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Using student-designed cases to foster creative and critical thinking skills in biochemistry

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Abstract:

BACKGROUND: In this novel intervention, we have tried to incorporate case-based learning with creative and critical thinking. Creative thinking indulges students to generate and apply new concepts in specific situations, seeing current situations in a new light, identifying alternative theories, and exploring new links that help generate a positive outcome. This may involve combining various hypotheses to form something original, sifting and refining ideas to discover possibilities, constructing new theories, and acting on intuition.

MATERIALS AND METHODS: This is a quasi-experimental study on educational intervention. First Bachelor of Medicine and Bachelor of Surgery (MBBS) students ($N = 80$) in their First MBBS students were randomly divided into control ($n = 40$) and study ($n = 40$) groups after they had undergone case-based learning in their first semester. The study group was asked to prepare three cases each on type II diabetes mellitus (DM), Fe deficiency anemia, and obstructive jaundice by discussion. Each case was prepared with a) an introduction consisting of presenting complaints, b) body comprising laboratory findings, and c) five questions related to the case. The cases were reviewed by a facilitator and presented to the other groups for discussion. Pretest and posttest questionnaires were collected and analyzed.

RESULTS: Based on the pretest scores, students were grouped as low, average, and high performers. Wilcoxon signed rank test was performed, which revealed significant improvement in the posttest scores of all students in the study group.

CONCLUSION: By designing new case histories themselves, students were able to understand the biochemical concepts of common diseases and apply these concepts in causation of diseases. Thus, case-based learning in this setting helped to foster creative and critical thinking skills of first MBBS students.

Keywords:

Case-Based Learning, creative thinking, critical thinking skills

Introduction

Case-based learning (CBL) has been followed for a long time in teaching medicine, with students being exposed to prepared case scenarios.^[1] In this activity, we have attempted to stimulate the creative and critical thinking skills of the students by involving students in the case preparation stage itself. Students

develop creative and critical thinking skills as they learn to generate and evaluate knowledge, clarify concepts and ideas, seek various possibilities, consider alternatives, and solve problems. Critical and creative thinking involves students thinking broadly and deeply using skills, behaviors, and attitudes like innovation, imagination, reason, logic, and resourcefulness in all learning areas and at all levels of learning.

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Kevin M. Bonney suggests that case studies, regardless of the source, are significantly more effective than other methods of content delivery at increasing performance on examination questions related to chemical bonds, mitosis and meiosis, and DNA structure and replication. This finding was positively correlated to increased student perceptions of learning gains associated with oral and written communication skills and the ability to recognize connections between biological concepts and other aspects of life.^[2] By applying a sequence of thinking skills, students develop an easy and better understanding of the underlying processes, which they can apply when they encounter problems, unfamiliar information, and new ideas. Alongside, progressive development of self-acquired knowledge and the practice of using thinking strategies make students more autonomous and confident problem-solvers and thinkers. This will help increase students' motivation and management of their own learning.^[3]

Critical thinking contributes to evidence-based medicine and practice. It is one of the important skills which can garner physicians and other health-care professionals "with the necessary skills and dispositions (habits of mind, attitudes, and traits) to support evidence-based practice."^[4] Critical thinking is the basis of most intellectual activity that challenges students to recognize or develop a hypothesis, use evidence in support of that hypothesis, draw conclusions in accordance, and use information to solve problems. Examples of critical thinking skills are interpreting, analyzing, evaluating, explaining, sequencing, reasoning, comparing, questioning, inferring, hypothesizing, testing, and generalizing.^[5]

On the other hand, creative thinking indulges students to generate and apply new concepts in specific situations, seeing current situations in a new light, identifying alternative theories, and exploring new links that help generate a positive outcome. Creative capacity is defined as the ability of a doctor with sufficient standardized knowledge and competence to adapt to a situation based on basic expertise.^[3] This may involve combining various hypotheses to form something original, sifting and refining ideas to discover possibilities, constructing new theories, and acting on intuition. The products of creative experience can involve complex representations and images, investigations and performances, digital and computer-generated output, or occur as virtual reality. "Making stuff" can help students prepare for unaccustomed or uncomfortable failures in a controlled environment that does not threaten their professional identities. Furthermore, doing so can facilitate students becoming resilient and creative problem-solvers who strive to find new ways to address vexing questions.^[6]

A study noted that CBL activities underpin the constructive alignment, and the introduction of CBL activities into the teaching and learning activities of functional biochemistry facilitates the development of problem-solving skills, consolidates student learning and understanding, and establishes linkages and alignment between the theoretical learning materials, practical experiences, and assessment items in a constructivist structure. The authors reported that the introduction of a set of CBL activities can work to positively influence the constructive alignment of the teaching and learning activities and the assessment items, and, overall, that this approach supports and boosts student satisfaction and leads to improved student performance.^[5] According to the Australian Curriculum, Assessment and Reporting Authority (ACARA), the key ideas for critical and creative thinking involve four interrelated elements in the learning continuum. They are as follows: a) inquiring – identifying, exploring, and organizing information and ideas; b) generating ideas, possibilities, and actions; c) reflecting on thinking and processes; and d) analyzing, synthesizing, and evaluating reasoning and procedures.^[4]

In this teaching–learning activity, we expose first year medical students in their second term of medical education to develop and solve case studies on particular topics of interest under the guidance of teaching staff.

Objectives

1. To stimulate creative thinking by asking students to design new cases on the topics provided
2. To require students to analyze concepts, sort out factual data, apply analytical tools, articulate issues, and draw conclusions
3. To develop analytical, communicative, and collaborative skills along with content knowledge

Materials and Methods

Study design and setting

This interventional study was conducted at Government Medical College, Kannur, Kerala, in the Department of Biochemistry.

Study participants and sampling

The first year undergraduate students of Bachelor of Medicine and Bachelor of Surgery (MBBS) studying in Government Medical College, Kannur, were recruited for the study at the end of their second term. The students had been exposed to CBL in their first and second terms. Eighty students opted to participate in the activity.

Data collection tool and technique

A questionnaire was designed and circulated among the staff of the department for peer review. Students who

opted for the study were randomly divided into two groups as study and control groups. Both the groups were administered a pretest questionnaire (Appendix 1).

First year medical students of this institute were recruited for the study after the students had undergone CBL in their second semester. Students were briefed about the project in simple terminology, and their consent was obtained. Students were divided into study ($n = 40$) and control ($n = 40$) groups randomly. The pretest questionnaire was distributed to both study and control groups simultaneously at the beginning of the session. The questionnaire included questions based on reference ranges, biochemical basis/pathophysiology, and principles of treatment of the respective cases. The questionnaire was designed to test knowledge gained by group discussion through creative and critical thinking. This indirectly reflects the students' ability to think through a case study. After the pretest, control group students were seated in a separate room for the period of activity.

The study group was randomly divided into four subgroups – A, B, C, and D – of 10 students each. So, each group consisted of a mix of students in terms of gender

and pretest scores. Supplemental study material (standard biochemistry textbooks) was provided, and the subgroups were asked to prepare three cases each on type II diabetes mellitus (DM), Fe deficiency anemia, and obstructive jaundice. The students were instructed to sit with their respective subgroups and discuss [Figure 1]. They were told that the cases should be prepared collectively by all students, and that each and every student should actively participate and contribute to the case study preparation. The subgroup facilitators were particularly instructed to ensure individual student participation.

Each subgroup was asked to prepare three cases each on type II DM, iron deficiency anemia, and obstructive jaundice. Three students from each subgroup were asked to present and discuss case each prepared by their subgroup with other subgroups as shown below.

Instructions for drafting the case:

- Each subgroup is to be guided by a facilitator.
- All students of the subgroup should actively participate and contribute to case study preparation.
- Each case should be prepared with
 - a) An introduction- consisting of presenting complaints and history;

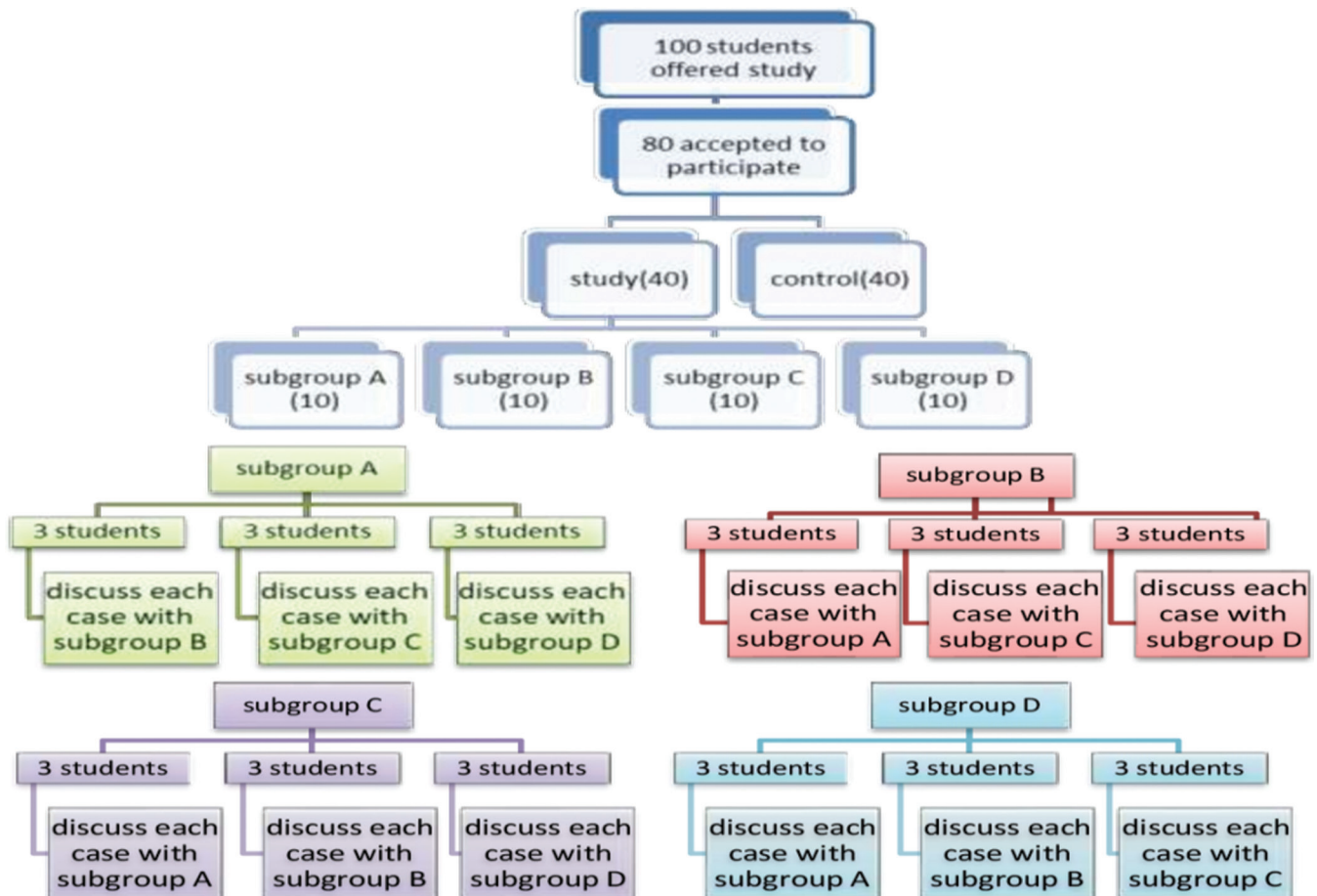


Figure 1: Methodology

- b) Body- comprising laboratory findings and investigations; and
- c) Five questions related to the case.

The cases were reviewed by the group facilitator and presented to the other subgroups for discussion. The control group was seated in a separate room for the period of the activity. They were provided with the same standard textbooks and asked to read the same topics on which cases were prepared and discussed. The facilitator also helped the students with their doubts.

The same questionnaire was administered as posttest to both study and control groups after completion of the activity. The questionnaire is attached as Appendix 1, and types of questions included in the questionnaire are attached as Appendix 2. One example of each case study prepared by the different subgroups is attached as Appendix 3 for reference. This may help the readers understand the activity undertaken and also the response of the students. The questionnaires were analyzed, and the results were recorded in pre-structured formats for analysis. Written, informal feedback was obtained from the faculty and students at the end of session. An example of student’s response to the pretest and posttest questionnaires is attached as Appendix 4, which can assist the readers to evaluate the effectiveness of the activity.

After completing the activity, the cases prepared by the study group were shared and discussed with the control group students. The entire timeframe of the activity is presented in Table 1.

Ethical consideration

Institutional Ethical and Research Committee approval was obtained before the study (IEC No. 11/2019/GMCK).

Results

When cases were presented by students of one subgroup, facilitators noted that the cases were well received by the other subgroups. There were in-depth discussions on the clinical presentations, treatment modalities, and laboratory findings. Overall, the cases prepared by the various subgroups appeared to be of similar quality for all four subgroups.

A total of 80 students were divided into two groups – study and control – with 40 in each group. Pretest scores out of 20 ranged from 9 to 17 in the control group and from 8.5 to 16.5 in the study group [Table 2]. Independent samples *t*-test was performed to compare the means of these groups in order to determine that the two groups were similar before the intervention. From the table 2 below, a look at the descriptives shows that the mean marks of the control group is only slightly higher

than that of the study group, but on performing the independent samples *t*-test for means, it is seen that there is no significant difference between the two means (as $P > 0.05$). Therefore, it was concluded that both groups were similar before the intervention.

We looked at the posttest marks of the two groups [Table 3]. Out of a possible score of 20, the scores ranged from 8 to 17 in the control group and from 12 to 19 in the study group.

We can see from Table 3 that the study group obtained a mean higher than the control group, and using independent samples *t*-test, this difference was found to be statistically significant.

Additionally, we can look into each group separately and see if there is a difference within the group when compared before and after the intervention.

From Table 4, we observe that the means of both the

Table 1: Timeframe of activity

Time	Study group	Control group
15 min	Pretest	Pretest
30 min	Case study preparation	Read textbooks
	Case discussion	Read textbooks
15 min	Subgroup A	
15 min	Subgroup B	
15 min	Subgroup C	
15 min	Subgroup D	
15 min	Posttest	15 min
30 min		Sharing and discussion with the control group

Table 2: Mean pretest scores of the study and control groups

Group	Mean pretest score	Std. deviation	P
Control	12.34	2.24	0.835
Study	12.24	2.03	

Table 3: Mean posttest scores of the study and control group

Group	Mean posttest scores	Std. deviation	P
Control	12.45	2.22	<0.001
Study	15.51	1.63	

Table 4: Pretest and posttest scores of the study and control groups

Group	Mean	Std. deviation	P
Control			
Pretest	12.34	2.24	
Posttest	12.45	2.22	0.018
Study			
Pretest	12.24	2.03	
Posttest	15.51	1.63	<0.001

groups have increased in the posttest compared to the pretest; the difference between the pretest and posttest means in the control group is 0.11, whereas in the study group, it is 3.28. Using paired samples *t*-test, it is seen that both these differences are significant. So, we can conclude that there has been a significantly higher increase in the study group compared to the control group, which leads to the conclusion that the intervention was effective.

According to the pretest scores, students were divided into three groups as high (15–20), moderate (10–14.5), and low (<10) performers. Wilcoxon signed rank test was performed to observe the degree of improvement in each group within the study and control groups [Table 5].

As seen from the table 5, all the three groups of low, average, and high performers of the study group showed significant improvement ($P \leq 0.0001$) in their posttest scores after the intervention. No significant difference was noted in the control group. The outcome of our study has been briefly presented below.

- Better student engagement and interaction: A high degree of student engagement was noticed during the case preparation stage. The students see this as a challenge and indulge with great enthusiasm and joy.
- Better interaction of students with staff: Since students are taking the first step toward learning, they see the teacher as one of their team members who also guide them through this process.
- Better utilization of time and resources: The same

amount of time was observed to lead to a better understanding of topics covered. The textbooks provided were read effectively, leading to in-depth knowledge and better retention of subject matter. Reflections of students and facilitators have been presented below in Table 6.

Discussion

Our study involved making students work in teams to dwell on creating novel case histories based on their collective creative thinking capacities and applying biochemical concepts of common diseases, which gauge their critical thinking skills. In a study by Nair SP *et al.*,^[7] CBL used as the medium of instruction was found effective in the medical curriculum for a better understanding of biochemistry among the medical students. CBL by itself has shown positive outcomes in terms of better understanding of subject, better retention of concepts, and better application of clinical and diagnostic theories.^[8-10] An open-ended investigative or inquiry-based approach in science education was found to build higher-order cognitive strategies such as mental simulation.^[11] Our intervention involved making students work in teams to build the case histories. Team-based learning, developed by L. Michelsen to address the concerns regarding student engagement in a large class, has concluded that properly formed teams and team assignments promote learning and team development, student accountability, and frequent and timely feedback to students.^[12,13] These findings are in

Table 5: Wilcoxon signed rank test analysis

Groups	Average pretest score	Average posttest score	Wilcoxon signed rank test	
			Z	P
Study group (n=40)				
Low performers (n=6)	9.5	14.0	-5.5109	<0.0001
Average performers (n=27)	12.0	15.5		
High performers (n=7)	15.5	17.5		
Control group (n=40)				
Low performers (n=4)	9.0	9.5	2.2014	NS
Average performers (n=29)	11.5	12.0		
High performers (n=7)	15.5	15.5		

NS=Not significant

Table 6: Reflections of students and facilitators

	Students	Teachers
Pluses	1) Interactive session helps in better retention of subject matter 2) Case presentation leads to increased self-confidence 3) A better opportunity to interact with teachers and peers 4) Session is engaging and not boring like didactic lectures	1) A novel method of case-based teaching also increases teacher engagement 2) Involving students in planning helps teachers understand students' learning process 3) Better utilization of time
Minuses	1) Not all students participated equally. Students who are introvert or shy find it difficult to express themselves in a group 2) Control group suggested that this activity has benefitted only the study group and should be repeated with them also	2) Number of students per faculty should be less. A single facilitator should be allotted only five to six students for a better teaching-learning experience 2) Facilitators felt that collective time spent by all faculties was more. But this time was well spent

alignment with our study results.

The 21st century brings along complex social, economic, and environmental pressures, which challenge our youth to be adaptable, creative, and innovative with the motivation, confidence, and skills to use critical and creative thinking purposefully. Critical thinking and creative thinking, two independent and desirable traits, are strongly linked, bringing complementary dimensions to thinking and learning.

Several innovative methods have been tried and experimented with CBL. This study was experimented by involving students in the case design stage itself. Similarly, another study indicates that iterative involvement of students in the process of developing new technological learning material enhances students' identification of important learning needs, and that the use of students' and teachers' knowledge in an adapted co-design process appears as the most optimal level of involvement for both students and instructors.^[14]

Based on the research findings of another study group, case study discussion would be more effective than an individual case study for teaching critical thinking and enhancing students' critical thinking abilities as it encouraged students to reflect, have a discussion with teachers, and get involved in group discussions.^[15] These findings are similar to our study findings.

A study aimed to develop a clinical teaching blended learning (CTBL) program with the aid of web-based clinical pedagogy (WCP) and CBL for nurse preceptors provided empirical evidence that the CTBL program increases the clinical teaching competencies and self-efficacies of preceptors and promotes positive attitudes toward web-based learning and better blended learning outcomes.^[16]

Another intervention, the flipped classroom, is a feasible and useful alternative to the traditional classroom. It is a method that embraces Generation Y's need for active learning in a group setting, while maintaining a traditional classroom method for introducing the information.^[17] Active learning increases student engagement and can lead to improved retention of material, as demonstrated in standard examinations.

The latest in the era of coronavirus disease 2019 (COVID-19) is distance learning, which refers to the use of technologies based on health care delivered from a distance and covers areas such as electronic health, tele-health (e-health), telematics, telemedicine, tele-education, and so on.

Creating new case histories helps students to think creatively simultaneously applying acquired biochemical concepts. Creative exercises, a specific form of open-ended assessment tools, have been shown to promote students' linking of previously and newly learned concepts within a course. Invoking the cognitive resources activation framework in discussing the findings highlighted the utility and relevance of creative exercises (CEs) in upper division courses that rely on the application of previous chemical knowledge to explain the new ones as well as the implications of the findings for research and teaching.^[18] Vanderlelie noted that the implementation of a creative, multimedia-based group project in biochemistry helped students gain deeper understanding of their chosen biochemical pathway and provided a range of presentations that neatly summarized the metabolism fundamentals. Students found this assessment task to be a useful learning and study tool that added a "fun" dimension to the course.^[19]

The study noted that students came up with unique and simple presentations of various clinical scenarios. Allowing students to come up with their own solutions to open-ended questions can foster creativity in the classroom. Critical thinking includes "analysis, inference, interpretation, explanation, synthesis, and self-regulation."^[20] The orientation/decision/do/discuss/reflect (OD3R) method can increase students' critical thinking based on Hoyo rubric, as seen from the students' comprehension in assembling a better investigation report in terms of abstract writing, information source presentation, the use of clear format, data interpretation skill and investigation result explanation skill, and the use of intelligible language.^[21] Critical thinking and clinical reasoning skills could be nurtured by encouraging students to more actively participate in learning activities. Medical educators need to interact with students, listen to them more often, encourage questioning, challenge students, and encourage them to reflect and explore the answers for themselves.^[20]

Critical thinking develops the ability and willingness to assess claims and make objective judgments on the basis of well-supported reasons and evidence rather than emotion or anecdote. In our activity, we noted that students created cases and questions related to those cases as a retrograde process which starts with the question why.

Analysis of reflections submitted by 188 medical students after a research protocol writing intervention indicated that majority of them found an improvement in their skills of critical thinking and collaborative learning.^[22] These results are in accordance with our study results. All participants agreed that the model helped in applying

concepts to new situations in the form of designing their own study, which reflected in enhanced higher-order cognitive skills.

Limitation and recommendation

This study involved only 100 phase 1 MBBS students and needs to be validated with a larger number of students. Students of other phases may be included to study the differences as the students progress from one phase to another. The study may be replicated across various specialties and subjects.

Conclusions

Medical education today must be innovative for our current medical students as well as for generations of physicians to come. Our study involved making students work in teams to dwell on creating novel case histories based on their collective creative thinking capacities and applying biochemical concepts of common diseases, which gauge their critical thinking skills. The newly introduced curriculum-based medical education (CBME) in India requires active participation of not only the teaching faculty, but also the dynamic and intellectual student forces. Students imagine possibilities and connect ideas through considering alternatives, seeking solutions, and putting ideas into action. They explore situations and generate alternatives to guide actions and experiment with and assess options and actions when seeking solutions. In imbibing and developing critical and creative thinking, students themselves create a professional body that is more competent in dealing with the emerging and challenging clinical situations. In the future, it could be informative to confirm our findings using a larger cohort, by repeating the study at different institutions with different topics, and by directly comparing the effectiveness of this method with additional forms of instruction, such as traditional chalkboard and slide-based lecturing, and laboratory-based activities. It may also be beneficial to examine whether demographic factors such as student age and gender influence the effectiveness of the case study teaching method. The use of case studies that involve hands-on activities should be emphasized to maximize the benefit of this teaching method. These changes are the essential components to a dynamic curriculum to ensure that high-quality educational content continues to be delivered to students.

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Declarations

Availability of data and material

All data and material will be made available if requested for.

Authors' contribution statements

All authors of the manuscript

- 1) made substantial contributions to the conception or design of the work; or the acquisition, analysis, or interpretation of data; or the creation of new software used in the work;
- 2) drafted the work or revised it critically for important intellectual content;
- 3) approved the version to be published; and
- 4) agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Ethics approval

The study was approved by the Institutional Ethics Committee and the Institutional Review Board.

Informed consent

Informed consent was obtained from all individual participants included in the study.

"Consent to participate" and "consent to publish" were obtained from the participants before the study.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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