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Effectiveness of case-based learning in medical and pharmacy education: A meta-analysis

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ABSTRACT

Case-based learning has drawn a lot of attention in medical education because it is a student-centered teaching model that exposes students to real-world situations that they must answer using their reasoning abilities and prior theoretical knowledge. The purpose of this meta-analysis is to see how successful case-based learning is in medical and pharmacy education. For that purpose, the PubMed and Medline databases were searched for related research through April 2023, and the qualifying papers were chosen using a thorough selection procedure based on PRISMA technique. 21 randomized controlled trials comparing case-based learning to other teaching methodologies used to educate medical and pharmacy students were found as a result of the current search. The highest percentage of selected studies has been conducted in USA (33%) followed by China (24%). The comprehensive analysis of each parameter from chosen studies revealed a high level of heterogeneity (I^2=93%, p<0.00001). Between case-based learning and traditional learning, random effects models revealed a significant difference in academic performance. Case-based learning, when compared to other techniques, can increase medical and pharmacy undergraduate students' academic performance as well as their capacity to analyze cases. It can be concluded that case-based learning is an active teaching method.

Keywords: undergraduate students, case-based learning, pharmacy education, medical education

INTRODUCTION

In health education, there is a global trend toward moving away from the old system and toward case-based and participatory/interactive teaching [1, 2]. During preclinical years, health care students have generally been exposed to non-case-based lectures. There are various problems and challenges in future medical education [3-6]. When students begin their clinical rotations, they will have more opportunities to interact in clinical settings [7]. Students must comprehend the value of preclinical learning in clinical practice, according to medical and pharmacy instructors all across the world. Case-based teaching/learning can help achieve this throughout the preclinical years [8]. Case-based learning is designed to prepare students for clinical practice by utilizing real-life clinical scenarios in a range of contexts. It employs inquiry-based learning methods to link theory to practice by applying knowledge to real-world scenarios. In [9, 10], it was observed that case-based learning has been shown to aid in the creation and implementation of significant curricular revisions by making it easier to identify and eliminate unnecessary lecture components. Case-based teaching can be delivered in a variety of ways. In teaching, cased-based learning is a revolutionary teaching style that combines regular lectures with modified problem-based learning [11-13]. Case-based learning is widely acknowledged as being beneficial in allowing undergraduate medical students to apply their knowledge to real-world clinical settings and hence build critical thinking abilities [14-16]. Case-based learning is more structured and led, with a more defined methodology and specified learning objectives [6, 15, 17, 18]. The majority of authors have discovered that case-based learning improves logical thinking and long-term memorization, both of which help students do better on tests [19-21]. Furthermore, case-based learning improves knowledge application, resulting in better health care professionals [9, 20, 22-24]. For undergraduate medical and pharmacy students, data on the effectiveness of case-based learning and student opinion on this teaching modality is scarce and equivocal [25, 26]. Therefore, current study has been designed to determine the effectiveness of case-based learning in medical and pharmacy education.

MATERIAL AND METHODS

In April 2023, we did a PubMed and Medline database search for this meta-analysis including most recent literature on randomized controlled trials (RCTs) for case-based learning in medical and pharmacy education. The terms case-based learning, case-based teaching medical education, pharmacy education, effectiveness, and RCTs were used in the search. During initial search, we also searched through the reference tracking of bibliographies and manual searches to see if there were any additional studies that were relevant. Titles and abstracts were separately reviewed for inclusion by authors.

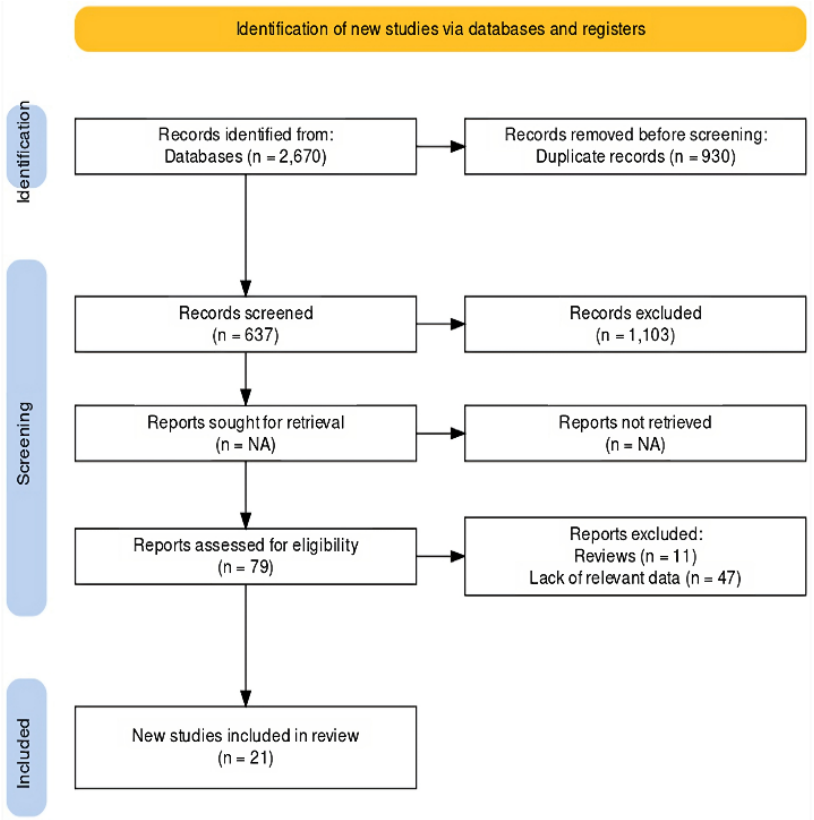


Figure 1. PRISMA flow chart to select papers for meta-analysis (Source: Author's own development)

Table 1. Inclusion/exclusion criteria for papers in analysis

Inclusion	Exclusion
Original article	Reviews
Randomized control trials	Meta-analysis
Case-control studies	Systemic reviews
Innervation measures	Books/documents
Undergraduate medical & pharmacy studies	Post-graduate medical & pharmacy studies

PRISMA approach was used to identify the studies, and the studies were only considered qualified if they met the inclusion criteria (**Figure 1**).

After discarding blatantly unrelated material, authors independently evaluated abstracts and full texts of research and then decided which papers to include on inclusion and exclusion criteria (**Table 1**). All authors addressed and resolved any problems or disagreements. Articles were also excluded for following reasons: inability to locate a complete article on the search engine, inability to locate an English language translation, article did not adequately describe case-based learning, article was not related to medicine or pharmacy, or article did not adequately describe human beings. Medical and pharmacy students were classified as undergraduates in studies included since they would need more training to be completely qualified to practice.

Data Analysis

The extracted data was analyzed using Review Manager 5.4 with 95% confidence interval. The random model was used to determine heterogeneity among studies. While forest plots were developed for determination of overall combined effects.

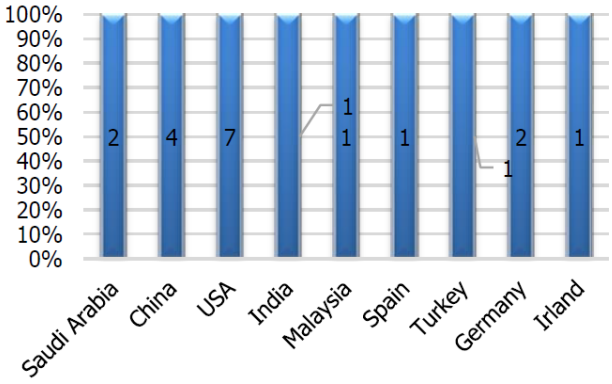


Figure 2. Country wise distribution of RCT studies in medical & pharmacy education (Source: Author's own development)

RESULTS

PRISMA flowchart presented in **Figure 1**, displays a schematic study selection process. The result of present search demonstrates 21 RCTs comparing case-based learning to other teaching approaches used to educate medical students were found. The highest percentage of selected studies has been conducted in USA (33%) followed by China (24%). While 9% of studies have been conducted in Saudi Arabia and Germany as presented in **Figure 2**.

The characteristics of 21 RCTs have been shown in **Table 2**, where only ten studies found eligible for inclusion in this meta-analysis to make forest plot. These studies included 3,318 students, with most studies demonstrating positive effect of case-based learning methods on students' performance compared to traditional learning methods.

Table 2. Characteristics of RCT studies for case-based learning in medical & pharmacy education

Article	Area of study	Participants	EG (n)	CG (n)	Findings
[27]	Nursing education	199 nursing students	PBL group (101)	Waitlist control group (98)	PBL & self-directed learning are critical abilities for advancement of nursing profession. It offers early evidence in favor of a structured problem-based learning intervention using an online strategy to enhance students' self-directed learning & problem-solving skills over both short & long terms. Organized principles for enhancing students' self-directed learning & problem-solving skills through individual & group learning style in interactive group work are thus promising.
[28]	Cardiovascular physiology	181 clinical pharmacy students	CBL (94)	Traditional learning (77)	Students loved CBL because it encouraged logical thinking & active engagement in class, which led to better exam results.
[29]	Orthodontic case diagnosis	95 dental undergraduates	CBL (47)	Traditional lecture-based learning (48)	CBL is an effective & acceptable teaching strategy for undergraduate dentistry students enrolled in an orthodontic diagnostic course when compared to standard lecture-based learning.
[30]	Thyroid disease	569 students	PBL & CBL group (276)	Traditional group (293)	PBL combined with case-based learning may be an effective strategy to improve performance & clinical abilities of medical students & residents.
[31]	Anatomy	313 undergraduate medical students	CBL	Small group discussions	Anatomy instruction can benefit from case-based learning activities.
[32]	Clinical cases	106 medical students	Clinical case discussions	Paper cases	For medical students, an outstanding & long-lasting clinical reasoning teaching resource is clinical case discussion technique. Subjective learning outcomes emphasize role of learner activity in acquisition of clinical reasoning abilities in setting of CBL.
[33]	Medical oncology	80 1st-year graduate students	CBL (40)	Traditional learning (40)	Case teaching technique is a more effective teaching strategy for boosting graduate students' abilities to address problems in medical oncology.
[34]	Disaster preparedness	60 nursing students	CBL (17); simulated teaching (16)	Simulated teaching (16); CBL (17)	CBL is used in short-term disaster preparation educational translation. Simulation exercises outperformed.
[35]	Physiology	64 medical & dental student volunteers	CBL (32)	PBL (32)	Case-based collaborative learning is a practical, engaging, & active form of learning. It may be especially beneficial to students who have struggled academically.
[36]	Oncology	74 2nd-year nursing students	CBL (26)	PBL (25); traditional learning (23)	PBL was determined to be the most effective learning approach, followed by case-based teaching and traditional methods.
[37]	Diabetic ketoacidosis & thyroid storm	174 pharmacy students	CBL (87); Simulated teaching (87)	Simulated teaching (87); CBL (87)	Human patient simulation outperformed CBL in teaching diabetic ketoacidosis and thyroid storm to final-year undergraduate pharmacy students.
[38]	Dentistry & endodontics	41 dental undergraduates	CBL (20)	Traditional learning (21)	Proper implementation of CBL in conservative dentistry & endodontics clinical internships helps students enhance clinical reasoning, synthetical analysis, & adaptation to various patients.
[39]	Pharmacotherapy skills	179 2nd-year MBBS students	CBL (96)	Traditional learning (83)	During tutorials, case-based teaching is more effective than traditional methods of instruction in that it facilitates the acquisition of rational medication.
[40]	Dental trauma	60 graduate dental interns	CBL (30)	Traditional learning (30)	CBL paradigm can help students improve not just their grades, but also their ability to self-study. In clinic, it can also cultivate pupils' positive thinking habits.
[41]	Cardiopulmonary resuscitation	90 university students	CBL (30)	Traditional learning (30); web-based instruction (30)	Students in conventional & case-based education groups fared better in cardiopulmonary resuscitation than students who learnt through video self-instruction in the web-based instruction group.
[42]	Resuscitation team leader	83 4th-year medical students	CBL (41)	Simulated teaching (42)	A single simulation-based training session dramatically improved student performance as a team leader.
[43]	Urinary tract disorders	110 3rd-year veterinary students	CBL & PBL (55)	Lecture-based learning (55)	There was no influence of teaching method on student performance in the second exam.
[44]	Cardiac problem	102 4th-year medical students	CBL (52)	Simulated teaching (50)	Human patient simulation training shows no benefit over CBL in terms of medical student performance on a chest pain objective structured clinical assessment.
[45]	Acute dyspnea management	38 internal medicine residents	Standard education & CBL (16)	Standard education (10)	Intervention & control groups showed no noticeable changes.
[46]	Medical	96 2nd-year medical students	CBL (32)	CD-ROM learning (32)	Addition of a 12-minute CD-ROM on subject to a small-group lecture appears to increase student knowledge of material being taught.
[47]	Surgical examination	614 medical students at university	Predetermined timetable, CBL & course book (136)	Traditional learning (478)	After engaging in a case-based teaming session, students' readiness for the surgical clinical examination course improved considerably.

Note. EG: Experimental group; CG: Control group; CBL: Case-based learning; & PBL: Problem-based learning

Table 3. Forest plot presenting overall effect of case-based learning on performance of medical & pharmacy students

Study/subgroup	Experimental group			Control group			Weight	Mean difference	Mean difference
	Mean	SD	Total	Mean	SD	Total		IV, random, 95%	IV, random, 95%
1.1.1 CBL vs. LBL or traditional learning									
[28]	81.24	4.81	94	79.00	3.90	77	13.0%	2.24 [0.93, 3.55]	
[29]	192.72	41.31	47	136.77	35.19	48	0.8%	55.95 [40.50, 71.40]	
[30]	70.51	14.56	276	71.97	9.09	293	11.4%	-1.46 [-3.47, 0.55]	
[31]	3.97	1.00	73	3.75	0.887	122	14.4%	0.22 [-0.06, 0.50]	
[38]	84.80	5.53	20	87.19	4.38	21	8.9%	-2.39 [-5.45, 0.67]	
[39]	32.69	6.75	82	30.07	6.82	61	10.8%	2.62 [0.37, 4.87]	
[46]	12.80	2.10	32	12.70	2.40	32	13.4%	0.10 [-1.00, 1.20]	
Subtotal (95% CI)			**624**			**654**	**72.8%**	**1.06 [-0.78, 2.90]**	
Heterogeneity: tau²=4.55; Chi²=68.78, df=6 (p<0.00001); I²=91%									
Test for overall effect: Z=1.13 (p=0.26)									
1.1.2 CBL vs. simulated teaching									
[34]	52.3	9.3	16	40.9	11.0	17	3.4%	11.40 [4.46, 18.34]	
[37]	93.5	6.9	87	92.3	7.2	87	11.2%	1.20 [-0.90, 3.30]	
[44]	31.4	4.1	52	31.2	3.6	50	12.6%	0.20 [-1.30, 1.70]	
Subtotal (95% CI)			**155**			**154**	**27.2%**	**2.36 [-0.98, 5.70]**	
Heterogeneity: tau²=6.03; Chi²=9.72, df=2 (p=0.008); I²=79%									
Test for overall effect: Z=1.38 (p=0.17)									
Total (95% CI)			**779**			**808**	**100%**	**1.26 [-0.20, 2.72]**	
Heterogeneity: tau²=3.84; Chi²=79.33, df=9 (p<0.00001); I²=89%									
Test for overall effect: Z=1.69 (p=0.09)									
Test for subgroup differences: Chi²=0.44, df=1 (p=0.51), I²=0%									

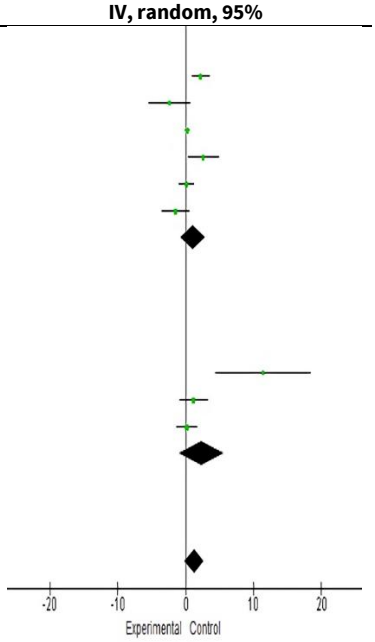
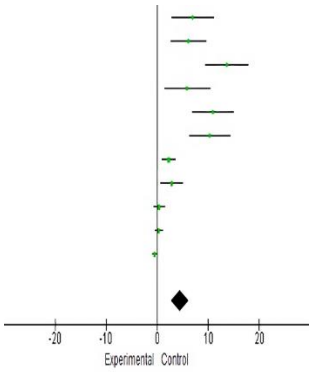


Table 4. Forest plot showing effect of case-based learning' individual parameters on performance of medical & pharmacy students

Study/subgroup	Experimental group			Control group			Weight	Mean difference	Mean difference
	Mean	SD	Total	Mean	SD	Total		IV, random, 95%	IV, random, 95%
[28]	34.69	9.19	47	27.77	10.98	48	7.2%	6.92 [2.85, 10.99]	
[29]	34.92	7.40	47	28.79	9.81	48	8.0%	6.13 [2.64, 9.62]	
[29]	33.13	10.19	47	19.50	10.69	48	7.0%	13.63 [9.43, 17.83]	
[29]	29.17	10.88	47	23.29	11.28	48	6.6%	5.88 [1.42, 10.34]	
[29]	32.81	10.30	47	21.83	9.83	48	7.2%	10.98 [6.93, 15.03]	
[29]	28.44	11.16	47	18.13	8.16	48	7.4%	10.31 [6.37, 14.25]	
[29]	81.24	4.81	94	79.00	3.90	77	11.3%	2.24 [0.93, 3.55]	
[38]	79.72	3.14	20	76.86	3.88	21	10.1%	2.86 [0.70, 5.02]	
[44]	15.90	2.80	52	15.50	2.80	50	11.5%	0.40 [-0.69, 1.49]	
[44]	9.00	1.90	52	8.70	1.90	50	11.8%	0.30 [-0.44, 1.04]	
[44]	6.50	1.30	52	7.00	1.20	50	11.9%	-0.50 [-0.99, -0.01]	
Total (95% CI)			**552**			**536**	**100%**	**4.45 [2.73, 6.16]**	
Heterogeneity: tau²=6.37; Chi²=140.34, df=10 (p<0.00001); I²=93%									
Test for overall effect: Z=5.08 (p<0.00001)									



From all-inclusive studies in meta-analysis, seven studies comprising case-based learning vs traditional learning while three studies comparing case-based learning with simulated teaching.

Studies investigated the impacts of case-based learning vs other approaches on student performance, as shown in **Table 3**. There was a lot of variation amongst the trials (I^2=87%, p<0.00001). Subgroup analysis was performed on the studies that were included. Seven of the studies compared case-based learning to traditional learning, and the studies were highly heterogeneous (I^2=91%, p<0.00001). Random effects models revealed no significant difference in academic performance between case-based and traditional learning (MD and 95% CI: 1.06 [-0.78, 2.90]). Three of the research looked at the differences between case-based learning and simulated training. The studies were very heterogeneous (I^2=79%, P=0.008), and random effects models revealed no significant differences in academic performance between case-based learning and simulated instruction (MD and 95% CI were 2.36 [-0.98, 5.70]). The comprehensive analysis of each parameter from chosen studies revealed a significant level of heterogeneity (I^2=93%, p<0.00001).

Random effects models revealed a substantial difference in academic performance between case-based learning and traditional learning (MD and 95% CI: 4.45 [2.73, 6.16]) (**Table 4**).

DISCUSSION

The classic combination of traditional lecturing with problem-based learning is case-based learning and teaching [9]. Although lectures are an excellent approach to convey information to a large group of students, they are sometimes dull and do not motivate students to interact, solve issues, or reason [48-51]. The conventional teacher-centered didactic lectures are giving way to student-centered active learning techniques, such flipped classrooms and case-based learning, which are becoming more and more common in medical school [52-54]. It was reported that virtual reality is a flexible technology that enables the development of extensive instructional resources [55]. It has, however, shown to be more

successful for other specialisations, such as the medical industry. Numerous studies have investigated the effectiveness of case-based learning to date, and nearly all of them came to the same conclusion: students valued the sessions and felt that they deepened their understanding [39, 56, 57]. With the help of the facilitator, introducing important case situations and triggering questions throughout the lecture encourages critical thinking and active conversation, transforming passive lectures into more participatory sessions, even in large groups [9, 58]. However, the consistency, coherence, and continuity of the preparation for the digital transformation are what ensure the efficacy of the development of the digitalization of education. Digital proficiency is also a requirement for the development of the teachers of the future [59]. It was reported that the ideal case for case-based education should be relevant, realistic, engaging, challenging, enlightening, enjoyable, and based on a real-world professional context [22]. Another crucial aspect in the efficacy of case-based teaching and learning was the participatory manner of delivery [19]. In terms of student satisfaction, the majority of research have discovered that students prefer case-based learning to traditional didactic lecturing [51, 60, 61].

Effectiveness of this teaching style can be demonstrated by comparing case-based learning with traditional learning exam results. Case-based learning has been demonstrated to encourage active participation, stimulate analytical and cognitive thinking, and help in idea understanding. Case-based teaching has been shown to boost long-term remembering, which improves exam performance [62-65].

In the current meta-analysis, 3,117 students from various fields of health care, including pharmacy and medicine, took part in RCTs to assess the efficiency of case-based learning. The highest percentage of selected studies has been conducted in USA (35%) followed by China (20%). While 10% of studies have been conducted in Saudi Arabia and Germany. The included study [28] demonstrated that students preferred case-based learning because it encouraged active participation and logical thinking in class, which resulted in better exam results. It was reported that case-based learning is highly acceptable and an effective teaching strategy for undergraduate dentistry students enrolled in an orthodontic diagnostic course when compared to standard lecture-based learning [29]. Similarly, the study [31] reported that case-based learning and e-Learning resource activities can help undergraduate medical students learn anatomy. In contrast, it was found that there was no discernible difference between lecture-based and case-based learning in terms of academic performance [43]. In [35, 45], it was found that the case-based learning group outperformed the control group academically, although the difference was not significant. The study [36] found that case-based learning was more effective at improving performance than traditional learning, but it was less effective than problem-based learning. It was found that the case-based approach outperformed the control treatment in terms of student achievement [40, 41]. However, research in [42] found that case-based learning has a lower ability to improve student performance than simulated instruction. It was found that case-based learning, according to the majority of students, can boost learning motivation and the pace of pre-class preparation [47]. In contrast, the study [37] found that case-based learning group was more satisfied than the simulated instruction group.

In current study, students' evaluations of case-based learning were recorded in 10 of 21 RCTs. There was a lot of variability among the studies (I^2=87%, p<0.00001). Subgroup analysis was performed on the studies that were included. Seven research compared case-based learning to traditional learning, and the results were highly disparate (I^2=91%, p<0.00001). There was no significant difference in academic achievement between case-based learning and traditional learning, according to random effects models (MD and its 95% CI were 1.06 [-0.78, 2.90]). The differences between case-based learning and simulated training were examined in three of the studies. There was a tremendous degree of variation in the experiments (I^2=79%, p=0.008). According to random effects models, there was no significant difference in academic accomplishment between case-based learning and simulated instruction (MD and 95% CI: 2.36 [0.98, 5.70]). The findings of this meta-analysis suggest that case-based learning can increase students' academic performance as well as their capacity to analyze cases, and that case-based learning/teaching is an effective strategy for training medical students. In the subgroup analysis, however, there was no significant difference in learning performance between case-based learning, simulated teaching, or traditional learning, which might be owing to the short number of studies and study populations included. In many ways, systematic analysis is challenging since the indicators used to evaluate case-based learning and other teaching techniques are not consistent. This study discovered that case-based learning can improve learning performance when compared to traditional learning, but that it has no evident advantages when compared to problem based learning and simulated teaching [29, 33, 36, 38-41, 45, 66]. Case-based learning was regarded positively by students in terms of subjective judgement. Case-based learning has been shown in several studies to boost student satisfaction [29, 33, 39], learning zeal, self-study prowess, and problem-solving prowess [33, 40, 47].

There is currently no clear worldwide definition of case-based learning, and academics from many nations have proposed definitions with varying features but the same essence [15, 67-71]. In the current meta-analysis of chosen research, the detailed examination of each parameter revealed a substantial degree of heterogeneity among the studies (I^2=93%, p<0.00001). The academic performance of case-based learning and traditional learning differed significantly, according to random effects models (MD and its 95% CI were 4.45 [2.73, 6.16]). Case-based learning, we believe, is an active teaching method that puts students at the center, uses cases as a bridge, and uses inquiry as a driving force to help students connect theoretical knowledge from books to complex clinical situations, allowing them to integrate their knowledge and adapt to clinical practice more quickly.

Traditional teaching approaches are currently unable to meet the demands of medical education. Educators are continually testing and improving new teaching approaches. Flipped classrooms, for example, have a better learning effect than regular instruction [72-74]; situational teaching can help you improve your clinical skills, boost your confidence, and relieve stress [75, 76]. Furthermore, case-based learning is constantly evolving; it not only comes in a number of forms, but it may also be combined with other teaching methods. The combination of case-based learning and issue based learning can improve students' academic performance and case analysis abilities when compared to traditional instruction [30,

77-79]; case-based learning offers a stronger learning effect and is more popular with students than a single standard teaching approach [80]. It can be concluded that case-based learning is an active teaching method. However, medical and pharmacy education has progressed and thrived, but it still need improvement to fulfil the needs of many specializations.

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Declaration of interest: No conflict of interest is declared by the author.

Data sharing statement: Data supporting the findings and conclusions are available upon request from the corresponding author.

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