

Original Research



Design, Implementation, and Evaluation of Student-centric learning in Physiology

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Abstract

Background: The quality of teaching and learning in health education determines the competency of doctors produced and ultimately the patient care. Realizing the necessity of active learning at the undergraduate level, curricular reforms are crucial to ensure that students play an active role in their learning process and absorb the prerequisite qualities of a competent health professional. The current study aimed to implement and evaluate case-based learning in a physiology curriculum.

Methods: The study included 150 first-year MBBS students using a mixed methods research design. A short lecture on anemia was followed by two sessions of case-based learning with a gap of one week. A structured questionnaire using a 5-point Likert scale was used to collect students' perceptions. The internal consistency of the questionnaire had a Cronbach's alpha of 0.8. Faculty feedback was collected using a Focus Group Discussion.

Results: Of 145 participants, 117 provided feedback. Students perceived that the case-based learning method promoted meaningful learning (83%); helped in the future application of knowledge (81%); helped to understand physiology concepts better (72%); improved student-teacher relationships (72%); was effective in understanding the anemia topic (71%); led to the development of problem-solving abilities (70%); encouraged teamwork (69%); motivated self-directed learning (66%); and improved communication skills (65%). Faculty members suggested developing an assessment plan for future case-based learning sessions.

Conclusion: According to student and faculty feedback, case-based learning is an effective, active teaching-learning tool that improves students' understanding of basic concepts, clinical knowledge, problem-solving abilities, teamwork, communication skills, student-teacher relationship, and self-directed learning.

Introduction

"Progress is impossible without change, and those who cannot change their minds cannot change anything"- George Bernard Shaw.

The journey of life itself, from conception to culmination, is the best example of change. The process of education - acquiring knowledge, skills, values, morals, and how these are acquired - has also seen profound changes over the centuries in its structure, understanding, and delivery. The purpose of medical education in India and in every other country is to train skilled health professionals who would serve society diligently to prevent the development of disease, cure illnesses, and promote the well-being of humanity.¹The quality of teaching and learning in health education determines the competency of doctors

produced and ultimately the patient care.

Most medical colleges in India teach basic sciences in 1st-year MBBS using traditional methods, where a curriculum decided by universities and higher governing bodies is delivered to students via lectures and practical sessions.^{1,2} The traditional style of teaching is often not well-received by the new generation of students who feel that it is boring and less interactive and is teacher-oriented. This method of teaching and learning is teacher-centered with minimal active participation from students. There is a widespread belief among medical educators throughout the world that lecture-based teaching alone is insufficient to address the needs of all learners and is not ideal for teaching higher-order cognitive skills, such as synthesis, analysis, and application, which are critical for medical

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practitioners.³ When students' involvement is low in the learning process, outcomes will also be less desirable.

Realizing the compelling necessity of active learning at the undergraduate level, curricular reforms are crucial to ensure that students play an active role in their learning process and absorb all the prerequisite qualities of a competent health professional.¹ Physiology is a basic science in the 1st MBBS and thus needs to be taught effectively and learned thoroughly in order to be placed in the context of disease when medical students begin attending their clinical postings during the 2nd MBBS. An emerging trend worldwide is to have a problem-based, integrated, student-centered medical curriculum that allows active participation from students and facilitates self-directed learning.⁴

There are many different ways of explaining how adults learn effectively.⁵ Likewise, many different learning strategies allow active participation of learners and the development of improved knowledge, skills, critical thinking, and values.⁶ Case-based learning (CBL) is a well-established pedagogical method where basic science concepts are studied in relation to clinical conditions. CBL enjoys various definitions across numerous disciplines and contexts. Essentially, it is a form of inquiry-based learning that uses clinical cases to aid teaching. It fits on the continuum between structured and guided learning.^{7,8} CBL integrates preclinical and clinical subjects, thus creating a link between theory and practice and allowing students to think holistically about the profession. The advantages of case-based learning are manifold: promotion of self-directed learning, development of clinical reasoning, acquisition of clinical problem solving, decision making, and communication skills, and stimulation of deep learning.^{3,4,7-12} Although many countries have shifted their curriculum from teacher-centered to student-centered training, most medical colleges in India are still practicing old-fashioned lecture-based teacher-centered pedagogy. During a literature search, we found that few Indian authors reported the inclusion of active learning methods such as CBL in their curriculum.^{3,4,10,11}

Although traditional teaching is useful in conveying a considerable amount of information to larger audiences, it is ineffective inactive learning. In traditional teaching, learners remain passive and are less attentive in the classroom, leading to reduced perception of information. In our institution, physiology is taught principally using this traditional style to convey basic and applied concepts of health and disease. Thus, it is the right time to reconsider our teaching styles and embrace modern, active teaching-learning methods in our curriculum.

There were a few reasons behind the initiation of these changes in our existing teaching styles and curriculum. Firstly, the training of our faculty members in a faculty development program (FDP) changed our awareness of teaching and learning in medical education. Secondly, it was feedback from previous batch students on learning

physiology. They felt learning physiology was boring and difficult. They noted many physiology concepts were imaginary and complex as well as difficult to learn and understand. Lastly, yet foremost, it was feedback from our colleagues in clinical departments who expressed their concerns around students' acquisition of prerequisite knowledge and skills before their first clinical postings.

Thus, the primary aim of this research was to design, implement, and evaluate case-based learning in our curriculum to facilitate active learning among students.

Materials and Methods

This study was conducted in the Department of Physiology of the Sri Manakula Vinayagar Medical College and Hospital, Puducherry. The Institutional Research and Ethics Committee permissions were obtained. The study involved all 150 first-year MBBS students of the 2017-18 batch. We used a mixed-methods research design (both quantitative and qualitative) in the current study. The framework of the study is outlined below (Figure 1).

Framework of CBL

To this end, a department meeting was arranged with all faculty members to solicit their cooperation in the study. In the meeting, all concurred with two decisions: first, to include an 'anemia' topic to teach in CBL and secondly, acknowledging and agreeing that all faculty members must be trained before the implementation of CBL. The principal investigator arranged a 'faculty training' session and prepared anemia-related clinical scenarios.

Later, a 'CBL Facilitation Program' was arranged in the department with the help of the Medical Education Unit (MEU). It was a truly interactive session, which provided the opportunity to understand the purpose of CBL, the role of teachers in CBL, how to prepare and validate paper-based clinical scenarios, and how to collect feedback from the stakeholders. Two clinical scenarios – Microcytic

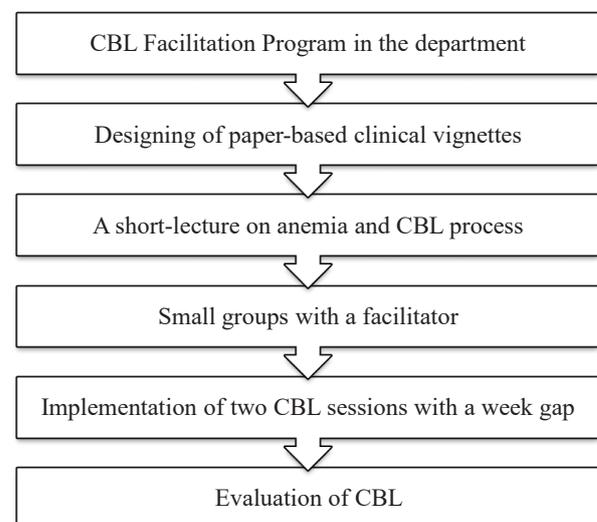


Figure 1. Outline of CBL

Anemia and Macrocytic Anemia – were prepared and validated over the next 15 days.

It was also necessary that students were briefed about new learning intervention as it completely differs from traditional learning. The principal investigator explained CBL to the students, including its design, purpose, and the roles of students and teachers in the learning process. It was also emphasized that students should note how CBL influenced their learning and give honest feedback when asked.

One of the most important characteristics of CBL, according to the CBL proponents, is that learners need to have some background knowledge on the selected topic. Therefore, a didactic lecture was given before CBL intervention on erythrocyte structure, function, production, and factors regulating erythropoiesis, with a brief introduction to anemia.

Two CBL sessions were planned with a gap of one week between them. Case scenarios on Microcytic Anemia and Macrocytic Anaemia were selected for the first and second sessions, respectively. The one week gap between the two learning sessions was to provide sufficient time for self-directed learning (SDL). Whatever additional information they gained during this period would help them in solving the new clinical vignette during the next CBL session. Moreover, it helped the teachers to know whether SDL is happening. Tutorial sessions were held every Friday between 2.30–4.30 pm.

As a start-up to implement CBL, the class of 150 students were divided into 5 tutorial groups and each group had a trained faculty member to facilitate the session. Each tutorial group of 30 students was subdivided into three small groups of 10 students each to enhance active involvement and learning.

The process of CBL during these two sessions was similar. Each CBL session had two hours: 10 minutes to read and understand the given clinical scenario; 60 minutes to discuss and solve the specific learning objectives (SLOs) by self-learning and group discussion; 30 minutes to interact with teachers to get guidance; and 20 minutes for the final conclusion. One volunteer student from each group was asked to read the scenarios to the rest of the group. Students were also allowed to take a snapshot of the case on their mobile phone and read it for themselves. They referred to textbooks to find the solution for SLOs during self-learning and group discussion. It is worth mentioning that the predominant purpose of CBL is to encourage learners towards active learning. The teachers' role was to guide them if or when students deviated from the main topic, to ensure that they actively participated in the learning, and that they achieved all SLOs by the end of the session. During the second CBL session, which happened on the next Friday, a new clinical scenario was given to discuss and solve the related SLOs. The CBL method proposes that learners acquire new information by self-learning and become more competent in problem-

solving with regular exposure to CBL.

Data collection and analysis

Students' feedback was collected after completing both the CBL sessions. The survey was anonymous and identifying information such as name, roll number, age, and gender were kept confidential. A structured questionnaire covering 11 different items (understanding, teamwork, communication skills, SDL, student-teacher relationship, problem-solving abilities, future application, etc) was used to collect students' perceptions of CBL. The internal consistency of the questionnaire was measured using Cronbach's alpha (0.8). Of the 11 questions, ten questions were closed-ended, asking for a rating on a 5-point Likert scale (indicating students' level of agreement from strongly agree to strongly disagree); the last question was open-ended.²⁶ As a program evaluation (Kirkpatrick level 1), the items were aligned with the purpose of CBL. Faculty feedback was collected through a Focus Group Discussion (FGD). For quantitative analysis, a simple frequency distribution table was used to summarize the data and a descriptive narration was selected for qualitative analysis of the open-ended question and the FGD data.²⁷

Results

Of 150 students, 145 participated in both the CBL sessions, and 117 provided feedback (for a response rate of 80.68%). All faculty members (N=7) gave their feedback during Focus Group Discussion.

Student feedback

The results of student responses to the CBL questionnaire (Table 1) show that most students agreed or strongly agreed that the CBL method promoted meaningful learning (97 of 117 students, 83%); helped in future application of knowledge (95 of 117 students, 81%); improved student-teacher relationship (83 of 117 students, 72%); helped them understand physiology concepts better (84 of 117 students, 72%); was effective in helping them understand the anemia topic (83 of 117 students, 71%); led to the development of problem-solving abilities (82 of 117 students, 70%); encouraged teamwork (81 of 117 students, 69%); motivated self-directed learning (82 of 117 students, 66%); and improved communication skills (76 of 117 students, 65%).

For the open-ended question, students were requested to share suggestions, comments, and experiences with the CBL sessions (refer to Table 2). Representative comments on CBL are shown below.

“Learned diagnostic skills”

“Freedom to learn”

“Acquired clinical knowledge”

“Referred additional books”

“Enjoyed new method”

“Improves relationships with friends”

They also suggested conducting more CBL sessions in the future, and giving assignments on clinically

important topics so that they can study them later. Students' suggestions requesting more CBL sessions and assignments indicate that they thoroughly enjoyed the CBL method and were motivated to learn.

Faculty feedback

Faculty feedback was collected around the following parameters: their experience with CBL sessions compared to regular teaching and their perception of students' participation and learning in CBL (refer to Table 3). All teachers expressed that CBL gave them a different teaching experience altogether. They were also surprised by students' active involvement in the CBL discussions. However, they mentioned two important areas of concern related to CBL sessions. First, there should be fewer students in each group so that monitoring and facilitation are easier to accomplish. Secondly, they all felt that a plan must be developed to assess what students have learned in the CBL sessions, creating a measure to assess their progress in learning. All health educators are well aware of the credo that "Assessment drives learning."

Discussion

The purpose of medical education in India is to create competent health professionals who recognize "health for all" as a national goal. It is the collective responsibility of the Medical Council of India (now the National Medical Commission), medical colleges, and health educators in India to train skilled Indian Medical Graduates (IMGs) who can effectively provide preventive, promotive, curative, palliative, and holistic care to the patients they serve.¹ This goal can be successfully be achieved by step-wise efforts beginning with the pre-clinical years through to the internship level.

The objectives of this study were to design and implement CBL in a physiology curriculum to encourage active learning and evaluate stakeholders' perceptions of CBL. The overall results indicate that students showed a strong preference for learning via CBL as it facilitated a better understanding of physiology concepts, meaningful

Table 2. Students' responses to open-ended question

S. No	Suggestions/Comments/Experiences	Percentage
1	To conduct more CBL sessions on clinically important topics	60
2	To reduce the number of participants in each group	46
3	Helps in peer learning	42
4	Learn diagnostic skills	34
5	Acquire clinical knowledge from many other sources	39
6	Freedom to learn in our own way	25
7	Improves relationships among students	21
8	To give assignments on the CBL topics	10
9	Enjoyed a new method of learning	30

Table 3. Faculty responses to CBL (N=7)

S. No	Experiences/Comments/Suggestions
1	It is a different teaching experience
2	CBL session covered only small topics
3	Good for teaching clinical related topics
4	Learning through CBL sessions should be assessed
5	Facilitation and monitoring were difficult
6	Students enjoyed the entire session
7	Students were active and did not sleep

Table 1. Students' responses to CBL questionnaire

S.No	Likert items/statements	Likert response options				
		SA* n(%)	A* n(%)	NAND* n(%)	D* n(%)	SD* n(%)
1	In understanding anemia topic, CBL sessions were useful	33(28)	50(43)	31(26)	2(2)	1(1)
2	Relevant and Interesting case scenarios were given to learn anemia	37(32)	47(40)	28(24)	5(4)	0(0)
3	CBL promotes meaningful learning than the regular lecture classes	46(39)	51(44)	14(12)	5(4)	1(1)
4	CBL encouraged me to work with my friends as a "team" in solving case scenarios	46(39)	35(30)	25(21)	8(7)	3(3)
5	CBL provides an opportunity to interact with friends and improve communication skills	40(34)	36(31)	32(27)	7(6)	2(2)
6	CBL method is useful in the future application of knowledge	54(46)	41(35)	21(18)	1(1)	0(0)
7	CBL motivated me to refer more learning resources such as textbooks, online search, etc. (self-directed learning)	30(26)	52(44)	30(26)	5(4)	0(0)
8	CBL facilitates a better and healthy student-teacher relationship	35(31)	48(41)	26(22)	4(3)	4(3)
9	CBL helped me develop problem-solving abilities	30(26)	52(44)	30(26)	5(4)	0(0)
10	CBL improved my understanding of physiology concepts better	34(29)	50(43)	28(24)	4(3)	1(1)
11	Briefly mention your learning experiences/comments/suggestions related to CBL sessions					

*SA=Strongly Agree, A=Agree, NAND=Neither Agree Nor Disagree, D=Disagree, and SD=Strongly Disagree. n=number of students

learning, and future application of knowledge. Learning physiology through systems-based didactic lectures alone is difficult for beginners, as the curriculum includes new medical terminologies, imaginary concepts, and less interaction with teachers.²¹ Guided learning, such as CBL, facilitates effective learning of basic sciences, which in turn is essential for better understanding of clinical subjects, interpretation of patients' clinical signs and symptoms, and analysis of laboratory results.¹⁶⁻²¹ This kind of exposure and training is essential for learners to succeed and even excel in their clinical years.

Most students felt that CBL encouraged teamwork and the development of communication skills, as it allowed them to interact, discuss and share during the learning process. Teamwork in the health care system, where two or more people interact and work for a common purpose and goal, is a key component to making decisions as a unit while giving patient care and communicating with patients' family and friends. It seems likely that repeated CBL exposure in the pre-clinical years would prepare these budding doctors for their future responsibility of handling teamwork and communication situations in a real context.^{11,13-15,18-20}

Students also felt that CBL learning helped them acquire and improve their problem-solving ability. The problem-solving ability, which involves mental processes to solve medical problems, can be defined as a hypothetical-deductive activity engaged in by experienced physicians, in which the early generation of hypotheses influences the subsequent gathering of information.²² Health professionals develop this ability over the years by accumulating medical knowledge and experience. Learners can be trained to acquire such skills early in their profession by exposing them to clinical case discussion and decision-making processes. CBL is one technique that helps train the problem-solving ability of future doctors and improves the quality of their decisions inpatient care.

The educational environment in any discipline has a definite impact on how students learn and progress. Amongst many factors, the curriculum, teaching-learning techniques, the type of teachers and their teaching styles, and the student support system are among those that determine the learning environment, student satisfaction, and academic achievement.²³ A friendly, supportive learning environment contributes to student well-being and enhances student empathy, professionalism, and academic success.²⁴ In our research, students agreed that CBL provided such learning environment and they felt it strengthened the student-teacher relationship.

Current research also notes that CBL stimulates self-directed learning (SDL) among students. Students revealed in the feedback that they referred to more learning resources during and between the two CBL sessions to solve the cases. Currently, SDL has gained more attention and popularity among health educators worldwide. In simple terms, it is a learning process in

which learners take the initiative and responsibility for their learning. One way of inculcating SDL among students is to give them case-based scenarios and then to guide the learners with questions, leading them to answers using recommended learning resources.²⁵ This approach enables health professionals to continue learning and updating their knowledge.

Students responded to the open-ended request for comments and suggestions by saying that more CBL sessions should be conducted on clinically important topics and suggested reducing the number of participants in each group. Students enjoyed learning in CBL sessions as these provided the opportunity to interact with each other, share their findings, make decisions, and, importantly, they have the freedom to learn at their own pace. Learning new information requires interest and involvement. CBL creates interest in learners' minds by exposing them to new clinical scenarios and showing them links between theory and practice.

It is worth mentioning that the successful implementation of any new curriculum requires adequate training and cooperation of faculty. During the focus group discussion, faculty members shared their experience with the CBL method. They all felt that it was a different teaching experience compared to regular classroom teaching. The role of teachers in CBL is to facilitate the learning process by guiding the students appropriately towards solving learning objectives. Our faculty mentioned that they can become better facilitators only after repeated participation in CBL. They felt that the major concern of the CBL method is that only small topics can be covered in a two-hour session, and it is a good method for teaching clinically-related topics but not for all topics. All faculties unanimously agreed that case-based learning was an effective teaching method as all students were active throughout the session and did not sleep at all.

The way forward

In our analysis, we identified some areas of improvement related to CBL implementation. Firstly, only the clinically important topics in physiology should be selected for teaching CBL. Secondly, an assessment for learning should be planned for assessing CBL sessions. Thirdly, a decision must be taken on how to conduct more CBL sessions in small groups with a minimum number of participants in each group. And finally, an approach must be determined on giving assignments in CBL sessions to facilitate self-directed learning. The findings of our study were shared with all faculty in the department and an evaluation report along with a future plan of action was submitted to the institutional curriculum committee for review and suggestions.

Conclusion

Medical education is a dynamic process that keeps changing with the advent of new information and innovative

teaching-learning methods. We aimed to facilitate the learning process by implementing CBL in a physiology curriculum. In our experience, CBL is an effective, active teaching-learning tool that improves students' understanding of basic concepts, clinical knowledge, problem-solving abilities, teamwork, communication skills, the student-teacher relationship, and self-directed learning. Therefore, we should adapt to effective learning strategies to train our students more effectively since, as we all know, "Today's learners will be tomorrow's doctors." Embracing new ideas and developments in teaching changes our concept of training and learning in medical education. These small changes made in the curriculum opened new opportunities for us to a novel learning experience.

Competing interests

None.

Ethical approval

This study was reviewed and approved by the Institute Research and Ethics Committee (No: SMVMCH-EC/DO/AL/1291/2017).

Authors' contribution

Dr. Shivayogappa. S. Teli contributed to the design of the study, data collection from students and faculties, data interpretation, and manuscript preparation. Dr. M. Senthil Velou and Dr. K. Soundariya contributed to critical review and final approval of the manuscript. Dr. Deepika Velusami, Mrs. Senthamil Selvi. K, and Dr. Mangani Mangalavalli. S, contributed to the implementation of the study and data collection from students.

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References

1. Competency-based Undergraduate Curriculum for the Indian Medical Graduate [internet]. New Delhi: Medical Council of India; 2018 [updated 2020; cited 2020 March 10]. Available from: <https://www.nmc.org.in/wp-content/uploads/2020/01/UG-Curriculum-Vol-I.pdf>.
2. MBBS curriculum [internet]. Pondicherry: Pondicherry University; 2019 [updated 2020; cited 2020 March 10]. Available from: <https://backup.pondiuni.edu.in/sites/default/files/downloads/MBBSCurriculum201913072020.pdf>.
3. Muthukrishnan SP, Chandran DS, Afreen N, Bir M, Dastidar SG, Jayappa H, et al. Planning, implementation, and evaluation of multicomponent, case-based learning for first-year Indian medical undergraduates. *AdvPhysiol Educ.* 2019;43(4):504-11. doi: 10.1152/advan.00080.2019.
4. Ghosh S. Combination of didactic lectures and case-oriented problem-solving tutorials toward better learning: perceptions of students from a conventional medical curriculum. *AdvPhysiol Educ.* 2007;31(2):193-7. doi: 10.1152/advan.00040.2006.
5. Taylor DC, Hamdy H. Adult learning theories: implications for learning and teaching in medical education: AMEE Guide No. 83. *Med Teach.* 2013;35(11):e1561-72. doi: 10.3109/0142159x.2013.828153.
6. Palis AG, Quiros PA. Adult learning principles and presentation pearls. *Middle East Afr J Ophthalmol.* 2014;21(2):114-22. doi: 10.4103/0974-9233.129748.
7. Thistlethwaite JE, Davies D, Ekeocha S, Kidd JM, MacDougall C, Matthews P, et al. The effectiveness of case-based learning in health professional education. A BEME systematic review: BEME Guide No. 23. *Med Teach.* 2012;34(6):e421-44. doi: 10.3109/0142159x.2012.680939.
8. McLean SF. Case-based learning and its application in medical and health-care fields: a review of worldwide literature. *J Med EducCurric Dev.* 2016;3. doi: 10.4137/jmecd.s20377.
9. Jhala M, Mathur J. The association between deep learning approach and case based learning. *BMC Med Educ.* 2019;19(1):106. doi: 10.1186/s12909-019-1516-z.
10. Gade S, Chari S. Case-based learning in endocrine physiology: an approach toward self-directed learning and the development of soft skills in medical students. *AdvPhysiol Educ.* 2013;37(4):356-60. doi: 10.1152/advan.00076.2012.
11. Jamkar A, Yemul V, Singh G. Integrated teaching programme with student-centred case-based learning. *Med Educ.* 2006;40(5):466-7. doi: 10.1111/j.1365-2929.2006.02438.x.
12. Dickinson BL, Lackey W, Sheakley M, Miller L, Jevett S, Shattuck B. Involving a real patient in the design and implementation of case-based learning to engage learners. *AdvPhysiol Educ.* 2018;42(1):118-22. doi: 10.1152/advan.00174.2017.
13. Dupuis RE, Persky AM. Use of case-based learning in a clinical pharmacokinetics course. *Am J Pharm Educ.* 2008;72(2):29. doi: 10.5688/aj720229.
14. Jacob SA, Dhing OH, Malone D. Perceptions of Australian and Malaysian educators in an undergraduate pharmacy program on case-based learning. *Am J Pharm Educ.* 2019;83(3):6597. doi: 10.5688/ajpe6597.
15. Williams B. Case based learning--a review of the literature: is there scope for this educational paradigm in prehospital education? *Emerg Med J.* 2005;22(8):577-81. doi: 10.1136/emj.2004.022707.
16. Kulak V, Newton G. A guide to using case-based learning in biochemistry education. *BiochemMolBiol Educ.* 2014;42(6):457-73. doi: 10.1002/bmb.20823.
17. Malau-Aduli BS, Lee AY, Cooling N, Catchpole M, Jose M, Turner R. Retention of knowledge and perceived relevance of basic sciences in an integrated case-based learning (CBL) curriculum. *BMC Med Educ.* 2013;13:139. doi: 10.1186/1472-6920-13-139.
18. Cliff WH, Wright AW. Directed case study method for teaching human anatomy and physiology. *Am J Physiol.* 1996;270(6 Pt 3):S19-28. doi: 10.1152/advances.1996.270.6.S19.
19. Fortun J, Morales AC, Tempest HG. Introduction and evaluation of case-based learning in the first foundational course of an undergraduate medical curriculum. *J Biol Educ.* 2017;51(3):295-304. doi: 10.1080/00219266.2016.1217909.
20. Yoo MS, Park HR. Effects of case-based learning on communication skills, problem-solving ability, and learning motivation in nursing students. *Nurs Health Sci.*

-
- 2015;17(2):166-72. doi: 10.1111/nhs.12151.
21. Tufts MA, Higgins-Opitz SB. What makes the learning of physiology in a PBL medical curriculum challenging? student perceptions. *AdvPhysiol Educ.* 2009;33(3):187-95. doi: 10.1152/advan.90214.2008.
 22. Shumway JM, Vargas ME, Heller LE. [Methods for teaching problem-solving in medical schools]. *Educ Med Salud.* 1984;18(1):46-61.
 23. Amaranathan A, Dharanipragada K, Lakshminarayanan S. Medical students' perception of the educational environment in a tertiary care teaching hospital in India. *Natl Med J India.* 2018;31(4):231-6. doi: 10.4103/0970-258x.258226.
 24. Dunham L, Dekhtyar M, Gruener G, CichoskiKelly E, Deitz J, Elliott D, et al. Medical student perceptions of the learning environment in medical school change as students transition to clinical training in undergraduate medical school. *Teach Learn Med.* 2017;29(4):383-91. doi: 10.1080/10401334.2017.1297712.
 25. Pai KM, Rao KR, Punja D, Kamath A. The effectiveness of self-directed learning (SDL) for teaching physiology to first-year medical students. *Australas Med J.* 2014;7(11):448-53. doi: 10.4066/amj.2014.2211.
 26. Artino AR Jr, La Rochelle JS, Dezee KJ, Gehlbach H. Developing questionnaires for educational research: AMEE Guide No. 87. *Med Teach.* 2014;36(6):463-74. doi: 10.3109/0142159x.2014.889814.
 27. Schifferdecker KE, Reed VA. Using mixed methods research in medical education: basic guidelines for researchers. *Med Educ.* 2009;43(7):637-44. doi: 10.1111/j.1365-2923.2009.03386.x.