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Research Article

Effectiveness of Concept Map Method as a Teaching Learning Tool to Foster Meaningful Learning in Physiology Students

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ABSTRACT

Background: Physiology is a complex subject that requires deep understanding and retention of concepts. This study aimed to teach use of concept mapping as a learning strategy to enhance meaningful learning in physiology, assess cognitive gains, compare its efficacy as a learning tool against traditional methods, and evaluate student responses to concept mapping. Concept maps are a potential visual learning tool that has been shown to enhance students' learning outcomes in various subjects, though they are already tested methods and not very much used as part of learning.

Material and method: First-year MBBS students participated in the interventional study. Students have been divided into groups A or B using convenience sampling technique. All students received a lecture on blood pressure regulation in the first part of the study, which was followed by a pretest. The interventional group A was assigned the task of creating a concept map on BP regulation, while the control group B was involved in a discussion regarding question-and-answer sessions using the traditional tutorial method. After 2 or 3 days, a surprise posttest was performed. All students attended a lecture on the pathophysiology of circulatory shock in the second section, which was followed by a pretest. The interventional group B was tasked with creating a concept map on circulatory shock, and the control group A's questions and answers were discussed. After 2-3 days, a surprise posttest was conducted. Knowledge gain was evaluated by comparing test scores before and after. A questionnaire was used to collect student input on concept mapping, and the student's t-test was utilized to analyse results.

Results: Using a paired t-test, both groups (interventional and control) for both topics in our study demonstrated significant differences in pre- or post-test scores ($P < 0.05$). When comparing the interventional group to the control group, the mean score of learning gain, raw gain (G0), absolute learning gain, relative learning gain, or average normalized gain demonstrated statistically significant performance improvement for both topics. The intervention groups for both topics had significantly higher post-test scores and percentage scores compared to the control groups ($p < 0.05$). For the topic regulation of BP, the average normalised gain (G1) was higher in the intervention group A (0.76 ± 0.01) compared to the control group B (0.46 ± 0.03). For the topic pathophysiology of circulatory shock, the average normalised gain (G1) was higher in the intervention group B (0.77 ± 0.01) compared to the control group A (0.46 ± 0.03).

Based on student feedback, concept mapping made difficult concepts easier for them to understand and integrate, promoting deeper understanding and retention.

Conclusion: Compared to the traditional tutorial method, the concept mapping strategy was more effective. An effective learning tool for physiology students is concept mapping, which enhances cognitive development and fosters meaningful learning. Its integration in physiology can potentially improve student academic performance and retention.

Keywords: Concept mapping, physiology, Teaching learning tool, Traditional tutorial method, Meaningful learning.

INTRODUCTION

The fundamental principle of competency-based medical education (CBME) is student-centred learning. MBBS students should develop critical appraisal and thinking skills that support lifelong and self-directed learning skills.

Physiology as the study of complex dynamic system from molecular pathway to organism level, demands more than rote memorization. Students must "be able to study physiology through meaningful learning. Critical thinking and the ability to clarify physiological responses and their variation in abnormal" conditions are essential skills for successful physicians. If they are capable of doing so, they have understood the subject. [1] Traditional lectures, while efficient for content delivery, frequently fail to foster deep conceptual connections, leading to fragmented knowledge and limited clinical application. These methods often focus on lower-order cognitive skills, which may not effectively address the diverse needs and learning preferences of all students. The different roles of Indian Medical Graduate cannot be satisfactorily fulfilled solely through didactic lectures and lecture-dominated tutorials. So, it's the need of the hour to modify teaching-learning methods from the traditional methods to enhance active learning and to make students more competent to adapt to diverse medical practices due to the recent changes in the curriculum. The use of active learning strategies instead of didactic lectures has been shown to accelerate learning. It emphasizes higher order thinking and often involves group work. [2]

Concept mapping involves developing teaching methods to help students develop their critical thinking, problem-solving, and clinical reasoning skills. [3] [4] Joseph Novak and Bob Gowin created it in 1972 at Cornell University.[5] The assimilation hypothesis of cognitivist David Ausubel, who emphasized the significance of existing knowledge in being able to take new concepts, is the foundation of Novak's work. Concept maps use connecting words or phrases to connect concepts and combine prior knowledge with new information to connect theory to practice [6]. As the learner examines and assesses topics and their relationships, the process of making concept maps stimulates critical thinking and improves deeper learning. It would be equivalent to synthesis and evaluation, the highest levels of Bloom's learning hierarchy. Concept maps can be utilized for training and thinking in addition to teaching and testing.[7]

The authors from international universities have investigated the application of concept mapping in problem-based and case-based learning, discovering that concept mapping enhances critical thinking and fosters the development of conceptual knowledge. [6,8]. To assess the use of concept mapping in the study of anatomy [9], physiology [10,11], biochemistry [12], pharmacology [13], and community medicine [14], several investigations were carried out in Indian medical "institutions. The purpose of the current study was to teach students how to use concept mapping as a learning tool to help meaningful learning in physiology, analyze the effectiveness of concept mapping (CM) as a learning tool by comparing its impact with traditional tutorial (TTM) methods, assess the impact of concept mapping on cognitive gain, and find out how students thought about concept" mapping.

MATERIALS AND METHODS

Study Design

The study had an experimental interventional design utilizing a pre-test/post-test methodology. The study was conducted in the "Department of Physiology at Indira Gandhi Government Medical College, Nagpur," utilizing accessible sampling, with all students asked for participation in the study. Out of 200 phase I students, 190 participated in the study.

Selection of Students

A cohort of 200 first-term students from the 1st-year MBBS 2024 batch was carefully chosen for study. Informed consent has been obtained for participation in this study. Students has been classified into 2 groups of 100 each using a convenience selection method. Group A received interventional exposure to concept mapping, while the control group B was subjected to just the Traditional Tutorial Method, which includes a question-and-answer session.

Ethical Issues

The proposed Educational Project has been approved via the Institutional Ethical Committee.

Inclusion Criteria: All first -year professional students who were present on the day of the didactic lecture, concept map session, MCQ test and provided voluntary informed consent through Google Forms to participate in the study.

Exclusion Criteria: Students who were unwilling, disinterested, or absent on the day of the didactic lecture, concept map session and MCQs test.

METHOD

A total of 190 students (Group A n = 96) & (Group B n = 94) participated in the study and also gave their feedback on concept mapping.

Their data has been utilised for all calculations. Two topics from cardiovascular module, arterial blood pressure (BP) regulation (PY 5.9) & Pathophysiology circulatory shock (PY5.11) were selected for the study. We divided study, in two parts. In the first part, a lectured-on blood pressure regulation for all students, followed by a pretest (MCQS in the Google form). An interventional group A was assigned to prepare a CM on BP regulation. In the tutorial (TTM) session, the question and answer for control group B were discussed. A posttest was administered as a surprise class in 2-3 days following the submission of the interventional group's assignment and the question-answer discussion for the control groups. In the second part, we swapped the groups for another topic i.e. Pathophysiology of circulatory shock (CS) to exposed Group B (interventional) to concept map (CM) technique and Group A (control) exposed to question answer tutorial (TTM) session. We followed same method as above. Our overall methodology is given in Figure 1.

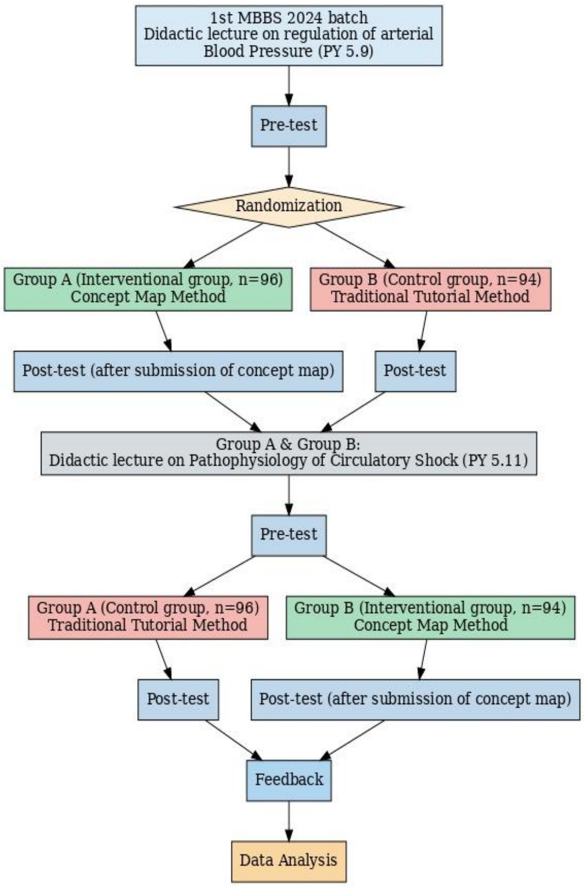

Figure 1: Flow Diagram Of Study Design

Data Collection Method

This study aimed to evaluate the learning gains and gather student opinions regarding the new instructional method of physiology through concept mapping.

For Learning Gain

A cognitive knowledge multiple-choice question was created for the pre and post-test evaluation of knowledge gain. There were twenty items totalling 20 marks. The questions were standardized for a certain topic. The students were given a pre-test prior to the start of the concept mapping intervention and a post-test following the CM intervention to determine their level of knowledge. Google Forms was used to get the data. Group A and Group B's pre- and post-test results were tabulated.

For Student's Feedback

A questionnaire was provided at the conclusion of the intervention program to groups A and B to evaluate the students' attitudes regarding concept mapping [Figure 2]. Participants were directed to systematically read each item and thereafter respond utilizing a 5-point Likert scale from strongly agree to strongly disagree [Figure 2]. Data have been gathered with Google Forms. The questionnaire's validity was evaluated by three experts from the medical education unit of institute, and its reliability was established through test-retest method. The concept reliability was assessed using Cronbach's Alpha to evaluate the reliability of tool, comprising a multiple-question Likert scale. The Cronbach's alpha coefficient was 0.7. An alpha coefficient ranging from 0.7 to 0.79 is determined to be sufficient for educational research. [15,16]

Data Analysis

We hypothesized that participation in this educational intervention for one month would provide enhanced student learning gains in cognitive knowledge.

The data was collected using Google Forms and downloaded from Google Sheets and analysis was done in Microsoft Excel. Data presented as AM±SD (AM: Average mean, SD: Standard deviation).

Statistical Methods

Learning Knowledge Gain

This study employed a pre or post-test methodology to evaluate learning gains and the efficacy of the educational intervention of CM in the study of physiology.

The "mean gain score in learning was determined by the difference among mean posttest and the mean pretest.

Raw Gain (G0) has been computed as the difference among the percentage scored in post-test or percentage scored in the pretest (G0 = % posttest score - % pretest score).

Absolute learning gain has been computed as the difference among posttest and pretest scores divided by the maximum score times a hundred. AGL = (posttest − pretest / max score) × 100.

Relative learning gain has been computed as the difference among posttest or pretest scores divided via pretest score times a" hundred. RGL = (posttest - pretest/pretest score) × 100.

Intervention Effectiveness

As a measure of learning intervention effectiveness, the average normalised gain (G1) was calculated.

(G1) = [(%posttest) − (%pretest)] / [100% − (%pretest)] [17]

According to Hake's criteria for educational tool efficacy, a minimum value (G) of 30% was used to characterize the educational intervention's effectiveness. [18]

The paired-sample *t*-test with a significance level of $\alpha = 0.05$ was employed to compare pre- and post-test scores.

The Unpaired Student's t-test has been employed for comparing the scores between the interventional groups and control group. A P value of < 0.05 has been measured statistically significant.

The quantitative data are reported in frequency distributions.

RESULTS

The study involved 190 first-year medical undergraduate students.

For THE TOPIC: Regulation oF Arterial Blood Pressure

1. The mean pretest score for the intervention (CM) group A (n = 96) was 9.11 ± 1.90 out of 20, while the control (TTM) group B (n = 94) had a mean score of 8.95 ± 2.23. A "statistically significant difference was not observed among the 2 scores when employing an unpaired t-test (P > 0.05).
2. The intervention group A (n = 96) had a mean posttest score of 17.42 ± 1.71 out of 20, while the control group B (n = 94) had a mean score of 14.09 ± 1.58. An unpaired t-test shows a statistically significant difference (P < 0.05) between the two scores.
3. The intervention group's average score on the pre- and post-test. A paired t-test shows a statistically significant improvement in performance (P < 0.05).
4. The mean score of the pre-test and post-test by the control group B showed statistically significant performance improvement employing a paired" *t*-test (P < 0.05) [Table 1].
5. An unpaired t-test revealed statistically significant performance improvement between the interventional group (A) or control group (B) based on mean score of learning gain, Raw Gain (G0), Absolute learning gain, and Relative learning gain (P < 0.05).
6. The average normalised gain (G1) compared between the intervention group A (0.76 ± 0.01) and control group B (0.46 ± 0.03) showed statistically significant performance improvement utilizing an unpaired *t*-test (P < 0.05) [Table 2].

For The Topic: Pathophysiology of Circulatory Shock

1. Intervention group B (n = 94) had a mean pretest score of 9.04 ± 1.44 out of 20, while control group A (n = 96) had a mean score of 8.95 ± 2.23. An unpaired "t-test showed no statistically significant difference between two scores (P = 0.72).

2. The intervention group B (*n* = 94) had a mean posttest score of 17.48 ± 1.66 out of 20, while the control group A (*n* = 96) had a mean score of 14.07 ± 1.15. An unpaired t-test showed a statistically significant difference ($P < 0.05$) between the two scores.
3. The mean score of the pre-test and post-test through the intervention group B exhibited statistically significant performance improvement using a paired *t*-test ($P < 0.05$).
4. 4. The control group's average score on the pretest and posttest. A paired t-test showed a statistically significant improvement in performance ($P < 0.05$) [Table 3].
5. Using an unpaired t-test, the mean score of learning gain, Raw Gain (G0), Absolute learning gain, and Relative learning gain" between the interventional group (B) and the control group (A) demonstrated statistically significant performance improvement ($P < 0.05$).
6. The average normalised gain(G1) compared in the intervention group B (0.77 ± 0.01) and control group A (0.46 ± 0.03) showed statistically "significant performance improvement utilizing an unpaired *t*-test ($P < 0.05$) [Table 4].

Table 1: Pretest score, % Pretest, Posttest score, % Posttest and P for Group A (CM)and B (TTM)

Topic: Blood pressure	Pretest score (Max marks 20)	% pre-test	Post test score (Max marks 20)	% post test	P value
Intervention group An(n=96)	9.11± 1.90	45.57±9.48	17.42± 1.71	87.08± 8.87	<0.05
Control group B (n= 94)	8.95± 2.23	44.73±11.15	14.09± 1.58	70.43± 7.92	<0.05
P- value	0.58(> 0.05)	0.58(> 0.05)	< 0.05	< 0.05	

Table2: Mean score of gain in learning, average learning gain, raw gain (G0), absolute learning gain, relative learning gain (RLG), and average normalized gain (G1) for Groups A(CM) and B(TTM)

Topic -Blood pressure	The mean score of gain in learning (Mean post test –Mean pre test)	Raw gain(G0) = %post test score -% pre test score	Absolute learning gain = (Post test-Pretest/max score)x 100	Relative learning gain= (Post test- pre test/ Pretest score) x 100	Average Normalised gain(G1) = % posttest-% pre est/ (100 - % pre test)
Intervention group A(n=96)	8.30 ± 0.18	41.51± 0.90	47.68±10.60	91.09±9.59	0.76±0.01
Control group B (N= 94)	5.13±0.64	25.69±3.23	36.48±40.83	57.43±28.99	0.46±0.03
P-value	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05

Table3: Pretest score, % Pretest, Posttest score, % Posttest, and P for Group B(CM) and A (TTM)

Topic: Circulatory shock	Pretest score (Max marks 20)	% pre-test	Post test score (Max marks 20)	% post test	P value
Intervention group B (n=94)	9.04±1.44	45.21±7.18	17.48±1.66	87.39±8.31	<0.05
Control group A (n= 96)	8.95±2.23	44.73±11.15	14.07±1.15	70.36±7.86	<0.05
P- value	0.72(> 0.05)	0.72(> 0.05)	<0.05	<0.05	

Table 4: Mean score of gain in learning, average learning gain, raw gain (G0), absolute learning gain, relative learning gain (RLG), and average normalized gain (G1) for Groups B(CM) and A (TTM)

Topic – Circulatory shock	The mean score of gain in learning (Mean post-test – Mean pretest)	Raw gain(G0) = %post test score - % pretest score	Absolute learning gain= (Post test-Pretest/max score) x 100	Relative learning gain = (Posttest-pre test/Pretest score) x 100	Average Normalised gain(G1) = % posttest-% pretest / (100 - % pre test)
Intervention group B (n=94)	8.44±0.22	42.18±1.14	48.27±38.87	93.29±15.85	0.77±0.01
Control group A (n= 96)	5.13±0.66	25.62±3.30	36.42±41.98	57.28±29.57	0.46±0.03
P-value	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05

Feedback Assessment

Students' feedback about working with CM was obtained on a 5-point Likert Scale" question [Figure 2]. Students had a positive perception of concept mapping, with a high percentage agreeing or strongly agreeing that it was a suitable tool for learning. The majority of students (97.4%) agreed and strongly agreed that learning CM was simple. Concept maps were easy to complete, according to a significant majority (78.4%) who strongly agreed. Concept mapping assisted students in combining and clarifying the relationships between educational elements, as per 88.2% of students who agreed and strongly agreed. Concept mapping encourages students to work and think independently, according to 82.3% of students who agreed and strongly agreed. Concept mapping helped lower barriers and increase students' enthusiasm in learning, according to 80.2% of students who agreed and strongly agreed. 37.3% of students were neutral, while 40.2% disagreed and strongly disagreed that idea maps required too long to create. Concept mapping is a valuable tool, as per 76.5% of students who agreed and strongly agreed, demonstrating that the majority of students considered it to be helpful.

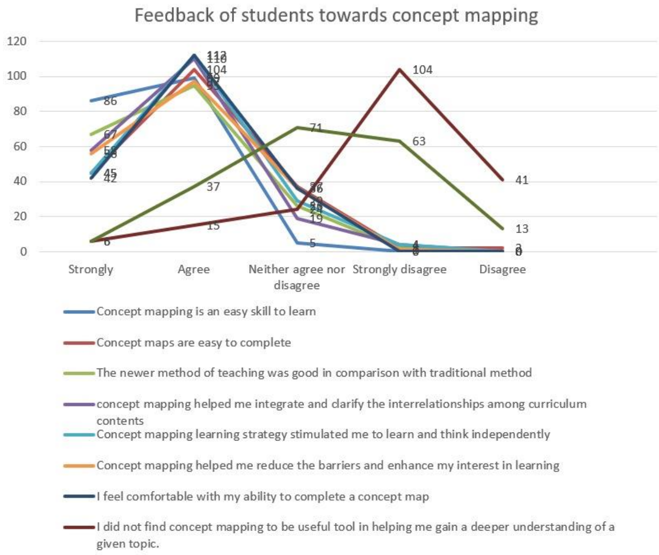

Figure2: Shows the Response in the Percentage Students for the 5-Point Likert Scale Question on the Concept Mapping Learning Method

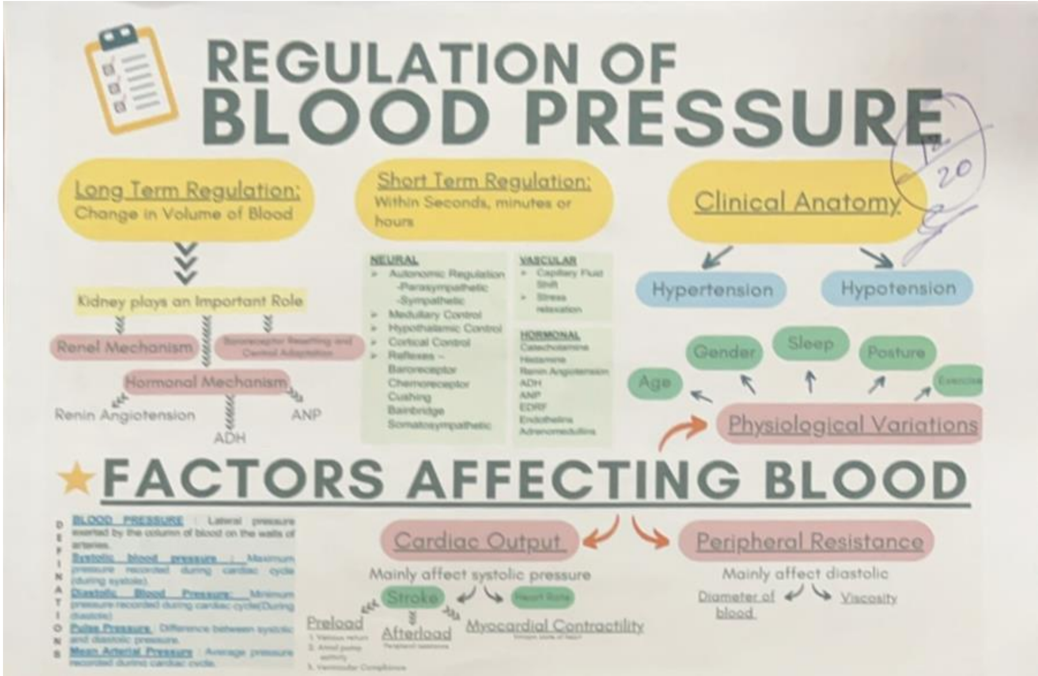

Figure 3: Concept Map on Regulation of Blood Pressure

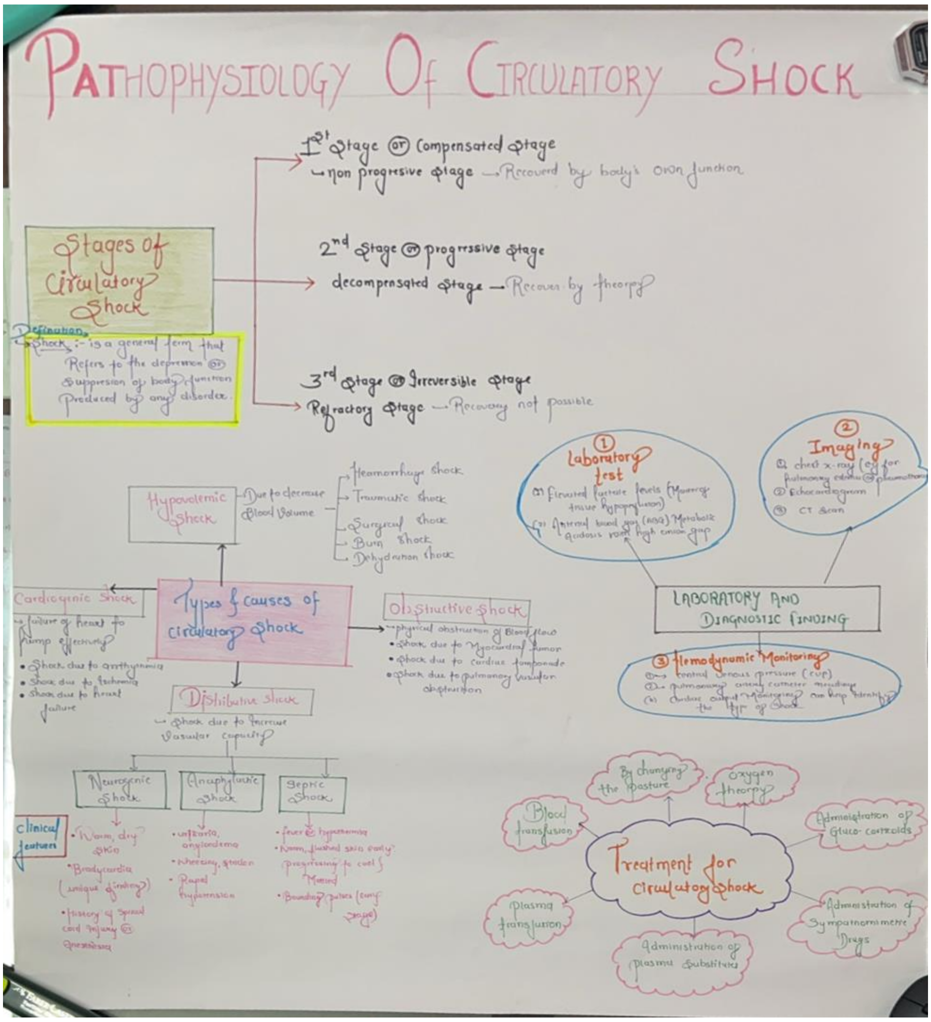

Figure 4: Concept map on Pathophysiology of circulatory shock

DISCUSSION

The change from teacher to facilitator of learning is the major pedagogic shift from a traditional teacher-centred approach to a student-centred approach. Concept maps were created via Novak & Canas (2006) and associates based on David Ausubel's "meaningful learning theory," which suggested that knowledge production is founded on integration and relevance compared to rote learning or arbitrariness. According to Ausubel, pre-existing cognitive structures facilitate the assimilation of new ideas, develop connections between concepts, and enable the creation and integration of new conceptions.[6] When utilized appropriately, concept maps enhance critical thinking and problem-solving skills, enabling students to transform theoretical information into knowledge that is relevant.

In our study, interventional and control group for topic blood pressure regulation and circulatory "shock, showed significant differences in the pretest and post test scores utilizing a paired *t*-test (P < 0.05), indicating that both the teaching method CM and question-answer discussion were" effective.

In the first part of the study (regulation of BP), "when we compared the mean post-test score of the intervention group A (17.42 ± 1.71) and the control group B (14.09 ± 1.58), a significant difference was observed (P < 0.05). Similarly, in" the second part (pathophysiology of circulatory shock) intervention group B (17.48 ± 1.66) "and control group A (14.07 ± 1.15), (P < 0.05) showed significant differences, indicating the CM technique was more effective than the question-answer discussion.

Using an unpaired t test (P < 0.05), the mean score of learning gain, G0, absolute learning gain, relative learning gain, and average normalized gain showed statistically significant performance improvement in both the interventional and control groups" for both topics (BP & CS). This suggests "that CM is an effective learning tool and improves cognitive gain. 76 sixth-year students in the 7-year MD curriculum clerkship phase participated in a study on "Diabetic Ketoacidosis" (DKA) by Saeidifard F et al. [8]. In the physiopathology section of the questions, students in the intervention group (CM) scored" far higher than those in control group (group discussion), but not in the treatment section.

100 second-year medical students enrolled in an anatomy course participated in a quasi-experimental study by Aslami Maryam et al. [9]. The California Critical Thinking Skills Test was used to evaluate medical students' CT levels. The CT scores of medical students who received instruction using idea mapping were higher than those of the control group.

Sorte SR et al [11] conducted study among 90 students of 1st MBBS in physiology on topic glomerular filtration. In this study, students were categorized as either rapid learners (RL) or potential learners (PL) based on their scores from prior internal assessments. Both groups were split into a control group (question-answer discussion) and an intervention group (concept mapping). The "pre-and post-test results for each of 4 groups differed significantly. Both the RL and PL groups demonstrated statistically significant improvements in performance when comparing the average normalized gain between the interventional group and the control group. 100 second-year medical students enrolled in an" anatomy course participated in a quasi-experimental study by Aslami Maryam et al. The California Critical Thinking Skills Test was used to evaluate medical students' CT levels. When compared to the control group, medical students who received instruction using idea mapping had higher CT results.

Agarwal P et al[10] conducted study "among 65 students of Phase I of MBBS in the year 2021. Assessment result of concept mapping is better than that of MCQ-based test. Joya" Ghosh, Richeek Pradhan, Sunita Vagah[12] conducted study on 100 students, divided into two groups based on their semester marks. They were taught a clinical topic in conventional and newer methods of concept maps, following didactic lectures. Learning gain and perception were assessed. A study showed a relative gain of knowledge in low scorers after teaching by concept mapping. Hence, this technique can be used for low scorers as a method of reinforcing knowledge. Mukhopadhyay K et al. [13] did a study utilizing Concept Mapping "for pharmacology students on the subject of "Drugs Affecting Calcium Metabolism." Significant enhancement in student performance was observed in both the interventional group (concept map approach) and the control group (traditional tutorial methods). No significant difference was observed among the groups in both low or high" scores.

Choudhary et al. [14] found that community-based teaching students who used mind maps and idea maps performed better than those who used question answers.

Meaningful learning with concept maps was well received by the students. Better subject understanding resulted from CM's ability to help individuals visualize the concepts, activate prior knowledge, and integrate it with new information. 88.2% of students agreed that concept mapping helped them integrate and clarify interrelationships among curriculum contents. 82.3% of students agreed that CM stimulate them to learn and think independently. 80.2% of students agreed that CM helped reduce barriers and enhance "their interest in the subject, and improved self-learning.

Educators could incorporate concept mapping into their teaching practices to enhance students' learning" outcomes. Concept mapping could increase students' motivation and participation in physiology classes, and students might retain physiological concepts more effectively, leading to improved academic performance.

Limitation and Recommendation

This pilot study has a limited sample size and is conducted at a single centre. A multicentric study with a high sample size should be carried out similarly. To improve its efficacy, more research on vertical and horizontal interdepartmental and multidisciplinary integration should be conducted.

CONCLUSION

Both of the teaching strategies—CM and traditional Q&A—were effective, but CM was more effective than Q&A. CM is a useful learning tool for enhancing cognitive development. CM has the potential to be a useful teaching and learning tool for physiology students.

Acknowledgment

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Ethical approval

The research/study approved via "Institutional Ethical Committee at Indira Gandhi government medical college Nagpur" number IGGMC/Pharmacology ICE/2392-93/2024 Dated:16/10/2024.

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Nil.

Conflicts of interest

Nil

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