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Concept Maps in the Modern Classroom

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ABSTRACT

Aim: To examine the theoretical foundations, instructional applications, assessment functions, pedagogical benefits, and practical limitations of concept maps, with particular attention to digital learning environments and collaborative knowledge construction. **Design:** A structured narrative literature review was conducted. **Method**: The review was organized according to the Search, Appraisal, Synthesis, and Analysis framework and reported with reference to the quality principles of the Scale for the Assessment of Narrative Review Articles. Searches were conducted between October and December 2025 in ERIC, Scopus, Web of Science, and Google Scholar; ResearchGate and Academia.edu were used only for supplementary source identification. Publications issued primarily between 2000 and 2025 were considered, while earlier seminal works were retained when necessary to establish the theoretical foundations of concept mapping. After eligibility screening, the final review corpus comprised 61 theoretical and empirical publications. The sources were critically appraised according to their methodological or conceptual quality and synthesized thematically, with attention to convergent findings, inconsistencies, and differences in educational context and study design. **Results:** The literature indicates that concept mapping can support the integration of prior and new knowledge, improve conceptual understanding and recall, and make learners' cognitive structures visible. It can also strengthen critical thinking, creativity, self-regulation, and metacognitive awareness. Concept maps can be used before, during, and after instruction for diagnostic, formative, and summative assessment. Collaborative concept mapping promotes dialogue, negotiation of meaning, and the co-construction of knowledge, while digital environments facilitate revision, multimedia enrichment, collaboration, and immediate feedback. However, the literature also identifies important limitations, including the time required for construction and analysis, the cognitive demands placed on inexperienced learners, the need for teacher training, and concerns regarding the validity, reliability, and subjectivity of scoring procedures. **Conclusion:** Concept maps are multidimensional tools that can support teaching, learning, reflection, collaboration, and assessment. Their educational effectiveness depends on explicit instruction, appropriate scaffolding, clear assessment criteria, and integration with complementary assessment methods. They should therefore be used as structured pedagogical tools rather than as isolated or purely decorative classroom activities.

Keywords: concept maps, meaningful learning, instructional organization, assessment, metacognition.

INTRODUCTION

Concept maps were developed by Joseph Novak at Cornell University in 1972, within a research program aimed at understanding changes in students' scientific knowledge. Their conception and theoretical foundation were based on David Ausubel's theory of meaningful learning (1963), according to which learning becomes meaningful when new information is integrated in a non-rote manner into existing cognitive structures (Ausubel, Novak, & Hanesian, 1978).

The central premise of this theory is that the most important factor influencing learning is what the learner already knows. Within this framework, concept maps function as visual tools for representing knowledge, enabling concepts and the relationships among them to be depicted hierarchically. Through concept mapping,

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knowledge ceases to be presented as fragmented information and is instead organized into coherent mental schemas.

Concept maps have been defined as “hierarchical graphic representations of concepts in which the relationships between concepts are indicated by linking words, thereby forming meaningful propositions (Novak & Gowin, 1984). According to Jonassen (2000), they are cognitive tools that support deep understanding through the organization and connection of information. Kinchin (2016) further emphasizes that concept maps are not merely diagrams but visual representations of thought that reveal the breadth, depth, and coherence of the learner's cognitive organization.

Structurally, a concept map contains nodes and links (Figure 1). Two nodes together with the link connecting them form a proposition. The nodes represent concepts, which are usually enclosed in a circle or another shape. Links consist of a line that may include an arrowhead when the direction of the relationship is to be shown.

The relationship between one concept and another is written on the line, usually in the form of a verb or linking phrase. Hierarchical organization and explicit links distinguish a concept map from other graphic representations. Using these elements, a concept map may be created with paper and pencil or with appropriate software (e.g., CmapTools or Inspiration). A concept map may be simple, connecting concepts at a first level, or more developed, linking families of concepts with other concepts (Novak & Cañas, 2008; Cañas & Novak, 2006; Cañas, Carff, Hill, Carvalho, Arguedas, & Safayeni Eskridge, 2005; Cañas, 2003).

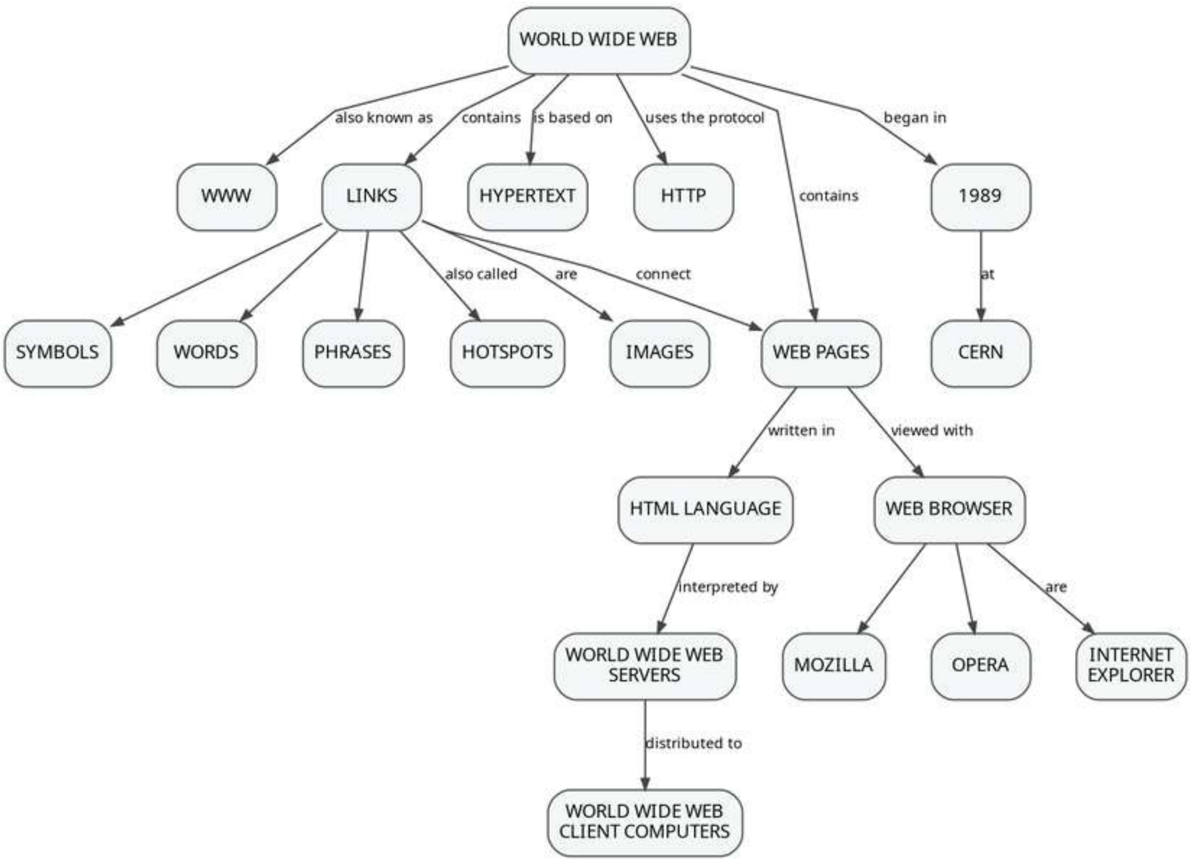

Figure 1. Georgiou, M. (2009), Master's thesis, p. 87.

Several types of concept maps exist. The following are indicative examples (Styla & Orovou, 2023; Aliakizoglou, 2009; Vardaka et al., 2004; Schroeder et al., 2018):

The spider concept map. Its organizing principle places the central topic at the center of the map. Subtopics are then arranged around the central point, forming a web similar to a spider's web (Figure 2).

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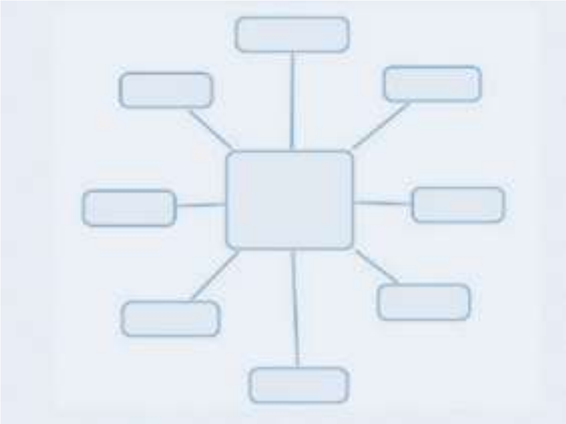

Figure 2. Spider concept map.

Hierarchical concept map. It presents information in descending order of importance, with the most important information placed at the top, and it may be divided into different hierarchical levels (Figure3).

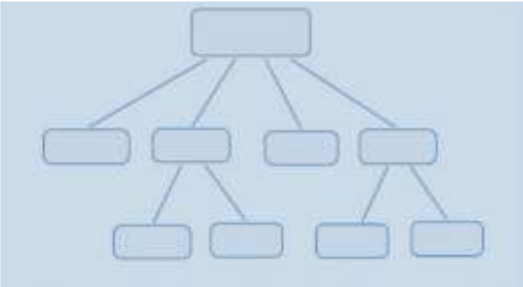

Figure 3. Hierarchical concept map.

Flowchart concept map. It organizes information in a linear sequence (Figure 4).

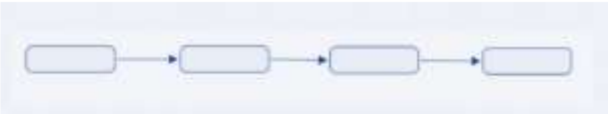

Figure 4. Flowchart concept map.

Systems concept map. It organizes information in a form similar to a flowchart, with the addition of inputs and outputs (Figure 5).

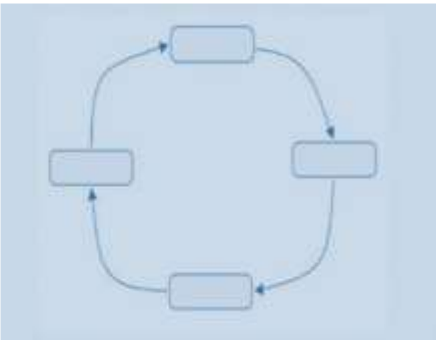

Figure 5. Systems concept map.

In contemporary pedagogical theory, concept maps are closely associated with constructivism and sociocultural approaches to learning, because they promote the active construction of knowledge, reflection, and the negotiation of meaning in collaborative environments. Over the last two decades, concept mapping has gained particular momentum in the fields of assessment, metacognitive development, and digital learning (Cañas, Novak, & Reiska, 2015; Lye & Koh, 2014; Kinchin, 2000). The present study provides a theoretical and pedagogical examination of concept maps as an educational tool. It seeks to highlight both their enduring and their contemporary value, given that concept maps have evolved as educational tools over time and with the support of new technologies. The study argues that concept mapping is simple in conception, economical in application, and particularly powerful in terms of its cognitive, metacognitive, and assessment potential.

METHODOLOGY

The study adopted a structured narrative review methodology to bring together diverse theoretical arguments, methodological approaches, and empirical findings concerning concept mapping. This design was considered more suitable than a meta-analytic approach because the reviewed literature varied substantially in its purposes, research designs, educational settings, participant populations, and reported outcomes. The review was guided by the Search, Appraisal, Synthesis, and Analysis framework proposed by Grant and Booth (2009). In addition, the reporting process was informed by the principles of the Scale for the Assessment of Narrative Review Articles developed by Baethge, Goldbeck-Wood and Mertens (2019), with particular emphasis on transparency, methodological clarity, and completeness.

The literature search was carried out between October and December 2025. Four principal academic databases and search services were consulted: ERIC, Scopus, Web of Science, and Google Scholar. ResearchGate and Academia.edu were not treated as primary bibliographic databases. Instead, they were used selectively to identify accessible author-deposited manuscripts or to retrieve publications previously located through reference-list and citation searches. The main search strategy combined terms referring to concept mapping with terms related to educational processes and applications. The core search expression was adapted to the requirements of each database and included the following combination: (“concept map*” OR “concept mapping”) AND (education OR teach* OR learn* OR assessment OR metacognition OR collaboration OR “digital learning”). Corresponding Greek-language terms for concept maps, concept mapping, teaching, learning, assessment, collaboration, and digital education were also employed. To broaden the coverage of the search, the reference lists of key studies and earlier literature reviews were examined for publications not identified during the initial database searches.

Publications were considered for inclusion when they focused explicitly on concept maps or concept-mapping practices within an educational setting. Eligible sources could address the theoretical basis of concept mapping, its use in instruction or assessment, its relationship with metacognition or collaborative learning, its digital implementation, or its reported educational advantages and limitations. The review included peer-reviewed journal articles, academic monographs and book chapters, master’s dissertations, doctoral theses, and papers published in conference proceedings. Only sources available in English or Greek were examined. The principal publication period extended from 2000 to 2025; however, influential earlier works were included when they were essential for explaining the historical development of meaningful learning theory or the conceptual origins of concept mapping.

Publications were excluded when their focus was limited to mind maps, argument maps, or other forms of visual representation that did not incorporate an explicit concept-mapping approach. Studies dealing solely with non-educational uses were also excluded. Additional exclusions involved software documentation, purely procedural tutorials, duplicate publications, less complete versions of the same study, and sources that did not contain sufficient theoretical, empirical, or methodological detail to support a meaningful appraisal.

The selection procedure consisted of two successive screening stages. During the first stage, titles and abstracts were reviewed to determine whether each record was relevant to the objectives of the study and consistent with the predefined eligibility criteria. Publications that appeared potentially suitable were subsequently retrieved and evaluated in full text. Duplicate database records were removed, while different versions of the same publication were compared and consolidated. Where more than one version was available, the most complete and academically informative version was retained. Following this process, 61 publications were included in the final body of evidence. These publications correspond to the concept-mapping works presented in the reference section of the article.

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Given the variety of source types represented in the final corpus, methodological quality was evaluated through criteria appropriate to each form of publication rather than through a universal quantitative scoring instrument. Empirical investigations were considered in relation to the precision of their research aims, the suitability of their methodological design, the adequacy of the description of participants and educational context, the transparency of their data-collection and analytical procedures, and the extent to which their conclusions were justified by the evidence presented. Theoretical and conceptual publications were evaluated according to their relevance to the review questions, the clarity and consistency of their central concepts, the coherence of their reasoning, and their contribution to the theoretical development or educational interpretation of concept mapping. Identified weaknesses and methodological constraints were documented and taken into account when assigning interpretive weight to individual sources during the synthesis.

A structured extraction process was used to record information from each included publication. The extracted material covered the type and year of publication, educational sector, disciplinary area, methodological design, participant characteristics where relevant, the nature of the concept-mapping task, the use of digital or paper-based formats, the instructional or assessment purpose of the activity, the main reported findings, and the methodological limitations acknowledged or identified in each study. The material was analysed using a combination of deductive and inductive thematic procedures. Broad analytical categories were initially developed from the objectives of the review and included theoretical perspectives, instructional practices, assessment applications, pedagogical contributions, and reported limitations. These preliminary categories were subsequently refined through an inductive examination of patterns that appeared repeatedly across the selected literature. This process enabled the identification of additional subthemes that were not fully anticipated before the analysis began.

The synthesis was designed to provide a critical comparison rather than a simple summary or numerical count of favourable results. Findings were examined across educational stages, subject areas, individual and collaborative learning arrangements, digital and paper-based mapping practices, and different forms of research design. Contradictory, conditional, and inconclusive findings were given particular consideration. These included differences in the cognitive demands placed on learners, the influence of previous mapping experience, the importance of teacher guidance and preparation, challenges associated with scoring consistency, and the contextual conditions that appeared to strengthen or reduce the educational effectiveness of concept mapping. Because the included publications were highly diverse in their methods, interventions, measures, samples, and outcomes, the evidence was not considered suitable for statistical aggregation, and no meta-analysis was conducted.

RESULTS OF THE LITERATURE REVIEW

Instructional Use of Concept Maps

Concept maps have been used in the educational process across a range of subject areas, including environmental education (Vasilopoulou, 2001); science education, such as biology, physics, chemistry, and mathematics (Shavelson et al., 1993; Nicoll et al., 2001; Soares & Valadares, 2006); language education (Riley & Åhlberg, 2004; Chularut & DeBacker, 2004); and history (Fortouni & Fragkaki, 2003), as well as at every educational level, including preschool, primary, secondary, and higher education. As an indicative example, Jonassen (1999, 2000) proposes the following steps for students creating concept maps: 1) Before beginning, students should prepare a plan for the concept map, considering what they wish to present, which points they want to develop, what kinds of information are needed to construct these points, and which learning objectives should be achieved. 2) Identify the important concepts. 3) Create, define, and format the nodes; then add images, explanatory text, and synonyms appropriate to each node. 4) Create links between concepts. 5) Expand the map. 6) Continue the process until the task is completed.

Within this educational framework, the concept map can first serve as an important assessment tool and may be used during diagnostic assessment to investigate students' prior conceptions, as well as during formative and summative assessment. It is especially valuable at the initial diagnostic stage, although this does not mean that it cannot also be used during ongoing and final assessment. During formative assessment, the qualitative analysis of students' maps can reveal the degree to which they understand the concepts, enabling the teacher to reflect on

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the instructional plan and modify it accordingly (Nicoll et al., 2001; Kinchin et al., 2000; Lin et al., 2000; Gouli et al., 2003; Gouli et al., 2005; Fortouni & Fragkaki, 2003).

Before a new unit is taught, concept maps can also provide highly useful information about students' prior conceptions, enabling the teacher to plan instruction on the basis of those conceptions or to ask students to: (a) construct a new map focusing on a central concept; (b) correct a map provided to them, for example by modifying or deleting displayed concepts; (c) extend a map by adding new concepts to a given map; (d) complete a map by filling in concepts in a partially completed map (Figure 6); or (e) undertake any combination of the above activities (Nesbit & Adesope, 2006; Wang et al., 2025).

Figure 6. Gouli, Gogoulou, Papanikolaou, and Grigoriadou (2005). Partially completed concept map. 3rd Panhellenic Conference on “Computer Science Education.”

In summary, concept maps can be used by teachers to organize and present a lesson in the classroom, as diagnostic tools for detecting and representing prior knowledge, and as tools for assessing learning before or after an instructional intervention. More specifically, they can be used in many ways: completed maps may be provided to students; students may be asked to construct or complete concept maps for selected concepts individually or in groups; and maps may be enriched manually or electronically with images and hyperlinks so that they become useful instructional resources ready for use whenever needed (Gouli, Gogoulou, & Grigoriadou, 2006, 2009; Gouli, 2007; Novak, 2010; Orue, Alvarez, & Montoya, 2008).

Advantages of the use of Concept Maps

The literature review highlights the value and usefulness of even the simplest types of concept maps, whether printed or digital, in the educational process from the perspectives of both teachers and students. This technique is not limited to the simple recording of information; rather, it functions as a tool that promotes active learning, conscious understanding, and the development of critical thinking skills. Various studies have found that the use of concept maps contributes substantially to improving the learning process and students' academic performance. This occurs through several dimensions: 1. Concise presentation of knowledge: Concept maps organize information within a clear and concise framework, facilitating understanding and rapid recall. This structured presentation helps students see the “big picture” and understand how individual concepts are connected. 2. Relating concepts and developing connections: Through mapping, students establish relationships among concepts and identify their interactions and interdependencies. This process not only strengthens understanding but also facilitates the transfer of knowledge to new contexts or problems. 3. Assessment of understanding by the teacher: Maps provide teachers with an immediate picture of how students understand concepts and their relationships, allowing misconceptions or knowledge gaps to be identified promptly and addressed through targeted intervention. 4. Ease of use as a revision tool: Concept maps are a practical means of reviewing and revising knowledge because they present key concepts and their connections in an accessible and organized form. 5. Active student participation: Constructing maps requires students to engage actively by analysing, categorizing, and synthesizing information. Such active involvement promotes deeper understanding and increases the likelihood of long-term knowledge retention. 6. Development of metacognitive skills: Through

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mapping, students gain metacognitive information; that is, they can observe how they think, how they organize their ideas, and which strategies they use to solve problems. 7. Cultivation of critical thinking: The process of generating, organizing, and revising ideas encourages students to evaluate, compare, and improve their initial thoughts. This iterative process strengthens their capacity to analyse and synthesize information, promoting both creative and critical thinking. 8. Enhancement of collaborative learning: When students work together to construct concept maps, the exchange of ideas and discussion promote deeper understanding by exposing them to different perspectives and ways of thinking. 9. Adaptability and flexibility: Maps can be used in any subject area and at any educational level, whether the content involves basic knowledge or more complex interdisciplinary themes. This makes them a flexible tool capable of supporting diverse learning needs and educational scenarios. Overall, concept maps provide a valuable means of combining the structured presentation of knowledge, students' active participation, and the assessment of learning. Their use can substantially improve students' understanding, memory, and critical abilities, while enabling teachers to adapt instruction to the actual needs of the class (Matsagouras & Kouloumbaritsi, 1999; Pernaa & Aksela, 2008; Kasumu, 2022; Eshuis, ter Vrugte, & de Jong, 2022).

It has also been found that concept mapping can improve learning performance in comparison with traditional note-taking methods, because it helps students organize and connect information in a clearer and more structured manner (Farrand et al., 2002). Unlike conventional note-taking, concept mapping promotes not only memorization but also an active understanding of concepts and their relationships. The international literature further emphasizes the potential of this technique by identifying additional dimensions of learning through mapping. Recent studies indicate that constructing concept maps enables teachers to identify students' alternative conceptions, monitor progress and changes in their conceptual structures, and intervene in a targeted manner where necessary. Beyond cognitive benefits, concept mapping also promotes the development of metacognitive skills, as students become accustomed to self-assessing their understanding and reorganizing their ideas. This process enhances creativity because students often discover new connections among concepts that initially appeared isolated or unrelated. In addition, mapping can function as a collaborative learning tool, because the exchange of ideas within groups enables concepts to be enriched, processed, and reconstructed from students' different perspectives. Overall, this technique is not restricted to improving memorization; it promotes a holistic, active, and creative approach to learning, strengthening both understanding and the application of knowledge to new and complex problems (Hay et al., 2008; Kinchin, 2000; Watson et al., 2016; Krieglstein, Schneider, Beege, & Rey, 2022).

The meta-analysis by Schroeder et al. (2018), which included 142 studies, demonstrated a positive effect on conceptual understanding. Machado and Carvalho (2020) likewise confirmed a positive association with deeper learning and metacognitive awareness. More specifically, the spider map, as the simplest form of concept map, offers immediate recording of prior knowledge, rapid diagnostic representation of conceptions, easy comparison before and after instruction, and a visual representation of conceptual understanding. In the same direction, evidence indicates that concept maps enhance metacognitive awareness (Ifenthaler, 2010), improve analytical thinking, support students with learning difficulties, promote inclusive education (Chen et al., 2016), and are associated with deeper and more meaningful learning rather than rote memorization (Davies, 2011; Machado & Carvalho, 2020). At the same time, the collaborative construction of maps promotes dialogue and the negotiation of meaning, a process that is crucial for learning (Bes Piá, Blasco-Tamarit, & Muñoz-Portero, 2011; Van Boxtel et al., 2000; Wang et al., 2025).

In early childhood education in particular, concept mapping is a useful educational tool because it requires analysis and reflection. It helps children organize their thoughts, develop their cognitive and scientific abilities, recall acquired knowledge, strengthen oral language, and identify possible misconceptions. Because concept maps are not constrained by the linearity of discourse, they can represent complex and demanding topics and support the collaborative construction of knowledge. Most studies indicate that young children encounter some difficulties when constructing free-form concept maps. These difficulties can, however, be overcome when children are explicitly taught the concept-mapping technique and receive a period of adult guidance. For this reason, most researchers initially construct group concept maps with the whole class and subsequently move to individual maps (Serrano et al., 2010; Tsiggidou, Michalopoulou, & Kostas, 2013, p. 76).

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In summary, the prevailing view is that concept maps offer multiple benefits (Stasinakis & Protopapadaki, 2007): 1. They provide immediate access to information concerning concepts and their relationships. 2. Collaborative map construction in groups can promote extensive discussion of content and the interactions among concepts. 3. Organizing ideas on paper or on a computer helps restructure concepts in the mind. 4. Through mapping, students transform vague or implicit relationships into clear and precise connections, which form the core of conceptual learning. 5. Constructing concept maps requires cognitive and metacognitive skills that become visible during the process. 6. Maps enable students to recognize subtle differences among ideas, which is a critical process for learning. 7. The more a person practises mapping, the more competent they become in organizing and connecting concepts. 8. Each time two concepts are connected in working memory, this information can be used in other cognitive processes. 9. Semantic structure is common to all types of knowledge. 10. Organized and structured knowledge is essential for immediate recall and comprehension. 11. Students assimilate structured knowledge more effectively. 12. Structured knowledge is crucial for problem solving. 13. Significant differences exist between novices and experts in the structure of their knowledge, because learning requires the novice to improve the organization of knowledge in order to approach the expert level. 14. Creating new connections among concepts leads to the production of new knowledge and strengthens students' creative thinking.

Disadvantages of the use of Concept Maps

Despite their documented advantages, concept maps also present certain limitations that have been identified in the international literature (Schwendimann, 2014; Narang & Lata, 2024; Baig, Tariq, Rehman, Ali, & Gazzaz, 2016; Carr-Lopez, Galal, Vyas, Patel, & Gnesa, 2014; Birbili, 2006), including the following:

A) Validity and reliability issues in assessment: The use of concept maps as an assessment tool raises questions about the validity of the conclusions drawn from them. In particular, subjectivity in scoring is a significant challenge because different assessors may award different scores to the same map. This occurs especially when clear rubrics, standardized criteria, or assessment guidelines are absent. Ensuring that a map genuinely represents a student's understanding requires careful design and coordinated implementation so that misunderstandings or inaccurate conclusions are avoided. B) Time-consuming construction and analysis: Constructing high-quality concept maps requires considerable time, both for familiarizing students with the process and for providing appropriate teacher guidance. Moreover, giving feedback on and analysing maps is especially demanding for teachers, particularly in classes with large numbers of students. The process involves assessing the structure, the relationships among concepts, and the completeness of the map, which may limit the systematic or regular use of concept maps for summative assessment. C) Need for teacher training: Effective use of concept maps requires teachers to understand constructivist theory, know the techniques used to construct and assess maps, and possess skills in using digital tools such as CmapTools or similar software. Without appropriate training, maps may be used superficially or mechanically, without exploiting their full potential for learning and for investigating students' understanding. D) Cognitive load and difficulty for some students: For students with limited metacognitive skills, constructing a concept map can be particularly demanding. Simultaneously selecting appropriate concepts, arranging them hierarchically, linking them through verbal phrases, and organizing the elements spatially can generate a high cognitive load, making the process difficult and potentially discouraging. In such cases, guidance and gradual familiarization are important so that learning is not hindered. E) Limited use as an assessment tool: Despite their potential and their benefits for learning, concept maps are used more frequently as tools for teaching, reflection, or revision than as formal assessment instruments. Difficulties in objective scoring, the time required for analysis, and the need for teacher training restrict their use in formal assessment. Consequently, maps are often used in a more mechanical manner, without fully realizing their potential to represent students' actual understanding.

DISCUSSION AND CONCLUSION

The use of printed and digital concept maps enables dynamic revision, the collaborative construction of conceptual structures, and the provision of immediate feedback. It strengthens the active role of the learner and makes the concept map not only a learning tool but also a means of assessing cognitive development. In addition, their visuospatial dimension facilitates deeper understanding of complex concepts, particularly in subject areas requiring integrative thinking. Concept maps are powerful tools for organizing and restructuring knowledge; however, their use requires clear pedagogical planning, defined assessment criteria, adequate training, and sufficient implementation time. Without these conditions, there is a risk that concept maps will be reduced to superficial activities involving low-level cognitive processing. Moreover, issues of validity and reliability in scoring, together with possible subjectivity in map interpretation, make it necessary to develop clear rubrics, such as those discussed by Styla and Michalopoulou (2014), and to combine concept maps with other assessment tools. Despite their limitations, the literature converges on their positive contribution to meaningful learning, metacognitive development, and the cultivation of critical thinking. In summary, the capacity to connect new and prior knowledge and to encourage reflective processes makes concept maps a multidimensional tool for teaching, learning, and assessment. As an extension of the present study, empirical research could be conducted to determine the proportion of Greek teachers who use this tool in their instructional preparation.

Ethical Approval

Ethical approval was not required because this literature-based study did not involve human participants, animals, or the collection of primary personal data.

Conflict Of Interest

The author(s) declare no conflict of interest.

Data Availability

No new datasets were generated or analyzed for this study. All materials considered in the review are identified in the reference list.

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