

CONCEPT MAP

Abstract

Concept maps are powerful educational tools that visually represent relationships among concepts, enabling learners to structure and integrate knowledge meaningfully. In the context of health professions education, concept maps serve as effective strategies for teaching, learning, and assessment, particularly in complex domains like clinical reasoning, pathophysiology, and interdisciplinary care. They help students move beyond rote memorization toward a deeper understanding of content, fostering critical thinking and reflective practice. By actively organizing information into hierarchies and interconnections, learners can better appreciate the dynamic and integrative nature of healthcare knowledge. Concept mapping also supports self-directed learning, as encouraged in competency-based medical education (CBME), and facilitates collaborative learning in small group settings. For educators, it provides insight into students' cognitive frameworks, allowing timely feedback and targeted remediation. When used as an assessment tool, concept maps offer a reliable measure of conceptual understanding and knowledge integration. Their adaptability across disciplines—including medicine, nursing, and allied health—makes them especially valuable in fostering interprofessional education. This chapter explores the theoretical underpinnings, design principles, implementation strategies, and evaluative approaches related to concept maps, emphasizing their role in enhancing educational outcomes and promoting lifelong learning among health profession learners.

Author

Dr. Pabithadevi

Professor and Head
Department of General Surgery
Tirunelveli Medical College
MHPE Scholar, Institute of Health
Professions Education, Sri Balaji
Vidyapeeth, Pondicherry.

I. DEFINITION

A concept map is a visual guide or diagram that illustrates the links between various ideas which helps us to understand the ideas better. All concept maps irrespective of their complexity will have two key elements. They are *nodes* and *crosslinks*.

Nodes – are the concepts or ideas which will be represented on the map as circles or boxes. These may differ in size depending on where they are in the map's hierarchy; for instance, more general nodes at the top may be larger than more specific nodes beneath them ^[1].

Crosslinks – are the links between the concepts or nodes represented by arrows which may or may not include the connecting or linking words like *causes or related to*. These words describe the nature of relationship between the concepts or nodes.

The fundamental goal is to introduce a key concept to the class. Other ideas that are connected to that concept and that which the pupils already understand are graphically mapped. Either an individual or a group can perform it. Instructor-led settings are another option. To connect the new concept to previously internalized notions, it is typically done at the beginning of a unit of instruction. However, it can also be done as an assessment.

History

Dr. Joseph D. Novak created the concept mapping method at Cornell University in the 1970s [2] and it is based on the *Assimilation theory of Ausubel*. The theories of Dr. David Ausubel, who emphasized the value of prior knowledge and a suitable learning set in being able to learn about new concepts through meaningful receptive learning, which serve as the foundation for a concept map ^[3].

Ausubel's Assimilation Theory

David Ausubel created the assimilation hypothesis of learning in the early 1960s. It is a cognitive learning theory. It has been widely used to explain how people learn significant linguistic information. It is founded on Piaget's genetic epistemology and revolves on the assimilation hypothesis, which assumes that fresh learning experiences are constantly assimilated into established knowledge structures. As a result, according to the assimilation theory of learning, new knowledge gets absorbed into or integrated into an anchoring structure that already exists in the pupil ^[4].

Meaningful Learning

The focus of Ausubel's theory is similarly on meaningful learning. His hypothesis holds that for learning to be meaningful, people need to connect new information to related ideas they already know ^[4]. The learner's existing body of information must interact with new knowledge.

Rote learning contrasts with meaningful learning. He supported the idea that learning should be meaningful rather than just memorizing facts. Meaningful learning has the advantage of being retained in long-term memory since it involves the recognition of connections among

concepts. How new knowledge is incorporated into the existing body of knowledge is the most important factor in meaningful learning. Ausubel consequently holds that knowledge is organised hierarchically and that new information only has significance when it can be connected to or anchored to what is already known ^[5].

Rote Learning

It is a method of learning where only memorizing the facts and information occurs. Knowledge acquired by rote learning is disconnected from pre-existing ideas and is therefore quickly forgotten. Even if the rote learning incorporates the new knowledge with the preexisting knowledge, it does so without interacting with the pre-existing knowledge structure. Accordingly, recalling lists of objects, like phone numbers, is done using rote memory. However, the learner is unable to utilize it to understand the connections between the items.

To convey their answers to focused questions, Novak taught learners who were as young as six years old how to create concept maps. According to Novak's assertion in his book 'Learning How to Learn', "meaningful learning involves the assimilation of new concepts and propositions into existing cognitive structures." ^[6] There have been numerous attempts to conceptualize the concept mapping process ^[7]. McAleese put forth the idea that by employing nodes and relationships to make knowledge explicit, a person might become conscious of what they know and, as a result, be able to change what they know ^[8]. Maria Birbili used the same concept to teach young children how to reflect on their knowledge. According to McAleese's concept of the knowledge arena ^[9], learners can explore their understanding and indifference in a virtual environment ^[8].

Psychological Basis of Concept Maps

Kids start to perceive patterns in their environment and start to associate these patterns with verbal labels or symbols from infancy to age three. When a child first learns an idea, it usually happens through a process called discovery learning, where the child observes patterns or regularities in occurrences or objects and recognises them as the same regularities that older people have labelled with words or symbols. All average humans have inherited this extraordinary talent because of evolution. After the age of three, learning new concepts and propositions is mostly mediated by language and occurs through a reception learning process in which new meanings are discovered by asking questions and seeking clarification of the connections between previously held beliefs and new ideas ^[10]. In addition to the difference between the discovery learning process, where the learner independently determines the qualities of concepts, and the reception learning process, where the learner receives language-based descriptions of the characteristics of concepts, Ausubel identified important difference between rote learning and meaningful learning.

According to Ausubel, meaningful learning needs three components:

- The information to be learnt must be given in a way that is cognitively explicit and relevant to the learner's prior knowledge, using language and examples.
- The student should have relevant prior knowledge.
- The student must decide to pursue meaningful learning.

To meet the first requirement, concept maps can help learners identify large general concepts they already possess before receiving instruction on more specific concepts. They can also help learners sequence learning tasks by progressively introducing more explicit knowledge that can be anchored into conceptual frameworks. The second requirement can be fulfilled after the age of three for almost any area of study, but it's important to create concept frameworks carefully and explicitly if one wants to demonstrate in-depth knowledge in any subject in later classes. Therefore, it is clear that conditions (1) The information to be learnt must be given in a way that is cognitively explicit and relevant to the learner's prior knowledge and (2) The student should have relevant prior knowledge are connected and both are significant. The one factor that neither the teacher nor the mentor has direct control over is the willingness of the students to learn by trying to integrate new meanings into their prior understanding rather than merely memorising definitions of concepts, propositional statements, or computational procedures. The primary factors that have an indirect influence on this decision are the educational methodologies and evaluation techniques employed. Meaningful learning is facilitated by instructional practises that place an emphasis on connecting new knowledge to the learner's prior understanding. Evaluation techniques that help students to connect their existing knowledge with new information also promote meaningful learning. Depending on the learner's mindset and how the instructional materials are structured, both direct presentation and discovery teaching techniques can result in either highly rote or highly meaningful learning. The learning may result in little to no improvement in the students' pertinent knowledge unless they have at least a basic conceptual understanding of the topic they are studying^[10].

Another significant development in our knowledge of learning is the realisation that the human memory is a complex network of interconnected memory systems rather than a single "vessel" to be filled. The short-term and "working memory" are the most important memory systems for storing information in long-term memory, even though all memory systems are interdependent (and have information travelling in both directions). By interacting with information stored in long-term memory, all incoming information is arranged and processed in the working memory. But working memory can only process between five and nine psychological units at a time, which is a limitation^[11]. This indicates that the processing power of working memory is roughly reached when analysing relationships between two or three concepts. The learner may be able to recollect only two to three words if the words are new or not known to them like technical terms. On the other hand, if the words are well-known and can be connected to information already stored in the learner's cognitive framework, such as the months of the year, 12 or more may be quickly recalled^[10]. It should be noted that both information learned meaningfully, and information learned by rote is retained in long-term memory; the difference is that with rote learning, there is little to no integration of new knowledge with previous knowledge, which has two unfavourable effects. The first thing you learn by heart is usually quickly lost unless you practise it a lot. To correct incorrect assumptions, the learner's knowledge structure or cognitive structure is not improved or modified. As a result, misconceptions will continue to exist, and the knowledge acquired will have little to no application in further learning or problem-solving^[12].

As new information is absorbed and processed, working memory and long-term memory must be used in an orderly sequence to shape vast amounts of knowledge. Although the structure must be built up piece by piece with small units of interdependent concept and propositional frameworks, we think that one of the reasons concept mapping is so effective

for the facilitation of meaningful learning is that it acts as a kind of template or scaffold to help organise and structure knowledge ^[13]. Many students and educators are taken aback by how this straightforward tool promotes meaningful learning and the development of potent knowledge frameworks that not only allow the use of the information in new contexts, but also keep long term memory. The saving of images from places we visit, people we meet, photos, and a wide variety of other images is a feature of iconic learning. These memories are often known as iconic memories ^[14,15]. While alphanumeric images are rapidly forgotten, other types of visuals are remembered for a considerably longer period. Our brains' ability to absorb and remember visual pictures of people or objects is astounding ^[16]. We think that employing concept mapping tools like CmapTools to include diverse types of images into a conceptual framework could improve iconic memory.

Epistemological Basis for Concept Maps

The area of philosophy known as epistemology is concerned with the nature of knowledge and the development of new knowledge. There are growing consensus among philosophers and epistemologists that the process of creating new knowledge is a positive one involving both our knowledge and our emotions. The desire to create new meanings and new ways to represent these meanings, are closely related. By learning by rote for the most of their lives, learners will struggle to generate efficient concept maps ^[17,18,19]. Rote learning, which at most makes a negligible contribution to our knowledge systems, cannot support creative thinking or creative problem solving. In any domain, concepts and propositions serve as a basis for knowledge. The development of the concept mapping technique for documenting students' understandings has opened up new possibilities for research into how people learn and generate new knowledge ^[10].

Constructivism and Concept Maps

Constructivism also served as the foundation for concept maps ^[20,21]. Constructivism is the theory that says learners construct knowledge rather than just passively take in information. As people experience the world and reflect upon those experiences, they build their own representations and incorporate new information into their pre-existing knowledge. The idea that students actively construct knowledge is central to constructivism.

Related to this are the processes of assimilation and accommodation.

- Assimilation refers to the process of taking new information and fitting it into an existing knowledge.
- Accommodation refers to using newly acquired information to revise and redevelop an existing knowledge.

This constructivism model was entrenched in learning theories by Dewey, Piaget, Vygotsky, Gagne, and Bruner^[20].

Constructivism is a theory with numerous components ^[22]. These guiding principles describe the theory as a whole and how it impacts students' learning. Following is a list of the key points of constructivism:

1. *Knowledge is created.* Every student starts their learning with some prior knowledge, which they then build upon as they progress. They will decide which parts of the knowledge encounter to include, ensuring that each person's knowledge is distinct.
2. *Learning is a collaborative process.* It's essential to interact with others to build knowledge. Understanding is created through encounters, group work, discussions, and dialogues. When we think back on our past interactions, we can see how our interpersonal interactions are directly related to the knowledge acquired^[22].
3. *Learning happens in context.* The best method to remember knowledge is not in isolation. By drawing links between what we already know and what we already believe, we learn. Along with the rest of our understanding, learning also takes place in real-world situations or in the context of our daily lives. We consider our life and categorise the new knowledge according to how it corresponds with our current viewpoint^[22.A].
4. *As people learn, they also learn how to learn.* Each learner improves at picking and organising material as they proceed through the learning experience. They can better categorise concepts and produce more insightful thought systems. They also start to understand that they are studying several concepts at once.
5. *Learning exists in mind.* Activity and hands-on learning are inadequate for memory retention. The learning path requires active participation and reflection. Students must also mentally experience activities to get a complete knowledge.
6. *Knowledge is subjective.* Everybody has a different perspective, so the knowledge acquired will also be different. Each person brings their unique experiences to the learning activity and will leave with different thoughts in mind. Every person's unique perspective and experiences are the foundation of the constructivist learning paradigm^[22].
7. *To learn, one needs to be motivated.* Motivation is essential for forging relationships and fostering understanding, much like active engagement. If students are unable to use their thinking processes and reflect on prior knowledge, they cannot learn. It is imperative that teachers make an effort to inspire their pupils to participate in the learning process^[23,24].

The goals of instruction are concept development and profound comprehension, not behaviours or abilities (Fosnot) [20]. Students must engage in the constructive process of learning. Student learning is active. Giving students the chance to build knowledge is the responsibility of the teacher (Glaserfeld, 1996)^[21].

To help students in developing understanding pertinent to problem-solving, the instructor must offer meaningful, authentic tasks (Wilson, 1996)^[25]. The importance of both the learning process and the material must be emphasised. Students should work in collaborative groups so they can test their knowledge and gain more insight into specific topics (Savery and Duffy, 1996) [26]. "Teachers summarise, review, and link main concepts at critical points throughout and at the conclusion of units and lessons. Teachers need to establish explicit linkages for students between new information taught in class and students' past and future experiences" (Ennis, 1994, p. 167)^[27].

When students encounter learning situations, their prior knowledge has an impact on their conceptual understanding. 'Preconceptions,' 'naive theories,' 'alternative frameworks,' or 'misconceptions' are among terms used to describe this prior knowledge (Kinnear, 1994, p. 6) ^[28]. The learners' prejudices and alternative frameworks must be questioned by teachers.

Concept mapping is a good fit for the constructivist educational philosophy, which holds that students should "construct their own idiosyncratic understanding of concepts" (Trowbridge & Wandersee, 1994, p. 460) ^[29]. A map can be used by the teacher to question students' presumptions about the relationships between topics. According to Russo, Scheurman, Harred, and Leubke (1995) ^[30], most college professors understand that students won't retain all of the details from a course. It is more crucial that pupils retain key ideas and have a knowledge of how these ideas are related. The teacher can help the students acquire important concepts rather than unimportant facts by using a concept map to organise the course. Additionally, it can be beneficial for the teacher to "construct a hypothetical model of the particular conceptual world of the students they are facing", since students may experience teaching differently from what an educator intended (Glaserfeld, p.7) ^[21].

Creation of a Concept Map

It's crucial to start with a familiar subject area while learning to create a concept map. A focus question, or a question that distinctly identifies the issue or problem the concept map should help to address, is a good way to provide the context for a concept map. Every concept map answers a focus question, and a good focus question might result in a concept map that is considerably more detailed.

The first step in developing a concept map is to identify a focus question that should have a broad concept with more subtopics to explore. When learning to create concept maps, students frequently stray from the core topic and create a map that may be relevant to the subject area but does not address the main question. So, focusing on the main question is important. The core idea of the concept map will be at the top centre and serves as a guide for further steps.

The first level of information that branches off from the core topic is called a key idea in concept map. Since the degree of precision of these concepts might vary, it is helpful to rank them from the most general to the most specific. Make a list of fundamental ideas and use it to gather thoughts before arranging them on the concept map. Next step in developing the concept map is to develop linking words to make connections between different concepts ^[31]. Look for crosslinks that connect ideas from several fields or domains after the concepts that connect directly have been recognised. Make sure that nothing has been missed and that the relationships which have been identified make sense by carefully going over what has been created.

Construction of a preliminary concept map is the next step. This can be done by writing the concepts on a paper, board or using computer software. Computer software help to build the concept maps by moving the concepts together with linking statements. If the computer software is used with projector, a greater number of people can work together to construct the concept map. We will add concepts to the concept map as we decide where they fit, we keep the list of concepts as a waiting list. As the map is being created, certain concepts might still

be in the waiting list if the mapmaker doesn't find a clear connection between them and other concepts ^[10].

Cross-links should be looked for after the preliminary map has been constructed. These connections between ideas in various knowledge segments or domains on the map helps in demonstrating how these domains are related to one another^[31.]. Cross-links are crucial for demonstrating that the learner is aware of the connections between the map's sub-domains. It's crucial to help pupils in understanding how one concept is connected to the others in some way. As a result, it's important to be cautious when finding cross-links and to be as specific as you can when finding terms that link concepts.. Students usually find difficulty in identifying crosslinks. This is due to their poor comprehension of the relationships between the concepts or their meanings, which are specified by the linking terms ^[10].

It's important to understand that a concept map is never complete. A preliminary map must always be revised after it has been created. You can add more ideas. Three to several revisions are normally necessary to produce good maps. One benefit of using software is for this reason. The map needs to be revised, concepts should be repositioned to improve overall clarity and structure, and a "final" map should be created. When using computer software, it is possible to go back and "dress up" the concept map by adding colours, changing the font size and style ^[10].

The creation of concept map is summarised as follows

1. **Decide on Your Primary Topic:** Decide on a main concept or focus question. That ought to be a big idea with many of subtopics. Your concept map's core idea will be at the top or centre and serve as a guide for the hierarchy.
2. **Recognise Significant Concepts:** The first level of information that branches off from your core topic is called a key concept. Since the degree of precision of these concepts might vary, it is helpful to rank them from the most general to the most specific. Your parking lot, where ideas go before being arranged on the concept map, is this list of crucial concepts.
3. **Compile and Link the Main Concepts:** Starting with the biggest notions that directly relate to your main concept, start transferring important concepts from the parking lot to the concept map. To clarify the relationship between various topics, use connecting terms.
4. **Format the Map and Double-Check the Information:** Look for crosslinks that connect ideas from multiple fields or domains once the concepts that connect directly have been recognised. Verify the meaning of your linking phrases and create cross-links to connect ideas across your map's various sections.
5. **Update the Concept Map as Needed:** The relationships created using the linking words should be self explanatory and should not miss anything important. Concept maps are dynamic and are meant to expand as you come up with new ideas. Every time you have an idea for a new concept, feel free to update or add to your concept map ^[32].

Alternatively, a 'spider' or cluster pattern of concept map can be created from the centre outward. Compare your maps against the work of others to gain insight into how different groupings or overall structures can be used.

Characteristics of Concept Map

Concept maps are visual tools for classifying and displaying information. They consist of concepts, which are typically denoted by variously shaped circles or boxes, and relationships between concepts, which are denoted by a connecting line joining two concepts. Linking words or linking phrases, often known as words on the line, define the connection between the two ideas. Concept is what we refer to as a labelled apparent regularity in events, objects, or records of events or objects. Though occasionally we utilise symbols like + or %, and occasionally more than one word is used, the majority of concepts are identified by words. A proposition is a statement that combines two or more concepts with linking words or phrases to make sense. These are referred to as semantic units or meaning units at times ^[10].

The concept map may be connected to a situation or event that is being tried to understand through the conceptualization of knowledge, providing the concept map with context. The concepts on concept maps are similarly organised hierarchically, with the most general concepts at the top and the more specific concepts organised below. The hierarchical structure of a particular body of knowledge is also impacted by its application or consideration. Therefore, it is crucial to develop concept maps in relation to a particular problem referred to as a focus topic.

The addition of cross-links is another key component of concept maps. These are connections or ties between concepts in various concept map domains or segments. Cross-links make it easier for us to understand how an idea from one area of knowledge shown on a map relates to a concept from another area of knowledge displayed on the map. Cross-links frequently signify innovative steps on the part of the knowledge producer in the creation of new information. The hierarchical structure that is portrayed in a good map and the ability to find and describe new cross-links are two aspects of concept maps that are crucial in the facilitation of creative thinking ^[10].

A concrete example of an event or object that assists in understanding the meaning of a concept is a final element that may be included to concept maps. These are typically not represented by ovals or boxes because they are concrete events or objects rather than concepts ^[10].

Concept map and Problem Based Learning

A shift from a teacher-centred to a student-centred approach has occurred in the pedagogical system over the past few years. The traditional lecture-based methods are largely being replaced with more efficient teaching strategies that help medical students learn, combine new ideas with prior knowledge, integrate critical thinking abilities, solve a variety of challenging clinical problems, retain, and apply this extensive knowledge in their future education, and work in the medical field ^[33].

Along with the traditional lectures that haven't always been effective in teaching medical students for problem-solving in clinical settings, Problem-Based Learning (PBL) has been one of the more well-known student-centred methodologies adopted in medical education (Hung et al., 2008; Qin et al., 2016) ^[34,35]. According to Kong et al. (2014) ^[36], PBL is an active, student-centred method of teaching that helps students develop their skills in self-directed learning, teamwork, problem solving, and critical thinking. The focus is shifted from a teacher-centred to a knowledge-centred system in PBL-based medical curricula, according to research (Colliver, 2000; Hagi & Al-Shawwa, 2011; Rovers et al., 2018; Urrutia Aguilar et al., 2011; Yew & Goh, 2016) ^[34-38]. This promotes deep learning and critical and clinical thinking of future clinicians ^[33].

When concept maps are used in the classroom, the teacher receives a snapshot of the knowledge and understanding of the students based on the concepts and linkages shown on the map, giving them insight into how concepts were retained (or not) by the students (Daley et al) ^[42]. As a result, it can be used as a tool for evaluating the understanding of the material and how it pertains to the general objectives of the course. Greater complexity and sophistication of knowledge are indicated by the number of connections and cross-links. They act by encouraging meaningful and in-depth learning because it has been demonstrated that through Concept Map building, students can shift from linear to integrated holistic thinking, integrate basic and clinical science knowledge, and showcase critical thinking (Veronese et al., 2013) ^[43].

When Concept Maps are applied in a group setting with highly different knowledge structures in a PBL context, there are considerable learning gains because Concept Maps work effectively across groups of learners with multiple and varied learning styles ^[33]. Concept mapping is seen to be a good complement to PBL since it encourages problem solving and critical thinking in medical students and involves active learning as opposed to more surface learning or rote memorization (Hung & Lin, 2015; Slieman & Camarata, 2019) ^[44,45]. Additionally, there are hints that Concept Maps may assess different cognitive domains than more traditional tests and that they have the greatest beneficial impact on learning improvement in students who enter the PBL study with the lowest levels of cognitive competence (thus, they could be used as a tool to assist such students). Additionally, Concept Maps serve as an extra learning resource since they can be used to establish PBL curricula, generate cross-departmental curricular learning objectives, and give alternative and innovative learning and teaching possibilities ^[33]. Concept Maps are pre-prepared by faculty and used in teaching. Particularly in the context of medical education, Concept Maps can help students develop their capacity for critical thought, clinical reasoning, and decision-making (Daley & Torre, 2010; Rendas et al., 2006) ^[46,47]. The time required to create a Concept Map or students' inability to comprehend how Concept Maps will afterwards help to raise performance scores can occasionally cause student opposition to employing Concept Maps. From the perspective of the faculty, it is important to realise that Concept Maps are an aspect of meaningful learning and that the fact that they change over time as students learn is not a problem with their reliability but rather a sign of how their learning has advanced over time, like the process of developing expertise ^[33].

Importance and Relevance

The findings of several studies that investigated how students felt about group Concept Maps indicate that students believe they gain a lot from group learning environments that encourage feedback from peers and instructors. One of the most advantageous uses of concept mapping, according to both students and instructors, is the use of Concept Maps to pinpoint knowledge gaps in pupils, enabling more targeted feedback and study. When thorough, Concept Maps give students a full understanding of a subject, enabling them to spot areas where their knowledge is less well-organized and cohesive. Additionally, students' active participation in making maps and establishing conceptual connections shows that they are aware of the relationships between various concepts ^[33]. As a result, Concept Maps give tutors and teachers a chance to identify where students are connecting ideas incorrectly and give targeted guidance. Concept Map usage among students is viewed differently across studies. The time-consuming nature of concept mapping, the fact that students already have their own learning styles, and the possibility that Concept Map may not be helpful to all students have all received criticism. On the other hand, some students have remarked that Concept Maps enable them to take a more active role in their learning and find this inspiring. Additionally, studies focus more on students' positive perceptions, with one research even including an open-ended question about the task's advantages but excluding any room for criticism. These issues raise question on the idea of requiring Concept Map incorporation within curricula. However, there is some evidence to suggest that perception of the learning environment does have an impact on academic achievement (Wayne et al., 2013) ^[48], and medical educators should take this into consideration. Student impression of Concept Maps may not reflect their utility as a learning tool. It is challenging to attribute all assessed consequences to the use of concept mapping alone since concept mapping exercises frequently involve additional learning or instructional resources, such as feedback and collaboration. This may also be a point in favour of Concept Maps as a tool that enables the blending of various educational approaches that might work better together and produce better results. Most of the research on the use of Concept Maps in medical education has been focused on certain courses or one year of medical school. Longitudinal studies will be necessary in the future to assess the long-term impact of Concept Maps on student learning and determine whether Concept Map integration into medical curricula assists medical students and knowledge organisation as they move into their future employment ^[33].

Why concept mapping is useful when other brainstorming techniques and tools, given that there are countless ways to explore and visualise ideas?

- Concept maps are an excellent tool for exploring and visualising ideas.
- concept maps facilitate gaining new perspective
- When attempting to address a problem, it's simple to become mired in the specifics and lose sight of the wider picture of what must be done. Prior to delving into the details, concept mapping urges you to zoom out and begin with a broad viewpoint.
- Makes use of various learning styles
- Many widely used frameworks and tools for strategic planning are centred on written exercises, which can be laborious for those who learn best visually. Visualisation, according to studies, can aid with memory recall. Concept mapping is naturally visible, which encourages participation from visual learners.

Concept maps provide a hierarchical framework and structure to organise thoughts, breaking complicated concepts down into smaller pieces, making complex ideas simple to understand. This not only helps you come up with ideas, but it also makes it simpler to present a lot of information in a lively, connected way.

Concept mapping is an excellent tool for idea generation in a team or group, even if it may also be done alone. Teams can more effectively synthesise ideas from many contributors who each bring their own distinct and valuable views to the table by using concept mapping ^[32].

Concept maps in Curriculum Planning

Concept maps can be extremely helpful when developing a curriculum. The most important ideas and rules to be taught are presented in an extremely succinct way. The hierarchical structure of idea maps indicates a more effective order for teaching materials. Since the integration of new knowledge with the learners' prior conceptual and propositional frameworks constitutes the fundamental characteristic of meaningful learning, moving from the broader, more inclusive concepts to the more specific information typically serves to promote and enhance meaningful learning. As a result, while developing a curriculum, we must create both a broad "macro map" outlining the key concepts we intend to cover over the entire course or curriculum, as well as more detailed "micro maps" outlining the knowledge structure for a given area of the teaching programme. Course syllabi or an entire curriculum can be redesigned by faculty working individually or in teams ^[10].

To make instruction "conceptually transparent" to students, concept maps are often used in curriculum preparation or instruction on a particular topic. Many students struggle to recognise the key ideas in a text, lecture, or other presentation. A part of the problem is caused by a method of learning that focuses solely on recollection of knowledge without any requirement for evaluation. Such students view learning as a haze of numerous facts, dates, names, equations, or procedural norms to be memorised because they are unable to build strong concept and propositional frameworks. For these pupils, the subject matter of most disciplines—especially physics, math, and history—represents a cacophony of facts to memorise, which they typically find tedious. Many people believe they cannot become experts in the subject at hand. Previously unsuccessful students can succeed in making sense of science and any other discipline, acquiring a sense of control over the subject matter, if concept maps are used in planning instruction and students are required to construct concept maps as they learn (Bascones & Novak, 1985; Novak, 1991, 1998) ^[50,51,19].

As per Edmondson, concept maps are essential to create the curriculum for a veterinary programme. According to Edmondson (1993), "Concept maps are effective tools for making the structure of knowledge explicit, and our hope is that by using them in our planning...the material will be more accessible and more easily integrated by students" ^[51]. Edmondson's description of a curriculum is based on constructivist ideas. It is both student- and problem-centered. The emphasis is on "what do I want students to learn," rather than "what do I want to teach?" ^[52]. Martin demonstrated educationists how to create lesson plans using concept maps, in a study carried out by him in 1994 ^[53]. The maps were very helpful to the study' teachers in creating their lesson plans. Concept mapping also helps teachers to design truly interdisciplinary classes by allowing them to build the concept map with a more thorough understanding of the material they are about to teach ^[52]. For organising and structuring

educational programmes and subjects, concept maps are ideal. The best way to raise awareness of the significance of the course is to provide a concept map that depicts the complete study programme. Students can immediately understand what level of knowledge they should have at the end of the course. To help students understand and be motivated, it might also show how the classes are related. Teachers and study programme directors can review their courses and ensure that they are coherent by using concept maps to represent the curriculum ^[2,54].

The following list of benefits of adopting concept maps for curriculum design was put together using research from Dyrud, Edmondson, and Martin, Allen, Hoffman, Kompella, and Sticht (1992) ^[51,53,55,56].

1. You can identify topics that appear insignificant and that you might wish to delete from the course by creating a concept map.
2. The themes you want to emphasise can be found.
3. You can question pupils' methods of thinking because you have a greater understanding of how they may see or organise knowledge differently than you do.
4. You can cross conventional academic boundaries by using the mapping technique to find concepts that are important to several disciplines.
5. You can choose the best teaching materials with the help of concept maps.
6. A course map that includes teaching techniques as well as time and task assignments for various sections of the course can be created.
7. Any course's objectives can be visually explained using the conceptual relationships that were utilised.
8. You can support initiatives that reconsider course material.
9. Concept maps represent the objectives of faculty—the integration you expect to occur—instead of being a standard outline for the course that assumes students will integrate learning.
10. Concept maps can be used to summarise key course concepts and to serve as a foundation for student debate.
11. A comprehensive approach to learning is aided by concept maps.
12. By merging concepts, concept mapping can improve your ability to give students meaning.
13. Using concept maps can help you see more ways that children can generate meaning.
14. You can create courses that are cohesive, properly sequenced, and have continuity by mapping the concepts.
15. According to Martin (p. 28), concept maps "help teachers design units of study that are meaningful, relevant, pedagogically sound, and engaging to students" ^[53].
16. Concept maps assist "the teacher in explaining why a particular concept is worth knowing and how it relates to theoretical and practical issues both within the discipline and without" (Allen et al.) ^[56].

Concept Map as an Assessment Tool

Concept Maps could also be used in evaluation. Through evaluation of the Concept Map creator's deliberate effort to link, differentiate, and relate various concepts can be done in a way different from the traditional assessments (Gomez et al., 2014) ^[57].

Numerous initiatives are currently being conducted in the USA and other countries to explore the use of improved evaluation tools, such as the usage of concept maps. In future, we should start to witness considerable advancements in this field. The usage of concept maps for assessment is made easier by a few improvements in the most recent iterations of CmapTools. For instance, the "Compare concept maps" tool enables the comparison of "expert" concept maps for a topic with student-made maps, and all conceptual and propositional differences as well as similarities are highlighted in colour ^[10].

Concept maps are excellent instruments to use in the classroom to assess students' understanding of concepts and provide feedback. They play a significant part in formative evaluation. The structural character of student knowledge, interruptions or distortions in students' understanding of the subject matter, and omission errors are crucial criteria if they are being used for evaluation (in Novak, 2008) ^[2]. Students can respond to a focused question by developing a concept map rather than writing answers in free text or selecting the best response from a predetermined selection of options. As in the past, the students may be given an incomplete skeletal map or the map may be developed from scratch. The students could also be given a blind map as an alternative. It might just contain concepts; therefore the students must establish the appropriate connections between them. The ideas could be prepared beforehand. or they might be arranged in a straightforward list, serving as a sort of parking lot for ideas from which the students choose and arrange them properly. The students' duty would then be to name the concepts accurately so that the links would make sense. Alternatively, the map might show relationships but include concepts without labels. The blank nodes can be filled with numbers. The students should be able to understand the map's intended structure if at least some fundamental concepts are left labelled. The job would then be to name the links appropriately. Another modification is to have blank relationships between labelled notions ^[2,54].

Evaluation of Concept Map as an Assessment Tool

In terms of expressing a deeper comprehension of the subject, there are a variety of characteristics that can be used to determine whether one Concept Map is "better" than another. Topological features (such as Concept Map structure and the number of links between concepts) and semantic features (such as the connections between concepts and the linking words employed) can both be used to undertake this assessment ^[33]. Comparing a Concept Map to one created by an expert and performing longitudinal comparisons of Concept Maps throughout the course are some ways to perform formal analysis of a Concept Map at a qualitative level, for example, counting the number of concepts and/or links and, thus, indirectly measuring the map complexity (Srinivasan et al., 2008) ^[58]. Three map attributes—the number of concepts, hierarchies, and cross-links across the hierarchies—are counted as part of "traditional" quantitative scoring (Besterfield-Sacre et al., 2004) ^[59]. The maps can also be subjected to informal analysis, which evaluates them for accuracy but isn't objective because there isn't a "right or wrong" answer. Caas and colleagues developed the "topological taxonomy" to categorise Concept Maps into seven tiers of increasing structural complexity, with expert Concept Maps at the top. Additionally, they created a computer programme that categorises Concept Maps according to their topology and annotates structural elements of the map (Valerio et al., 2008) ^[60]. The technique was validated by determining the fundamental composition of the Concept Maps without taking semantic information into account. Kinchin and colleagues propose a qualitative approach of

evaluation in which they suggest a rapid technique of classifying student Concept Maps into three categories (spoke, chain, and net) based on their shape, with Concept Maps classed as "net" suggesting meaningful learning (Kinchin et al., 2000) ^[61]. The potential use of Concept Maps as a component of formal assessment is complicated by the lack of an objective method of rating Concept Maps. The study of graph theory may provide a fresh answer (Wilson, 1996) ^[62]. The visual representation of a Concept Map (directed graph of concepts and linking phrases) is remarkably similar to the visual representation of a network in graph theory applications, in which each concept and its connections with other concepts are represented by "nodes" and "edges" respectively (Hevey, 2018; Watts & Strogatz, 1998) ^[63,64]. It may be possible to use Concept Maps for summative assessment by treating each Concept Map as a network and employing quantitative graph-theoretical measurements to define the "network" complexity (Concept Map) ^[33].

The format and structure of the Concept Maps created by the students were evaluated in comparison to the "benchmark" Concept Maps created by the expert using both qualitative (word clouds) and quantitative (graph theory) methods. The fundamental themes that distinguish the participant-developed Concept Maps from the "benchmark" Concept Maps were examined through qualitative analysis. All qualitative analysis was done using NVivo (Release 1.4 (4)), specialised software for qualitative and mixed-methods research. A word cloud of the concepts was obtained (NVivo) to aid in the identification of important concepts that pop up more frequently in the Concept Maps. A word cloud is a graphic representation of text data that can be used to see free form text or to find keywords. It is accomplished by using a higher font size for terms that are used more frequently in the text. Each word in the word cloud is represented by a font size that is proportionate to how frequently it appears in the text. Which words (concepts) the participants prioritised were shown in the word clouds derived from the Concept Maps. Comparisons and contrasts between the main concepts mentioned by the experts in the many PBL instances might give qualitative insight into whether or not the students' capacity to understand important concepts has changed over time. The depth of the ideas found in the word clouds was also related to modifications in participant clinical/critical thinking as revealed by the questionnaires that were provided out at various points throughout the study [33].

While word clouds offer a brief visual description of the main concepts, the innovative use of graph theory to Concept Maps allows for quantification of the depth of the concepts and the density of connections between them. We utilised the free network visualisation tool Gephi to estimate the graph-theoretical measures. Gephi was utilised to import the expert and student Concept Maps, and the following measurements were estimated: Graph density, which measures a graph's connectivity. It is calculated as a percentage of the total number of potential edges as the actual number of connections (edges) in the graph. It informs us of a network's connectivity in relation to its potential connectivity. More connections between the nodes can be inferred from higher density. As information can spread quickly from one node to all others rather than from one node to another, this may point to a more effective movement of information across the network. However, in the context of Concept Maps, a highly connected network could also refer to a network in which all concepts are interconnected without respect to any structure or function.

The degree to which a network may be separated into distinct, non-overlapping groups (number of communities) is known as its modularity. It offers a way to divide bigger

networks into fundamental "building blocks," or internally densely connected clusters with weaker connections to one another. High modularity networks have a strong sense of community, and the more modularity there is, the more diverse those communities of tightly connected nodes are. If the modularity is less than 0.4, there aren't many differences between the various clusters, and the majority of the nodes are equally densely connected to one another across the whole network. A modularity of 0.4 or higher indicates that the network has a very pronounced community structure. Higher modularity in terms of the Concept Maps would mean that the primary concepts are also grouped into more compact units that represent unique and focused characteristics of the subject ^[33].

In 2004, Besterfield et al. devised one method for evaluating Concept Maps ^[59]. A different method of assessment of concept map was put out by Novak and Gowin in 1984 ^[65] and is based on the components and design of the map. In this system, points are given for:

- Valid Propositions (1 Point Each),
- Levels Of Hierarchy (5 Points for Each Level),
- Number Of Branching (1 Point for Each Branch),
- Crosslinks (10 Points For Each Valid Cross-Link),
- And Specific Examples (1 Point for Each Example).

Advantages of Concept Map in Learning

1. Making decisions for building the concept maps requires active learning.
2. It groups thoughts and facts to organise information; learning is more advanced than merely memorising facts.
3. It groups thoughts and facts to organise information; learning is more advanced than merely memorising facts.
4. Cross-links are used to show how different facts and ideas relate to one another.
5. Exam reviews are quicker and more efficient when they are easy to visualise. It directs reading to avoid linear attention, and the requirement to look for groupings and comparisons encourages reading in order to provide an answer.
6. It encourages lifelong, self-directed learning.
7. Use mapping to organise thoughts, analyse relationships, and put things into perspective.
8. In order to understand more clearly about cause and effect and the new information required to decide diagnosis or treatment, use mapping to organise a subject or a case. Patient data can be organised in this way.
9. Using maps, you may combine both old and new knowledge.
10. When studying for exams, keep your maps and go over them. They can be expressed once more as a "story" ^[66].

Usually, there are numerous ways to make a map on a single subject. Even if two map authors were given the identical entering knowledge and the same set of concepts to map, they would likely produce slightly different structures (or layouts) and relationships. As a result, it could be challenging to understand someone else's map. On the other hand, concept maps work best when each student creates the map independently or at the very least modifies a map that has already been made to suit her needs. Students may think that generating and revising concept maps is time-consuming, however contemporary software tools like Context Minds make it simple and quick to create new maps. In accordance with

the context established by the concepts already present in the map, Context Minds, for instance, automatically offers new concepts appropriate for adding to the map. Students can almost entirely avoid typing when creating the map and concentrate on considering the relationships ^[54].

Concept maps are believed to promote creativity and are used to inspire the creation of ideas ^[2]. Brainstorming sessions frequently involve the use of concept mapping. Concept maps can be utilised to convey complicated ideas, even though they are frequently unique and unusual.

Software design uses formalised concept maps, where one frequent use is diagramming with the Unified Modelling Language in conjunction with related standards and development techniques.

Similar to argument maps, concept mapping can be used flexibly to express formal argument and can also be considered as the first stage in ontology construction.

Uses of Concept Maps

They are frequently employed in both business and education. Uses include:

- Taking notes and summarising information from documents and source materials to identify significant concepts, their connections, and their hierarchies.
- Institutional knowledge preservation (retention), such as eliciting and mapping employees' expert knowledge prior to retirement.
- Collaborative knowledge modelling and the transfer of expert knowledge
- Facilitating the development of shared vision and shared understanding within a team or organisation
- Concept maps are employed in instructional design as Ausubelian "advance organisers" that offer a preliminary conceptual framework for subsequent knowledge and learning ^[67].
- Evaluating the learner's comprehension of the learning objectives, ideas, and connections between those topics ^[68]
- Lexicon creation
- For training, concept maps are employed as Ausubelian "advanced organisers" to describe the context of the training and how it relates to participants' employment, the organization's strategic goals, and training objectives.
- Expressing intricate concepts and arguments and examining the symmetry of intricate concepts, reasoning, and terminology
- Outlining an idea, train of thought, or line of reasoning from beginning to end (with the express purpose of revealing flaws, errors, or holes in one's own reasoning) for the review of others.
- Improving metacognition (the process of being more aware of one's own ignorance).
- Developing linguistic skills ^[67].

Benefits of Using Concept Maps in Medical Education

Concept maps serve four key purposes: (i) fostering meaningful learning; (ii) acting as a supplementary learning resource; (iii) allowing teachers to give feedback to students; and (iv) carrying out learning and performance assessments.

Today's medical students must learn in meaningful and integrated ways due to the rapid advances in medical knowledge and the requirement for future practitioners to maintain competence as the medical environment changes. Medical students benefit greatly from meaningful learning, which is the capacity to comprehend and relate pertinent medical concepts by tying them to prior information. Additionally, developing future doctors' critical thinking, clinical reasoning, and clinical problem-solving skills is crucial ^[69].

The fundamental advantage of concept mapping is to replace rote learning with meaningful learning, which helps pupils learn knowledge more effectively and retain it for longer. Additional benefits of concept maps include the following:

They can be used to actively engage students by giving them a partially filled map to complete. They can be used to give students a quick, systematic overview of the subject matter. They emphasise relationships among concepts. Their quality can be (to some extent) automatically assessed through evaluation rules ^[54]. They can be utilised as a basis for discussions, are better retained by students with strong mental images than text and can be used into the curriculum to promote integration and continuity in the course. It may also raise awareness of the course's significance. They assist in demonstrating why the suggested concept is important to understand (Allen 1993) ^[56]. They foster both critical and creative thinking in the kids as well as encourage both.

- Concept maps are utilised in the field of education as both a learning aid and an evaluation tool to measure student learning.
- Promote meaningful learning by assisting students in making connections between what they already know and the new information they learn; • Arrange information on a subject for speedy examination.
- Evaluate students' comprehension to see where their knowledge needs to be improved.
- Conduct analytical brainstorming around a subject; Simplify difficult-to-understand concepts; and organise educational materials for classes or curricula

Students can use it as a starting point for discussions, to help them distinguish between true and false beliefs, to encourage critical and creative thinking, and as an alternative to standard notetaking and writing projects ^[1].

Concept Maps in Business

- Concept maps are ideal for business assessment through design. Concept maps are frequently employed in the corporate world to store, create, and transfer knowledge.
- To lead team brainstorming sessions to generate fresh ideas for strategies, businesses, etc.
- Encourage an innovative and results-driven attitude to business development.

- Can be utilised as a methodical means of imparting to others professional business insights, ideas, etc.
- Support with the planning and writing of business documents, presentations, etc ^[1].

Concept Maps in Research

- Concept maps are a rigorous research strategy in qualitative research.
- Can be used to organise research projects.
- Can assist in condensing large amounts of text-based material into manageable amounts without losing meaning.
- Analyse the data provided by interviewees in a study and assist the researcher in maintaining the significance of the interview by analysing the material presented. It helps to present findings effectively ^[1].

Experience of the educators on concept map- review of studies In one of the studies conducted in a graduate medical school, All and Huycke ^[70] employed serial concept maps to show how a student's thinking changed over time. A serial concept map is "a series of evolving maps created about a single concept over a specified time period," according to All and Huycke ^[70], serial idea maps have offered a method for sporadically monitoring student development, explaining incorrect conceptual interactions, and promoting the connections between academic knowledge and clinical practise. Interesting information on the use of concept maps in medical education can be found in the work by González et al. ^[71]. The results show that the concept map-using group greatly outperformed the other groups in the problem-solving test. They performed similarly to the conventional group on the multiple-choice test. González et al.'s findings ^[71] appear to support Roberts' ^[72], findings who discovered substantial connections between concept map scores and practical assignment scores but no significant change in concept map scores over time. They also seem to support the findings of West et al. ^[73], who claimed that concept map evaluations may be evaluating different cognitive domains than assessments with more conventional tests. The conclusion that employing concept maps in problem solving had the greatest influence on students who entered the research with the lowest levels of cognitive ability is even more interesting in the González et al. study ^[71].

Concept maps, in accordance with Pinto and Zeitz ^[74], can help students comprehend how key concepts are organised and connected. In order to learn more about how students feel about concept maps as an additional learning tool, Laight ^[75] designed a study. Concept maps that had already been produced were incorporated into conventional teaching strategies. Concept maps were evaluated their usefulness in surveys, which also provided space for further remarks.

Most students said that using concept maps that had already been created helped them learn. Therefore, according to Laight ^[75], concept maps that have already been produced may present different and creative teaching and learning opportunities in large courses.

Both Patrick et al. ^[76] and Weiss and Levison ^[77] mention concept maps as a tool for teaching and developing curricula. To promote the construction of PBL curricula, Patrick et al. ^[76] demonstrate how concept maps might help with curriculum databases in medical institutions.

According to Castro et al. ^[78] and Willemssen et al, ^[79] concept maps can be used as a learning resource in one of the most creative ways. According to these writers, concept maps can be useful when creating knowledge models.

Concept maps can help students better comprehend a subject, and teachers can use them to give feedback and identify misconceptions among their students ^[72]. In the opinion of Kinchin and Hay ^[80], Concept maps, are viewed as a tool for communication between students and teachers that reveals how the students form connections.

In a qualitative study, Edmondson and Smith ^[81] examined how students reacted to the use of concept maps as a teaching and learning method. A concept map was deemed an effective teaching tool by almost half of the pupils. As a teaching tool, the concept map gave the instructor insight into the students' mistakes, enabling him or her to give feedback and make content and performance clearer.

We gain a more thorough understanding of the role that feedback might play in concept map teaching and learning from Morse and Jutras ^[82]. According to the study's findings, concept maps without feedback had no discernible impact on students' performance, whereas concept maps with feedback led to a considerable improvement in students' problem-solving abilities and a decline in failure rates ^[82].

Numerous studies have used concept maps as an assessment method to evaluate student clinical performance, comprehend their thought and reasoning processes, and contrast their maps with those of experts. Concept maps can be used to evaluate learning rather than only as a means to an end, according to Williams ^[80]. However, Roberts ^[72] asserts that "a scoring method which suits the particular type of map must be chosen" because "maps can vary greatly in style."

Concept maps were employed by Daley et al. ^[84] as a teaching and evaluation method. In a clinical context, 54 students produced three concept maps over the course of a semester that showed the connections between the clients, pathophysiologic factors, pharmacologic factors, and therapeutic nursing interventions. These maps served as discussion starters in post-conferences to help students make connections between the theoretical course material and the patients they were caring for ^[84]. The results show a statistically significant difference between the semester's first and last concept map ratings. Using concept maps, Hicks-Moore and Pastirik ^[85] did another study to gauge the degree of critical thinking. According to their findings, creating maps in a therapeutic setting improved critical thinking as determined by the Holistic Critical Thinking Scoring Rubric ^[85].

Additionally, West et al. used concept mapping in their pre- and post-test study ^[73]. West et al. ^[73] discovered, like Daley et al.,^[84] that concept mapping assessment (CMA) scores increased during course teaching, but that CMA scores did not correspond with end course or standardised test scores. The lack of a positive correlation, according to West et al. ^[73], "suggests that CMA measures a different knowledge characteristic than do multiple-choice examinations." As a result, Concept Mapping Assessment has the potential to assess how students or residents organise and use knowledge in a way that traditional assessments cannot.

In a quantitative study conducted by Mc Gaghie et al. ^[86], concept maps were assessed for internal coherence, resemblance between students and instructors, and correlations to final exam outcomes. Although descriptive analysis did not reveal a relationship between student-instructor concept map similarity scores and test scores, student scores were internally consistent, and after training, the degree of similarity between student maps and instructor maps grew noticeably. Additionally, Mc Gaghie et al. ^[86] discuss three other research that aimed to contrast concept maps created by faculty members with those created by medical students. Findings show that student and expert maps were more comparable following a 3-week pulmonary physiology unit posting ^[86].

By modifying the CMA scoring system created by West et al. ^[73], D'Antoni et al. ^[87] revealed that the concept of linkages, cross-links, hierarchies, examples, illustrations, and colours may all be used to evaluate the depth of a map. Finally, a study to evaluate the dependability of CMAs was created by Srinivasan et al. ^[58]. They developed four scoring methods and discovered that the hybrid system, the scoring system that focused on both the quality and relevance of concepts as well as the map, and the scoring system that focused only on the map's structure all had similar dependability and were, in general, more dependable.

Concept maps operate as scaffolding by making conceptual understanding evident at various learning levels for both undergraduate and graduate students, according to Jorge Villalon et al ^[88]. The concept map generator Concept Map Miner (CMM), which creates concept maps from student writing automatically, is discussed in the paper. Utilising Concept Maps (CM) is difficult because it takes time and money. CMM is an automated technology that creates concept maps and finds concepts and connections between them. CMM can be incorporated into an e-learning setting.

According to A.M.M et al. ^[89], Manufacturing is a knowledge-intensive activity. We all know that the Internet can assist us in developing concept maps for Internet-Assisted Manufacturing (IAM). The interaction between IAM and C-map is described in this study. C-map is a powerful tool for representing both previously acquired knowledge and newly discovered knowledge. Knowledge is an interpretation of reality that is based on logic or perception, not reality itself. Evidential ordering and eliminatory explanation are two types of justification that can be used to create emergent knowledge from exploratory and general knowledge. The knowledge underpinning difficult engineering challenges is represented using C-map.

A type of context-aware hand-drawn concept map with RFID tags is suggested in Yingying Jiang et al. ^[90]. and is particularly helpful for pan-based mobile devices. In the suggested method, the hand-drawn concept map's structure is first retrieved, after which users can give concept nodes RFID tags.

In an experiment on engineering students, Susan M. Zvacek et al. ^[91] found that while they are good at memorising a lot of material, their capacity to apply it to complicated problem solving, critical thinking, or creative endeavours is still somewhat limited. The paper discusses the use of idea maps for training before outlining a pilot project for incorporating them into a mechanical engineering course. Finally, researchers look at how much better students perform on practically all metrics of the final grading scale when they apply concept

mapping in their homework and lab sessions as opposed to when they are only exposed to it in a few theoretical lectures.

In Chei-Chang Chiou et. Al. ^[92], an experimental study involving 124 students enrolled in an advanced accounting course at a management school in Taiwan was conducted. In addition to examining whether idea mapping may be utilised to assist students learn more effectively and more engagingly, the author also finds that students' academic performance has significantly improved when compared to the typical expository teaching technique. The concept mapping Meta learning technique, which may aid in skill improvement, was well received by the students. The final suggestion in the study is to switch from the "transfer of knowledge" approach to "learning to learn."

A way to provide course curriculum was suggested in Gul Tokdmir et al.^[93] paper. Numerous issues, such as the diversity of the concepts taught in courses, have plagued universities, institutes, and organisations. Students find it very challenging to visualise the computer engineering field. In a similar vein, it might be challenging to integrate course material at the student level.

Martin Davies et al. ^[94] have made recommendations for the use of software mapping tools for a variety of educational purposes. These resources are designed to teach students analytical and critical thinking abilities and the connection between concepts and evaluation methods. These instruments all rely on diagrammatic relationships.

In M.J.H. Van Bon Martens et al. ^[95], the authors advised using concept mapping as a technique for arriving up with solutions for complicated situations, with the idea maps serving as a roadmap for dealing with complex subjects. Studying concept maps provides a better means of comprehending scientific and practical knowledge in order to advance theories. The assignment was assigned to five Dutch research fellows who work in various public health sectors. These researchers' main objectives were to develop a theoretical framework for effective regional public health reporting, to devise and put into practise techniques for comprehensive local health policy, guide the establishment of a local combined approach to youth obesity and overweight, direct the creation of a questionnaire to assess the efficacy of physiotherapy following a disaster, and conceptualise and formulate goals and objectives for the new youth health care programme of local health services. This study demonstrates how concept mapping can enhance theory development. By using concept maps, we can merge scientific and practical knowledge while carefully choosing a topic from a variety of research fields.

Authors describe how idea mapping could be useful in the field of preventive medicine in Heather M.Hanson et. al. ^[96]. The major goal of this study is to develop a walking schedule for seniors that keeps them engaged and completely active throughout the day. To do this, writers have examined how local elders interact with their environment and how this affects their priorities. The authors' research revealed that crosswalks and sidewalks were among the senior citizens' top walking priorities. They came to the conclusion that senior citizens' walking habits will be influenced by environmental factors that foster social interaction.

Using concept mapping approach, Roshanak Mehdipanah et al. ^[97] investigated how a group of local inhabitants saw a large-scale renovation programme in Barcelona and its significance

to them. The bulk of urban revitalization measures, including better walkability, the creation of additional public spaces, and more community programmes, the author discovered, have significant and positive effects. The paper on participants' general well-being introduces a novel approach that departs from the conventional outcome-based evaluation studies frequently applied in the industry.

Software Used Create Concept Map

When choosing a concept map software to develop a concept map, we should take into account a number of important factors. The success of a project in general can be strongly influenced by making the correct choice about interaction, idea presentation, and other factors.

The following are some of the most important characteristics to consider:

1. There should be options to modify the concept map's visual cues, appearance, and making templates for concept maps that can be used again in the future.
2. From a variety of platforms and devices, including browsers, desktop applications, and mobile devices, users should be able to connect using desktop and mobile apps.
3. Teamwork features which like the ability to write comments, discuss and amend concept maps in real-time, and assign tasks should be available.
4. Platform security, including data encryption, access limits, and regular backups should be present to safeguard sensitive data.
5. Integrations to link with other professional apps, such as file-sharing sites, communication apps, or project management software should be present to optimise processes and boost productivity.
6. Concept maps should be able to be accessed and edited using a contemporary interface with minimal learning time.

The following are some of the softwares which can be considered:

1. **Aibase:** Lacks up-to-date certificate. It is a creative data manager. Aibase is optimized for structuring thoughts and ideas in an efficient information space, leading to many positive effects on learning, creative work, task solving and project management.
2. **ConceptDraw:** published by CS Odessa LLC.
3. **Qiqqa:** It's a open source free software.
4. **Lucidchart:** developed by Lucid Software, Inc. it's a HTML-5 based collaborative diagramming tool.
5. **MindManager:** developed by Mindjet. Basic and pro versions are available for desktop.
6. **MS Visio:** developed by Microsoft and it's part of MS family.
7. **Semantica:** developed by Semantic Research.

8. **3D Topicscape:** licensed by 3D-Scape Limited. It's a desktop application.
9. **Visual Understanding Environment (VUE):** It is licensed by Educational Community. The Visual Understanding Environment (VUE) project intends to develop customizable tools for managing and integrating digital resources to enhance learning, teaching, and research. VUE provides a flexible visual environment for well-structured presentation and sharing of digital information. Students and professors can create semantic networks of digital resources using local and remote file systems, digital libraries, and digital libraries^[98].
10. **CMap Tools:** Utilised as a tool for concept mapping. The Florida Institute for Human and Machine Cognition (IHMC) developed CMAP tools^[98].
11. **Coggle:** It is a mind-mapping Freeware web application. Coggle creates documents that are branching trees-like in hierarchy. In contrast, traditional collaborative editors like Google Docs only offer tabular (spreadsheet) or linear (text document) document types. Its authors guarantee that it will remain "free forever". Coggle offers export options for vector PDF files and PNG images^[98].
12. **Compendium:** It makes managing and outlining arguments and thoughts easier. Compendium examines concepts and demonstrates many links between distinct assertions and perspectives. It is used as a tool for groups of people to communicate concepts to one another through visual pictures while working cooperatively^[98].
13. **Docear:** Docear is a word processor, PDF editor, and academic search engine all rolled into one. Docear enables the import of PDF annotations, including text highlights, comments, and bookmarks. The most crucial details in a document can be conveniently organised in this fashion. Docear can open the PDF on the page the bookmark links to if additional information is needed than what the bookmark or remark itself gives. A mind map is used to organise all the data. A mind map is a more effective and efficient way to store information than a basic list or social tags^[98].
14. **FreeMind:** FreeMind has a wide range of exporting possibilities. With the help of FreeMind, you can edit a hierarchy of concepts. It helps with coming up with fresh plans and projects. FreeMind is a Java application that runs on various platforms while maintaining the same user experience^[98].
15. **Freeplane:** Freeplane is used to make electronic outlines and mind maps. Although Freeplane only partially supports the FreeMind file format, FreeMind is still completely supported by Freeplane. It adds features and tags that FreeMind does not support; these are ignored when the programme loads^[98].
16. **MindMup:** The source code for MindMup is accessible via GitHub and is made available under the MIT Licence. At mindmup.com, MindMup is also accessible as a free anonymous web service. enables users to work in real time with other users while storing maps on a variety of cloud storage services, including GitHub, Amazon S3, and Google Drive^[99].

- 17. SciPlore MindMapping:** It is the first mind mapping programme that incorporate reference management. It makes it possible to import PDF bookmarks. The programme is compatible with the FreeMind 0.9 file format ^[99].
- 18. WikkaWiki:** A lightweight and standards-compliant wiki engine is WikkaWiki. Pages are saved using MySQL and are created in PHP. It is made with speed, granular access control, extensibility, and security in mind ^[99].
- 19. XMind:** It is software that can be used to handle complex information, capture thoughts, and encourage teamwork. In addition to many others, it supports mind maps, Ishikawa diagrams, organisational charts, tree diagrams, and spreadsheets. XMind is used to organise knowledge and manage tasks. In the XMind pro edition, you may export the mind maps as FreeMind and Mindjet MindManager documents, Microsoft Word, PowerPoint, Excel, and PDF files ^[99].

Challenges in Using Concept Maps

Both students and teachers frequently view concept maps as a novel approach to learning, and as a result, it takes some time for everyone involved to comprehend and adopt mapping as a teaching tool. When concept mapping is first introduced into the medical school curriculum, students can occasionally show resistance. The length of time it takes to develop maps is typically a factor in this resistance. The kids' incapacity to comprehend how making maps and learning in a meaningful way can help them perform well on standardised examinations may potentially be a contributing factor ^[65,73].

Helping teachers to realise that maps have been designed to implement the notion of meaningful learning presents another barrier when using maps. As a result, the professor's emphasis moves from imparting knowledge to assisting the student in conceptualising and comprehending the meaning of the concepts in the context of his or her medical practise. Students' maps will include both the curriculum's content and their experiences from clinical practise as they gain a grasp of meaning. This suggests that the maps the students produce will evolve as their understanding increases. And in fact, it shows the uniqueness of the maps how the students' learning has evolved and grown over time. The method by which expertise is developed can be assessed using this development. Doctors' knowledge of specific issues improves and deepens as their level of expertise rises. If two specialists are asked to create maps on the same subject, it is likely that these maps will differ because they reflect the various cognitive structures and clinical experiences of those experts. Concept mapping is a learning technique that calls for adaptation on the parts of both students and teachers.

Over 25 years, concept maps have been used in the classroom. When a student connects new knowledge to prior knowledge, better integrated cognitive knowledge structures are created, which results in meaningful learning. According to the studies, students were able to connect basic and clinical science knowledge, shift from linear to more integrated holistic thinking patterns, and display critical thinking skills within their fields through the usage of concept maps. Online concept maps were also used to produce this kind of meaningful learning, according to Ertmer and Nour ^[100]. First, in problem-based learning (PBL) methods used in medical and health professions education, concept maps are being incorporated. Concept maps have been used effectively in the PBL's discussion section, according to Hsu ^[101].

According to her findings, the experimental group's concept maps had much higher proposition and hierarchy scores than those of the control group. Similar results are described by Rendas et al. ^[47], who state that their findings "appear to indicate the use of concept maps stimulated meaningful learning within a PBL course." They continue, saying: "PBL and concept mapping proved to be complementary tools because the method of gathering data, generating hypotheses, and identifying learning problems allowed for the exposure of a wide range of knowledge needs that were visualised."

Secondly, concept maps are employed in the teaching of the medical and health professions to promote the growth of group and collaborative learning. When assessing students' concept maps, Kinchin and Hay ^[61] conducted a qualitative study and found three key patterns or structures. The spoke, chain, and net patterns or structures were recognised as markers of various developmental understandings. Later, Kinchin and Hay ^[80] expanded on this research and looked at concept mapping in group learning. Students were divided into groups of three, and they were instructed to create a concept map on the subject of pathogenic bacteria. Students who were in triads comprising individuals with highly distinct knowledge structures shown better learning gains than students who were in groups with more comparable knowledge structures, according to the findings. These results concur with those of Boxtel et al. ^[102], who discovered significant learning benefits when idea mapping was employed as a group activity. Thirdly, new studies have looked at whether and how concept maps can help students with particular learning styles. According to studies by Kostovich et al. ^[103] and Laight ^[75], learning style has little bearing on one's capacity to do well on concept maps. According to these experts, concept maps can be useful for groups of students who have a wide range of learning styles.

II. CONCLUSION

The most inclusive, widely used concepts are presented at the top of concept maps, while fewer common concepts are displayed hierarchically below. When it comes to fostering higher order thinking skills, concept maps clearly outperform many other types of instructional tactics. Making a concept map needs cognitive abilities that cannot be acquired merely through memory or even the application of heuristics. It also demands a clear knowledge of how ideas are related to one another. Concept Maps were more effective at helping students remember information than passive learning methods like lectures, reading portions from books, and even taking part in class discussions. Although Concept Maps do help students understand physiology in a meaningful way and improve their capacity to solve problems, they might be most helpful to children who don't perform as well academically. Even though it takes more time to finish the maps, students will find it encouraging to take an active part in their learning by creating Concept Maps. Concept Maps assisted tutors in discovering gaps in students' knowledge and reasoning, helping them to give more precise constructive feedback. The Concept Maps were beneficial to students in "identifying areas of weakness," which encouraged them to seek clarification. The introduction of Concept Maps as a formative online assessment tool gives students guidance on where to concentrate their studies for the remainder of the semester by automatically providing feedback. Presenting their concept maps to their classmates and defending the relationships between concepts was cited by students as the concept mapping activity that helped them identify any "distortions" in their understanding ^[33]. Hence concept maps can be tried in an undergraduate curriculum as a learning resource and assessment tool.

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