alternative note-taking technique. Its greatest educational potential lies in using mapping as a process of thinking, a process in which students question, select, organise, connect, explain, evaluate, revise, and reflect on knowledge.

In this respect, concept mapping can contribute to the pedagogical transformation envisioned by NEP 2020 and NCFSE 2023, particularly when it is embedded within inquiry, discussion, formative assessment, problem solving, and reflective learning.

RECOMMENDATIONS

Based on the findings of the present study, the reviewed literature, and the identified implementation challenges, the following recommendations are proposed.

Integrate Concept Mapping into Regular Classroom Teaching

Concept mapping should be incorporated into regular teaching-learning processes rather than being restricted to occasional enrichment activities. Teachers can use mapping at different stages of a lesson for activating prior knowledge, developing conceptual understanding, consolidating learning, and reviewing students' understanding.

Emphasise Student-Constructed Concept Maps

Students should be given opportunities to construct their own concept maps rather than merely copy or study teacher-prepared maps. This recommendation is supported by Schroeder et al. (2018), whose meta-analysis found greater learning benefits associated with constructing concept maps than studying pre-constructed maps.

Link Concept Mapping with Critical-Thinking Questions

Teachers should combine mapping activities with questions requiring students to analyse, infer, evaluate, explain, and justify relationships. Simply asking students to create a map may not provide sufficient opportunity for critical thinking.

Questions such as “Why are these concepts connected?”, “What evidence supports this relationship?”, and “What would happen if this relationship changed?” can increase the cognitive demand of the activity.

Provide Professional Development for Teachers

Schools and teacher-education institutions should provide systematic training on concept mapping. Training should cover:

- theoretical foundations;

- construction of concept maps;
- focus-question development;
- selection of appropriate concepts;
- linking words and propositions;
- cross-links;
- collaborative mapping;
- formative assessment;
- integration of mapping with critical-thinking activities.

This recommendation directly responds to the teachers' reported concern regarding inadequate training.

Develop Subject-Specific Concept-Mapping Activities

Concept mapping should be adapted according to the nature of the subject and topic. Teachers should identify concepts and relationships that are particularly appropriate for mapping in science, mathematics, social science, language, environmental education, and other curricular areas.

Use Collaborative Concept Mapping

Teachers should encourage pair and group concept mapping where appropriate. Collaborative mapping can provide opportunities for students to compare interpretations, explain their reasoning, negotiate relationships, and revise their understanding.

Use Concept Maps for Formative Assessment

Teachers should use students' concept maps as a source of formative-assessment information. Assessment should focus on:

- conceptual accuracy;
- meaningful propositions;
- hierarchy;
- relationships among concepts;
- cross-links;
- completeness;
- students' explanations.

The visual attractiveness of a map should not be the primary criterion of assessment.

Develop Simple Assessment Rubrics

Schools and teacher educators should develop practical rubrics for assessing concept maps. A rubric can help teachers evaluate students' conceptual understanding consistently and provide meaningful feedback.

Use Low-Cost Resources Alongside Digital Tools

Concept mapping should not depend exclusively on digital technology. Where technological resources are limited, teachers can use notebooks, blackboards, chart paper, cards, and sticky notes. Where appropriate, digital tools can subsequently be introduced to facilitate editing, collaboration, storage, and presentation.

This recommendation is particularly relevant because insufficient technological resources were identified as an implementation challenge in the present study.

Conduct Empirical Studies with Direct Measures of Critical Thinking

Future researchers should conduct experimental and quasi-experimental studies involving direct assessment of students' critical-thinking abilities. Such studies could compare concept mapping with conventional instruction and other learner-centred approaches.

This recommendation is particularly important because the present study examines teachers' perceptions rather than students' measured critical-thinking performance.

Examine Different Forms of Concept Mapping

Future studies should compare different approaches, including:

- student-generated versus teacher-generated maps;
- individual versus collaborative mapping;
- guided versus unguided mapping;
- paper-based versus digital mapping;
- complete versus partially completed maps.

This is justified by evidence that the design of mapping activities influences learning outcomes (Schroeder et al., 2018) and by methodological concerns identified in the recent systematic review of concept mapping and critical thinking (Jeong et al., 2025).

REFERENCES

1. Aguiar, J. G., & Correia, P. R. M. (2017). From representing to modelling knowledge: Proposing a two-step training for excellence in concept mapping. *Knowledge Management & E-Learning*, 9(3), 366–379. <https://doi.org/10.34105/j.kmel.2017.09.021>
2. Aslami, M., Dehghani, M., Shakurnia, A., Ramezani, G., & Kojuri, J. (2021). Effect of concept mapping education on critical thinking skills of medical students: A quasi-experimental study. *Ethiopian Journal of Health Sciences*, 31(2), 409–418. <https://doi.org/10.4314/ejhs.v31i2.24>
3. Barta, A., Fodor, L. A., Tamas, B., & Szamoskozi, I. (2022). The development of students' critical thinking abilities and dispositions through the concept mapping learning method: A meta-analysis. *Educational Research Review*, 37, Article 100481. <https://doi.org/10.1016/j.edurev.2022.100481>
4. Government of India, Ministry of Education. (2020). National Education Policy 2020.
5. Hussain, M. A., & Unnisa, V. (2025). Using concept mapping as an innovative technique for teaching science. *The Academic*, 3(5), 1011–1020. <https://doi.org/10.5281/zenodo.15652676>
6. Jeong, A. C., Wong, R., & Mbanzabugabo, J.-B. (2025). A systematic review of concept mapping and critical thinking: Methodological gaps & research directions. *Educational Technology Research and Development*, 73(6), 3543–3567. <https://doi.org/10.1007/s11423-025-10562-2>
7. Johnson, B. (2017). Teacher perceptions of concept mapping as a tool for critical thinking development. *Journal of Educational Strategies*, 90(2), 45–56.

8. Kinchin, I. M. (2014). Concept mapping as a learning tool in higher education: A critical analysis of recent reviews. *The Journal of Continuing Higher Education*, 62(1), 39–49. <https://doi.org/10.1080/07377363.2014.872011>
9. Kumar, B. (2024). Use of concept mapping as an innovative learning strategy in science: A qualitative study using thematic analysis. *International Journal for Research in Applied Science & Engineering Technology*, 12(6), 2304–2306. <https://doi.org/10.22214/ijraset.2024.63478>
10. National Council of Educational Research and Training. (2023). *National Curriculum Framework for School Education 2023*. NCERT.
11. National Institute of Educational Planning and Administration (NIEPA). (2022). *State of School Education in India: Policy and Practice Review*. Ministry of Education, Government of India.
12. 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>
13. Novak, J. D., & Cañas, A. J. (2006). *The theory underlying concept maps and how to construct and use them*. Institute for Human and Machine Cognition.
14. Novak, J. D., & Gowin, D. B. (1984). *Learning how to learn*. Cambridge University Press.
15. Paul, R., & Elder, L. (2014). *The miniature guide to critical thinking concepts and tools*. Foundation for Critical Thinking.
16. Schroeder, N. L., Nesbit, J. C., Anguiano, C. J., & Adesope, O. O. (2018). Studying and constructing concept maps: A meta-analysis. *Educational Psychology Review*, 30(2), 431–455. <https://doi.org/10.1007/s10648-017-9403-9>
17. Sharma, J., & Sharma, R. (2025). Effectiveness of concept mapping on students' academic achievement in biology at the secondary school level. *International Journal of Research – Granthaalayah*, 13(3), 437–444. <https://doi.org/10.29121/granthaalayah.v13.i3.2025.6035>
18. Tseng, S.-S. (2020). Using concept mapping activities to enhance students' critical thinking skills at a high school in Taiwan. *The Asia-Pacific Education Researcher*, 29(3), 249–256. <https://doi.org/10.1007/s40299-019-00474-0>
19. UNESCO. (2021). *Reimagining our futures together: A new social contract for education*. Paris: UNESCO.