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Evaluating the Efficacy of Concept Maps as a Learning Aid among Dental Students: A Randomized Controlled Trial

Abstract:

Background: Healthcare professionals, particularly dental students, face numerous challenges throughout their education and clinical practice. In India, dental education spans four years, covering 19 subjects, followed by a one-year clinical internship. Despite the interconnectedness of concepts across these subjects, students often struggle to integrate knowledge, resulting in gaps in applying theory to clinical practice. This study hypothesizes that using concept maps as a learning aid can enhance students' learning capabilities. While concept maps have been studied in other fields, evidence in dental education is limited.

Aim: The present study was conducted to assess the efficacy of Concept Maps (CM) as a learning tool among students enrolled in the BDS course at a dental college.

Methods: The present study was a parallel design randomized controlled trial conducted to evaluate the efficacy of concept maps as a learning aid among dental students. A total of 77 subjects were recruited from third-year BDS students. For baseline assessment, 66 students attended common lectures. After exclusions, the scores of the remaining 50 subjects were analyzed. In GROUP I, subjects were given an additional lecture about concept maps as a learning aid, whereas in GROUP II, no additional lecture was given. Initially, there were 39 subjects in GROUP I (concept map group) and 38 subjects in GROUP II (control group). After the first assessment, there were 30 subjects in GROUP I and 27 subjects in GROUP II. After the 2nd assessment, there were 25 subjects in both groups.

Results: Concept maps were found to aid deeper learning compared to the conventional note-taking method.

Conclusion: From the present study, it can be concluded that concept mapping can be an effective study strategy for dental students, helping them to learn, organize information, and retrieve it more effectively.

Key-words: anticariogenic mechanism, concept map, dental students, fluoride

Introduction:

Everyday, new challenges are faced by health care professionals during their educational years as well as in clinical practice. Since its inception, the dental profession has experienced changes not only in terms of knowledge but also regarding the information that needs to be absorbed and assimilated by the students.[1]

In India, the curriculum for dental education is divided into 19 subjects taught over a span of four years, followed by a one-year clinical internship. A dental student must navigate subjects ranging from general anatomy, which includes basic information about the structure of the human body, to specific dental subjects like oral medicine and prosthodontics during the Bachelor of Dental Surgery (BDS) course. The sequence of subjects throughout these four years is designed in order to make the student well-versed with fundamental knowledge of the human body. For instance, general anatomy taught in the

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first year is crucial for learning proper injection techniques in Oral Surgery, which is covered in the fourth year. Similarly, biochemistry taught in the first year has applications in pharmacology taught in the second year and in prescribing medicines during clinical practice in the fourth year and beyond. This shows the interconnectedness of concepts across subjects that students should understand by the time they enter the clinics.

Unfortunately, this integration of concepts is not well understood in the present academic and clinical framework. The prevalent trend is to cram and pass examinations each year with minimal application of previously studied subjects. As a result, upon completing the degree, students are often unable to compile and apply their knowledge confidently while examining or treating the patients. Therefore, there is a need to address the gap in integrating knowledge delivered throughout the dental education course. In the pursuance of above, it is hypothesized that the introduction of concept maps as a learning aid can enhance learning capability of students.[2,3,4]

Although a number of studies have evaluated the use of concept maps to enhance learning abilities among secondary education, undergraduate, or medical students,[5-9] evidence in dental education is minimal. Hence, the present study was designed with an aim to assess the efficacy of concept maps as a learning tool compared to the note-taking method among third-year BDS students at a dental college.

The objective of the study is to evaluate and compare assessment scores among students who were given a lecture on "the anti-cariogenic mechanism of fluorides" after being taught about concept maps as a learning tool, compared to students who were not taught about concept maps at baseline and after a one week interval.

Material and Methods:

Trial Design:

The present study was a parallel-design Randomized Controlled Trial (RCT) with two arms, in which the outcome assessors and data analysts were blinded. However, the person providing the intervention could not be blinded. The study was approved by the Institutional Ethical Committee of the Dental College and registered in the Clinical Trials Registry of India (CTRI) with registration number CTRI/2019/09/021206. The trial was conducted in accordance with Good Clinical Practice guidelines and reported in compliance with the CONSORT guidelines.

Sample Size Calculation:

The study was designed as a superiority trial. The sample size estimation was done using Sealed Envelope Ltd. (2012) Power calculator for continuous outcome superiority trials [Online] Available from: https://www.sealedenvelope.com/power/continuous-superiority. A total of 32 patients were required to have an 80% chance of detecting a significant increase, at the 5% significance level, in the primary outcome measure (assessment scores) from 15 in the control group to 22 in the experimental group. Anticipating a 10% attrition rate in both the experimental and control groups, the software adjusted the final total sample size to 50 (25 per group).

Study Population & Study Setting:

The study participants were third-year Bachelor of Dental Surgery (BDS) students enrolled at a Dental College. The study was conducted in the lecture hall of the Dental College, with prior permission from the authorities.

Inclusion Criteria:

- Students enrolled in the third year of the BDS professional course.

Exclusion Criteria:

- Students with prior knowledge of concept maps.
- Students who did not attend one or more assessments conducted as part of the study.

Topic to be taught for the Study:

A lecture on the "Mechanism of Anti-Cariogenic Action of Fluoride" was delivered twice, each for 60 minutes via PowerPoint presentation, to the third-year BDS students.

- First lecture: Delivered one week before randomization of the study population into two groups.
- Second lecture: Delivered after randomization, with students assigned to the intervention and control groups.

Intervention Groups:

Students were randomly divided into two groups:

- Group I (Intervention Group): Students in this group received a 45-minute lecture on concept maps and their application as a learning tool. During this lecture, they were also taught how to create a concept map on a topic unrelated to the subsequent lecture topic.

- Group II (Control Group): Students in this group did not receive a lecture on concept maps.

Intervention Protocol (Experimental Design, Randomization, and Allocation Concealment):

This was a randomized controlled trial with a parallel study design and two arms, in which the outcome assessor and data analyst were blinded.

- Week one: A lecture on the "Mechanism of Anti-Cariogenic Action of Fluoride" was delivered to all third-year students for 60 minutes via PowerPoint presentation.
- Week two: Students who attended the initial lecture were randomized into two groups, Group I and Group II, using a random number list.
- A randomization list was created by a random number generator (QuickCalcs Online Random Numbers, GraphPad Software) by a different examiner who was not included in provision of intervention and was kept locked in a separate, closed, opaque envelope.

In Group I, students received a lecture on concept maps, which included an introduction to concept maps, their uses as a learning tool, and methods for constructing them, lasting 45 minutes.

In Group II, students did not receive a lecture on concept maps.

Later on the same day, a combined lecture on the "Mechanism of Anti-Cariogenic Action of Fluoride" was delivered to both groups by the same lecturer. After the lecture, a 30-minute revision session was held for both groups:

- In Group I, students were asked to create concept maps to revise the lecture, with assistance from an investigator.
- In Group II, students participated in a group discussion without a facilitator for the same time frame.
- After the 30-minute revision period, a common assessment test was administered to both groups.
- A second assessment test was conducted seven days later. Feedback was also collected from the students regarding the use of concept maps as a learning tool.

Assessment Forms

Three assessment forms were used in the study:

- Assessment Form I: This form collected information about demographic factors (age, location, gender), scores in previous year examinations, and knowledge of concept maps (Annexure I).
- Assessment Form II: This form contained questions from the topic of the common lecture, based on SOLO taxonomy (Annexure II).
- Assessment Form III: This form contained a different set of questions from the topic of the common lecture, also based on SOLO taxonomy (Annexure III).

These assessment forms were prepared and evaluated by two teachers from the Public Health Dentistry department, using well-defined criteria based on the SOLO taxonomy (Structure of the Observed Learning Outcome[19]). Both teachers had taught the relevant subject, had a minimum of 10 years of teaching experience in the field, and participated in the design of the study program related to Public Health Dentistry.

Solo Taxonomy[19]:

It is a method of evaluation of learning outcomes. It has five levels of learning quality. They are Pre-Structural level, Uni-structural Level, Multi-Structural Level, Relational Level and Extended Abstract Level. In this study, the assessment forms included two questions from each of the above categories. Both assessment forms were graded out of 30 marks.

Data Collection:

- Baseline data was collected before the randomization of students into two groups. This data Included demographic information and the students' prior knowledge of concept maps.
- Two assessment examinations were conducted based on the topic of the initial lecture, first exam immediately after the lecture and second exam, 7 days after the lecture.
- Both exams included questions based on the SOLO taxonomy from the topic of the common lecture, with each exam carrying a total of 30 marks.
- On the 7th day of assessment, feedback from the students was also collected regarding the use of concept maps as a learning tool.
- Quantitative data collected in this study included the participants' scores on the assessment exams at different time points and responses from a student survey, which gathered feedback on the learning tools used.

Outcome Measures:

- Primary Outcome: The primary outcome measure for this study was the assessment of scores from both groups in their respective exams.

- Secondary Outcome: The secondary outcome measure was the analysis of students' feedback on the use of concept maps as a learning tool.

Statistical Analysis:

Data were analyzed using the Statistical Package for Social Sciences (SPSS) version 21. Categorical variables were summarized as frequencies (absolute and relative). Assessment scores were summarized as means and standard deviations (SD). Categorical data were compared using the Chi-square test, and the level of statistical significance was set at 0.05. Graphs were prepared using Microsoft Excel. The average scores from both assessment evaluations were calculated.

Results:

A total of 77 third-year BDS students were recruited for the study. Sixty-six (66) students attended the common lectures, but only 57 students took the first assessment, leading to the exclusion of 9 subjects. An additional seven students did not participate in the second assessment, leaving scores from 50 subjects to be analyzed. Participants were randomized into two groups in a 1:1 ratio. In **Group I** (CM group), subjects received an additional lecture on concept maps (CM) as a learning aid, while in **Group II** (control group), no additional lecture was given. Initially, there were 39 subjects in **Group I** and 38 subjects in **Group II**. After the first assessment, there were 30 subjects in **Group I** and 27 subjects in **Group II**. Following the second assessment, there were 25 subjects remaining in each group.

When the distribution of males and females between the two study groups was compared using the Chi-square test, no significant difference was found.

Baseline data showed that the aptitude of the subjects in both groups was homogenous or comparable. When asked about their knowledge of concept maps, none of the subjects in either group—**Group I** (CM group) or **Group II** (control group)—were familiar with the concept of concept maps. This implies that none of the participants had prior knowledge of concept maps before the study.

Intergroup Comparison of Mean Scores for the first Assessment:

The analysis of the mean scores from the first assessment revealed that **Group I** (CM group) had significantly higher mean scores than **Group II** (control group). This suggests that subjects in the CM group could retain more information compared to the control group, as evident by the significant difference in scores between the two groups.

Intergroup Comparison of Mean Scores for the second Assessment:

Although **Group I** had higher mean scores than **Group II** in the second assessment, the difference was not found to be statistically significant. Hence, long term retainability using concept maps could not be established.

Intergroup Comparison of Mean Scores Based on SOLO Taxonomy Categories for the first Assessment:

When the category-wise mean scores based on SOLO taxonomy for the first assessment were compared between the two groups using an independent t-test, a statistically significant difference was observed in **Category 3 (Multi-structural)**, **Category 4 (Relational)**, and **Category 5 (Extended Abstract)**. This indicates that **Group I** (CM group) had higher mean scores than **Group II** (control group) in categories associated with deeper learning. Thus, concept maps were found to facilitate deeper learning compared to the conventional note-taking method (Table 1).

Table 1- Category wise Intergroup comparison of mean scores according to Solo taxonomy for the first assessment

Solo taxonomy categories (1st assessment)	Intervention group	Mean ± Std. Deviation	p^b-value
Category 1 (Pre-structural)	Group I (CM group)	94.00 ± 14.93	0.158,NS
	Group II (control group)	88.00 ± 14.65	
Category 2 (Uni-structural)	Group I (CM group)	67.50 ± 19.76	0.351, NS
	Group II (control group)	62.00 ± 21.49	
Category 3 (Multi-structural)	Group I (CM group)	80.00 ± 34.19	<0.0001,S
	Group II (control group)	44.00 ± 31.60	
Category 4 (Relational)	Group I (CM group)	50.25 ± 23.35	0.012,S
	Group II (control group)	32.50 ± 24.80	
Category 5	Group I (CM group)	32.20 ± 16.01	0.045,S
(Exte	Group II (control group)	22.60 ± 17.02	

[b]Independent-t-test, S-statistically significant, NS-Not statistically significant (p>0.05)

Category-wise Intergroup Comparison of Mean Scores Based on SOLO Taxonomy for the 2nd Assessment:

When the category-wise mean scores based on SOLO taxonomy for the second assessment were compared between the two groups using an independent t-test, no statistically significant differences were found in any of the categories.

This suggests that information retention was comparable between **Group I** (CM group) and **Group II** (control group) in the second assessment (Table 2).

Table 2: Category wise Intergroup comparison of mean scores according to Solo taxonomy for the second assessment.

Solo taxonomy categories (Second assessment)	**Intervention group**	Mean ± Std. Deviation	p^b-value
Category 1 (Pre-structural)	Group I (CM group)	89.00 ± 20.51	0.661,NS
	Group II (control group)	86.00 ± 27.08	
Category 2 (Uni-structural)	Group I (CM group)	41.50 ± 19.67	0.228,NS
	Group II (control group)	34.50 ± 20.82	
Category 3 (Multi-structural)	Group I (CM group)	20.86 ± 9.87	0.209,NS
	Group II (control group)	24.57 ± 10.73	
Category 4 (Relational)	Group I (CM group)	16.22 ± 11.67	0.114,NS
	Group II (control group)	11.33 ± 9.69	
Category 5 (Extended abstract)	Group I (CM group)	14.00 ± 13.65	0.954,NS
	Group II (control group)	14.25 ± 16.98	

[b]Independent-t-test, S-statistically significant, NS-Not statistically significant (p>0.05

Discussion:

Assessment of learning outcomes and information retention is an important part of evaluating the quality of dental education, as it directly impacts the competence of graduating dentists.[10] A dental student is expected to meet specific standards of competency upon completing their graduation. In other words, a dentist must have a thorough understanding of the etiology and pathological processes of oral diseases to facilitate their prevention, diagnosis, and management.[11]

This necessary knowledge is primarily delivered in classrooms during the educational years. While a number of teaching methods exist for the same[12], lecture-based learning (LBL) remains the most common teaching strategy for dental undergraduate programs. In this method, learning often relies on note-taking and memorization skills, which are undeniably useful. However, considering the mammoth of information in higher medical sciences like dentistry, this approach may not be ideal for all students and situations. In particular, these courses require information to be well-integrated to understand the complex and interrelated mechanisms of the human body.

Thus, there is a growing need for alternative learning methods. With the rising interest in higher education and medical sciences, concept maps have emerged as a powerful tool for relaying new knowledge.[13,14] This prompted the present study, where we compared two learning aids among third-year dental undergraduate students: traditional fortified note-taking after lectures and the newer learning tool—concept maps.

At baseline, both groups were comparable in terms of age and previous year marks, making them equal in terms of their mental capacity to understand the material. Additionally, none of the students had prior knowledge of concept maps, eliminating any bias from pre-existing familiarity. A lecture on an unfamiliar topic was delivered to all third-year dental students. This was followed by a lecture on concept maps (CM) for the intervention group, while the control group did not receive any such lecture. This was followed by two assessments, each worth 30 marks, conducted at a one-week interval.

The results of the first assessment revealed that the scores of the CM group were significantly higher than those of the control group, suggesting that the concept mapping method was more effective than traditional note-taking. These findings align with those of Saeidifard et al[13] where they found that concept mapping was a more successful teaching method than lecture-based learning. Another study[14] reported similar results, where students in one group were trained using concept maps and in another group through book reading. When pre- and post-test scores were compared, the concept map group showed significantly higher scores. Although the first assessment was conducted immediately after the lecture and did not measure students' recall of knowledge, it can be concluded that learning and integrating information were more effective and rapid through the concept mapping method.

The second assessment, conducted one week later, showed no significant difference between the two groups, suggesting that long-term retention using concept maps is uncertain. Several factors could explain this. First, the subjects were third-year students who were exposed to the topic for the first time, making it challenging to grasp. Second, the second assessment was administered without prior information, indicating that students were not prepared. Additionally, although the students were asked to avoid discussing study details with those in the control group, the fact that both groups consisted of a single class may have caused contamination bias, potentially affecting the study process and results.

In the present study, SOLO taxonomy was used as a method of evaluating learning outcomes. Developed by Biggs and Collis (1982)[10], it is a way of evaluating students' responses and their performance in assessments, thereby evaluating the quality of learning. SOLO taxonomy has been reported as a useful tool for developing and assessing deep learning in dentistry.[14] It categorizes learning quality into five levels[19]: pre-structural (A), unistructural (B), multi-structural (C), relational (D), and extended abstract (E) . At the Pre-Structural level (A), the student lacks any kind of understanding, uses irrelevant information, and/or completely misses the point altogether. At the Uni-Structural Level (B), the student deals with one aspect and makes obvious connections, using terminology, reciting (remembering things), performing simple instructions'/algorithms, paraphrasing, identifying, naming, or counting. At the Multi-Structural Level (C), the student can manage several disconnected aspects, being able to enumerate, describe, classify, combine, apply methods, structure, execute procedures, etc. At the Relational Level (D), the student begins to understand the relationships between different aspects, forming a cohesive structure. This understanding allows them to compare, relate, analyze, apply theory, and explain in terms of cause and effect. At the Extended Abstract Level (E), the student generalizes the structure beyond what is provided, perceiving it from many different perspectives and transferring ideas to new areas. At this stage, they may have the competence to generalize, hypothesize, criticize or theorize.

In its early stages (A-C), most of the learning requires more of retention and is quantitative and the amount of detail increases and becomes qualitative with later stages (D-E). An increase in knowledge is reflected by quantitative dimension whereas deeper understanding is contemplated by qualitative dimension.[15] Our educational curriculum aims to support both quantitative knowledge acquisition and qualitative comprehension.

All categories of the SOLO taxonomy were compared between the two groups in this study for the 1st and 2nd assessments. The intergroup comparison for the 1st assessment revealed that, except for categories A and B, scores for all other categories were higher in the CM group. This suggests that memorization or quantitative learning is supported by both conventional learning methods and concept maps. However, deeper, qualitative learning was more prominent in the CM group, as evidenced by significantly higher scores in categories C, D, and E.

This finding implies that concept maps facilitate deeper learning. Students in the CM group were better and quicker at recognizing or recalling information in the multi-structural category (C), analyzing and categorizing in the relational category (D), and synthesizing or hypothesizing in the extended abstract category (E).

Similar results were observed in a study by Eshwar et al. (2016)[14], where they compared two educational methods—Mind Mapping (MM) and Lecture-Based Learning (LBL)—using SOLO taxonomy. In that study, the MM group scored higher in both the C and E categories. It was interpreted that the students performed better not only in the multi-structural (C) category but also in the extended abstract (E) category, suggesting that the use of the mind map strategy improved deep learning among the students. Another study by Ilguy et al. (2014)[15] compared Case-Based Learning (CBL) and Lecture-Based Learning (LBL) using SOLO taxonomy. The results of their study showed that students in the CBL group performed better in the D and E categories, indicating that case-based learning enhanced students' ability to relate and understand at a deeper level.

Studies conducted on the development of meaningful learning and problem-solving skills using concept mapping (CM) have indicated that through concept mapping, basic and clinical knowledge can be well integrated, which may help move from linear thinking patterns to more integrated, holistic patterns.[16,17] Meaningful learning has been documented to be stimulated through the use of CM within a problem-based learning (PBL) course.[18,19] In the study by Veronese et al. (2013),[16] exam scores demonstrated modestly better performance by students in CM groups compared to students in non-CM groups, suggesting that students exposed to CMs may have developed a better understanding of concepts and/or been more effective in applying information to solve case-based problems. It was concluded that CMs may improve students' performance by beneficially affecting the way they organize knowledge and approach problems. The use of concept maps enabled instructors to better observe students' thought processes and identify areas of weakness or misunderstanding.

Furthermore, concept maps may find applications in problem-based and case-based learning,[20,21] where they can help stimulate active and deep learning of basic sciences. Along with this, they might aid in better retention of knowledge, thus facilitating better application of this knowledge to novel or clinical problems. As a consequence, CMs may be a tool to bridge the gap between basic science and clinical practice. Additionally, their expanded use in pre-clinical courses may help students appreciate the importance of exploring multiple hypotheses before deciding on a diagnosis, reducing cognitive errors and misdiagnosis. Since concept mapping is a newer concept in the field of dentistry, the results of the present study could not be compared with other dental studies due to the paucity of similar literature.

Framing a concept map requires translating information learned from textbooks and lectures into a network of knowledge that has meaning, value, and recognized utility.[22] Thus, it may encourage brainstorming other possible physiological hypotheses before formulating a final diagnosis, thereby increasing diagnostic accuracy and reducing the risk of cognitive errors from premature closure.[23]

Our brain has a stronger memory for pictorial information.[24] Being a graphic illustration, concept maps actively involve students in creating maps using different colors, shapes, and designs for different concepts, helping them retain more of what they create. While making CMs, students were also able to identify gaps in their knowledge and understood the need to seek clarification. Thus, this may prove to be an effective method for generating ideas by consolidating different concepts in one or more ways.

Students enjoyed learning about concept maps and were more keenly focused on drawing the information they learned into a map. Feedback from the CM group highlighted different aspects that support the efficacy of CMs, including enhancement of critical thinking, self-identification of knowledge gaps, promotion of practical learning, and the ability to compile vast knowledge into a single illustration. The main concerns with CMs were related to difficulties in organizing maps into compact spaces, sometimes resulting in perplexing final outcomes that were difficult to interpret and review. However, this can improve with practice. Although creating CMs was occasionally described as time-consuming, the time and effort invested may result in less time needed for multiple future revisions. Students also felt that CMs helped them learn better, and most agreed they would use them in the future to organize information.

One limitation of the present study was the small number of subjects enrolled from one dental college, which affects the generalizability of the results. Additionally, students created concept maps with the help of a facilitator who also taught and motivated them to learn CMs. In contrast, the control group only participated in group discussions, with their doubts being clarified. The role of the facilitator in the CM group might have influenced the results.

Further studies are recommended, with a series of lectures on interrelated subjects over a period of time, to assess retention of information among students.

Conclusion:

The present study was a randomized controlled trial conducted to evaluate the efficacy of concept maps as a learning tool among third-year dental students. Greater efforts should be made to support a deeper approach to learning compared to traditional educational strategies, especially in India, where lecture-based teaching methods predominate.

Within the limitations of this study, it can be concluded that concept mapping can be an attractive study strategy for dental students, helping them learn, organize, and understand information more effectively. It may facilitate deeper learning, which is essential for information retention and the development of reflective thinking. By using concept maps, students can understand material more quickly, relate it to the most relevant evidence, and make better judgments about their patients' conditions in clinical settings. Ultimately, this will lead to more accurate diagnoses and the best possible treatments.

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