Impact of an integrated Structured BOPPPS model Workshop conducted on Arterial Blood Gas (ABG) Analysis Skills and Knowledge Among MBBS Students.

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Abstract

Purpose: Arterial Blood Gas (ABG) analysis is a critical diagnostic tool in clinical practice. However, students often struggle with ABG interpretation due to limited practical exposure. The aim of this workshop was to evaluate effectiveness, including the acquisition of knowledge and skills about arterial blood gas (ABG) analysis and its interpretation. It also addressed the gap by combining hands-on training, interactive learning, and case-based discussions.

Methodology: An educational intervention using the BOPPPS model was conducted on MBBS students enrolled in the *Gas Savy* workshop organized by the Research Cell of our institution. Retrospective analysis was done for anonymized data. The structured, validated pre-test, post-test questionnaires, and feedback data were used to assess the workshop's effectiveness and overall impact on participants' learning outcomes.

Statistical analysis: Descriptive statistics, Paired t test for pre- and post-test data, and feedback analysis were conducted through Jamovi 2022 (Version 2.3) and ATLAS.ti software. A p-value of <0.05 was considered statistically significant.

Results and discussion: The Chi-square test performed on pre- and post-test showed statistically significant improvement in knowledge acquisition with a p-value of <0.001. Cohen's d was calculated to measure the impact, and it was found to be 1.34, showing a high impact of the workshop on students' understanding of ABG. The feedback highlighted positive responses emphasizing the enhancement of clinical reasoning skills for the participants and appropriate resource management, sequencing, and designing of the workshop by the organizers. Participants also opined that case discussions, hands-on ABG sample collection, and pre-analytical error analysis were highly useful. Topics on compensation, respiratory abnormalities, and mixed ABG cases enhanced understanding. Interactive sessions and practice questions were valuable, while areas for improvement included simplifying calculations and more practice with arterial lines as revealed by thematic analysis of qualitative data.

Conclusion: The study showed that the structured integrated workshop significantly increased the knowledge acquisition of the MBBS students and was an effective method of imprinting the knowledge of ABG.

Key words: BOPPPS Model, Arterial blood sample, ABG, Acid-base balance, simulation, Gas Savy, Structured workshop, hands-on workshop, preanalytical errors

Background:

Workshops with clear learning goals, based on experiential learning, fit well with modern medical education. They encourage interactive teaching, deeper understanding, and efficient use of time when carefully planned. Workshops are great for group discussions, building relationships, and offer structured in-person learning. They can be used consistently across different locations and teaching styles, making them flexible yet effective.(1,2) Workshops are cost-effective and engage learners more than individual study methods. They support learning at all levels—undergraduate, postgraduate, and continuing education—and are ideal for developing both professional and personal skills. They're especially useful for problem-solving, building practical skills, and increasing self-awareness.(3–7)

One key challenge in emergency and intensive care units is interpreting acid-base disorders using the results from point-of-care testing (POCT) devices. (8,9) New medical graduates are often apprehensive about performing arterial blood sampling and arterial blood gas (ABG) interpretation. Hence, it needs collaborative approaches to enhance their understanding of the accurate method required in terms of sample collection, transportation and interpretation (10,11). Innovatively teaching these essential skills can help bridge the gap by preparing learners to contribute effectively as Indian medical graduates (IMGs).

"The BOPPPS model (Bridge-in, Learning Objective, Pre-assessment, Participatory Learning, Post-assessment, and Summary) is a teaching approach." (12–14). The pioneer of this approach is Douglas Kerr's team at the University of British Columbia.(15) The approach in the BOPPPS model is student-centric, flexible and by design, enhances teaching. It focuses on students' emotions, communication, and personal experiences, directly influencing student engagement and motivations. (16–20) Hence, this workshop was conducted to bridge the gap between ABG analysis and interpretation and MBBS students' understanding of it. The data was analyzed retrospectively to evaluate the effectiveness of such workshops for medical students.

Methods

Ethical consideration: The study was approved by the Institution Ethics Committee (IEC-DHR Registration EC/NEW/INST/2022/2810) of Manipal Tata Medical College Jamshedpur (Ethics approval number: MTMC/IEC/2024/93) and adhered to the Declaration of Helsinki.

Study Design: The study was a retrospective analysis aimed at evaluating the efficacy of the *Gas Savvy* workshop conducted during the *Erudite* Student Conference. The workshop focused on improving students' knowledge and skills related to arterial blood gas (ABG) analysis, its interpretation, and clinical applications.

Study Setting: The workshop was held for MBBS students attending the conference. The hands-on and case-based learning sessions were designed to simulate real-life clinical situations.

Study Participants:

Student participants: Thirty-five MBBS students from different phases (academic year) registered for the conference. Out of the 35 registered students, six students were among the organizing committee; hence, they were excluded from the study. Of the remaining 29 students, 20 completed the pretest, post-test, and feedback. All the available data were analyzed using Jamovi software. The total cohort was divided into five subgroups to facilitate participatory and interactive learning.

Resource persons: Five expert Biochemists, one expert pulmonologist, two student coordinators, 6 student cohelpers.

Study Tools: Two tools were utilized for data collection and evaluation.

All students were assessed for baseline knowledge and its improvement by pre- and post-test, respectively. Quantitative and qualitative feedback was obtained to evaluate the workshop's effectiveness.

Tool 1: Pre- and post-test: The questionnaire consisted of two parts, A and B, for the pretest and only part B for the post-test. Part A included Demographic data. Part B included 20 questions, as given in Table 2, to assess understanding through multiple-choice and true/false questions. All questions used were validated. The questioning pattern is shown in Table 1.

Tool 2: Post-workshop feedback: Students' perceptions of the workshop's effectiveness were collected using Google Forms, as shown in Table 5.

BOPPPS Model Implementation (Figure 1): The workshop followed the BOPPPS model (Bridge-In, Objectives, Pre-Assessment, Participatory Learning, Post-Assessment, and Summary) to ensure structured learning. Training Preparation (Before Workshop): A case scenario on acid-base disturbances was prepared, and instructional videos demonstrating ABG sample collection, transportation, and reporting were recorded using a real ICU patient. Materials for hands-on biomedical waste management (BMW) and cases addressing preanalytical errors were prepared. **Bridge-In** (During Workshop): The sessions commenced with a role play by resource persons to introduce clinical scenarios, engage participants and conceptualize the importance of ABG analysis. **Objectives** (During Workshop): The workshop aimed to teach the importance of blood pH regulation and arterial blood sampling, identify and prevent preanalytical errors, manage biomedical waste (BMW), and interpret acid-base imbalances. **Pre-Assessment** (Before Workshop): A pre-test using the validated questionnaire assessed participants' baseline knowledge of ABG concept, techniques, and clinical applications **(Table 1). Participatory Learning** (During Workshop): Participants engaged in theoretical instruction, hands-on sample collection using mannequins (21) and the transportation of samples in cold-storage boxes with ice packs. They also learned BMW protocols, discussed preanalytical errors, and participated in case-based learning to interpret ABG results and manage acid-base disorders. **(Table 2) Post-Assessment** (After Workshop): The same questionnaire used for pretest (**Table 1)** was administered to measure knowledge improvement and conceptual clarity. **Summary** and Feedback (After Workshop): Student feedback was gathered to evaluate the overall effectiveness of the workshop and identify areas for improvement. This structured and interactive methodology ensured comprehensive learning, combining theoretical knowledge with hands-on experience to enhance understanding and application in clinical settings.

Figure 1:

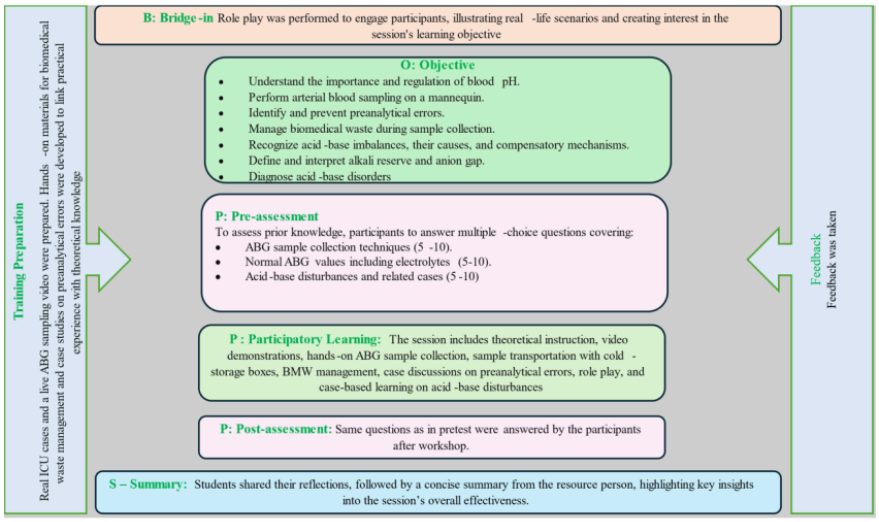

Table 1: Questioning pattern for pre and post test.

Question Topics	**Number of questions**	**Bloom's taxonomy cognitive levels**			
		C1	**C2**	**C3**	**C4**
ABG sample collection	6	2	4	-	-
Normal values of ABG, electrolytes & calculation of anion gap	6	5	1	-	-
Acid-base disturbances, including cases	8	-	-	2	6

According to Bloom's Taxonomy, six questions related to ABG sample collection were included: two assessed recall (C1) and four tested understanding (C2). For questions on normal values and calculations, five focused on recall (C1) and one on understanding (C2). Case-based learning questions included two application-level (C3) and six analysis-level (C4) items.

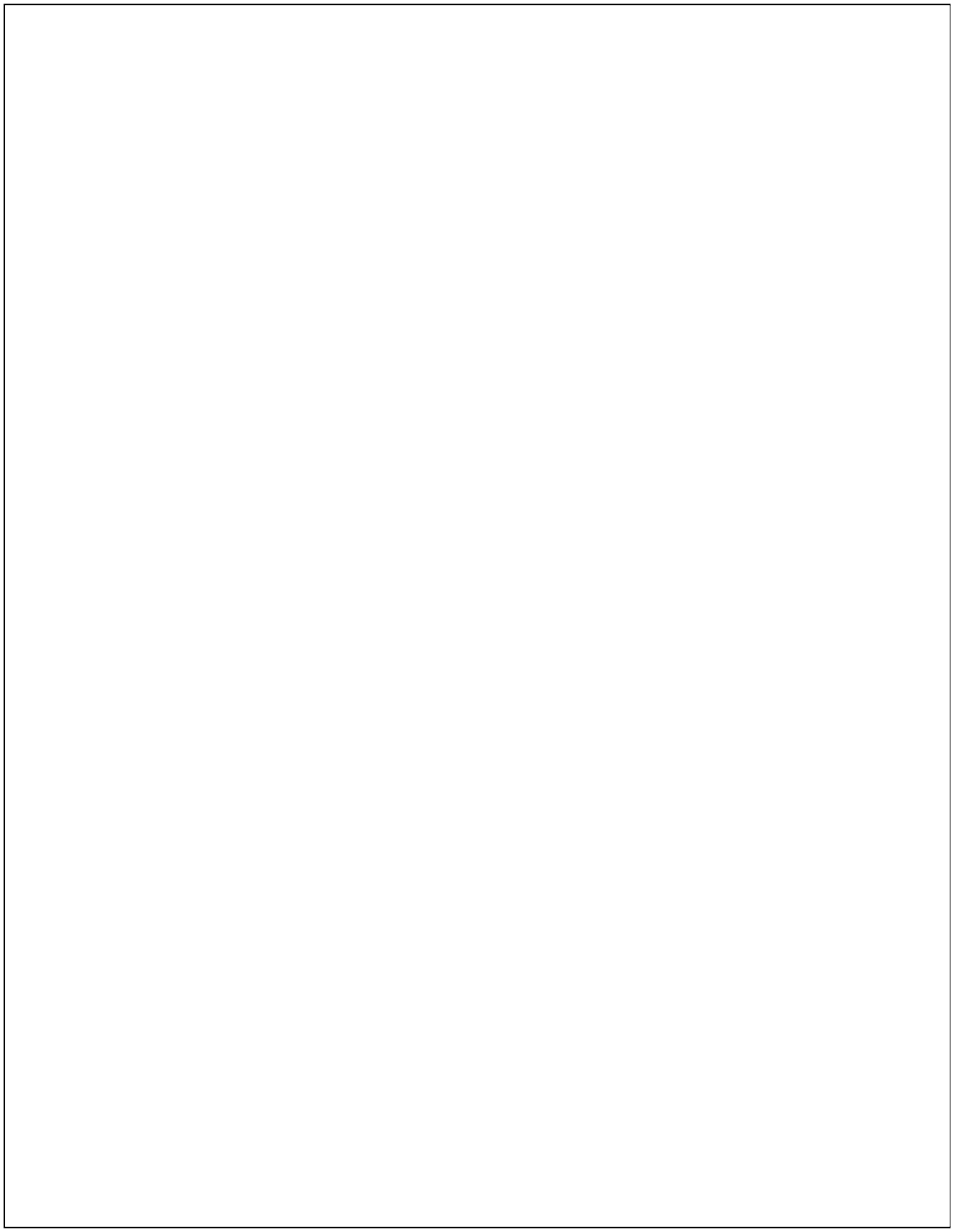

Table 2: Protocol for participatory learning:

Session	TLM	Duration
Ice breaking, Pretest		15
Introduction to the workshop	Role play	5
Sample collection for ABG	Videography teaching followed by hands-on using a mannequin	25
Biomedical waste management **(Figure 2)**	Activity	5
Preanalytical errors: Patient identification, heparin-induced dilution, wrong positioning of needle, air bubbles, clotting of blood, hemolysis, transport, and storage.	Jigsaw	15
Blood pH maintenance	Interactive didactic lecture	25
Approach to ABG analysis	Interactive didactic lecture	15
Case discussion and interpretation- simple	CBL	25
Case discussion and interpretation - compensated	CBL	25
Management	CBL	15
Post-test, feedback	Online	10

The workshop incorporated diverse teaching-learning methods (TLM) including videography, role-play, jigsaw, interactive lectures, and case-based learning (CBL). It effectively covered key areas such as ABG sample collection, biomedical waste management, preanalytical errors, pH regulation, and interpretation of ABG reports. Online tools were used for assessment and feedback, enhancing engagement and learning outcomes.

Figure 2: BMW pictures used for activity

Figure 3: Color bins preparation activity

Students prepared the colored bins and labeled them as biohazard (Figure 3). The pictures of the waste generated (Figure 2) were discarded in red, yellow, blue, and puncture-proof bins.

Statistical analysis:

The demographic details, including age, gender, course, and batch, were summarized using descriptive statistics.

Data was checked for normal distribution. The pretest and posttest scores of the participants were compared using a paired t-test to determine the statistical significance of knowledge improvement. The results were analyzed using Jamovi version 2.3(22) to calculate the mean and standard deviation of the scores, providing insights into the overall performance trends. The effect size was calculated to measure the magnitude of the knowledge gain, highlighting the practical significance of the workshop by Cohen's d.

Feedback collected through Google Forms was analyzed both quantitatively and qualitatively. Quantitative data from Likert-scale responses were summarized as percentages, while thematic analysis using Atlas-ti was used to evaluate open-ended responses. This provided valuable insights into the participants' perceptions, the strengths of the workshop, and areas requiring improvement.

This comprehensive analysis clearly explains the workshop's effectiveness and its impact on the participants' learning outcomes.

Results:

Table 3 Descriptive statistics of the participants' learning outcomes

Parameters	Pretest	Post Test	Difference
N	27	20	20
Mean + SD	9.7±2.93	14.25±2.92	5±3.33
Maximum	14	18	
Minimum	1	7	
P Values	**<0.001**		
Cohen's d	**1.34**		

The analysis revealed a significant improvement in knowledge and skills after the workshop. The mean score increased from 9.7 ± 2.93 in the pretest to 14.25 ± 2.92 in the post-test, with a mean difference of 5 ± 3.33, which was statistically significant (p value < 0.001).

Table 4: Descriptive statistics on the gender-based differences in learning outcomes

	Pretest		Post Test		Difference	
Parameters	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**
N	11	16	7	13	7	13
Mean ± SD	10±2.35	9.50±3.25	15.7±1.98	13.5±3.10	6.14±2.48	3.54±3.45
Maximum	13	14	18	18	7	9
Minimum	6	1	13	7	3	-3
P Value	0.657		0.064		0.069	

The analysis showed notable improvements in knowledge in both male and female participants following the workshop. Males exhibited a mean score increase from 10 ± 2.35 to 15.7 ± 1.98, while females improved from 9.50 ± 3.25 to 13.5 ± 3.10. The mean difference was 6.14 ± 2.48 for males and 3.54 ± 3.45 for females. Statistical significance was not achieved for the differences, with p-values of 0.657 for males and 0.064 for females, indicating both genders had equal benefits from this workshop.

Table 5: Descriptive statistics on the academic year (phase)-based differences in learning outcomes.

Parameter	Academic year	N	Mean ± SD	P Value
Pretest	2nd MBBS	10	9.5±3.72	0.667
	3rd MBBS	8	9.25±2.6	
	4th MBBS	9	10.33±2.4	
Post-test	2nd MBBS	7	14.71±3.25	0.813
	3rd MBBS	7	13.57±3.64	
	4th MBBS	6	14.50±1.64	
Difference	2nd MBBS	7	4.29±4.23	0.976
	3rd MBBS	7	4.43±3.64	
	4th MBBS	6	4.67±2.16	

The study showed consistent improvements in knowledge and skills across different MBBS academic years after the workshop. While pretest versus post-test scores improved in all groups, there were no statistically significant differences in performance between 2nd, 3rd, and 4th MBBS students.

Table 6: Quantitative feedback on the workshop effectiveness:

Parameter	Yes	No	Yes %
Goals were specified at the initiation of the workshop	21	0	100%
The workshop was able to clear the "clinical reasoning" to me	21	0	100%
The workshop was successful in achieving its objectives	16	5	76%
Teaching aids used in the workshop were appropriate	20	1	95.2%
The teaching-learning methods employed were appropriate	18	3	90.5%
Resource material was meticulously planned and arranged	21	0	100%
Workshop instructors were well-versed in the scientific content	21	0	100%
The sequence of the subtopics of the workshop was designed appropriately	21	0	100%
The time allotted for the workshop was appropriate	21	0	100%
There was ample opportunity to practice on the issues raised	20	1	95.2%
Summary	**20±1.61**	**1±1.61**	**96±0.07%**

The workshop received highly positive feedback, with most participants agreeing that the goals were clearly defined, the content was well-delivered, and there was ample opportunity for practice. Key strengths included the appropriateness of teaching aids (95.2%) and effective resource material and instructors (100%). However, a few respondents (24%) felt that some objectives were not fully achieved.

Table 7 A: Student reflection on individual sessions

Sl No	Aspect of Workshop	Key Positive Feedback	Suggested Improvements
1	Overall	All content was well received.	None
2	Activities	Interactive and engaging.	None
3	Pre-analytical Errors	Helped students identify their mistakes.	None
4	Heparinized Injection and with Pre-heparinized Syringe	Effective demonstration.	None
5	Sample collection in video and mannequin, Waste Management Activity	Highly enjoyable and interactive, helped consolidate skills through hands-on practice	Incorporate sampling practice with an arterial line.
6	ABG Analysis	Detailed and informative.	Simplify the explanation of calculations.
7	Diagnosis of abnormalities	Cleared complex concepts well.	Slightly shorten the session to maintain engagement.
8	Practice Questions on ABG	Reinforced knowledge effectively.	Include sampling practice with arterial lines for additional realism.

Table 7A: Thematic analysis of the feedback:

Theme	Sub-themes	Example Feedback
Content Clarity	Prolonged Sessions	"It was a little prolonged, maybe shortening it would have perfected it."
	Simplification Needed	"The calculation part could have been explained in a more simplified manner."
Engagement and Interaction	Fun Activities	"The injection mannequin and also the waste management interactive activity were very fun."
	Opportunities for Practice	"There was ample opportunity to practice on the issues raised."
Teaching Effectiveness	Clear Objectives	The workshop was able to clear the 'clinical reasoning' to me."
	Appropriate Teaching Aids	"Teaching aids used in the workshop were appropriate."
Resource Management	Well-Planned Materials	Resource material was meticulously planned and arranged."
Feedback on Specific Topics	Mixed ABG Cases	"The topic on mixed ABG cases cleared my concepts."
	Compensation Analysis	"Compensated and uncompensated part analysis of acute and chronic compensation."
Areas for Improvement	Time Management	"Time management could be improved."
	Additional Practice Needed	"Sampling practice with arterial line."

The workshop was highly effective, with hands-on activities, case discussions, and interactive sessions being particularly appreciated. Minor improvements suggested include better time management, simplifying complex topics like calculations, and including additional sampling practices with arterial lines.

Discussion:

The workshop was structured effectively as per the BOPPPS model.(12,14) As shown in the study by Shen et al., the BOPPPS model fits with the requirements of continual learning involving interactive training principles. It promotes active engagement, fostering deeper understanding by creating a learning atmosphere.(2,23–25) It facilitates clear goal setting, interactive teaching, skill practice, and knowledge evaluation, ensuring a comprehensive and impactful learning experience.

The findings of this study demonstrate a significant enhancement in knowledge and skills related to arterial blood gas (ABG) analysis among participants following workshop which was consistent to the findings of the studies like Wang et al & others(12,23,23,26,27). The mean pretest score of 9.7 ± 2.92 improved to a post-test mean of 14 ± 2.92, with a mean difference of 5 ± 3.33. This improvement was statistically significant, as evidenced by a p-value of <0.001 and a large effect size (Cohen's d = 1.34), indicating a strong impact of the workshop on learning outcomes. These results emphasized the efficacy of hands-on, interactive teaching methodologies in improving students' understanding of ABG analysis.

Gender-based analysis revealed distinct trends in learning outcomes. Male participants showed a greater improvement (mean difference: 6.14 ± 2.48) compared to their female counterparts (mean difference: 3.54 ± 3.45). However, the differences in pretest and post-test scores between genders were not statistically significant ($p = 0.657$ for males and $p = 0.064$ for females), similar to the study done by Xu et al. (28). This suggests that while male participants appeared to gain slightly more from the workshop, the overall benefits were equally accessible to both genders. The variability in scores could be attributed to factors such as prior knowledge or learning styles, which merit further exploration.

Academic year-based analysis revealed consistent improvements across all levels, with no statistically significant differences in pretest, post-test, or score changes among 2nd, 3rd, and 4th-year MBBS students ($p > 0.05$ for all comparisons). This uniform enhancement underscores the adaptability of the workshop's content to diverse academic backgrounds. Notably, 4th-year students showed slightly higher mean pretest scores, possibly reflecting greater baseline knowledge due to clinical exposure, yet all groups benefited comparably.

The workshop's feedback indicates an overwhelmingly positive response from participants, highlighting its success in achieving the intended goals.(23) All participants agreed that the workshop's goals were clearly specified at the outset, ensuring a clear understanding of the objectives. The workshop was particularly praised for its effectiveness in clarifying "clinical reasoning," with participants feeling confident in applying critical thinking to clinical scenarios. Every respondent also affirmed that the workshop successfully achieved its objectives, with content delivery and practical engagement well-aligned with the learning outcomes.

The teaching methods and aids were universally appreciated, with participants noting that the resources were appropriately chosen and meticulously planned. The workshop instructors were seen as highly knowledgeable, and the sequence of topics was considered logical and conducive to learning. The time allotted for the workshop was also deemed appropriate, allowing sufficient opportunity to cover all material while also providing ample hands-on practice.

However, despite the overwhelmingly positive feedback, a small percentage of responses indicated areas where the workshop could have been improved. Specifically, there were a few "No" responses (approximately 2-3%) to certain questions. These responses highlight a small number of participants who felt that some aspects of the workshop, such as the adequacy of time or the sequence of subtopics, could have been better tailored to their needs. However, these "No" responses were minimal and did not significantly detract from the overall effectiveness of the workshop.

The qualitative data of the feedback highlighted the workshop's strengths, including engaging activities, effective demonstrations, and practical skill-building. Students appreciated the comprehensive content, particularly on ABG analysis and pre-analytical errors. Suggested improvements included simplifying calculations, incorporating arterial line sampling, and optimizing session length for sustained engagement.

The feedback from the workshop participants is overwhelmingly positive, with every aspect of the workshop being rated highly by the majority. The clarity of goals, expert delivery, appropriate teaching methods and aids, and ample opportunity for practice were key strengths. While there were a few isolated instances where participants had reservations, the overall feedback indicates that the workshop was successful in meeting its objectives and providing valuable learning experiences. The small areas for improvement identified should be considered for future sessions to further enhance participant satisfaction and the overall effectiveness of the workshop.

Limitations of the study: The study have several limitations, which includes limited sample size, may not fully represent the diverse medical students from all Indian regions. The findings are specific to a single institution with few participants from other institutions, reducing their generalizability to other contexts. A multicentric study would be beneficial in this regard. It was also not planned as a prospective study, restricting insights into long-term impacts and trends. Further, likely biases in self-reported feedback may have influenced the evaluation of the training methodology. In the last the study focuses primarily on immediate learning outcomes, with minimal emphasis on long-term skill retention and application.

Conclusion:

This study highlights the effectiveness of a structured, interactive workshop in enhancing knowledge and skills in arterial blood gas (ABG) analysis among medical students. The significant improvement in post-test scores across all participants demonstrates the value of incorporating participatory learning methods, such as hands-on practice, case-based discussions, and interactive teaching. While gender and academic year-based analyses revealed minor variations in outcomes, the workshop was equally beneficial across all demographic groups, reinforcing its versatility and adaptability.

These findings highlight the importance of well-designed educational interventions in bridging knowledge gaps and establishing essential diagnostic skills in medical education in India. Future studies could explore long-term retention of knowledge and incorporate additional components like problem-based learning to further enhance students' learning outcomes.

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