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Evaluation of concept maps as a teaching–learning tool in teaching immunology to Phase II MBBS students and to assess their perception towards its use

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Abstract: **Background:** Immunology is a core subject in medical education that requires integration of complex concepts and clinical reasoning. Traditional teaching methods may limit meaningful learning and long-term retention. Concept mapping is an active learning strategy designed to enhance conceptual understanding, critical thinking, and student engagement. **Objectives:** To evaluate the effectiveness of concept mapping as a teaching–learning strategy in immunology among Phase II MBBS students and to assess students' perceptions regarding its role in promoting meaningful learning. **Methods:** An educational interventional study was conducted in the Department of Microbiology at Dr. B. R. Ambedkar State Institute of Medical Sciences, Mohali, Punjab, India, from October to December 2024, after taking approval from Institutional Ethics Committee. Phase II MBBS students (n = 100) were enrolled, of whom 94 completed the study. Two immunology topics—innate and acquired immunity; and cytokines—were taught using concept mapping. Pre-test and post-test assessments using multiple-choice questions were conducted. Students participated in guided and self-directed concept mapping sessions. Student-generated maps were reviewed, and perceptions were assessed using a pre-validated five-point Likert scale questionnaire. Data were analyzed using SPSS version 27.0. Paired t-test was applied, and a p-value < 0.05 was considered statistically significant. **Results:** The mean pre-test score was 9.41 ± 2.80, which significantly increased to 10.80 ± 2.27 in the post-test ($p < 0.001$). In the Stage 2 assessment, 80.3% of students achieved excellent scores. Feedback analysis revealed high satisfaction for quick revision (87.2%) and summarization skills (86.1%). More than 70% of students reported enhanced independent learning, problem-solving ability, and increased interest in immunology. **Conclusion:** Concept mapping is an effective, student-centered teaching–learning strategy that improves conceptual understanding, academic performance, and learner engagement in immunology. Its integration into undergraduate medical curricula may promote meaningful learning, critical thinking, and lifelong learning skills.

Keywords: Concept mapping; Active learning; Immunology education; Medical students; Meaningful learning; Undergraduate medical education.

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INTRODUCTION

Immunology is a core subject in medical education that requires mastery of specialized terminology, development of critical thinking skills, clinical reasoning, and integration of concepts for effective clinical application [1]. Medical students often face difficulty in correlating immunological principles with disease mechanisms, which may affect their understanding and performance [1, 2]. Therefore, innovative teaching strategies are required to enhance conceptual clarity and meaningful learning.

Active-learning approaches emphasize student engagement, self-regulation, and reflection, thereby fostering lifelong learning skills [3, 4]. Concept mapping, introduced by Joseph Novak in 1970, is a learner-cantered instructional strategy designed to promote active participation, meaningful learning, and formative assessment [5]. Concept maps are graphical representations of concepts organized hierarchically around a central focus question, interconnected through linking phrases and cross-links that demonstrate relationships among subtopics [6].

Compared to conventional assessment methods such as multiple-choice questions, which primarily assess recognition and elimination skills, concept maps enable learners to demonstrate depth of understanding, organization of knowledge, and integration of ideas across disciplines [4, 7]. Several studies in medical education have reported that concept mapping facilitates meaningful learning, provides supplementary learning resources, supports constructive feedback, and serves as an effective assessment tool [3, 6, 7].

Meaningful learning involves the assimilation of new knowledge into existing cognitive frameworks, resulting in improved motivation, confidence, and problem-solving abilities [5]. Concept maps enhance long-term retention through visual encoding and promote creative and analytical thinking [8]. Additionally, they strengthen communication between students and instructors and help identify learning gaps and allow concise summarization of complex concepts [9, 10]. The present study aimed to evaluate the effectiveness of concept mapping as an active teaching–learning strategy in immunology among Phase II MBBS students.

Aim & Objectives

To introduce concept mapping as a teaching–learning strategy in immunology.
To sensitize students and faculty to the use of concept mapping in medical education.
To assess students' perceptions regarding the effectiveness of concept mapping in promoting meaningful learning in the immunology course.

METHODOLOGY

This study was designed as an educational research study. Ethical clearance was taken from Institutional Ethical Committee before commencement of the study, *Letter no. AIMS2024-IEC-HR-29-IP-03.* The study was conducted in the Department of Microbiology, Dr. B. R. Ambedkar State Institute of Medical Sciences, Mohali, Punjab, India. The study population comprised Phase II MBBS undergraduate students of the academic year 2024–2025 and study was conducted over a period of three months, from October 2024 to December 2024.

Inclusion Criteria

Phase II MBBS undergraduate students who were willing to participate in the study.

Exclusion Criteria

Students who did not provide informed consent.
Students who did not complete all components of the study, including the pre-test, active learning session, post-test, and feedback questionnaire.

Study Procedure

Two topics in immunology, namely *Immunological Mechanisms (Innate and Acquired Immunity)* and *Cytokines*, were selected to be taught using the concept mapping method. A briefing session was conducted to explain the objectives of the study and to seek students' cooperation, emphasizing accuracy and honesty in completing the questionnaires and providing feedback.

The study was carried out in two stages

Stage 1: Faculty Sensitization and Guided Concept Mapping

A sensitization session was conducted for faculty members regarding the concept mapping technique. Two concept maps on immunological mechanisms were developed using the *CmapTools* software (Institute for Human and Machine Cognition, Florida, USA).[10] These maps were reviewed by the Microbiology faculty for reliability and feasibility.

An introductory didactic lecture on innate and acquired immunity was delivered prior to the intervention. This was followed by a multiple-choice question (MCQ) test to assess baseline knowledge, and the scores were recorded as pre-test scores.

Then the participants were sensitized to the concept mapping tool, including its components and construction methods. A PowerPoint presentation and demonstration of the *CmapTools* application were used to familiarize students with concept map development. Information regarding available learning resources was also provided.

Subsequently, two pre-designed concept maps (Figure 1) were introduced using *CmapTools* software. Students participated in small-group learning sessions of two hours' duration. The class was randomly divided into groups of 8–10 students, and each group was provided with the pre-designed concept maps. Students were encouraged to engage in critical discussion and understand the relationships among concepts using appropriate linking words and phrases. Faculty members acted as facilitators and guided the learning process.

Concept Map 1 - Innate Immunity

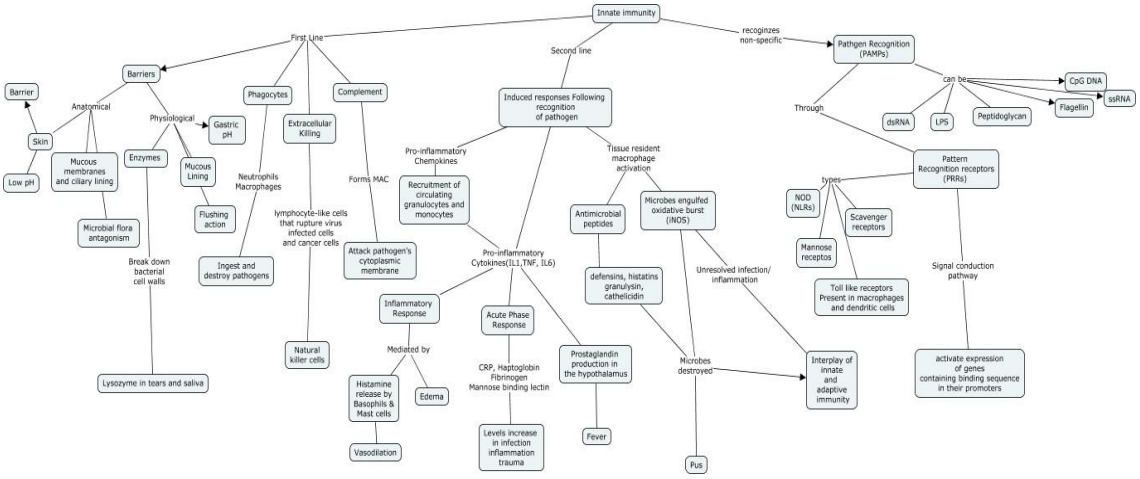

Figure 1. Pre-designed Concept Maps by Faculty (using *CmapTools* software)

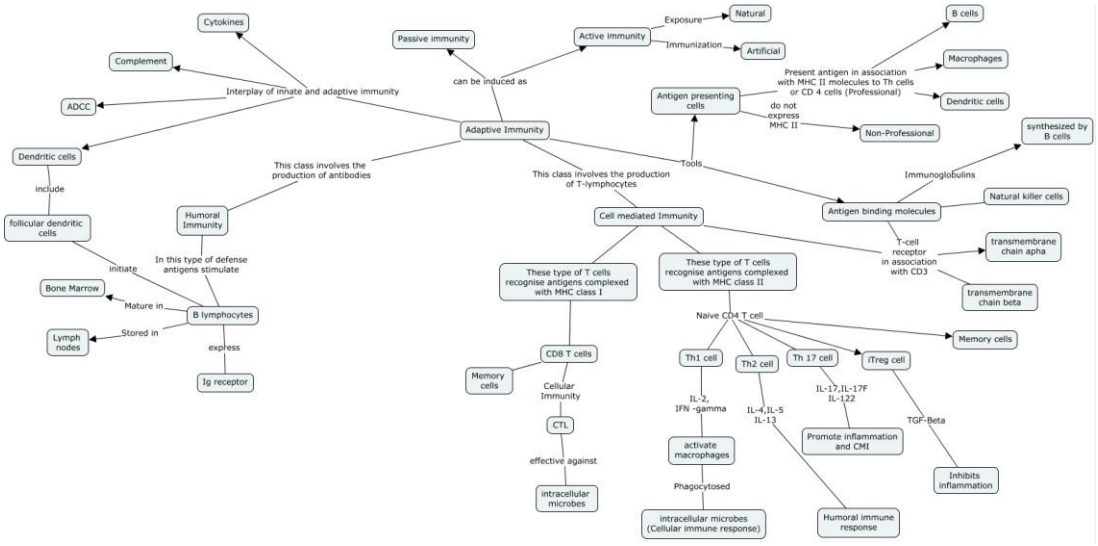

Figure 2. Pre-designed Concept Map of Adaptive Immunity by Faculty (using *CmapTools* software)

Concept Map 2 - Adaptive Immunity

At the end of the session, the same MCQ test was administered, and the scores were recorded as post-test scores.

Students were informed about the subsequent self-directed learning session on *Cytokines*. Specific learning objectives were shared, and students were instructed to prepare their own concept maps, followed by an MCQ assessment.

Stage 2: Student-Generated Concept Mapping and Feedback

In the second stage, students constructed their own concept maps on cytokines in alignment with the learning objectives. They were encouraged to identify key concepts, generate linking phrases, and organize the content independently. Necessary learning resources were provided by the department.

Students were randomly divided into ten groups comprising approximately ten students each. Each group prepared a concept map and submitted a PDF copy through a designated Google Form. (Figure 2)

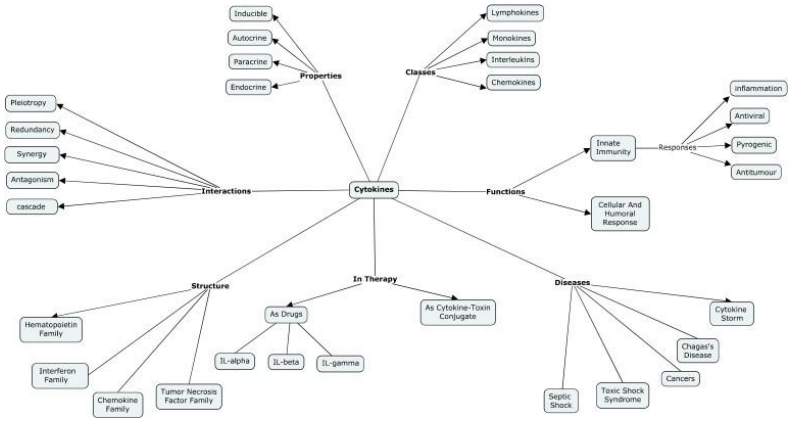

Figure 3. Examples of Concept maps of Cytokines by Students

Faculty members reviewed the submitted maps and conducted group discussions. Students were appreciated for their efforts, and variations in conceptual organization were noted.

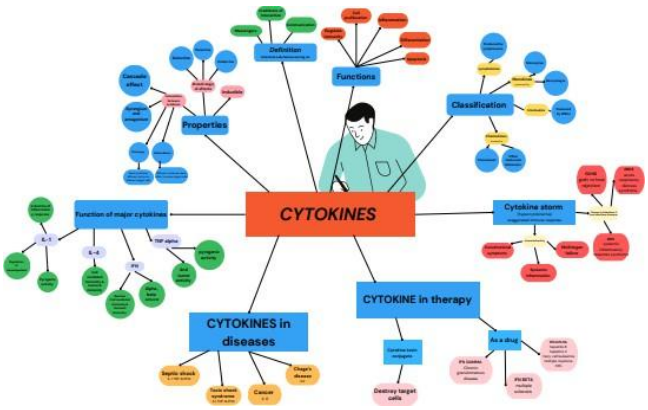

Figure 4. Examples of Concept maps of Cytokines by Students

Following this session, an MCQ test consisting of 20 questions (one mark each) was administered to assess learning outcomes.

A pre-validated feedback questionnaire based on a five-point Likert scale (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree) was administered to both students and faculty to assess their perceptions of concept mapping. Feedback responses were analyzed as percentages to calculate the satisfaction index. Data were collected using a structured Google Form and systematically analyzed.

Statistical Analysis

Data were analyzed using Statistical Package for the Social Sciences (SPSS) version 27.0. Pre-test and post-test scores were calculated for each student and compared statistically. A paired *t*-test was applied to determine the significance of differences in scores. A *p*-value of less than 0.05 was considered statistically significant.

RESULTS AND OBSERVATIONS

Out of 100 MBBS students enrolled in the study, 94 students successfully completed all components, including the pre-test, post-test, self-directed learning session, and feedback questionnaire, yielding a participation rate of 94%. Six students were excluded due to incomplete participation.

Comparison of Pre-test and Post-test Scores

Table 1 presents the comparison of pre-test and post-test scores on *Innate and Acquired Immunity*. The mean pre-test score was 9.41 ± 2.80, while the mean post-test score increased to 10.80 ± 2.27. Statistical analysis using the paired *t*-test demonstrated a highly significant improvement in post-test scores ($p < 0.001$), indicating enhanced conceptual understanding following the concept mapping intervention.

Table 1: Comparison of Pre-test and Post-test Scores on Innate and Acquired Immunity (n = 94)

Parameter	Mean	SD	N	p-value
Pre-test	9.41	2.80	94	<0.001*
Post-test	10.80	2.27	94	

Performance in Stage 2 Concept Mapping Assessment

The distribution of participants based on Stage 2 MCQ scores on *Cytokines* is shown in Table 2. A majority of students, 75 (80.3%), achieved excellent scores, while 16 (16.9%) demonstrated average performance. Only 3 students (2.8%) scored in the poor category

.

Table 2: Distribution of Participants According to Stage 2 Scores (n = 94)

Performance Level	Score Range	Frequency	Percentage
Poor	<11	3	2.8%
Average	11–16.5	16	16.9%
Excellent	>16.5	75	80.3%
Total	—	94	100%

Students' Perceptions of Concept Mapping

Students' perceptions regarding the concept mapping technique are summarized in Table 3. Overall, responses indicated a positive attitude toward the intervention.

High satisfaction indices were observed for statements related to quick revision of facts (87.2%) and development of summarization skills (86.1%). More than 70% satisfaction was reported for items assessing independent learning, problem-solving ability, achievement of learning objectives, and enhanced interest in immunology.

Notably, none of the participants selected "strongly disagree" for any statement, reflecting favourable acceptance of the concept mapping approach.

Table 3: Students' Feedback on Concept Mapping Technique (n = 94)

S. No.	Feedback Questions	Strongly Agree; n (%)	Agree; n (%)	Neutral; n (%)	Disagree ; n (%)	Strongly Disagree; n (%)	Satisfaction Index
1	Concept mapping helps break boredom/monotony of traditional teaching learning method	26(27.3)	38(40)	21(22.3)	9 (9.5)	0	68%
2	Concept map learning strategy stimulated me to learn and think Independently	25(26.5)	44(46.8)	18(19.1)	7(7.4)	0	73.4%
3	Concept mapping improves problem solving ability	28(29.7)	42(44.6)	15(15.9)	9(9.5)	0	74.4%
4	Concept mapping was effective in helping me achieve the learning Objectives	30(31.9)	40(42.5)	20(21.2)	4(4.2)	0	74.4%
5	I find concept mapping to be a useful tool in helping me gain a deeper understanding of a given topic.	27(28.7)	44(46.8)	17(18)	6(6.3)	0	75.5%
6	Concept mapping helps in quick revision of facts	36(38.2)	46(48.9)	10(10.6)	2(2.1)	0	87.2%
7	It has increased my interest in learning Immunology	25(26.5)	47(50)	15(15.9)	7(7.4)	0	76.5%
8	Learning through concept mapping is interesting	24(25.5)	44(46.8)	19(20.2)	7(7.4)	0	72.3%
9	Concept mapping helps in developing critical thinking skills	25(26.5)	40(42.5)	21(22.3)	8(8.5)	0	69.1%
10	Concept mapping develops skill of summarizing the topic	34(36.1)	47(50.0)	11(11.7)	2(2.1)	0	86.1%
11	I could easily adapt to this Technique	22(23.4))	41(43.6)	21(22.3)	10(10.6)	0	67%

12	Should concept maps be used to teach other Microbiology topics as well	22(23.4)	41(43.6)	19(20.2)	12(12.7)	0	67%

(Five-point Likert scale: 1 = Strongly Disagree to 5 = Strongly Agree)

DISCUSSION

The present study was conducted to introduce a concept map–based teaching–learning strategy in the immunology course with the aim of promoting meaningful learning among students.

The findings revealed a highly significant improvement in post-test scores following the introduction of concept maps. Similar results were reported by Baliga *et al*. [7], who observed significantly higher post-test scores ($P < 0.001$). Mukhopadhyay *et al*. also reported greater improvement in median scores in the concept map group than in the book-reading group [6]. A meta-analysis by Izci and Akkoc [8] confirmed the effectiveness of concept maps in enhancing academic achievement, supporting their broader implementation in medical education similar to present study. Sargolzaie *et al*. [9] also reported significant improvement in post-test scores in intervention groups ($P < 0.001$), supporting the effectiveness of instructional strategies.

Although the post-test was conducted later than the pre-test, allowing time for recall and revision, previous studies have demonstrated that concept mapping facilitates rapid and meaningful learning.[10] Nagpal *et al*. [11] showed that learning and information integration were more effective through concept mapping, even when immediate assessments were used. In the present study, students were first oriented to concept maps using pre-designed templates. Subsequently, they were instructed to construct their own maps based on learning objectives, supported by software demonstrations and self-directed learning sessions.

While several studies have reported the benefits of concept mapping, few have objectively evaluated student-generated concept maps. In the present study, learning outcomes were assessed using an MCQ-based test, in which most students achieved high scores, highlighting the effectiveness of active learning strategies.

Previous studies have emphasized the importance of learner autonomy in concept mapping. Slieman *et al*. [12] allowed students complete freedom in map construction, which promoted deeper understanding. Zeitlin and Asadi [13] reported high compliance with map formats, with many students producing creative and enriched maps, indicating strong engagement.

In the present study, 72% of students reported increased interest in immunology learning. Similar findings were reported by Sannathimmappa *et al*. [3] and Jain *et al*. [14], who observed positive perceptions among more than 80% of students. Additionally, 76% of students in the present study reported improved conceptual understanding through concept mapping.

Most students perceived concept maps as useful tools for quick revision (87.2%) and summarization (86.1%). Kaiser [15], Masood *et al*. [16], Collins and Nyenhuis [17], and Bala *et al*. [18] also reported improved knowledge retention and mastery through concept mapping. These findings suggest that concept maps serve as effective revision aids, particularly before examinations.

However, the construction of concept maps may be time-consuming, which can limit their routine use. The development of user-friendly digital platforms may help overcome this limitation.

Critical thinking is a key outcome of professional education. In the present study, 70% of students reported improvement in critical thinking and problem-solving abilities through concept mapping. Similar improvements were reported by Maryam *et al*.[19] and Mohamed Amira *et al*. [20].

A study by Traylor *et al*. [21] suggested that combining 3D simulations with CM is an effective strategy for teaching complex medical concepts and warrants further exploration of its long-term impact. Baxa *et al*. [22] incorporated collaborative concept mapping into team-based learning and reported improved identification of learning gaps among students. However, moderate acceptance of this approach suggests the need for further refinement.

Limitations and Future Directions

The present study did not evaluate the concept maps generated by all student groups due to time constraints. In addition, the study primarily assessed students' perceptions of the effectiveness of concept map–based learning in fostering lifelong learning skills. Objective measures of effectiveness, such as comparison of examination performance on topics taught using concept mapping versus conventional methods, were not undertaken.

Furthermore, the relatively small sample size may limit the generalizability of the findings. Future studies with larger, multi-institutional samples and objective assessment tools are recommended. Incorporation of standardized rubrics for evaluating student-generated concept maps may provide more comprehensive insight into learning outcomes. Longitudinal studies may also help determine the long-term impact of concept

mapping on knowledge retention and clinical application.

CONCLUSION

Concept mapping is an effective, student-centered teaching–learning strategy in medical education, particularly for complex subjects such as immunology. It promotes quick revision, deeper conceptual understanding, and enhanced summarization skills. The positive perceptions of both students and faculty indicate strong support for its continued and expanded implementation.

Sustained faculty development, integration with existing curricula, and the use of user-friendly digital tools are essential to ensure seamless adoption and to maximize the educational benefits of concept mapping in undergraduate medical training.

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DECLARATIONS

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Author Contribution

Concept and design of the study – Sonia Mehta
Collection and curation of the data – Sonia Mehta, Amit Aggarwal, Diljot Sandhu, Ritu Garg
Analysis of Data- Sonia Mehta, Amit Aggarwal, Shreya Singh.
Drafting the manuscript- Sonia Mehta, Amit Aggarwal, Alisha Aggarwal
Critical Review and editing the manuscript – Diljot Sandhu, Alisha Aggarwal, Shreya Singh
Supervision – Sonia Mehta

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