

ORIGINAL RESEARCH

Integrating Physiology and Pharmacology Through Simulation-Based Learning of the Autonomic Nervous System: Perceptions of Phase II MBBS Students at a Medical College in Northeast India

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ABSTRACT

Background: Simulation-based learning (SBL) offers a safe, interactive setting for linking theoretical knowledge with clinical application. The autonomic nervous system (ANS) is a demanding topic that requires students to integrate physiology, pharmacology, and clinical reasoning. This study assessed Phase II MBBS students' perceptions of SBL for the integrated teaching of ANS physiology and pharmacology. **Methods:** A cross-sectional study was conducted from January to March 2026 jointly by the Departments of Physiology and Pharmacology of a medical college in Northeast India. Of 100 students invited, 86 consented to participate. Students attended six one-hour SBL sessions on ANS physiology and pharmacology using the Ex-Pharm computer-assisted learning simulation software. Perceptions were then recorded with an expert-validated 15-item questionnaire on a five-point Likert scale and analysed descriptively. **Results:** Participants had a mean age of 21.3 ± 1.39 years; 46 (53.5%) were female. Perceptions were largely favourable, with mean scores of 3.72 to 4.03 on all 12 items describing benefits. The highest-rated item was understanding the clinical relevance of ANS pharmacology (87.2% agreement; mean 4.03 ± 0.66), followed by active engagement (86.0%; 3.98 ± 0.74) and a realistic, safe learning environment (83.7%; 3.97 ± 0.69). Most students also reported better integration of physiological and pharmacological concepts (77.9%) and greater confidence in clinical application (76.7%). Views on the limitations of SBL were divided: only 37.2% agreed that it should replace real-patient contact in clinical examinations, and the same proportion that it reduces the need for teacher involvement. **Conclusion:** Students perceived SBL as a useful complement to, but not a substitute for, teacher-guided learning and real-patient interaction in integrated ANS teaching. Studies using objective learning outcomes and comparison groups are needed to establish its effectiveness.

Keywords: Simulation training; autonomic nervous system; integrated curriculum; physiology; pharmacology; undergraduate medical education

INTRODUCTION

Medical education has moved steadily towards integrating the basic and clinical sciences, with the aim of making training more coherent and efficient and, ultimately, improving patient care [1]. In India, the competency-based undergraduate curriculum implemented from 2019 formally encourages horizontal and vertical integration so that foundational knowledge is learnt in the context of its clinical use [2]. Simulation-based learning (SBL) has become an important pedagogical approach within this shift. Because it offers a safe and controlled environment, simulation allows students to make errors and learn from them, which in turn encourages critical thinking [3]. It also supports the development of knowledge, skills, and attitudes without exposing patients to avoidable risk [4].

Simulation also changes the role of the student from passive recipient to active participant. Simulation experiences built into basic science curricula have been reported to strengthen students' confidence, empathy, and grasp of basic science concepts [5], and simulation has been used successfully to teach the basic sciences themselves, not only clinical skills [6]. In pharmacology, simulation-based teaching has been associated with better learning and retention than traditional

teaching among undergraduate medical students [7]. Integration of this kind may deepen students' understanding of foundational knowledge and its clinical application and may, in time, contribute to sounder diagnostic and therapeutic reasoning.

The autonomic nervous system (ANS) is a core component of both physiology and pharmacology. To master it, students must connect basic concepts, such as sympathetic and parasympathetic pathways, autonomic reflexes, and neurotransmitter actions, with their clinical and therapeutic applications, including receptor mechanisms, drug actions, and adverse effects. Autonomic pharmacology is widely regarded as difficult because it demands the synthesis of anatomy, physiology, pharmacology, and clinical reasoning, usually early in the course [8,9]. Students often find the topic abstract and hard to retain, particularly when it is taught in compartmentalised, discipline-specific formats [9].

In conventional teaching, the ANS is often presented largely as theory with limited clinical correlation, and students may struggle to appreciate the physiological basis and pharmacological implications of autonomic function. SBL adds a dynamic dimension to integrated teaching by letting students observe drug effects and work through clinically relevant situations, such as vasovagal syncope, the administration of autonomic drugs, or postural hypotension. Learning thereby becomes more contextual, interactive, and memorable. Computer-based simulation models are well suited to this purpose: in an Indian study, simulated experiments with autonomic drugs improved students' understanding of drug mechanisms in less time than conventional animal demonstrations, while avoiding unnecessary use of animals [10]. Virtual patient simulation has similarly been shown to support knowledge gain and its retention over time [11].

Simulation is most effective when it is embedded within the curriculum rather than offered as an isolated activity, so that learners can apply classroom knowledge in a simulated clinical context [12]. This is particularly relevant to ANS teaching, where students frequently find it difficult to link foundational knowledge with clinical scenarios [8,9]. Medical simulators can serve a wide range of learning needs, from reinforcing basic science principles to refining advanced clinical skills and fostering empathy and self-assurance [5]. Nevertheless, simulation-based medical education remains relatively underused in India [13], and little has been published on its role in the integrated teaching of physiology and pharmacology. The present study was therefore undertaken to assess Phase II MBBS students' perceptions of SBL as a method for the integrated teaching of ANS physiology and pharmacology.

MATERIALS AND METHODS

Study design and setting

This cross-sectional study was conducted by the Department of Pharmacology in collaboration with the Department of Physiology of a medical college in Northeast India between January and March 2026.

Ethical considerations and participants

The study was approved by the Institutional Ethics Committee (Ref. No. 5/2/CMC-ETHICS COMM/2024/17/13/2025). One hundred Phase II MBBS students were invited to participate using convenience sampling [14]. The purpose and procedure of the study were explained to them, and written informed consent was obtained before data collection. Eighty-six students consented and were enrolled; the remaining 14 declined and were excluded, giving a participation rate of 86%.

Simulation-based learning intervention

The intervention consisted of six one-hour sessions held in the Department of Pharmacology. The first session included an orientation to the study, the collection of informed consent, and a pre-session briefing. The sessions followed a structured SBL design that addressed concepts of the ANS by combining its physiological and pharmacological components, in line with the curricula of both disciplines.

The simulations were run on the Ex-Pharm (Experimental Pharmacology) series software, a computer-assisted learning (CAL) package that reproduces classical animal experiments and allows students to observe and interpret the effects of

drugs on different organ systems. Faculty members supervised the students throughout each session, facilitating their learning and providing guidance where needed.

Data collection instrument

At the end of the final session, participants completed a feedback questionnaire on SBL that had been designed and validated by experts of the institutional Medical Education Unit for Phase II MBBS students. The questionnaire contained 15 closed-ended statements: items 1 to 12 addressed perceived benefits of SBL, such as engagement, realism, understanding, integration, retention, and confidence, and items 13 to 15 addressed its potential limitations. Each item was rated on a five-point Likert scale scored as strongly agree = 5, agree = 4, neutral = 3, disagree = 2, and strongly disagree = 1.

Statistical analysis

Data were entered and analysed using SPSS version 21 (IBM Corp., Armonk, NY, USA). Descriptive statistics, namely frequencies, percentages, means, medians, and standard deviations (SD), were used to summarise demographic characteristics and responses to each item. For reporting, the “strongly agree” and “agree” categories were combined as agreement, and the “disagree” and “strongly disagree” categories as disagreement. Percentages were calculated using all 86 participants as the denominator.

RESULTS

Participant characteristics

All 86 participants were Phase II MBBS students aged 18 to 27 years (mean 21.3 ± 1.39 years; median 21 years). Of these, 46 (53.5%) were female and 40 (46.5%) were male. Most students (65, 75.6%) were between 20 and 22 years of age. The age and sex distribution of the participants is shown in Figure 1.

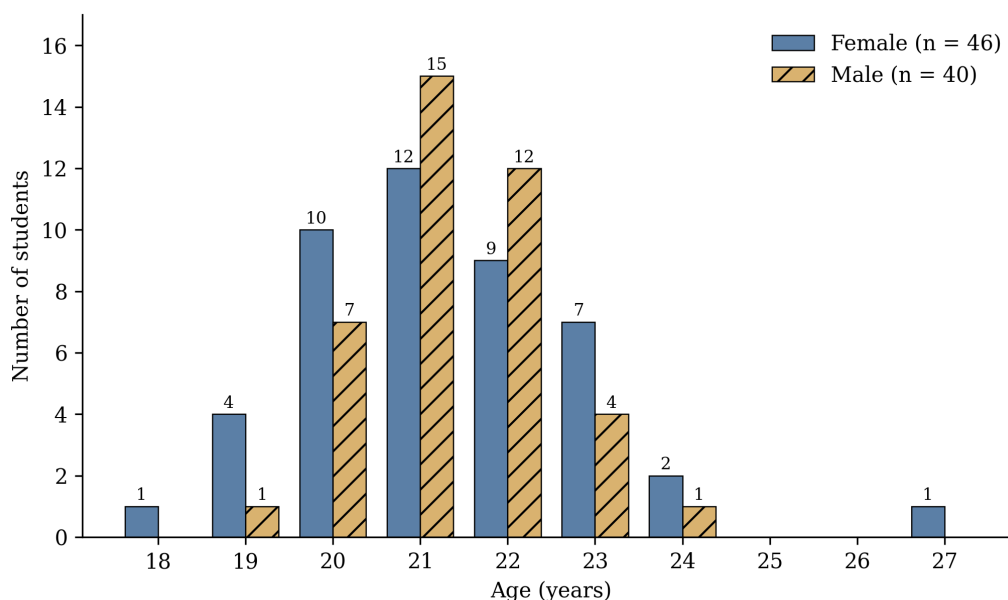


Figure 1. Age and sex distribution of the participants (n = 86)

Perceptions of simulation-based learning

Responses to the 15 questionnaire items are presented in Table 1. Overall, perceptions of SBL were positive: all 12 items describing potential benefits had mean scores between 3.72 and 4.03 and a median score of 4 (agree).

Table 1. Perceptions of Phase II MBBS students regarding simulation-based learning of the autonomic nervous system (n = 86)

N o.	Statement	Strongly agree n (%)	Agree n (%)	Neutral n (%)	Disagree n (%)	Strongly disagree n (%)	Mean $\pm$ SD
Perceived benefits							
1	The simulation sessions kept me actively engaged in learning.	15 (17.4)	59 (68.6)	9 (10.5)	1 (1.2)	2 (2.3)	3.98 $\pm$ 0.74
2	SBL provided a realistic and safe environment for understanding ANS concepts.	15 (17.4)	57 (66.3)	10 (11.6)	4 (4.7)	0 (0.0)	3.97 $\pm$ 0.69
3	Simulation helped me better understand the clinical relevance of ANS pharmacology.	17 (19.8)	58 (67.4)	8 (9.3)	3 (3.5)	0 (0.0)	4.03 $\pm$ 0.66
4	SBL helped me integrate physiological and pharmacological aspects of the ANS.	10 (11.6)	57 (66.3)	15 (17.4)	4 (4.7)	0 (0.0)	3.85 $\pm$ 0.68
5	I found it easier to retain and apply knowledge after the simulation sessions.	10 (11.6)	53 (61.6)	19 (22.1)	4 (4.7)	0 (0.0)	3.80 $\pm$ 0.70
6	The sessions made complex ANS concepts easier to understand.	7 (8.1)	61 (70.9)	14 (16.3)	4 (4.7)	0 (0.0)	3.83 $\pm$ 0.64
7	The simulation enhanced my confidence in the clinical application of ANS knowledge.	17 (19.8)	49 (57.0)	16 (18.6)	4 (4.7)	0 (0.0)	3.92 $\pm$ 0.75
8	I feel better prepared to apply ANS concepts in clinical case scenarios.	14 (16.3)	50 (58.1)	16 (18.6)	5 (5.8)	1 (1.2)	3.83 $\pm$ 0.81
9	SBL can improve decision-making in real-life clinical practice.	13 (15.1)	46 (53.5)	23 (26.7)	4 (4.7)	0 (0.0)	3.79 $\pm$ 0.75
10	I am satisfied with the quality and conduct of the SBL sessions.	11 (12.8)	45 (52.3)	25 (29.1)	5 (5.8)	0 (0.0)	3.72 $\pm$ 0.76
11	SBL should be included in the curriculum for other integrated topics.	17 (19.8)	48 (55.8)	16 (18.6)	5 (5.8)	0 (0.0)	3.90 $\pm$ 0.78
12	I would recommend simulation-based learning to my peers.	11 (12.8)	50 (58.1)	22 (25.6)	3 (3.5)	0 (0.0)	3.80 $\pm$ 0.70
Perceived limitations							
13	SBL should replace real-patient contact in clinical examinations.	5 (5.8)	27 (31.4)	25 (29.1)	23 (26.7)	6 (7.0)	3.02 $\pm$ 1.05
14	SBL reduces the need for teacher involvement in student learning.	6 (7.0)	26 (30.2)	23 (26.7)	26 (30.2)	5 (5.8)	3.02 $\pm$ 1.06
15	Using SBL too often may reduce students' communication and empathy skills.	9 (10.5)	32 (37.2)	17 (19.8)	25 (29.1)	3 (3.5)	3.22 $\pm$ 1.09

ANS, autonomic nervous system; SBL, simulation-based learning; SD, standard deviation. Scores: strongly agree = 5, agree = 4, neutral = 3, disagree = 2, strongly disagree = 1. Percentages are calculated with n = 86 as the denominator.

The highest-rated statement was that simulation helped students understand the clinical relevance of ANS pharmacology, with which 75 students (87.2%) agreed or strongly agreed (mean 4.03 $\pm$ 0.66). Similarly, 74 students (86.0%) agreed that the sessions kept them actively engaged in learning (mean 3.98 $\pm$ 0.74), and 72 (83.7%) agreed that SBL provided a realistic and safe environment for understanding ANS concepts (mean 3.97 $\pm$ 0.69).

Students also perceived SBL as aiding the integration, comprehension, and application of knowledge. Agreement was reported by 67 students (77.9%) for the integration of physiological and pharmacological aspects of the ANS (mean 3.85 $\pm$ 0.68), by 68 (79.1%) for making complex ANS concepts easier to understand (mean 3.83 $\pm$ 0.64), and by 63 (73.3%) for easier retention and application of knowledge (mean 3.80 $\pm$ 0.70). In addition, 66 students (76.7%) reported greater confidence in the clinical application of ANS knowledge (mean 3.92 $\pm$ 0.75), 64 (74.4%) felt better prepared to apply ANS concepts to clinical case scenarios (mean 3.83 $\pm$ 0.81), and 59 (68.6%) believed that SBL could improve decision-making

in clinical practice (mean 3.79 ± 0.75). Satisfaction with the quality and conduct of the sessions received the lowest score among the benefit items, with 56 students (65.1%) in agreement (mean 3.72 ± 0.76). Sixty-five students (75.6%) supported extending SBL to other integrated topics, and 61 (70.9%) would recommend it to their peers.

Responses to the statements on potential limitations were more evenly spread, as reflected in their lower means, median scores of 3 (neutral), and wider standard deviations. Thirty-two students (37.2%) agreed that SBL should replace real-patient contact in clinical examinations, while 29 (33.7%) disagreed and 25 (29.1%) were neutral (mean 3.02 ± 1.05). Likewise, 32 students (37.2%) felt that SBL reduces the need for teacher involvement, whereas 31 (36.0%) disagreed (mean 3.02 ± 1.06). Nearly half (41, 47.7%) agreed that frequent use of SBL might reduce students' communication and empathy skills (mean 3.22 ± 1.09). Taken together, these responses indicate that students regarded SBL as an effective complementary strategy, but no majority considered it a replacement for teacher-guided learning or real-patient interaction.

DISCUSSION

This study found that Phase II MBBS students viewed SBL favourably as a means of integrating the physiology and pharmacology of the ANS. Agreement was strongest for the clinical relevance of ANS pharmacology, active engagement, and the realism and safety of the learning environment. At the same time, students were divided on whether simulation could substitute for teachers or for contact with real patients.

SBL has become an established component of medical education. By providing realistic, immersive experiences that resemble clinical situations, it allows learners to develop technical and non-technical skills in a safe and controlled setting and so improves their preparedness for clinical practice [15]. One of its main strengths is the opportunity for deliberate practice, in which learners repeat tasks with feedback and refine their performance without risk to patients [16]. Such repetition is central both to acquiring proficiency and to maintaining it over time [17]. Simulation also lets learners make mistakes and learn from them safely, which is essential for effective learning [18]. Immediate feedback and structured debriefing are key elements of this process: after a simulation, learners reflect on their performance, receive feedback, and discuss how to improve, which reinforces learning, corrects errors, and promotes reflective practice [19]. In the present study, the software allowed experiments to be repeated, and continuous faculty facilitation provided opportunities for immediate feedback, which may partly explain the high ratings for engagement and understanding.

Medical training must at some point involve real patients, yet clinicians are also obliged to provide optimal treatment and to protect patient safety and well-being. Balancing these two obligations is a fundamental ethical tension in medical education. SBL helps to ease this tension by building the knowledge, skills, and attitudes of health professionals while protecting patients from unnecessary risk, much as simulation training has long been used in other high-hazard fields such as aviation, nuclear power, and the military [20].

Although the value of simulation-based education is widely recognised, it is not yet common in Indian medical education [13]. Where it has been studied in India, medical students have generally reported favourable perceptions of SBL [21]. The present findings suggest that SBL may be particularly useful for teaching complex, interconnected topics such as the ANS, in which students must integrate physiological mechanisms with pharmacological principles and their clinical applications. The high level of agreement regarding improved understanding of the clinical relevance of ANS pharmacology, and regarding the integration of its physiological and pharmacological aspects, indicates that simulation may help to bridge the gap between theoretical knowledge and clinical application. These observations are consistent with earlier reports that simulation promotes active learning and improves students' understanding and application of basic science concepts in clinically relevant contexts [5,7,22]. They also agree with the earlier Indian experience in which computer simulation of autonomic drug experiments improved students' understanding of drug mechanisms [10], and with meta-analytic evidence that technology-enhanced simulation is associated with substantial gains in knowledge and skills compared with no intervention [23].

The students' reservations deserve attention. Over a third of them agreed that SBL should replace real-patient contact in clinical examinations or that it reduces the need for teacher involvement, while a similar proportion disagreed, and nearly half were concerned that frequent use of SBL might erode communication and empathy skills. This concern may reflect

the screen-based format used here, which involves little interpersonal interaction, whereas manikin-based simulation has been associated with gains in empathy [5]. These mixed views support the use of simulation as an integrated complement to clinical exposure and teacher-led instruction rather than as a stand-alone substitute [12]. They also suggest that the purpose and scope of SBL should be explained clearly to students when it is introduced.

Several limitations should be considered when interpreting these findings. The study was conducted at a single institution with a modest sample, which limits generalisability. It assessed students' perceptions rather than objective changes in knowledge or clinical performance, and therefore corresponds to the first, or reaction, level of Kirkpatrick's model of training evaluation [24]. Self-reported responses may also be influenced by social desirability bias. The internal consistency of the questionnaire was not reported, although this is recommended for survey instruments in educational research [25]. Finally, the 14 students who declined to participate may have held different views from those who took part. The positive responses should therefore be read as evidence of acceptability and perceived educational value rather than as definitive proof of improved learning outcomes.

Even so, the study adds to the evidence on the acceptability of SBL among undergraduate medical students and supports its inclusion in the integrated teaching of the basic and clinical sciences. Future studies with larger, multicentre samples, comparison groups, and pre- and post-intervention assessments of knowledge, retention, and clinical competence would provide stronger evidence of the effectiveness of simulation-based teaching.

CONCLUSION

Phase II MBBS students perceived SBL as an effective approach for teaching the ANS. Most reported that it improved their understanding of the clinical relevance of ANS pharmacology, kept them engaged, helped them integrate physiological and pharmacological concepts, and increased their confidence in applying this knowledge to clinical scenarios.

These findings suggest that SBL can serve as a valuable complementary strategy in the integrated teaching of the basic and clinical sciences. However, students did not broadly endorse simulation as a substitute for teacher-guided learning or real-patient interaction, which highlights the need for a balanced approach. Extending well-designed SBL activities to other integrated topics may enhance learning, provided that opportunities for communication, empathy, and clinical exposure are preserved.

DECLARATIONS

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Conflicts of interest: None declared [authors to confirm].

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AI transparency statement: The artificial intelligence system evaluated in this study was used for acoustic voice classification. No generative AI system was used to generate or modify the study data.

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