



Study Of Some Reviews On The Effectiveness Of Concept Mapping Approach On Students' Achievement

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Abstract : This research paper provides a comprehensive review of existing meta-analyses and systematic reviews examining the impact of concept mapping on students' academic achievement across various educational domains. Concept mapping—originally developed by Novak and Cañas—has been widely applied as a visual and constructivist learning strategy that encourages meaningful learning, higher-order processing, and improved retention. Concept mapping, a visual tool for organizing and representing knowledge, has been widely studied for its potential to enhance learning outcomes. Drawing from multiple high-quality sources, this synthesis reveals consistently positive effects, with moderate to strong effect sizes reported in general academic achievement, science, STEM, nursing education, and critical thinking. Key findings indicate that concept mapping is particularly effective in secondary education, science subjects, and when students construct maps independently. Moderators such as educational level, subject area, and pedagogical approach influence outcomes. The review synthesizes findings from empirical studies, meta-analyses, and experimental research to evaluate the overall impact of concept mapping on achievement. Implications for educators and future research are discussed, emphasizing the integration of concept mapping in curricula to boost student performance.

Keywords : Concept mapping, Positive effect, Academic achievement, STEM, Meta Analysis, Student performance.

I. INTRODUCTION

Concept mapping is a pedagogical strategy developed by Joseph Novak in the 1970s, based on Ausubel's theory of meaningful learning. It involves creating visual diagrams that represent relationships between concepts, typically using nodes for ideas and links for connections. This approach encourages students to organize knowledge hierarchically, identify cross-links, and integrate new information with existing schemas, thereby promoting deeper understanding and retention.

In educational settings, concept maps serve multiple purposes: as tools for instruction, assessment, and student-led learning. Teachers may provide pre-constructed maps as advance organizers, or students may build them collaboratively or individually to summarize lessons. The effectiveness of this method has

been scrutinized in numerous empirical studies, leading to several meta-analyses that quantify its impact on academic achievement.

The purpose of this paper is to synthesize these reviews, providing a meta-review of the evidence on concept mapping's role in enhancing students' achievement. By focusing on high-level analyses, we aim to offer educators and researchers a consolidated view of the findings, highlighting consistencies, variations, and gaps in the literature.

Here is an example of a concept map used in education:



Fig. 1 : Concept Map - Active Learning at UGA

II. THEORETICAL BACKGROUND

Concept mapping is a graphical and instructional strategy designed to represent knowledge visually by illustrating concepts and the relationships among them. The theoretical foundation of concept mapping is deeply rooted in **constructivist learning theory**, **Ausubel's theory of meaningful learning**, **cognitive psychology**, and **dual coding theory**. These theoretical perspectives collectively explain why concept mapping is effective in enhancing students' understanding and academic achievement.

1. Constructivist Learning Theory

Constructivism posits that learners actively construct knowledge rather than passively receive information. Learning occurs when individuals integrate new information with their existing cognitive structures. Concept mapping aligns closely with this perspective as it requires learners to actively identify key concepts, organize them hierarchically, and establish meaningful relationships among them. By engaging students in the construction of their own concept maps, learning becomes learner-centered, reflective, and meaningful.

According to constructivist theorists, meaningful learning is promoted when learners are encouraged to explore, connect ideas, and reorganize their understanding. Concept mapping facilitates this process by allowing students to visualize their thinking and revise misconceptions, thereby strengthening conceptual understanding.

2. Ausubel's Theory of Meaningful Learning

The most significant theoretical foundation of concept mapping comes from **David Ausubel's theory of meaningful verbal learning**. Ausubel emphasized that learning becomes meaningful when new knowledge is consciously related to relevant concepts already present in the learner's cognitive structure. He argued that "the most important single factor influencing learning is what the learner already knows."

Concept mapping operationalizes Ausubel's ideas by providing a structured framework for linking new concepts with prior knowledge. Hierarchical organization—placing more general concepts at the top and specific concepts below—reflects Ausubel's principle of progressive differentiation. Cross-links between concepts further promote integrative reconciliation, another key element of meaningful learning.

3. Cognitive Learning Theory

From a cognitive psychology perspective, learning involves information processing, organization, storage, and retrieval. Concept maps help reduce cognitive load by organizing complex information into manageable units. They enhance comprehension by making abstract relationships explicit and visible.

Concept mapping supports higher-order cognitive processes such as analysis, synthesis, and evaluation. By requiring learners to determine relationships between concepts, concept maps promote deep processing rather than surface-level memorization. This cognitive engagement leads to improved retention and transfer of knowledge.

4. Dual Coding Theory

Dual coding theory, proposed by Allan Paivio, suggests that information is better understood and remembered when it is processed through both verbal and visual channels. Concept maps combine textual information (concept labels and linking words) with visual representations (nodes, arrows, and spatial organization). This dual representation enhances memory retention and recall by engaging multiple cognitive pathways.

The visual nature of concept mapping is particularly beneficial for learners who struggle with purely verbal instruction, as it provides alternative means for understanding and organizing information.

5. Metacognitive Theory

Concept mapping also has a strong metacognitive dimension. When students construct concept maps, they monitor their own understanding, identify gaps in knowledge, and reflect on conceptual relationships. This self-regulatory process enhances metacognitive awareness, enabling learners to plan, monitor, and evaluate their learning more effectively.

Teachers can also use concept maps as diagnostic tools to assess students' prior knowledge, misconceptions, and conceptual growth over time.

6. Social Constructivist Perspective

From a social constructivist viewpoint, learning is a socially mediated process. Concept mapping can be implemented collaboratively, allowing students to discuss, negotiate, and refine concepts collectively. Collaborative concept mapping promotes peer interaction, shared understanding, and co-construction of knowledge, which further enhances learning outcomes.

Concept maps are rooted in constructivist learning theory, which posits that learners actively construct knowledge by integrating new information with prior knowledge. Concept mapping aligns with dual-coding theory by combining visual and verbal representations to enhance memory and comprehension. These theoretical foundations support the use of concept maps to improve learning outcomes and academic performance.

III. METHODOLOGY

This review adopts a systematic approach to identify and synthesize meta-analyses and systematic reviews on concept mapping's effectiveness. Searches were conducted using academic databases and web tools for terms such as "meta-analysis concept mapping student achievement" and related variants. Inclusion criteria required studies to be peer-reviewed meta-analyses or systematic reviews published between 2000 and 2024, focusing on quantitative effects on academic achievement or related outcomes like critical thinking. Excluded were individual empirical studies or non-quantitative reviews.

A total of six key meta-analyses were selected for in-depth analysis, covering general achievement, science, STEM, nursing, and critical thinking. Data extracted included effect sizes (e.g., Cohen's d , Hedges' g), number of studies, sample sizes, moderators, and conclusions. Synthesis involved narrative integration and comparison of findings, with attention to heterogeneity and biases.

IV. RESULTS

The reviewed meta-analyses consistently demonstrate positive effects of concept mapping on student achievement, though effect sizes vary by context.

General Academic Achievement

A meta-analysis of 78 studies (2005–2017) found a strong positive effect of concept maps on academic achievement, with an effect size of 1.08 (random effects model). This indicates concept mapping significantly improves performance across disciplines, supporting its broad application in education.

An earlier meta-analysis from 2006, reviewing 55 studies with 5,818 participants, reported moderate effects on knowledge retention ($d = 0.42$ for construction, $d = 0.59$ for studying maps) and transfer. Student-constructed maps showed stronger benefits for higher-order learning.

Science Education

In science, a meta-analysis of 55 studies (1980–2020) involving 5,364 students from grades 3–12 yielded a moderate overall effect size ($g = 0.776$). Subgroup analyses showed variations: $g = 0.671$ for biology, $g = 0.590$ for chemistry, and $g = 1.040$ for physics/earth science (non-significant differences). Effects were robust across instructional settings, with stronger impacts in high-income countries, journal publications, and recent studies. Heterogeneity was high, suggesting contextual influences.

STEM Education

A 2024 meta-analysis of 37 studies (2004–2023) in STEM reported a moderate effect size ($ES = 0.630$). Greatest impacts were in secondary education, science/technology subjects, and short interventions (1 week–1 month). Student-independent construction and inquiry-based pedagogies enhanced outcomes. Digital and paper-based tools showed comparable moderate effects.

Nursing Education

In nursing, a systematic review and meta-analysis of 44 studies (up to 2024) found concept mapping significantly increased educational performance ($SMD = 1.693$, 95% CI: 1.305–2.081, $p < 0.001$). Effects were stronger in students than working nurses (non-significant). High heterogeneity ($I^2 = 95.58\%$) and publication bias were noted, but sensitivity analyses confirmed stability.

Critical Thinking and Related Outcomes

A meta-analysis of 21 studies (1,695 students) showed concept mapping improved critical thinking ability ($g = 0.531$) and disposition ($g = 0.648$). Randomized studies yielded stronger effects ($g = 0.739$ for ability). This indirectly supports achievement gains, as critical thinking correlates with academic success.

Domain	Number of Studies	Overall Effect Size	Key Moderators
General Achievement	78	1.08 (d)	N/A
Science	55	0.776 (g)	Subject area, country income
STEM	37	0.630 (ES)	Educational level, duration, construction mode
Nursing	44	1.693 (SMD)	Student vs. nurse
Critical Thinking	21	0.531–0.648 (g)	Randomization

V. DISCUSSION

Across domains, concept mapping demonstrates moderate to strong positive effects on achievement, aligning with cognitive theories emphasizing active learning and knowledge integration. Stronger effects in student-constructed maps suggest benefits from metacognitive engagement. Variations by subject (e.g., higher in physics) may reflect concept mapping's suitability for hierarchical knowledge structures.

Heterogeneity in most analyses indicates moderators like educational level, duration, and pedagogy play roles. For instance, secondary students and inquiry-based approaches amplify benefits. Publication bias in some reviews (e.g., nursing) warrants caution, but overall evidence is robust.

Limitations include reliance on existing meta-analyses, potential overlap in primary studies, and focus on quantitative outcomes. Future research should explore digital tools, underrepresented regions, and long-term effects.

Another example of concept mapping in practice:



Fig.2 : Information Technology Services | Training and Workshops.

VI. CONCLUSION

Concept mapping serves as a powerful tool for improving students' academic performance, with numerous meta-analyses highlighting its effectiveness across various educational settings. This strategy encourages students to visually organize and represent knowledge, which can lead to deeper understanding and retention of information. Educators, particularly in the fields of STEM and science, should actively integrate concept mapping into their teaching practices, as it promotes active learning and critical thinking skills. By guiding students in the construction of their own concept maps, teachers can maximize the educational

benefits of this approach. Furthermore, policymakers have a crucial role in advocating for professional development programs that equip educators with the skills necessary to implement concept mapping effectively, thereby fostering an environment conducive to meaningful learning experiences.

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