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Bridging Theory and Practice: Effects of BOPPPS-Based Clinical Education on Theoretical Knowledge and Procedural Skills Among Undergraduate Operating Room Technology Students

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Abstract

Background

Clinical education in the operating room plays a crucial role in developing students' ability to integrate theoretical knowledge with procedural skills in a dynamic practice environment. The present study aimed to investigate the effects of the BOPPPS on theoretical knowledge and procedural skills among undergraduate operating room technology students during clinical internships.

Methods

A quasi-experimental two-group pre-test/post-test study was conducted among undergraduate operating room technology students. Pre-existing internship groups were retained as the intervention (n = 25) and control (n = 26) groups without randomization by the research team. The intervention group received 12 BOPPPS-based educational sessions over 14 weeks, whereas the control group received traditional clinical instruction. Theoretical knowledge was assessed using a 40-item multiple-choice questionnaire (MCQ), and procedural skills were evaluated using Direct Observation of Procedural Skills (DOPS) across ten operating room skills.

Results

Both groups showed significant improvements in theoretical knowledge and procedural skills following the educational period ($p < 0.05$), with greater improvements observed in the BOPPPS group. Mean MCQ scores increased by 7.08 points in the BOPPPS group and by 1.72 points in the control group, and the between-group difference in post-test scores remained significant after adjustment for baseline values ($p = 0.034$). Mean DOPS scores increased by 260.36 points in the BOPPPS group compared with 141.26 points in the control group ($p < 0.001$). Significant improvements were observed across all ten assessed procedural skills.

Conclusions

BOPPPS-based clinical education was associated with greater improvements in theoretical knowledge and procedural skills compared with traditional clinical instruction. The findings suggest that a structured, learner-centered approach incorporating active participation and feedback may support the integration of theoretical and procedural learning during operating room clinical education.

Introduction

The operating room (OR) is a critical hospital department where complex surgical procedures are performed, and high levels of knowledge and technical skills are required (1). Surgical technologists play

a vital role in supporting surgeons and ensuring surgical safety, with responsibilities spanning pre-, intra-, and post-operative phases (2). Given the practical, high-stakes nature of this field, the education of these professionals is crucial (3). Clinical internships play a critical role in developing these competencies; therefore, effective educational approaches are needed to ensure the achievement of competency (4). Moreover, clinical education in the OR faces numerous challenges, including a persistent gap between theoretical knowledge and procedural skills, reliance on traditional (lecture-based teaching) methods (5), a shortage of skilled instructors (6), and ineffective educational planning (7). These deficiencies not only affect students' skills but also compromise patient care quality and safety (8). Traditional pedagogical approaches in clinical settings often emphasize passive knowledge transmission, which may fail to engage learners or foster the critical decision-making and technical competencies required in dynamic environments such as the OR (9,10).Traditional internships and instructor-centered teaching approaches may be insufficient to prepare students for the increasing complexity of surgical care, where patient safety, rapid decision-making, and effective interdisciplinary collaboration are essential (11). This misalignment between teaching strategies and real clinical demands highlights the urgent need for structured, student-centered frameworks that promote active learning (12). Learning transfer, defined as the effective application and maintenance of acquired knowledge, skills, and attitudes in professional contexts, is considered a key indicator of educational quality and effectiveness (13). However, the theory–practice gap remains a major challenge in healthcare education worldwide, as students frequently experience difficulties in applying theoretical concepts to real clinical situations (14,15). In operating room technology students education, inconsistencies between theoretical instruction and clinical duties, unclear educational objectives, the stressful operating room environment, and limitations in clinical instruction can hinder clinical learning, highlighting the need for structured opportunities to integrate theoretical knowledge with procedural practice and develop professional competence (16). This challenge is particularly important in high-risk environments such as the operating room, where patient safety, technical proficiency, and interdisciplinary collaboration are essential (17). Therefore, there is a need for educational interventions that can facilitate the integration of theoretical knowledge with procedural skills and better prepare students for clinical practice (13,15). In response to these challenges, innovative teaching approaches such as the BOPPPS model have been introduced. Grounded in constructivist and communicative learning theories, the BOPPPS model is a student-centered, structured framework that emphasizes active learner participation, continuous feedback, and the integration of theory and practice (18,19). It consists of six phases: Bridge-in, Objective, Pre-assessment, Participatory learning, Post-assessment, and Summary, collectively forming a feedback-driven instructional cycle that enhances both engagement and educational outcomes (20). The BOPPPS model differs from traditional lecture-based instruction by emphasizing learner engagement, participatory learning, and continuous feedback (21). This model encourages interactive and scenario-based training, which is crucial for developing both technical skills and non-technical competencies such as communication, teamwork, and situational awareness, all vital for OR safety and efficiency (22,23). In addition, the BOPPPS model enables continuous feedback and individualized monitoring of student progress, thereby improving skills more effectively than traditional approaches (24). Previous studies have demonstrated the effectiveness of the BOPPPS model in improving knowledge, procedural skills,

critical thinking, and student satisfaction in various medical disciplines, including physiology (18), gynecology (25), thoracic surgery (26), and nursing (27). The existing evidence in operating room education appears to be limited to specific aspects of clinical competence, and it remains unclear whether BOPPPS can simultaneously improve theoretical knowledge and a broader range of procedural skills among undergraduate operating room technology students during clinical internship (28). However, despite growing evidence supporting the effectiveness of the BOPPPS model across several healthcare disciplines, evidence regarding its application in undergraduate operating room internships remains limited. In particular, its potential to integrate theoretical knowledge with procedural skills in operating room education has not been fully investigated. Therefore, the present study aimed to evaluate the effects of BOPPPS-based clinical education on theoretical knowledge and procedural skills among undergraduate operating room technology students during clinical internships.

Methods

Study design and setting

A quasi-experimental study with a two-group pre-test/post-test design was conducted during the 2025–2026 academic year (October–January) at Alborz University of Medical Sciences. The study included fifth-semester students enrolled in Technical Internship I and seventh-semester students enrolled in Field Internship. The inclusion of these cohorts was intentional, as both were in the later stages of undergraduate operating room technology education, had completed foundational courses, and were familiar with scrub and circulating roles. At this stage, students were expected to gradually perform clinical tasks with greater independence. Because all eligible students were accessible, census sampling was used. Of 56 initially eligible students, two were excluded for not meeting the inclusion criteria, leaving 54 students who participated according to their pre-existing internship groups. Group membership was determined by the students' semester and pre-existing internship groups. Due to the structure of the internship program, individual randomization was not feasible; therefore, the pre-existing groups were retained as the intervention or control group without allocation by the research team. The intervention group received BOPPPS-based clinical education, whereas the control group received traditional instruction. Baseline characteristics, including pre-test scores, age, sex, and grade point average, were assessed after group formation to examine the initial comparability of the groups. Despite their previous theoretical and practical education, students had not previously received standardized, structured clinical education specifically targeting the theoretical knowledge and procedural skills addressed in the intervention. Three students were subsequently excluded due to absence from educational sessions or failure to complete the final assessment. Thus, 51 students (25 interventions and 26 control) were included in the final analysis. Intention-to-treat analysis was not performed, and participants excluded from the final analysis were not included in the analyses (Figure1). The study was reported in accordance with the Transparent Reporting of Evaluations with Nonrandomized Designs (TREND) statement.

Inclusion and exclusion criteria

Inclusion criteria were: (1) enrollment in the fifth or seventh semester of the undergraduate operating room technology program; (2) willingness to participate and provision of written informed consent; (3) successful completion of at least three core surgical courses (6 credits) in orthopedic, neurosurgical, and general surgery; and (4) completion of theoretical and practical courses related to scrub and circulating roles in the operating room. Exclusion criteria included: (1) withdrawal from the study at any stage; (2) absence from educational sessions; and (3) previous exposure to the BOPPPS educational model.

Training Procedure

This study was conducted over 14 weeks, including 12 educational sessions. The study was carried out in the educational and clinical settings affiliated with Alborz University of Medical Sciences. The duration was identical for both groups, and both groups used the same curricular content and learning materials based on the official operating room internship curriculum. The theoretical component focused on three core duties of surgical technologists in general surgery, orthopedic surgery, and neurosurgery. For procedural skills, ten essential operating room competencies were selected, including electrosurgical plate placement operating table preparation surgical scrubbing sterile opening of surgical packs suturing surgical site preparation (skin preparation) gowning and gloving (closed technique) specimen collection, documentation, and transfer surgical draping instrument and sponge counting. All participants underwent theoretical and clinical assessments at baseline (first week) and after completing the training program (week 14) using the same instruments. The outcome measures were the changes in multiple-choice question (MCQ) knowledge scores and direct observation of practical skills (DOPS) clinical skill scores from pre-test to post-test.

Control group overview

The control group received traditional instructor-led instruction, which is the same as the lecture-based teaching approach in operating room training. Lecture-based teaching was used for theoretical content and demonstration and practice for procedural skills. This approach supported the acquisition of theoretical knowledge and clinical competencies through observation, guided practice, and exposure to real operating room environments.

Intervention group overview

The intervention group used the BOPPPS model to carry out teaching. The BOPPPS intervention was delivered through six sequential instructional components:

In Bridge-in phase, a Telegram group was created for the intervention group, and short clinical videos or images related to operating room procedures, procedural skills, or relevant theoretical concepts were shared to capture students' attention and activate prior knowledge. These materials were accompanied by challenging clinical questions designed to stimulate clinical reasoning. For example, students were

asked how they would respond to a breach of sterility during surgery or an unexpected intraoperative complication.

In Objective phase, the general learning objectives of the course were presented, along with specific, measurable objectives for each session. These objectives addressed both theoretical knowledge and procedural skills expected of operating room technology students. Depending on the topic, session objectives included understanding surgical indications, distinguishing scrub and circulating responsibilities, identifying surgical instruments and equipment, and applying relevant principles to common operating room challenges.

In the Pre-assessment phase, the instructor used oral questions to assess students' baseline theoretical knowledge and to identify their learning needs. Questions addressed key concepts and clinical scenarios relevant to the upcoming session, including students' understanding of procedural steps, scrub and circulating responsibilities, and appropriate responses to common operating room situations. Students' responses were used to identify knowledge gaps and tailor the emphasis and depth of subsequent instruction before practical application.

Participatory Learning constituted the core of the intervention. Students first engaged with relevant theoretical concepts and then applied this knowledge through scenario-based and simulated clinical activities reflecting common operating room procedures. For the skills component, activities were conducted in a simulated operating room environment using patient simulators rather than real patients. Students assumed scrub or circulating roles and applied their theoretical knowledge and procedural skills to respond to simulated challenges, including breaches of sterile technique, equipment-related problems, procedural difficulties, and intraoperative decision-making. This integration of theoretical content with simulated procedural practice provided opportunities for active participation and application of the learned concepts and skills in a controlled clinical environment.

Post-assessment was performed through oral questions and practical demonstrations aligned with the learning objectives. For example, students were asked to explain the rationale for a procedural step and then demonstrate its correct execution, allowing the instructor to provide immediate corrective feedback and reinforce the link between knowledge and skills.

The Summary phase involved a brief review of key theoretical concepts and their procedural skills, followed by discussion and questions. The instructor then provided a final synthesis to reinforce the main concepts and skills addressed during the session. Figure 2 illustrates the essential procedures and organizational steps involved in conducting an effective session.

Assessment of baseline characteristics

Baseline demographic characteristics, including sex, marital status, and age, were collected using a structured demographic checklist. Grade point average (GPA) was self-reported by students based on their overall cumulative academic average.

Assessment of theoretical knowledge

Theoretical knowledge was assessed using a researcher-developed 40-item multiple-choice questionnaire (MCQ) based on the course curriculum, administered before and after the intervention. Each correct answer received 0.5 points, for a total score range of 0–20. (No negative marking was applied for incorrect or unanswered items). The test was completed within 45 minutes; submissions completed in less than 20 minutes were excluded. Content validity was established by a panel of 10 experts in operating room technology and medical education. Item analysis was conducted in a pilot study to evaluate the difficulty index and discrimination index. Internal consistency reliability was confirmed (Cronbach's $\alpha = 0.83$). The same questionnaire was administered at both time points, with question order and response options rearranged at post-test to reduce recall effects.

Assessment of procedural skills

Procedural skills were assessed using the Direct Observation of Procedural Skills (DOPS) method in a simulated operating room environment within the hospital setting. A trained evaluator observed each student for 15–20 minutes and assessed performance using standardized DOPS checklists. A separate DOPS checklist was used for each of the ten procedural skills, with each checklist comprising multiple performance items rated on a 6-point descriptive-quantitative scale (1 = below expectations to 6 = excellent). Item scores were summed to generate the total score for each procedural skill, and the overall DOPS score was calculated as the sum of the scores across all ten procedural skills. Structured feedback was provided for 5–10 minutes following each assessment. The DOPS checklists used in this study, previously developed and validated, demonstrated excellent content validity (CVR = 0.99; CVI = 0.924).

Procedural skills assessment protocol

Procedural skills were assessed individually in a simulated operating room environment using patient simulators rather than real patients. Each student performed the designated procedures according to a standardized assessment protocol, assuming the appropriate scrub or circulating role. Performance was evaluated using the structured DOPS assessment criteria across the predefined procedural skills. The same assessment procedures and evaluation criteria were applied at both pre-test and post-test.

Statistical analysis

All statistical analyses were performed using SPSS version 26.0. The normality of continuous variables, including age, GPA, theoretical knowledge scores, and procedural skills scores, was assessed using the Shapiro–Wilk test. As these variables showed an approximately normal distribution ($p > 0.05$), parametric tests were used for subsequent analyses. Baseline differences between groups were assessed using the chi-square test for categorical variables (sex and marital status) and the independent-samples t-test for continuous variables (age and GPA). To evaluate intervention effects while controlling for baseline differences, analysis of covariance (ANCOVA) was used for post-

intervention scores, with baseline values as covariates. Effect sizes were calculated using partial eta squared (η^2). A p-value < 0.05 was considered statistically significant. In an additional analysis, changes in theoretical knowledge and procedural skills were examined according to academic semester, including the main effects of group and semester and their interaction.

Results

Demographic information

Baseline characteristics of the participants are presented in Table 1. No statistically significant differences were observed between the control and intervention groups in terms of sex ($p = 0.493$), marital status ($p = 0.967$), age ($p = 0.445$), or GPA ($p = 0.552$). These findings indicate that the groups were comparable with respect to the assessed baseline characteristics.

Table 1
Baseline characteristics of the study groups

Variable	control (N = 26)	Intervention (N = 25)	*p*-value
Sex%, n			
Male	65.4% (17)	56% (14)	0.493
Female	34.6% (9)	44% (11)	
Marital status%, n			
Single	7.7% (2)	8.0% (2)	0.967
Married	92.3% (24)	92.0% (23)	
Age, mean ± SD	23.73 ± 0.69	22.48 ± 0.52	0.445
GPA, mean ± SD	16.89 ± 0.48	16.33 ± 0.88	0.552

Theoretical knowledge outcomes

Baseline theoretical knowledge scores were comparable between the intervention and control groups, with mean pre-test MCQ scores of 8.66 ± 1.54 and 8.63 ± 2.18, respectively. Following the intervention, mean post-test scores increased to 15.74 ± 2.03 in the intervention group and 10.35 ± 1.85 in the control group. Paired-samples t-tests demonstrated significant improvements in theoretical knowledge in both groups. The mean increase was 7.08 points in the intervention group ($t = 13.005$, $p < 0.001$) and 1.72 points in the control group ($t = 2.799$, $p = 0.010$) (Table 2). The improvement in MCQ scores was significantly greater in the intervention group than in the control group, with a mean between-group difference of − 4.96 points (95% CI: −6.49 to − 3.42; $t(49) = - 6.488$, $p < 0.001$) (Table 3). ANCOVA was subsequently performed to compare post-test MCQ scores while controlling for baseline scores. The assumption of homogeneity of regression slopes was met, as the group × pre-test interaction was not

significant (F = 0.001, p = 0.978). After adjustment for baseline scores, a statistically significant group effect was observed (F = 4.787, p = 0.034, partial η^2 = 0.092) (Table 3).

Table 2
Summary of theoretical knowledge outcomes

Group	Pre-test (mean ± SD)	Post-test (mean ± SD)	mean change	*t*-value	*p*-value
control (N = 26)	8.63 ± 2.18	10.35 ± 1.85	1.72	2.799	0.010
Intervention (N = 25)	8.66 ± 1.54	15.74 ± 2.03	7.08	13.005	< 0.001

Table 3
Summary of theoretical knowledge outcomes

Analysis	Test statistic	*p*-value	95% CI	*Partial η²*
Difference in change scores	t(49) = − 6.488	< 0.001	−6.49 to − 3.42	
ANCOVA, group effect	F = 4.787	0.034		0.092

Procedural skills outcomes

Both the intervention and control groups showed significant improvements across all ten procedural skills following the educational program (all $p < 0.05$). The intervention group consistently showed greater improvements than the control group across the ten assessed procedural skills. The greatest improvements in the intervention group were observed in suturing (50.68 ± 4.93 to 84.12 ± 4.90; $t = 24.763$, $p < 0.001$), operating table preparation (57.84 ± 8.44 to 103.40 ± 7.82; $t = 18.302$, $p < 0.001$), and electrosurgical plate placement (50.32 ± 5.37 to 68.96 ± 4.72; $t = 18.490$, $p < 0.001$). In the control group, improvements were also significant but smaller, particularly in suturing (47.73 ± 5.56 to 63.03 ± 7.43; $t = 9.336$, $p < 0.001$) and operating table preparation (60.50 ± 9.88 to 89.23 ± 5.02; $t = 13.479$, $p < 0.001$). Across all skills, the intervention group consistently achieved higher post-test scores and larger effect sizes compared with the control group, indicating that the change was consistently greater among students who received BOPPPS-based instruction than among those receiving traditional clinical education (Table 4).

Overall procedural skills outcomes

Baseline overall procedural skills scores were comparable between the intervention and control groups, with mean pre-test scores of 555.96 ± 31.53 and 547.92 ± 25.98, respectively. Following the intervention, mean post-test scores increased to 816.32 ± 34.14 in the intervention group and 689.19 ± 29.65 in the control group. Paired-samples t-tests demonstrated significant improvements in overall procedural skills in both groups. The mean increase was 260.36 points in the intervention group (t = 37.848, $p < 0.001$) and

141.26 points in the control group (t = 21.088, $p < 0.001$) (Table 5). The improvement in overall procedural skills was significantly greater in the intervention group than in the control group, with a mean between-group difference of − 119.09 points (95% CI: −138.38 to − 99.80; t (49) = − 12.404, $p < 0.001$) (Table 5). ANCOVA was subsequently performed to compare post-test procedural skills scores while controlling for baseline scores. The assumption of homogeneity of regression slopes was met, as the group × pre-test interaction was not significant (F = 0.456, $p = 0.503$). After adjustment for baseline scores, a statistically significant group effect was observed (F = 208.592, $p < 0.001$, partial $\eta^2 = 0.816$) (Table 6).

Additional analysis by semester

To examine whether changes in theoretical knowledge and procedural skills differed according to semester, a univariate analysis of score changes was performed. A significant group effect was observed for both procedural skills (F = 133.029, $p < 0.001$, partial $\eta^2 = 0.739$) and theoretical knowledge (F = 42.162, $p < 0.001$, partial $\eta^2 = 0.488$). In contrast, neither the main effect of semester nor the group × semester interaction was statistically significant for procedural skills or theoretical knowledge (all $p > 0.05$).

Discussion

This study demonstrated that the BOPPPS educational model was associated with greater improvements in both theoretical knowledge and procedural skills among operating room technology students compared with traditional instruction. Improvements were observed in overall procedural skills as well as across all ten assessed procedural skills, suggesting that the intervention supported learning across both cognitive and practical domains. The improvement in theoretical knowledge is consistent with previous studies evaluating BOPPPS in health professions education. Liu et al. reported that a BOPPPS-hybrid teaching model significantly improved academic performance and learning abilities among physiology students (18). Similarly, Fan et al. found that BOPPPS enhanced theoretical learning outcomes and practical competence among undergraduate otolaryngology students (21).

Table 4
Summary of procedural skills outcomes

procedural skills	Group	mean (± SD)		*t*-value	*p*-value
		pre-test	post-test		
Electrosurgical plate placement	control	44.57 ± 7.8	58.88 ± 4.32	11.952	< 0.001
	intervention	50.32 ± 5.37	68.96 ± 4.72	18.490	< 0.001
Operating table preparation	control	60.5 ± 9.88	89.23 ± 5.02	13.479	< 0.001
	intervention	57.84 ± 8.44	103.4 ± 7.82	18.302	< 0.001
Surgical scrubbing	control	87.65 ± 7.38	103.30 ± 12.15	10.13	< 0.001
	intervention	82.04 ± 9.93	120.48 ± 11.88	11.407	< 0.001
Sterile opening of surgical packs	control	46.57 ± 5.78	57.84 ± 7.86	6.158	< 0.001
	intervention	51.28 ± 4.53	74.28 ± 4.73	15.368	< 0.001
Suturing	control	47.73 ± 5.56	63.03 ± 7.43	9.336	< 0.001
	intervention	50.68 ± 4.93	84.12 ± 4.90	24.763	< 0.001
Surgical site preparation (skin preparation)	control	65.15 ± 14.25	85.38 ± 11.76	6.232	< 0.001
	intervention	66.88 ± 9.16	93.32 ± 16.80	6.880	< 0.001
Gowning and gloving (closed technique)	control	65.46 ± 7.36	79.42 ± 11.85	7.070	0.001
	intervention	67.64 ± 12.89	94.64 ± 13.19	7.176	< 0.001
Specimen collection, documentation, and transfer	control	40.65 ± 8.90	46.11 ± 5.29	3.800	< 0.001
	intervention	42.12 ± 9.16	54.60 ± 6.40	5.000	< 0.001
Surgical draping	control	44.96 ± 8.97	54.69 ± 9.26	5.099	< 0.001

procedural skills	Group	mean (± SD)		*t*-value	*p*-value
		pre-test	post-test		
Instrument and sponge counting	intervention	44.08 ± 7.88	62.36 ± 8.39	8.565	< 0.001
	control	42.50 ± 10.07	51.26 ± 8.42	6.866	< 0.001
	intervention	42.98 ± 8.12	55.62 ± 8.66	5.94	< 0.001

Table 5
Summary of overall procedural skills

Group	Pre-test (mean ± SD)	Post-test (mean ± SD)	Mean change	*t*-value	*p*-value
control (N = 26)	547.92 ± 25.98	689.19 ± 29.65	141.26	21.088	< 0.001
Intervention (N = 25)	555.96 ± 31.53	816.32 ± 34.14	260.36	37.848	< 0.001

Table 6
Between-group analysis of overall procedural skills

Analysis	Test statistic	*p*-value	95% CI	*Partial η²*
Difference in change scores	t(49) = − 12.404	< 0.001	−138.38 to − 99.80	
ANCOVA, group effect	F = 208.592	< 0.001		0.816

Consistent with this, Khalafi et al. reported that BOPPPS significantly improved theoretical knowledge and clinical skills among nurse anesthesia students compared with traditional teaching. (29) Evidence from recent systematic reviews has further suggested that the BOPPPS educational model is associated with improved learning performance and learner engagement across a variety of healthcare disciplines (30, 31). The consistency of these findings across different disciplines suggests that the structured sequence of BOPPPS may provide a supportive framework for organizing learning activities around explicit objectives and continuous assessment. Students in the intervention group showed greater improvements across all ten skills, and these findings are consistent with previous reports. Yang et al. reported improved clinical competence and practical performance among nursing interns receiving BOPPPS-based education in the operating room (28). Similarly, Xu et al. found that BOPPPS-based teaching improved procedural performance among students undertaking gynecology internships (25). These findings suggest that the benefits of BOPPPS may extend beyond acquisition of theoretical knowledge to the development of practical competencies in clinical learning environments, while studies conducted in general surgery and nursing education have reported improvements in skills, self-directed learning, and critical thinking following the implementation of the model. Several mechanisms may

explain these findings. The structured sequence of BOPPPS aligns learning objectives, assessment, learning activities, and feedback within a single instructional cycle. In the present intervention, students' prior knowledge was assessed before instruction, followed by participatory and scenario-based activities in which theoretical concepts were applied to simulated operating room situations. This progression may have facilitated the translation of theoretical knowledge into procedural performance rather than treating knowledge acquisition and skill development as separate learning processes. Immediate feedback during post-assessment may have further helped students identify and correct deficiencies, reinforcing both conceptual understanding and practical performance. Thus, the effectiveness observed in this study may be related not simply to increased learner participation, but to the structured integration of theoretical content, clinical application, assessment, and feedback. An important contribution of the present study is its application of the BOPPPS framework within undergraduate operating room internships while simultaneously evaluating theoretical knowledge and procedural skills. Previous studies across various healthcare disciplines and clinical settings have reported that BOPPPS-based instruction can improve skills, self-directed learning, and critical thinking, including in general surgery and nursing education (32, 33). However, evidence specifically addressing the use of BOPPPS in operating room technology student's education and its potential to connect theoretical learning with procedural skills remains limited. By assessing both domains within the same intervention, the present findings provide preliminary evidence that a structured, learner-centered framework may help bridge the theory–practice gap in operating room education. Alongside previous evidence, these findings may inform educational decision-making and contribute to the evidence base for structured, student-centered approaches to clinical education in the health professions. This study has several strengths. First, the quasi-experimental pre-test/post-test design with a control group enabled assessment of changes in both theoretical knowledge and procedural skills while accounting for baseline performance. Second, the study evaluated both cognitive and practical outcomes using structured assessment tools, including the MCQ and DOPS covering ten core operating room skills. Third, the BOPPPS intervention was delivered through a standardized and structured sequence, supporting consistency in intervention implementation. Several limitations should also be considered. The single-center setting and relatively small sample size may limit the generalizability of the findings to other educational settings. Although baseline analyses indicated no statistically significant differences in the assessed characteristics between the two academic semesters, differences in prior clinical exposure and educational experience may still have influenced the learning process. In addition, differences in the baseline difficulty and complexity of the assessed procedural skills may have influenced the magnitude of improvement across individual competencies. Finally, the absence of long-term follow-up prevented assessment of whether the observed improvements in theoretical knowledge and procedural skills were sustained over time. Future research should evaluate the BOPPPS model in larger, multicenter populations to enhance the generalizability of the findings. Longer-term follow-up is also warranted to determine whether improvements in theoretical knowledge and procedural skills are retained beyond the immediate post-intervention period. Qualitative or mixed-methods studies could further explore students' and instructors' experiences, as well as the facilitators and barriers to implementing BOPPPS in clinical education settings.

Conclusions

BOPPPS-based clinical education was associated with greater improvements in theoretical knowledge and procedural skills among undergraduate operating room technology students compared with traditional clinical instruction. The findings suggest that a structured, learner-centered approach incorporating active participation and feedback may support learning across both theoretical and procedural domains during operating room internships. Further multicenter studies with larger samples and longer follow-up are needed to assess the generalizability and longer-term sustainability of these findings.

Declarations

Ethical Considerations

All methods were performed in accordance with the Declaration of Helsinki. The study was approved by the Ethics Committee of Alborz University of Medical Sciences, Alborz University of Medical Sciences [IR.ABZUMS.REC.1404.240]. Written informed consent was obtained from all participants before enrolment. Participation was voluntary and had no effect on students' academic evaluation or course grades. All data were collected anonymously.

Consent for publication

Not applicable.

Competing interest

The authors declare that they have no competing interests.

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Author Contribution

Mohammad Mahdi KohanTorabi: Conceptualization, methodology, study design, investigation, data curation, interpretation of results, writing – original draft, writing – review and editing, and project administration.Mahmoud Kohan: Conceptualization, methodology, supervision, investigation, validation of the study procedures and assessment instruments, interpretation of findings, and writing – review and editing.Rana Abjar: Supervision, validation, critical review of the manuscript, and writing – review and editing.

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Data Availability

The datasets used during the current study are available from the corresponding author on reasonable request.

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Figures

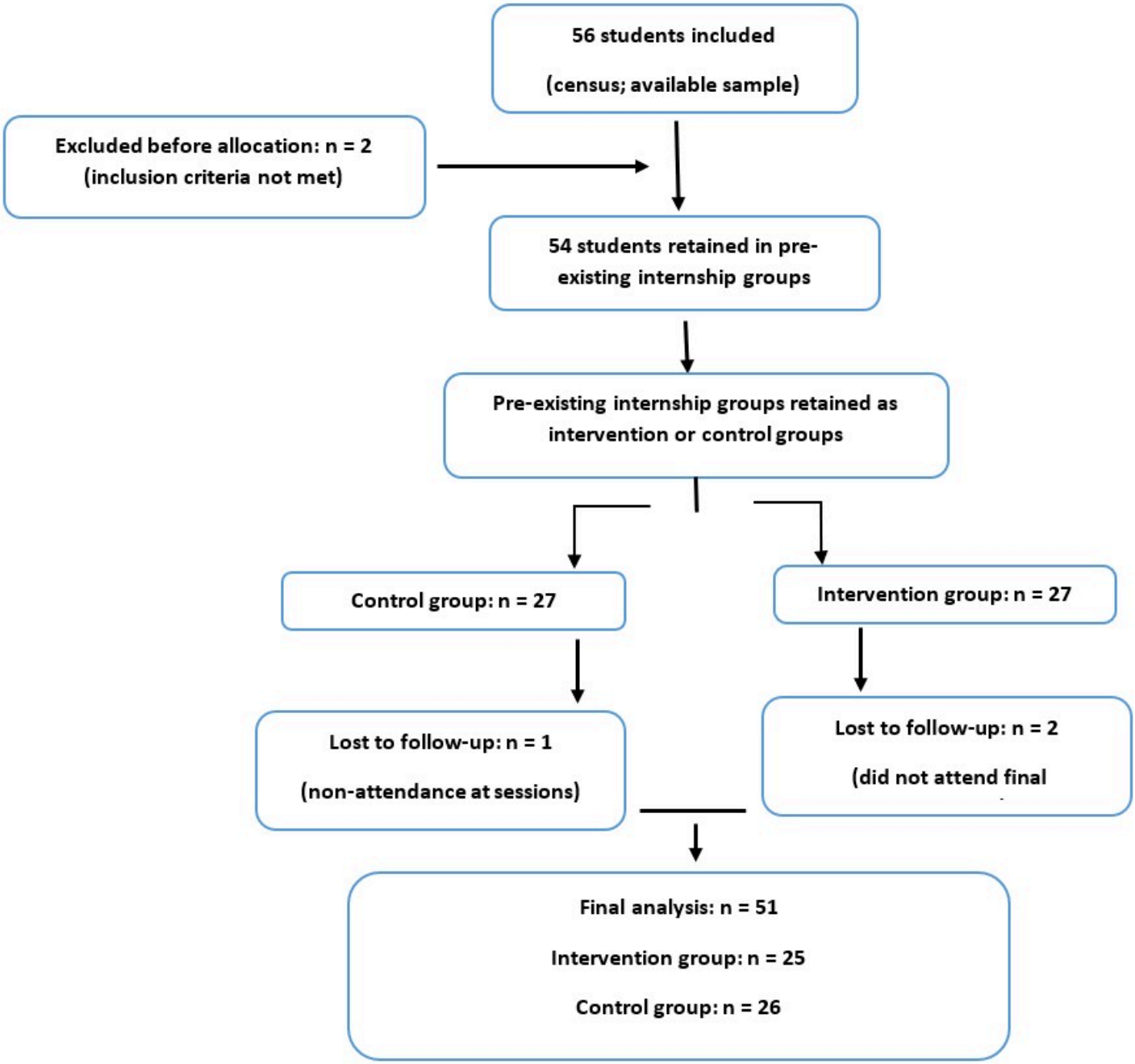


Figure 1

Participant Flow Diagram

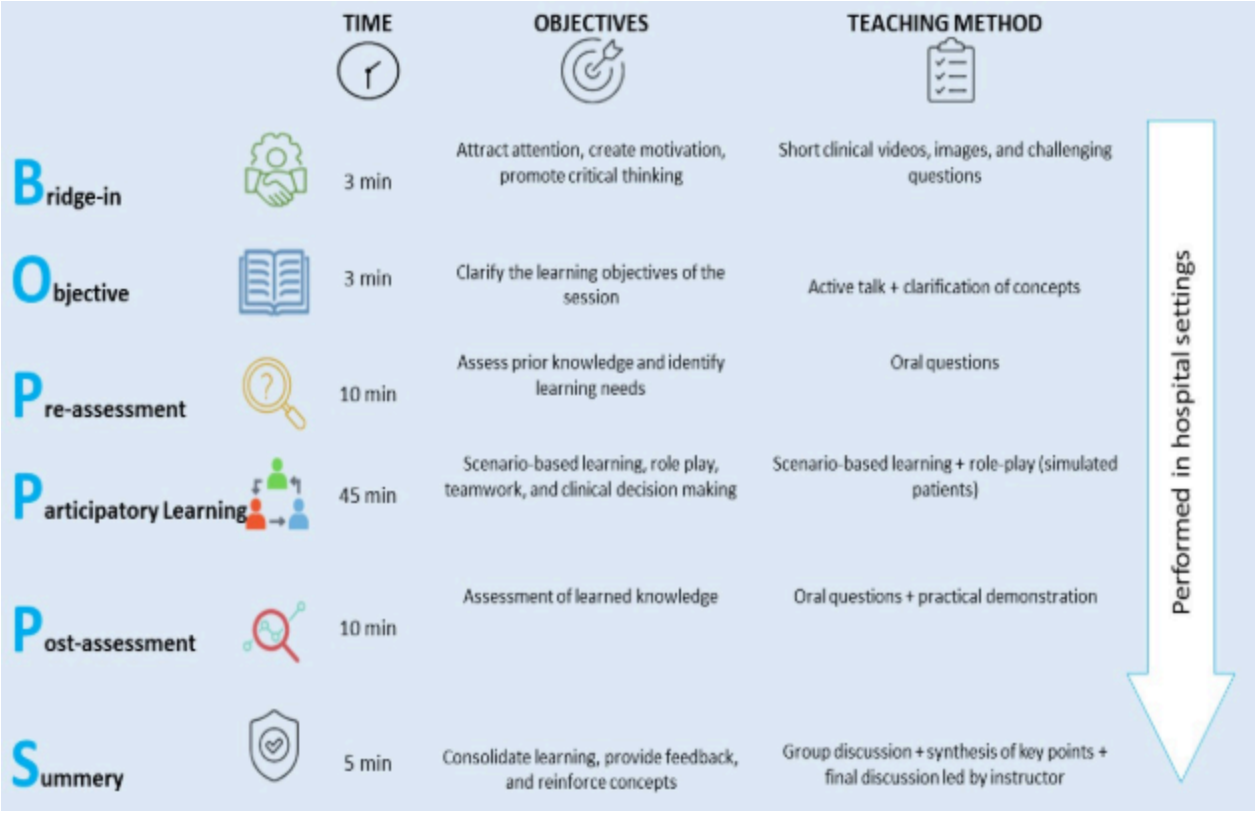


Figure 2

Flow chart of BOPPPS session implementation Process

Supplementary Files

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- SupplementaryMaterial2.docx
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