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Original Research Article

TRANSFORMATIONAL LEARNING STRATEGIES IN OPERATIVE DENTISTRY AND ENDODONTICS: IMPACT ON CLINICAL REASONING AND STUDENT LEARNING EXPERIENCE

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ABSTRACT

Background: Clinical reasoning is an essential competency in operative dentistry and endodontics, where undergraduate dental students must integrate diagnostic findings, radiographic interpretation, treatment planning, procedural risks, and patient-centred decision-making. Traditional teaching methods may not fully develop higher-order reasoning and reflective judgment. Transformational learning strategies, including case-based discussion, simulation, reflection, peer-assisted learning, and structured feedback, may improve students' clinical reasoning and learning experience. The Objective is to evaluate the impact of transformational learning strategies on clinical reasoning and student learning experience among undergraduate BDS students in operative dentistry and endodontics.

Materials and Methods: This quasi-experimental pre–post educational study was conducted at de'Montmorency College of Dentistry Lahore, Pakistan from August 2025 to January 2026. A total of 120 undergraduate BDS students were included. The intervention consisted of structured case-based discussions, endodontic diagnostic scenarios, operative treatment-planning exercises, reflective writing, peer-assisted discussion, simulation-based procedural reasoning, and facilitator-led feedback. Clinical reasoning was assessed before and after the intervention across domains including diagnostic hypothesis generation, treatment planning, evidence-based justification, risk recognition, reflective reasoning, and collaborative decision-making. Student learning experience was assessed using a five-point Likert-scale questionnaire. Data were analyzed using SPSS, and a p-value of ≤0.05 was considered statistically significant.

Results: The mean age of participants was 22.48 ± 1.31 years, and most were female 73 (60.8%) and final-year BDS students 62 (51.7%). The overall clinical reasoning score significantly increased from 58.7 ± 9.6 before the intervention to 75.9 ± 8.4 after the intervention, with a mean improvement of 17.2 points (95% CI: 15.4–19.0; $p < 0.001$). Significant improvement was observed in all clinical reasoning domains, including diagnostic hypothesis generation, treatment planning, evidence-based justification, risk recognition, and reflective reasoning. Most students reported a favourable learning experience, with 101 (84.2%) agreeing that the strategy helped link theory with clinical practice, 98 (81.7%) reporting improved diagnostic reasoning, and 108 (90.0%) recommending regular use of this strategy in operative dentistry and endodontics. High post-intervention clinical reasoning scores were significantly associated with final-year academic status, higher CGPA, previous simulation-based training, and high session engagement.

Conclusion: Transformational learning strategies significantly improved clinical reasoning and produced a positive learning experience among

undergraduate BDS students in operative dentistry and endodontics. Incorporating case-based learning, simulation, reflection, peer discussion, and facilitator feedback into dental curricula may strengthen diagnostic reasoning, treatment planning, reflective judgment, and clinical decision-making.
Keywords: Clinical Reasoning, Dental Education, Endodontics, Operative Dentistry, Problem-Based Learning.

INTRODUCTION

Clinical reasoning is a core competency in dental education because undergraduate students must integrate biomedical knowledge, patient history, clinical findings, radiographic interpretation, procedural risk, material selection, and patient-centred treatment planning before performing operative and endodontic procedures. In contemporary health professions education, clinical reasoning is no longer viewed as simple diagnostic recall; rather, it is a dynamic process through which learners gather, prioritize, interpret, and apply information to make safe clinical decisions.[1] Consensus recommendations on undergraduate clinical reasoning curricula also emphasize that learners should be explicitly taught diagnostic reasoning, uncertainty management, cognitive bias recognition, patient safety, communication, and reflection rather than being expected to acquire these skills passively during clinical exposure.[2]

Operative dentistry and endodontics are particularly suitable disciplines for structured clinical reasoning training. Students are required to identify carious, pulpal, periapical, periodontal, and restorative factors; select appropriate investigations; judge risks such as pulp exposure, perforation, missed canals, postoperative pain, and restoration failure; and justify treatment options using evidence-based principles. In Pakistan, a national cross-sectional study reported that dental students and new graduates perceived deficiencies in several clinical and soft-skill domains, including endodontic preparedness and evidence-based decision-making, indicating the need for stronger educational strategies that bridge preclinical learning with supervised clinical practice.[3] Similarly, Ahmed et al. found measurable variation in diagnostic thinking among Pakistani dental students, supporting the need for structured clinical reasoning approaches within undergraduate dental curricula.[4]

Traditional lecture-based teaching remains useful for delivering foundational knowledge; however, it may be insufficient for developing higher-order reasoning, reflective judgment, and confidence in complex clinical situations. A systematic review and meta-analysis by Pang et al. showed that emerging teaching models, including problem-based learning, case-based learning, team-based learning, and flipped classrooms, can improve dental education outcomes compared with conventional lecture-based teaching.[5] In operative dentistry, Khattak et al. demonstrated that case-based learning improved students' confidence and performance in cavity preparation by allowing them to apply theoretical concepts to clinical scenarios, discuss treatment rationale, and receive structured feedback.[6] Simulation-based learning has also gained importance in endodontics, where Ba-Hattab et al. reported that virtual reality simulation positively influenced undergraduate students' endodontic learning experience by providing a safe environment for repeated practice before patient care.[7]

Reflective learning is another important component of transformational education. It encourages students to analyse clinical errors, recognize gaps in understanding, and develop self-regulated learning habits. Campbell et al. highlighted that reflective practice in dentistry can support professional development, self-awareness, and deeper learning when it is structured and supported by feedback.[8] Case-based and reflective approaches are also increasingly being applied across dental specialties. Shafique et al. reported favourable undergraduate dental student experiences with case-based learning in orthodontic education, suggesting that clinically contextualized learning can enhance student engagement and perceived relevance of theoretical knowledge.[9] Meanwhile, global endodontic education data suggest that undergraduate endodontic training varies widely across institutions, reinforcing the need for adaptable, competency-oriented strategies that can improve clinical preparedness despite differences in resources and case exposure.[10]

Transformational learning strategies combine these educational principles by moving students from passive information reception to active interpretation, discussion, simulation, reflection, and feedback-guided improvement. In operative dentistry and endodontics, such strategies may help students understand why a treatment decision is appropriate, not only how a procedure is performed. They may also strengthen diagnostic hypothesis generation, treatment planning, evidence-based justification, risk recognition, reflective reasoning, and collaborative decision-making.

In Pakistan, undergraduate BDS education is expanding rapidly, but variability in clinical exposure, faculty feedback, simulation resources, and structured reasoning training remains a concern. Operative dentistry and endodontics require precise decision-making because errors in diagnosis, access preparation, treatment planning, and procedural risk assessment can directly affect patient safety and treatment outcomes. Although active learning approaches are increasingly discussed in dental education, local evidence regarding transformational learning strategies in operative dentistry and

endodontics remains limited. Therefore, the present study was designed to evaluate the impact of structured transformational learning strategies on clinical reasoning and student learning experience among undergraduate BDS students, with the aim of generating context-specific evidence to support curriculum improvement in Pakistani dental institutions.

MATERIALS AND METHODS

This quasi-experimental pre–post educational study was conducted at de'Montmorency College of Dentistry Lahore, Pakistan from August 2025 to January 2026. The study included undergraduate Bachelor of Dental Surgery students who were actively enrolled in clinical or pre-clinical operative dentistry and endodontics rotations during the study period. A total sample size of 120 students was selected. Students who provided informed consent and completed both pre- and post-intervention assessments were included, whereas students who were absent from more than one learning session, submitted incomplete questionnaires, or declined participation were excluded from the final analysis.

The educational intervention was designed around transformational learning principles, with emphasis on critical reflection, clinical problem-solving, structured dialogue, and application of knowledge to authentic clinical scenarios. The learning package included case-based discussions, endodontic diagnostic scenarios, operative treatment planning exercises, reflective writing, peer-assisted discussion, simulation-based procedural reasoning, and facilitator-led feedback. Cases were developed from commonly encountered Pakistani tertiary care dental presentations, including deep carious lesions, reversible and irreversible pulpitis, periapical pathology, failed restorations, access cavity planning, rubber dam decision-making, caries risk assessment, and complications during endodontic treatment. Each session required students to identify key clinical findings, generate diagnostic hypotheses, justify radiographic and clinical decisions, select treatment options, and reflect on potential errors or patient-safety concerns.

Before the intervention, all participants completed a structured demographic form, a baseline clinical reasoning assessment, and a student learning experience questionnaire. The clinical reasoning assessment included domains related to diagnostic hypothesis generation, treatment planning, evidence-based justification, patient-safety risk recognition, reflective reasoning, and collaborative decision-making. The student learning experience questionnaire used a five-point Likert scale and assessed perceived engagement, relevance to clinical practice, confidence, feedback quality, reflective learning, and peer-assisted learning. The questionnaire was reviewed by subject experts in operative dentistry, endodontics, dental education, and medical education research to establish content validity. A pilot test was conducted among students not included in the final sample to assess clarity, comprehension, and approximate completion time.

The intervention was delivered over structured teaching sessions during the routine academic schedule. Faculty facilitators used standardized case templates to reduce variation in delivery. Students worked in small groups and presented diagnostic and treatment-planning decisions, followed by guided discussion and feedback. Reflective prompts were used after each case to encourage students to reconsider assumptions, compare alternative diagnoses, and identify gaps in reasoning. Post-intervention assessments were conducted after completion of the learning sessions using the same clinical reasoning framework and learning experience scale.

Data were entered and analyzed using IBM SPSS Statistics. Continuous variables, including age and clinical reasoning scores, were reported as mean and standard deviation. Categorical variables, including gender, academic year, domicile, baseline educational exposure, and student responses, were reported as frequencies and percentages. Pre- and post-intervention clinical reasoning scores were compared using the paired-sample t-test after assessment of normality. Chi-square test or Fisher's exact test was applied to assess associations between categorical variables and high post-intervention clinical reasoning performance. Pearson correlation analysis was used to determine the relationship between learning experience domains and clinical reasoning gain. A p-value of ≤ 0.05 was considered statistically significant. The internal consistency of the study tools was assessed using Cronbach's alpha, with values above 0.70 considered acceptable for educational research.

RESULTS

A total of 120 undergraduate BDS students completed both pre- and post-intervention assessments and were included in the final analysis. The mean age of participants was 22.48 ± 1.31 years. Most participants were female 73 (60.8%), belonged to the final year 62 (51.7%), and were from urban backgrounds 76 (63.3%). The demographic profile of the study participants is presented in [Table 1].

Table 1: Demographic characteristics of undergraduate BDS students included in the study

Variable	Category	Frequency (n)	Percentage (%)
Age group	≤21 years	36	30.0
	22–23 years	61	50.8
	≥24 years	23	19.2

Gender	Male	47	39.2
	Female	73	60.8
Academic year	Third year BDS	58	48.3
	Final year BDS	62	51.7
Domicile	Urban	76	63.3
	Rural	44	36.7
Residence	Day scholar	65	54.2
	Hostel resident	55	45.8
Previous exposure to case-based learning	Yes	49	40.8
	No	71	59.2

Most students had moderate baseline academic performance, with 57 (47.5%) reporting a CGPA between 3.00 and 3.49. Prior formal exposure to reflective portfolios was reported by 38 (31.7%) students, while 52 (43.3%) had previous simulation-based operative or endodontic training. Baseline educational characteristics are shown in [Table 2].

Table 2: Baseline academic and educational characteristics of participants

Variable	Category	Frequency (n)	Percentage (%)
CGPA category	<3.00	28	23.3
	3.00–3.49	57	47.5
	≥3.50	35	29.2
Previous simulation-based training	Yes	52	43.3
	No	68	56.7
Previous reflective portfolio use	Yes	38	31.7
	No	82	68.3
Self-rated confidence in clinical reasoning at baseline	Low	34	28.3
	Moderate	67	55.8
	High	19	15.8
Preferred learning method before intervention	Traditional lecture	46	38.3
	Case-based discussion	39	32.5
	Simulation/practical demonstration	35	29.2

The internal consistency of the clinical reasoning assessment tool was high, with Cronbach's alpha of 0.88. The student learning experience scale also showed excellent reliability, with Cronbach's alpha of 0.91. After implementation of transformational learning strategies, the overall clinical reasoning score increased from 58.7 ± 9.6 at baseline to 75.9 ± 8.4 after the intervention, with a mean improvement of 17.2 points (95% CI: 15.4–19.0; $p < 0.001$). Significant improvements were observed across all assessed domains, including diagnostic hypothesis generation, treatment planning, evidence-based justification, risk recognition, reflective reasoning, and collaborative decision-making. These findings are presented in [Table 3].

Table 3: Pre- and post-intervention comparison of clinical reasoning scores

Clinical reasoning domain	Pre-intervention Mean ± SD	Post-intervention Mean ± SD	Mean difference	95% CI	p-value
Diagnostic hypothesis generation	11.4 ± 3.0	15.3 ± 2.5	3.9	3.3–4.5	<0.001
Treatment planning	10.8 ± 2.8	15.1 ± 2.4	4.3	3.7–4.9	<0.001
Evidence-based justification	11.6 ± 2.7	15.5 ± 2.2	3.9	3.4–4.4	<0.001
Risk recognition and patient safety	12.1 ± 2.6	15.8 ± 2.1	3.7	3.1–4.3	<0.001
Reflective reasoning	12.8 ± 2.9	14.2 ± 2.3	1.4	0.9–1.9	<0.001
Overall clinical reasoning score	58.7 ± 9.6	75.9 ± 8.4	17.2	15.4–19.0	<0.001

Student learning experience improved substantially after the intervention. Most students agreed or strongly agreed that transformational learning strategies improved their ability to link theoretical concepts with operative and endodontic clinical scenarios 101 (84.2%), enhanced diagnostic confidence 96 (80.0%), promoted reflective thinking 99 (82.5%), and made learning more interactive 106 (88.3%). Student perceptions of learning experience are summarized in [Table 4].

Table 4: Student learning experience after transformational learning intervention

Statement	Agree/Strongly agree n (%)	Neutral n (%)	Disagree/Strongly disagree n (%)
The strategy helped me link theory with clinical practice	101 (84.2)	13 (10.8)	6 (5.0)
Case discussions improved my diagnostic reasoning	98 (81.7)	15 (12.5)	7 (5.8)
Reflective activities improved my understanding of clinical errors	99 (82.5)	14 (11.7)	7 (5.8)
Simulation improved my confidence in operative/endodontic planning	96 (80.0)	17 (14.2)	7 (5.8)
Group discussion improved peer-assisted learning	103 (85.8)	11 (9.2)	6 (5.0)
Feedback from facilitators improved my clinical decision-	100 (83.3)	14 (11.7)	6 (5.0)

making			
The learning sessions were more engaging than traditional lectures	106 (88.3)	9 (7.5)	5 (4.2)
I would recommend regular use of this strategy in operative dentistry and endodontics	108 (90.0)	8 (6.7)	4 (3.3)

When post-intervention outcomes were categorized, 82 (68.3%) students achieved a high clinical reasoning score, defined as ≥75 out of 100. High post-intervention reasoning performance was more frequent among final-year students, those with previous simulation-based training, students with CGPA ≥3.50, and those reporting high engagement during sessions. The association between participant characteristics and high clinical reasoning achievement is shown in [Table 5].

Table 5: Factors associated with high post-intervention clinical reasoning score

Variable	Category	High score n/N (%)	p-value
Gender	Male	30/47 (63.8)	0.392
	Female	52/73 (71.2)	
Academic year	Third year	34/58 (58.6)	0.028
	Final year	48/62 (77.4)	
CGPA	<3.00	14/28 (50.0)	0.006
	3.00–3.49	39/57 (68.4)	
	≥3.50	29/35 (82.9)	
Previous simulation-based training	Yes	42/52 (80.8)	0.011
	No	40/68 (58.8)	
Previous case-based learning exposure	Yes	38/49 (77.6)	0.092
	No	44/71 (62.0)	
High session engagement	Yes	59/72 (81.9)	<0.001
	No/moderate	23/48 (47.9)	

Correlation analysis demonstrated a positive relationship between improvement in clinical reasoning and student learning experience domains. The strongest correlations were observed for perceived improvement in diagnostic reasoning, facilitator feedback, and reflective learning. These findings are presented in [Table 6].

Table 6: Correlation between learning experience domains and clinical reasoning gain

Learning experience domain	Pearson r	p-value
Perceived improvement in diagnostic reasoning	0.61	<0.001
Quality of facilitator feedback	0.57	<0.001
Reflective learning engagement	0.54	<0.001
Peer-assisted learning	0.48	<0.001
Simulation-based confidence	0.52	<0.001
Overall learning experience score	0.66	<0.001

Overall, transformational learning strategies in operative dentistry and endodontics were associated with a significant improvement in clinical reasoning and a favourable student learning experience. The improvement was not limited to knowledge recall but extended to diagnostic reasoning, treatment planning, reflective judgement, and clinical decision-making, suggesting that structured case-based, simulation-supported, reflective, and feedback-oriented teaching may strengthen higher-order learning among undergraduate dental students.

DISCUSSION

The present study demonstrated a significant improvement in undergraduate BDS students' clinical reasoning after implementation of transformational learning strategies in operative dentistry and endodontics. The overall clinical reasoning score increased from 58.7 ± 9.6 to 75.9 ± 8.4, with a mean gain of 17.2 points, indicating that the intervention strengthened not only factual understanding but also diagnostic hypothesis generation, treatment planning, evidence-based justification, risk recognition, reflective reasoning, and collaborative decision-making. This finding is consistent with Ijaz et al., who reported that both WhatsApp-based and face-to-face case-based learning improved undergraduate dental students' learning outcomes in Pakistan, suggesting that structured clinical cases can support reasoning even when delivered through different learning interfaces.[11]

The improvement observed in diagnostic reasoning and treatment planning is also supported by Abdel-Wahed et al., who found that integrating role play into case-based learning enhanced critical thinking and teamwork among dental students.[12] Similarly, Rao et al. reported that a hybrid model combining case-based learning, simulated clinical encounters, and simulator practice produced better clinical thinking and communication outcomes than lecture-based learning in dental education.[13] These studies support the present finding that students learn clinical decision-making more effectively when

cases are discussed actively, simulated realistically, and followed by facilitator feedback.

In the current study, learning experience was highly favourable, with 84.2% of students reporting better linkage of theory with practice, 81.7% reporting improved diagnostic reasoning, and 90.0% recommending regular use of the strategy. These findings align with Huang et al., who found that a blended model incorporating problem-based learning, case-based learning, and seminar teaching improved chairside operative dentistry and endodontics teaching quality and students' subjective evaluations.[14] Yuetqi et al. similarly reported positive student perceptions of hybrid team-based and case-based learning in undergraduate endodontics education, particularly in perceived effectiveness, team interaction, and learning environment.[15]

Simulation appeared particularly relevant to students' confidence and clinical reasoning achievement. In this study, students with previous simulation-based training were more likely to achieve high post-intervention reasoning scores than those without such exposure. This is comparable to Heidaridarani et al., who reported that virtual reality simulation improved competence in preclinical operative dentistry and may serve as a useful supplement to conventional teaching.[16] These findings suggest that simulation may prepare students to analyse clinical problems before real patient encounters, especially in procedures requiring visual-spatial judgment and risk anticipation.

Reflective learning also contributed meaningfully. Although reflective reasoning showed a smaller mean gain than diagnostic and treatment-planning domains, it remained statistically significant. Genaro et al. reported that critical-reflective self-assessment can help dentistry students analyse clinical activities and identify learning needs, supporting the role of structured reflection in competency development.[17] The positive correlations in the present study between clinical reasoning gain and reflective learning engagement, facilitator feedback, and diagnostic reasoning further indicate that students benefit when learning activities are accompanied by feedback and self-assessment. Li et al. also found that senior dental students generally valued blended learning, although engagement remained an area requiring deliberate instructional design.[18]

Academic year, CGPA, previous simulation exposure, and high session engagement were significantly associated with high post-intervention clinical reasoning scores. This suggests that transformational strategies may be most effective when students already possess sufficient foundational knowledge and actively engage with learning tasks. Surti et al. highlighted the relevance of cognitive psychology principles in teaching from the perspective of undergraduate medical and dental students, supporting the need to design teaching around attention, retrieval, feedback, and application rather than content delivery alone.[19] Burgess et al. also emphasized that team-based and case-based learning can scaffold knowledge and skills by requiring learners to prepare, discuss, apply, and justify decisions.[20]

The findings also have implications for endodontic education, where students commonly report difficulty with procedural steps and decision-making. Almutairi et al. identified several challenges faced by undergraduate students during endodontic procedures, supporting the need for preparatory strategies that improve confidence before independent clinical work.[21] Wang et al. further showed that case-based learning improved dental students' diagnostic decision-making compared with lecture-based learning in dental fluorosis assessment, reinforcing the broader value of case-based reasoning in dental diagnosis.[22]

This study has some limitations. The pre–post design without a parallel control group limits causal inference, and outcomes were assessed over a relatively short educational period. Student learning experience was self-reported, which may introduce response bias. However, the use of reliable assessment tools, statistically significant domain-wise improvements, and correlation between learning experience and reasoning gain strengthen the findings. Overall, the results suggest that transformational learning strategies can be feasibly incorporated into operative dentistry and endodontics teaching in Pakistani BDS programs to enhance clinical reasoning, reflective judgment, and student engagement.

CONCLUSION

Transformational learning strategies were effective in improving clinical reasoning and student engagement in operative dentistry and endodontics. The findings suggest that structured case-based discussions, simulation, reflective learning, peer-assisted activities, and facilitator feedback can help undergraduate dental students connect theoretical knowledge with real clinical decision-making. Regular integration of these strategies into BDS teaching may enhance students' confidence, diagnostic ability, treatment-planning skills, and preparedness for safe clinical practice.

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