Pharmacology Teaching Methods and Affective Factors in Their Success in Educating Undergraduate Medical Students: A Scoping Review

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Abstract

Background: Pharmacology is one of the crucial subjects of medical courses because drugs are the basis of disease treatment. A basic drug description is needed to optimize benefits and reduce side effects. Therefore, proper education for medical students is necessary.

Objectives: This scoping review aims to investigate the methods, ideas, and recommendations for educating undergraduate medical students in pharmacology.

Methods: To achieve the purpose of the study, related studies in English and Persian were reviewed within 2010 to 2022. A comprehensive systematic literature search was carried out in PubMed, Web of Science, SCOPUS, Google Scholar, and ProQuest databases to conduct this review. Two independent reviewers evaluated the retrieved publications and extracted the data using the Joanna Briggs Institute's standardized tools. Primary study findings were read and reread to identify teaching methods used in the studies for undergraduate medical students. The extracted findings were categorized based on their similarity.

Results: A total of 56 studies were included in this scoping review. More than 70% of articles have been performed in India **.** The results were presented according to the teaching methods used in educating: team-based learning, computer-assisted learning, the autobiography of medicines, role-play, integrated education, case-based learning, problem-based learning, student-led objective tutorials, e-learning module, museum, pre-lecture, concept mapping, crossword puzzles, game, flipped classroom, and mixed methods.

Conclusion: This review provided a new vision about the methods of pharmacology education that have been used worldwide. The information obtained can be used to revise traditional teaching methods of pharmacology in medical schools.

Keywords: Pharmacology, Teaching Methods, Medical Students

Background

The field of pharmacology is considered a separate pre-clinical field in the standard curriculum of medical sciences. In most cases, it is offered together with other pre-clinical lessons (e.g., anatomy, physiology, and biochemistry). The scientific basis for the rational and safe prescription of drugs is discussed in pharmacology; therefore, incorrect and insufficient training and a lack of skill in prescribing and providing advice on how to use medicines correctly can threaten the health of patients or lead to death. Due to the importance of this field, pharmacology should be considered a required course in medicine, nursing, pharmacy, dentistry, and many other medical curricula (1).

Traditional pharmacology education is lecture-based and deals with learning factual knowledge about drugs, which causes students not to be adequately trained in therapeutic applications. In this type of education, professors are the main body of education teaching abstract knowledge to students, which reduces their ability to practice and solve problems. In addition, decreasing the power of active learning and independent thinking is another disadvantage of traditional education (2). To revise the educational goals and align with the

required competencies, a curriculum should be developed as necessary in education.

Based on the importance of pharmacology education, the analysis of teaching and evaluation methods should be prioritized, and modifying these methods based on students' feedback can be effective (3). Active learning is one of the most influential and essential parts of education that enables students to use the acquired knowledge by involving them in the learning process. Lack of active learning can neglect learned knowledge, and using this information without understanding it makes future discussion difficult Students usually recognize pharmacology as one of the most tedious and time-consuming courses. However, active learning increases motivation, promotes critical thinking, and improves students' performance compared to individuals exposed to traditional and common education fields (4).

Nowadays, the use of new teaching techniques is considered a necessity due to the increase in the number of drugs and the acquisition of more and more accurate information about the mechanisms of drug action, especially at the intracellular and genomic levels (generally, pharmacological characteristics), require revisions in traditional teaching methods. The development of society and the progression of the standard of living mean that conventional medical services do not respond to the needs of patients, and individuals demand higher standards of health services, which themselves require initiative in education (5). Therefore, the challenge of effective pharmacology education has attracted much attention, and its goal is to empower students to make rational treatment decisions in clinical scenarios.

Considering that teaching the essential and elusive topics of pharmacology effectively is necessary, it was decided to examine pharmacology education methods for medical students systematically.

Objectives

This scoping review aimed to detect the most promising educational methods in pharmacology and identify their weaknesses and strengths. By using the results of this review, it will be possible to identify the most effective and applicable teaching method and improve the quality of the learning process.

Methods

In this scoping review, following the Joanna Briggs Institute (JBI) instruction (6), the methods of pharmacology education for undergraduate medical students and the factors affecting the success of their usage in educating medical students were reviewed and categorized.

Research Questions

1. What study designs have been done in teaching pharmacology to undergraduate medical students?
2. What are the main concepts of teaching pharmacology to undergraduate medical students?
3. What methodology has been mainly used in related studies?
4. Which country accounts for the largest share of studies?
5. Which of the methods of pharmacology education are more prominent worldwide?
6. Since what year has the role of using new methodologies in education become more eminent?
7. How do various educational methods contribute to the success and effectiveness of teaching pharmacology to undergraduate medical students?

Inclusion Criteria

To screen the various studies obtained from the search phase, we set specific criteria to select the ones related to the research topic and to exclude the studies that did not include the specified conditions. The inclusion criteria were as follows:

Participants (population): The studies included undergraduate medical students.

Concept (intervention): Studies included one of the methods of teaching pharmacology.

Context: All medical schools in the world.

Outcome: Students' final grade, satisfaction with the teaching method, and student participation rate.

Type of studies: Original quantitative studies with different study designs and qualitative studies with different methodologies were included. Studies that were not written in English or Persian, published as an abstract only, and listed in databases other than those mentioned were excluded.

Search Strategy

This scoping review searched both published and unpublished (gray literature) studies. An initial search was conducted on MEDLINE and CINAHL databases to develop a search strategy. The main keywords for search, based on the research question, were pharmacology, teaching, teaching methods, medical students, educational methods, and training. Search strategies are attached in Appendix 1.

This review was limited to studies published in English and Persian. Only publications published after 2010 were included to evaluate the latest teaching methods. The following databases were searched in this

review: PubMed, SCOPUS, Web of Science, Cochrane, and ProQuest. The Google Scholar database was also searched for Persian studies.

Papers published in 2021 and 2022 in medical education journals, such as Medical Education, BMC Medical Education, Academic Medicine, Teaching and Learning in Medicine, Clinical Teacher, and Medical Teacher, were searched manually. Websites of associations, including "The International Association for Medical Education (AMEE)", "ACGME (Accreditation Council for Graduate Medical Education)", "World Federation for Medical Education (WFME)" or "The Association for the Study of Medical Education (ASME)", were also searched. The articles' reference lists were also explored.

A comprehensive search was conducted in corresponding databases, such as ProQuest, GreyNet, and Google Scholar, to assess related gray literature. In case of any missing data or confusion, the authors of primary studies were reached. The references and citations of included studies were examined to prevent any missing articles. To complete the data and prevent any misunderstanding, further connection was made with the principal authors of related fields.

Study Selection

After searching each database, the items found were entered into EndNote x8 software (Clarivate Analytics, PA USA), and duplicate items were removed. Later, the relevant file regarding the articles' titles and abstracts was reviewed and screened separately by two independent reviewers. The full text of the studies which met the inclusion criteria were then screened. In the event of disagreement between the two reviewers, the relevant cases referred to a third reviewer.

Data Extraction

The data extracted from the full text of the articles were further reviewed and analyzed to provide collected data on research questions. The data were extracted from the full text of the articles by two independent reviewers using the specified checklist (Appendix 2). No errors were found in the extracted data, including information related to the citation, country, type of study, teaching method, number of participants in each training course, the role of professors, teaching skills, and resources.

Data Synthesis

After extracting all the papers' findings, they were grouped based on their concepts and similarities to develop categories. One of the reviewers extracted findings and developed categories, which other reviewers then checked for accuracy.

Results

Study Inclusion

Initial search results across all databases resulted in 1,286 articles. After removing duplicate items (n = 412) and screening the titles and abstracts, 479 articles remained. The full texts of these studies were investigated for further details. Another 423 articles were removed, and 56 articles were finally included in this review (Table 1). The results of the article selection are depicted in Figure 1.
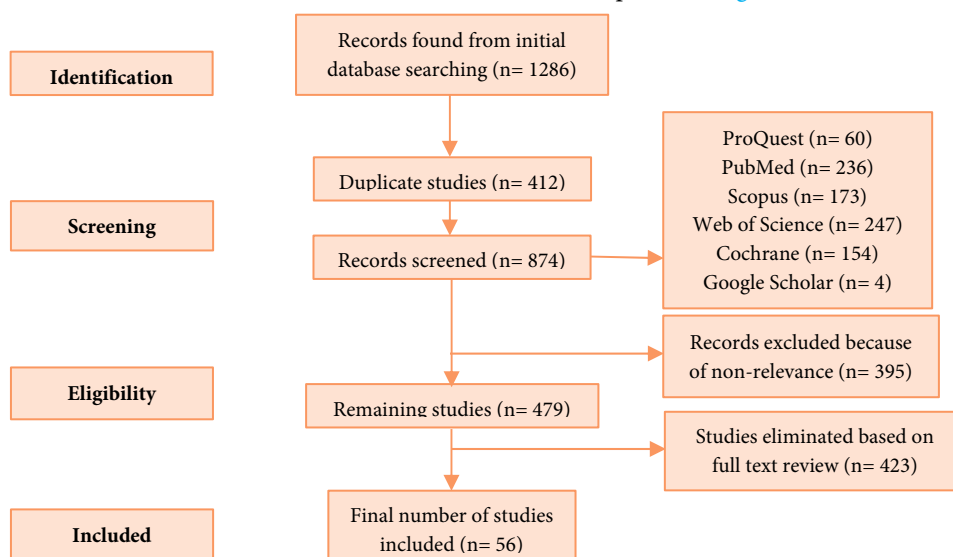

Figure 1. PRISMA study selection and inclusion process

Table1. Studies Included in the Scoping Review

No.	First Author	Year of Publication	Country	Study Design	Educational Context
1.	NK Zgheib (7)	2010	Lebanon	Case-based	Team-based learning
2.	ParamaSengupta (8)	2017	India	NM	Computer-assisted learning (CAL)
3.	Sunil Nettath (9)	2019	India	Quasi-experimental	
4.	R. Amirtha (10)	2017	India	NM	
5.	Anuradha Joshi (11)	2015	India	NM	Autobiography of medicines
6.	BhargavPurohit (12)	2020	India	NM	
7.	Supriyo Choudhury (13)	2015	India	Cross-sectional	Role-play
8.	S.H. Lavanya (14)	2016	India	Questionnaire-based	
9.	S. Daniel Gotardelo (15)	2014	Brazil	Questionnaire-based	
10.	Preeti P Yadav (16)	2016	India	NM	Integrated teaching module
11.	Shahram Ejtemaei (17)	2011	Iran	NM	
12.	Gurleen Kaur (18)	2020	India	NM	Case-based learning
13.	Ameya A. Hasamnis (19)	2019	Malaysia	NM	
14.	Kanchan Gupta (20)	2014	India	NM	
15.	UK Chiranjeevi (21)	2022	India	Questionnaire-based	
16.	Sandhya K. Kamat (22)	2012	India	NM	
17.	Amit Kumar (23)	2016	India	NM	
18.	Sachidananda Adiga (24)	2010	India	NM	Problem-based learning (PBL)
19.	KD Karpa (25)	2013	USA	NM	
20.	Parama Sengupta (26)	2021	India	Quasi-experimental	
21.	Anupama Sukhlecha (27)	2016	India	Prospective	Student-led objective tutorials (SLOTs)
22.	Kriti Arora (28)	2016	India	NM	
23.	MNS Adiga (29)	2020	India	NM	
24.	P. B. Patel (30)	2018	India	Prospective, single-group, pre-post intervention	E-learning models (ELMs)
25.	Raakhi K Tripathi (31)	2017	India	Prospective, single-group	
26.	Nitin Gaikwad (32)	2013	India	Quasi-experimental	
27.	Urwashi I. Parmar (33)	2018	India	Prospective interventional	Pharmacology museum
28.	Marya Ahsan (34)	2016	India	Randomized controlled trial	Pre-lecture assignment (PLA)
29.	Sarmila Nath (35)	2021	India	Cross-sectional interventional study	Concept mapping module
30.	Vimala Ananthy (36)	2021	India	Quasi-experimental	
31.	Nitin Gaikwad (37)	2012	India	Open-label, randomized, controlled, parallel-group intervention	Crossword puzzles
32.	FA dos Reis Lívero (38)	2020	Brazil	NM	Game-based learning (GBL)
33.	AM Gudadappanavar (39)	2021	India	NM	
34.	Anuradha Joshi (40)	2015	India	Randomized control	
35.	John Wilhelm (41)	2021	USA	NM	
36.	Sarah A. Aynsley (42)	2018	United Kingdom	NM	
37.	H Jaiprakash (43)	2022	Malaysia	NM	Flipped classroom
38.	Sushil Sharma (44)	2017	India	Interventional study	Scenarios approach
39.	Margaret Shanthi FX (45)	2016	India	Crossover, Randomized	Tutorial/Self-study
40.	Jennelle Richardson (46)	2021	USA	NM	Over recorded lectures
41.	IPK Demak (47)	2021	Indonesia	Quasi-experimental	Peer tutoring methods
42.	Helen Qin (48)	2022	Australia	NM	Peer teaching initiative
43.	Dinesh K Badyal (49)	2018	India	Mixed method	Immediate feedback
44.	Amy C. Halliday (50)	2010	United Kingdom	NM	Primary research resources
45.	Dinesh K. Badyal (56)	2010	India	NM	Mix method
46.	Raakhi K. Tripathi (57)	2015	India	NM	
47.	R Ramachandrudu (58)	2016	India	NM	
48.	Vikas Seth (59)	2010	India	NM	
49.	HS Amane (60)	2013	India	NM	

50	Preethi J Shenoy (61)	2021	India	NM	
51..	Rajesh Kumar (62)	2021	India	Questionnaire-based	
52.	Patil Banderao (63)	2018	India	Cross-sectional	
53.	Parimala K (64)	2013	India	Questionnaire-based	Mix method
54.	Vasudha Devi (65)	2016	India	Review	
55.	Rashmi Raghava Rao (66)	2020	India	Cross-sectional	
56.	Uma A. Bhosale (3)	2013	India	Cross-sectional	

NM, not mentioned

While screening articles, the reviewers did not identify any scoping review articles assessing pharmacology teaching methods and their features.

Review Findings

The studies differed in the type of training method, the number of participants, and the outcome measures. All participants were undergraduate medical students, and the length of the educational intervention was different. A summary of the included studies based on indicators, such as first author, study design, and number of participants, is shown in Table 1. Most of the studies (43 studies) were from India. The remaining 13 studies were conducted in the USA (3), United Kingdom (2), Brazil (2), Lebanon (1), Malaysia (2), Iran (1), Indonesia (1), and Australia (1). From 2015 onwards, studies show an increasing tendency.

The results are reported based on different teaching methods used in educating undergraduate medical students (Figure 2).

Team-Based Learning: Team-based learning (TBL) is an innovative teaching approach that enhances active learning, with studies indicating improved student performance. Zgheib et al. (7) described TBL in three phases. Phase 1 involves PowerPoint lectures introducing educational materials and explaining the TBL method. In phase 2, students individually answer "true/false" and "multiple-choice" questions, and in phase 3, they form groups for collaborative question-solving and class discussions. Positive student feedback and improved test results were observed, compared to traditional courses.

Computer-Assisted Learning: Computer-assisted learning (CAL) is a method used in medical education. It can replace traditional lectures and complement conventional teaching methods. Sengupta et al.(8) used "EP Dog version 1.1.0" and Nettath et al. (9) and Amirtha et al. (10) used "Ex-Pharm T 1.0 Software", for teaching to evaluate the change in knowledge gained by students compared to conventional lecture-based methods. Multiple-choice questions analyzed students' knowledge. Studies have shown that integrating CAL with previous teaching methods can improve students' performance and increase their scores.

Autobiography of Medicines: Medicine autobiography is an educational method where medications provide information about their characteristics, pharmacokinetics, pharmacodynamics, dosage, pharmaceutical form, uses, mechanisms, and side effects. Joshi et al. (11) and Purohit et al. (12) used this method, which shows that combining this method with traditional education has many advantages. Still, it cannot replace the lecture-based method. The biography can be used at the end of classes to review the materials taught, which will increase the enthusiasm and curiosity of the students.

Role-Play: Role-playing effectively facilitates active learning, enhancing students' communication skills in pharmacology education. Choudhury et al. (13) demonstrated its application in teaching the mechanism of antimicrobial drugs inhibiting bacterial protein synthesis. Students assumed roles, such as the peptidyl site, host site, t-RNA, and tetracycline, guided by the teacher. Lavanya et al.(14) limited role-playing to three students per session, playing doctor, patient, and observer after a lecture. A post-session Likert scale assessment indicated positive effects on learning and communication skills. In another study, Gotardelo et al. (15) explored role-playing's impact on medicine-related information implementation through a show format, revealing dynamism, efficiency, and creativity in education according to Likert scale and DREEM results.

Integrated Education: Integration is an effective teaching method in medical education. The lack of integrity in conventional teaching methods has caused students to have a poor understanding. Using an integrated method in education can improve students' performance. Yadav et al. (16) and Ejtemaei-Mehr et al. (17) designed and implemented integrated training in the following topics: "basal ganglia,""epilepsy, and tuberculosis and their treatment management." In integrated education, topics related to anatomy, physiology, pharmacology, neurology, microbiology, and pathology were formed. The students noticed and welcomed these sessions and improved their reasoning and self-directed learning.
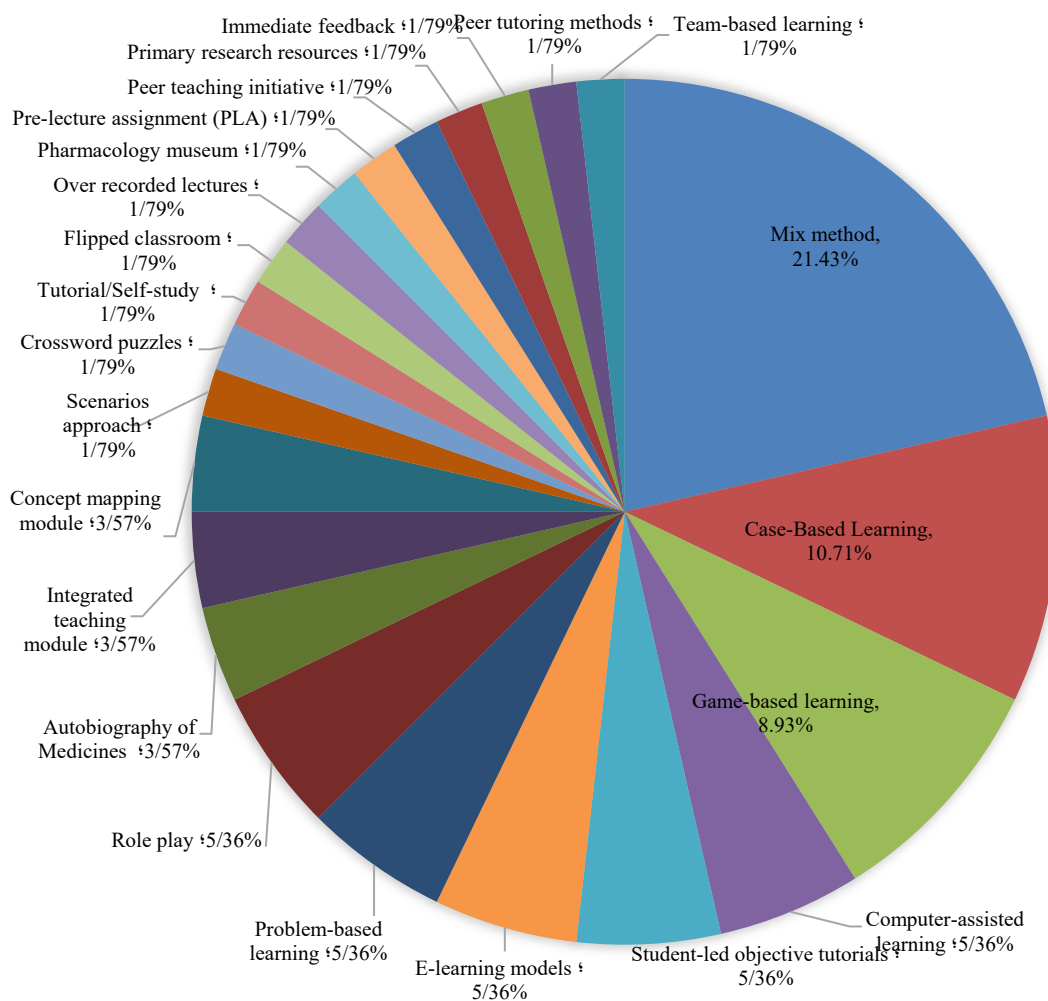
Figure 2. Teaching methods in included studies based on frequency percentage

Case-Based Learning: Case-based learning (CBL) is a globally applied, creative teaching method utilizing clinical cases as training stimuli. This approach enhances students' understanding of real-world situations, facilitating better retention of educational material. Numerous studies comparing lecture-based and CBL methods consistently demonstrate the latter's effectiveness. Pre- and post-tests consistently indicate improved performance and increased scores among students taught using CBL, compared to traditional methods (18-23).

Problem-Based Learning: Problem-based learning (PBL) is a student-centered approach where students collaborate to solve real-world problems. Studies by Adiga et al. (24) and Karpa et al. (25) emphasize PBL's integral role in education. The method involves group discussions to address unfamiliar issues, fostering interactive learning. Sengupta et al. (26) compared PBL in the classroom and on WhatsApp. In both settings,

students respond to problems, with WhatsApp offering a hybrid approach. Although not a classroom replacement, WhatsApp's use aligns with the global rise in social media usage, providing an additional avenue for PBL implementation.

Student-Led Objective Tutorials: Student-led objective tutorials (SLOTs) are one of the methods to increase students' motivation and strengthen active learning through group work. Sukhlecha et al. (27), Aroraet al. (28), and Adiga et al. (29) investigated the effectiveness of using SLOTs compared to using conventional methods (CT). The students were divided into two groups: the first group received traditional training, and the second group used the SLOT method. Both groups initially received traditional lectures. In SLOTs, subgroups created and presented multiple-choice questions, fostering active engagement. The results indicated that SLOTs improved learning, increased interest, and strengthened active learning,

compared to CT. Student-led objective tutorials can be integrated into curricula alongside traditional methods.

Electronic Learning Module: Electronic learning (E-learning) is one method that strengthens self-directed learning and provides easy access to educational content. This method can be used to complete lecture classes. Patel et al. (30) used the Microsoft 2007 and iSpring Suite (8.3) for this task. The perception of students and professors was collected using the Survey Monkey tool. Tripathi et al. (31) and Gaikwad et al. (32)also investigated the effectiveness of this method through a pre-and post-test. The results show that this method can be combined with the traditional method and is simple and affordable.

Pharmacology Museum: Parmar et al. (33) used the pharmacology museum as a teaching and learning method. The museum includes medicinal samples in different medicinal forms. The teaching-learning method (TL) consists of 2 phases. In step 1, students are instructed to visit the museum and observe various forms of medicine. A pre-and post-test was taken for evaluation. In step 2, the students will be allowed to volunteer at the museum and solve their problems with pharmaceutical forms. The results showed that the museum could strengthen students' knowledge about medicinal forms; however, making the environment attractive for students can be challenging.

Pre-lecture Assignment: Ahsan et al. (34) used pre-lecture assignment (PLA) as a teaching technique. In this method, students were randomly divided into two groups. For the first group, before the lecture session, a clinical case of peptic ulcer was explained in detail, and they were asked to give an assignment about the treatment approach of the case. Pre-lecture assignment was done 5 days before the presentation of the speech. The first group only participated in the lecture session. The results showed that this method can make learning more active and reduce teacher-centeredness in education.

Concept Mapping: A concept map is a graphic, educational method in which concepts and the relationship between them are displayed in a visual form. Understanding the whole concept using a single figure makes this method more effective for medical students. Nath et al. (35) and Ananthy et al. (36) showed that this technique can complement the educational program.

Crossword Puzzle: Crossword puzzles are an attractive way to review and identify keywords and critical information. It can be used as a self-testing tool. Gaikwad et al. (37) used a crossword puzzle on the topics of antihypertensive and antiepileptic drugs. Pre- and post-tests were taken from the students. The results showed that this method can be used as a self-education tool to improve students' knowledge.

Game-Based Learning: Game-based learning (GBL) is increasingly employed in education for its ability to enhance motivation and engagement. In pharmacology education, various games have been explored. Lívero et al. (38) examined 11 games (Appendix 3); however, Gudadappanavar et al. (39) implemented the "hot seat race" method, demonstrating its effectiveness through pre-test and post-test results. Joshi et al. (40) used cricket as an innovative teaching tool, finding no significant test score difference but increased student engagement. Wilhelm et al. (41) investigated virtual games during the coronavirus disease 2019 (COVID-19) pandemic, with Trivia being preferred and positively impacting pharmacology learning. Aynsley et al. (42) utilized the "Braincept" card-based game, noting improved self-confidence and practical pharmacological knowledge in students after gameplay. The aforementioned findings collectively emphasize the potential of GBL in diverse educational contexts.

Flipped Classroom: The use of this method became common during COVID-19. Heethal Jaiprakash (43) used this method to measure the knowledge of students trained using online tools. Before the training session, materials for reading, including PowerPoint and AMBOSS links, were sent to the students. The students were taken pre-and post-tests during the session, and their feedback was evaluated using a 4-point Likert scale. The results showed that the students better understood the subject, which improved their knowledge.

Other Methods: In addition to the methods mentioned earlier, noteworthy approaches deserve attention. Sharma et al. (44) explored the use of end-of-lecture scenarios, enhancing students' application of medicinal knowledge. The results indicated increased student engagement and improved grades. Shanthi FX et al. (45) compared traditional education to self-study, emphasizing the necessity of instructor-led education for better comprehension. Richardson (46) employed pre-class recorded lectures to provide students with prior knowledge, fostering increased interaction during class.

Demaket al. (47) investigated peer tutoring, noting increased motivation but no significant improvement in

scores, highlighting the importance of selecting committed peer tutors. Qin et al. (48) implemented peer-led training using Pecha Kucha principles, yielding positive results for review sessions. Badyal et al. (49) introduced immediate feedback in training, demonstrating deeper student understanding and improved grades. Halliday et al. (50) utilized primary research sources for student-led seminar sessions, leading to enhanced learning and competition for utilizing research articles in education.

Mixed Methods: In addition to the studies that have been reviewed, a series of studies also investigated two or more methods side by side and identified the most appropriate and effective method, which are summarized in Appendix 4.

Discussion

This scoping review was conducted to assess teaching methods of pharmacology for undergraduate medical students. Synthesizing the obtained results indicated that the main teaching methods used in the included studies were TBL, CAL, autobiography of drugs, role-play, integrated education, CBL, PBL, SLOTs, e-learning module, museum, pre-lecture, concept mapping, crossword puzzles, game, flipped classroom, and mixed methods.

The traditional curriculum follows the lecture-test method and is teacher-centered, which today has lost its place as a valuable and targeted educational method and has been replaced by new learning and teaching strategies. Learner-centered education causes lifelong learning with greater understanding, improves critical thinking, and allows students to manage the acquired knowledge in different situations and clinical scenarios. The teacher's presence is still necessary in all the methods reviewed in this paper. New approaches do not eliminate the teacher, although the teacher's role and task might differ. As an educational facilitator, the teacher is next to the students and helps them, who need appropriate expertise and knowledge. The need for innovation in training methods is the use of specialized personnel; therefore, in addition to changes in training methods, training of specialized and literate personnel should also be performed(51).

In most cases, the presentation of pharmacology courses is limited to lecture classes; however, it is worth mentioning that lecture classes can also be helpful if the principles of the lecture method are followed. There are many tricks to increase interaction and attention that

should be taught to teachers, which are often neglected and again remind us of the training of experts.

The number of publications related to pharmacology teaching methods has increased significantly in recent years, showing professors' growing interest in alternative teaching methods. In a review by Gill et al. in 2019 (52), several educational strategies used to teach pharmacology to undergraduate baccalaureate nursing students were summarized and compared based on their impact on maintaining pharmacology information, practical pharmacology, and student satisfaction. In this study, online, simulation, and integrated teaching methods were considered more effective and practical, resulting in student satisfaction. However, in contrast to traditional lectures, PBL and flipped classrooms were identified as the least effective methods for education.

Considering the increasing progress of technology and easier access to technology tools, it seems that online learning methods can be effective and in line with the world's needs, which is confirmed by the study of Gill et al. Pharmacology, as a primary subject of medical courses, can be challenging both for teaching and studying. Therefore, newly investigated online methods can be helpful for students and professors. As demonstrated in the included studies, these methods might need further authorization to fit into the education system.

Trullàs et al. (53) in 2022 conducted a scoping review on the effectiveness and efficiency of the problem-based teaching method. According to this study, the PBL method has achieved high student satisfaction because it increases students' communication, social skills, and problem-solving abilities. However, this method is still not recognized globally and is not implemented because it requires human resources and proper and continuous training, which can become a limiting factor for the correct and appropriate implementation. As mentioned in the study of Gill et al., PBL was not the priority of students' choice for education. In this regard, another study was conducted in Iran in 2022 by Sayyah et al. (54), which systematically investigated the use of PBL for the education of medical and nursing students. The results showed that using this method brings better results than traditional education; nevertheless, professors still require more attention for the correct and effective use of this method for teaching. Based on previous results, a suitable platform for using these methods should be provided in medical science universities. Therefore, it is not only challenging to use a new teaching method but

also its accurate and correct implementation is a significant challenge that affects both students and professors and requires further investigation.

In another study by Chen-Lin Xiao (55), a network meta-analysis (NMA) was conducted to evaluate the use of 24 different strategies for pharmacology education. The scores of the theoretical and experimental tests and the students' satisfaction were examined. The results obtained showed that PBL and CBL increased students' grades. Additionally, using PBL, TBL, flipped classroom (FC), and CBL methods is an effective strategy for pharmacology education.

The results of this study indicated the necessity of using innovative methods and active learning in educational curricula. Maintaining the attractiveness of the classroom environment and motivating students requires a change in the usual and traditional methods, as in a study conducted in 2010 by Badyal et al. (56). Based on the feedback they got from the students in 2006, they used innovative education methods. A written questionnaire that included all the different aspects of teaching methods was used in 2007 to evaluate the effectiveness of these strategies.

The results again indicated that the students preferred new teaching methods to traditional teaching and lectures, and their acceptance rate also increased. It is also important to note that students had more demand for practical and clinical training, which indicates the increasing need for changes in lecture-based methods for training. Among the included studies, GBL, CBL, and the use of combined methods accounted for a larger volume of studies. This finding shows that further investigations should be carried out for other possible effective methods.

According to the result of this review, further investigation should be conducted to examine the probable teaching methods that can be suited to education systems. In addition, further studies can evaluate how these methods are entered into daily teaching processes in medical schools.

In general, the conducted studies show that improving the educational methods of pharmacology can ultimately improve healthcare, which has a significant value for society. However, further research is needed to use new and creative teaching methods to educate students.

Strengths and Limitations: This scoping review provides a thorough and detailed summary of teaching approaches in worldwide pharmacology. The review was completed painstakingly by searching different databases and using a research selection methodology that can be replicated, including independent reviewers. An impressive advantage of this study is its incorporation of a significant number of research papers (n = 56) from a wide range of nations, resulting in strong and comprehensive findings about different teaching methods on a worldwide level. One of the limitations of this study is the lack of critical appraisal of each article to extract the merits and drawbacks of suggested approaches, and it is suggested that future studies perform such an evaluation. At the time of this study, the ERIC database was also not available and, therefore, was not searched. It is suggested that the ERIC database should also be searched to update the results of this review according to accessibility.

Conclusion

This scoping review surveyed the existing literature on instructional approaches employed in pharmacology education for undergraduate medical students. The review emphasized a growing inclination toward integrating contemporary interactive methods that enhance students' readiness for clinical practice by promoting deeper interactivity, self-directed learning, and problem-solving. However, traditional lectures continue to be widely used. Although no single approach has been definitively proven to be superior, certain strategies, such as collaborative learning, CBL, computer-assisted modules, role-plays, and games, have shown the potential to improve motivation, knowledge retention, and skill development. Integrated teaching and multi-modal approaches have also been found to optimize outcomes. However, the selection of methods should be customized to educational priorities and context. Further rigorous comparison studies are required to enhance the evidence on optimal practices since the field is always evolving in response to changing demands. Ongoing research is crucial to optimize the training of future medical professionals.

Conflict of interest: There is no conflict of interest.

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Appendix 1. Search strategies

Search number	Query	Sort By	Filters
4	(((("Pharmacology"[Mesh]) OR (Pharmacology [Title/Abstract])) OR (Pharmacologist [Title/Abstract])) AND ((((((("Teaching"[Mesh]) OR ("Education"[Mesh])) OR (Teaching [Title/Abstract])) OR (Training [Title/Abstract])) OR (Education [Title/Abstract])) OR (Educational [Title/Abstract]))) AND (("Students, Medical"[Mesh]) OR (Medical Student*[Title/Abstract]))		
3	("Students, Medical"[Mesh]) OR (Medical Student*[Title/Abstract])		
2	((((("Teaching"[Mesh]) OR ("Education"[Mesh])) OR (Teaching [Title/Abstract])) OR (Training [Title/Abstract])) OR (Education [Title/Abstract])) OR (Educational [Title/Abstract])		
1	(("Pharmacology"[Mesh]) OR (Pharmacology [Title/Abstract])) OR (Pharmacologist [Title/Abstract])		

Appendix 2. Data extraction table

Data extraction table								
ID								
Title								
1st Author								
Year of publication								
Journal name								
Country								
Objective of the paper								
Type of study								
Setting								
Method of teaching								
The number of participants per session								
The role of teacher								
Skills necessary for teaching								
Resources necessary for teaching								
Conclusion								
Recommendation								

Appendix 3. Eleven Types of Games in Francislaine Aparecida dos Reis Lívero's Study

No.	Type of game	Procedure	Helper sites	Advantages	Disadvantages
1.	Gameof words	The teacher writes two lesson-related sentences in large font, cuts each word, and shuffles them. Students receive these jumbled word papers in envelopes and reconstruct the sentences.	-	1. Increasing student participation 2. Low cost 3. Easy activity	-
2.	Hunting words	The teacher chooses the keywords. It is used at the beginning or end of the session.	Educolorir.com	1. Increase students' attention 2. Remembering keywords 3.Low cost 4. Easy activity	1. Individual activity 2. Lack of interaction between students 3. Lack of critical thinking
3.	Puzzle	The teacher creates four puzzles in different subjects using PowerPoint. After printing and laminating, the 16 pieces are mixed and distributed to groups for arrangement.	-	1. Increasing student participation 2. Increasing discourse among peers 3. Low cost 4. Easy activity	-

4.	Crossword	The teacher selects keywords and essential content and turns them into a crossword puzzle.	Educolorir.com	1. High variety in producing crosswords with the same concept 2. Low cost 3. Easy activity	1. Individual activity 2. Lack of interaction between students 3. Lack of critical thinking
5.	Tic-tac-toe	In this game, students are divided into two groups and assigned colors. They answer questions to change the color of a square on a board. Correct answers allow them to alter a square to their group's color, while incorrect answers pass the opportunity to the opposing group. The winning group forms a row, column, or diagonal line in their color.	-	1. Increasing interaction and participation of students 2. Using emotional intelligence 3. Low cost 4. Easy activity	1. The possibility of time-consuming construction of boards and facilities
6.	Target shooting	The teacher assigns difficulty scores (1 to 10) to questions and places them in balloons. Groups take turns throwing darts at balloons on the board and answering questions inside. Unanswered questions result in points for the opposing group. The group with the highest points wins. Empty or bonus point balloons add excitement to the game.	-	1. Increasing interaction and participation of students 2. Using emotional intelligence 3. Low cost 4. Easy activity	-
7.	Bingo	The teacher creates a game with 24 questions and answers using Bingobaker.com. Students in groups of 4 or 6 play by listening to questions called out when a bingo ball is spun. Each group marks their cards with the correct answers. The first group to fill a row or column shouts "Bingo" and can win if their answers are correct.	-	1. Increasing interaction and participation of students 2. Using emotional intelligence 3. Group work practice	-
8.	Racetrack	In PowerPoint, the teacher arranges a table with 12 columns for the race route, including start and end points and race rounds. The number of rows corresponds to the number of groups associated with a different machine. In each competition round, the teacher presents two factual/false statements, and groups move forward one step for each correct answer, aiming to reach the path's end.	-	1. Increasing interaction and participation of students 2. Using emotional intelligence 3. Group work practice	1. It takes time to move the cars of each group
9.	Trail	The teacher sets up a course with empty, question, and challenging houses for a dice-based activity. Students split into two groups, taking turns rolling the dice. Correct answers let them stay, while incorrect ones send them back. The first team to finish the course wins.	-	1. Increasing interaction and participation of students 2. Using emotional intelligence 3. Group work practice	1. Large physical space 2. Construction cost
10.	Memorang	Memorang is an educational game designed for content memorization. Teachers create a link to input subject-related cards, and the program generates intelligence games and multiple-choice questions. Students can choose their activities, allowing them to work at advanced levels based on performance. The software enables teacher supervision of each student's progress.	Memorangapp.com	1. Memorizing keywords 2. Easy access to course content throughout the course 3. Creating interest and participation	1. Lack of critical reasoning 2. The English language of the program

| 11. | Rally | The teacher creates a 100-question sample test based on recent topics. The class is split into two groups, each further divided into test and support teams. Test teams answer questions independently, while support teams can use all resources to review. They are situated in separate rooms. Team members can switch roles within an hour, and the team with the most correct answers wins. | - | 1. Increasing interaction and participation of students
2. Using emotional intelligence
3. Low cost
4. Easy activity
5. teamwork | - |

Appendix 4. Studies Included Mixed Methods

First Author	Methods	Procedure	Results
Tripathi et al. (57)	Problems about case scenarios, critical appraisal of prescriptions, and drug identification vs. traditional teaching	1) In the case scenario, the group analyzes a case for drug therapy determination. 2) In prescription evaluation, students correct errors in a prescription related to a specific disease. 3) In drug identification, students present a drug's characteristics through a drug autobiography covering pharmacodynamics and pharmacokinetics.	Improving students' grades according to pre-and post-test results, and students prefer active teaching methods.
Ramachandrudu (58)	Chalk talk teaching vs. PowerPoint teaching	Students were split into two groups, one exposed to a chalkboard lesson and the other to a PowerPoint presentation. Subsequently, a questionnaire was administered for evaluation.	Students preferred using PowerPoint and showed better comprehension and retention.
Vikas Seth et al. (59), Amane (60)	The lectures using chalkboard, the lectures using PowerPoint presentations, and the lectures utilizing transparencies with an overhead projector	Students were divided into three groups, each receiving the lecture differently. A test was conducted to evaluate the students' performance and check the effectiveness of the implemented methods.	Students preferred presenting lectures with PowerPoint and considered using this method to be more effective.
Badyal (56)	Lectures, tutorials, seminars, demonstrations, experimental pharmacology, revision class, clinical pharmacology	A written questionnaire evaluated the different methods implemented and examined various aspects of the teaching method.	The students evaluated the use of revision classes as the best method, which is held at the end of the class, and then practical demonstrations were identified as an effective method. The lectures were evaluated as average or ineffective.
Shenoyet al. (61)	Crossword puzzles vs. student-led objective tutorials (SLOT)	Two groups of students were formed: one employed the crossword method, and the other used the SLOT method, involving a contest with self-designed multiple-choice questions. Results were analyzed via an independent t-test using SPSS version 15.	SLOT improves students' grades more than crosswords because it improves critical thinking and teaches teamwork.Students mentioned crossword puzzles to memorize drug names, but it did not affect students' deep learning.
Kumar et al. (62)	Didactic lectures, PowerPoint presentations, case-based learning (CBL), group discussions	The mentioned methods were used during 18 months of student training, and the quality of each method was evaluated using a survey.	The result showed that CBL was recognized as the most effective method, and after that, group discussions and presentations using PowerPoint were accepted.

Banderao et al.(63)	Lectures, audio-visual, discussion of a subject in tutorial classes, interactive learning such as asking questions during pharmacology classes, discussion of graphs	Based on the survey, the teaching methods were investigated, and the perception and feedback of the students were evaluated.	The results show that using audio-visual facilities, for example, educational video clips, helps increase students' understanding. Participating in group discussions increases students' motivation and interest.
Parimala K et al. (64)	Theory lectures, tutorials, student seminars, group discussions, quiz programs, clinical pharmacology sessions	A questionnaire with several options was designed to evaluate the teaching methods, and the results were analyzed.	Based on the results, students evaluated theoretical lectures and clinical pharmacy sessions as more beneficial than other methods. Secondly, group discussions were identified as one of the most effective methods.
Devi et al. (65)	Lecture classes, SDL sessions, problem-based learning (PBL), and case-based learning (CBL)	Methods were evaluated by a short essay and multiple true-false questions (MTF).	The results show an increase in the ability to think critically and problem-solve, the active participation of students, presentation skills, and an increase in information about drugs.
Bhosale et al. (3)	Audiovisual demonstrations, tutorials, student seminars, museum study,clinical (patient-related) pharmacology, integrated teaching, problem-based learning,microteaching	A 22-item questionnaire was designed to examine students' opinions about the quality of teaching methods.	The majority of students preferred clinical pharmacology. As the second priority, they found the use of audio-visual facilities functional. Microteaching and problem-based learning were also prioritized, and students expressed interest in these methods. Seminars and museum studies were also considered educational aids.
Rao et al. (66)	Classroom lecture/ PowerPoint (PPT)/ blackboard/audio video demonstrations/ task-based learning/problem-based learning/assessment for learning/student seminars/small group discussion/integrated teaching	A questionnaire was distributed among students, and their opinions about teaching methods were collected.	Among the mentioned methods, group discussions got the most points among other methods. Among integrated teaching and problem-based learning, students preferred integrated teaching, and lectures were less helpful.