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ORIGINAL RESEARCH

Enhancing Practical Skills in Medical Education: Evaluating the Efficacy of Virtual Simulation Teaching Through Kolb's Experiential Learning Model

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Objective: This study examines the efficacy of virtual simulation pedagogy grounded in Kolb's experiential learning model to enhance clinical practice skills and learning experiences among medical undergraduates.
Methods: A cohort of 527 medical undergraduates were randomly assigned to a traditional teaching group (N = 264) or a virtual simulation teaching group based on Kolb's experiential learning model (N = 263). Comparative analysis was conducted through practical skill assessments, self-evaluations, and course satisfaction surveys.
Results: The results demonstrated that the virtual simulation teaching group based on Kolb's experiential learning model significantly outperformed the traditional teaching group in both practical skills and self-assessment (P<0.01). In addition, this group shows significantly high levels of course satisfaction.
Conclusion: Virtual simulation teaching based on Kolb's experiential learning model effectively enhances medical undergraduate practical competencies and learning motivation, providing a viable approach for optimizing medical education methodologies.
Keywords: Kolb's experiential learning model, virtual simulation teaching, medical education, practical skills

Introduction

With the ongoing advancement of medical education, cultivating clinical competencies in undergraduate students has become a central focus of pedagogical reform. Traditional teaching models, constrained by limited clinical scenarios and insufficient hands-on practice opportunities, increasingly struggle to meet the complex demands of modern medical training.[1,2] This gap is particularly evident in Basic Life Support (BLS) instruction—a critical skill set for medical students, as proficiency in BLS has been shown to improve out-of-hospital cardiac arrest survival rates and reduce secondary neurological complications when applied in clinical settings.[3]

Current traditional BLS teaching methods have three key limitations. First, traditional training methods result in significant skill decay over time, particularly for procedural operations.[4,5] Second, training often fails to replicate real emergency dynamics, hindering skill transfer to clinical practice.[6–8] Third, feedback mechanisms lack real-time assessment, impeding correction of critical technique flaws.[9]

In this context, virtual simulation emerges as an innovative solution, overcoming traditional training challenges through high-fidelity scenarios, interactive features, and unlimited repeatability.[10,11] By enabling risk-free immersive practice with real-time performance feedback, this technology bridges the gap between static traditional teaching and dynamic clinical realities. Notably, Kolb's experiential learning model provides a robust theoretical framework for such simulations in BLS training—our study systematically integrates this framework with dynamic scenario-based training, differing from prior research that focused on single-stage simulation or isolated skill drills. The approach leverages the model's four-stage cycle: concrete experience via immersive simulation, reflective observation with real-time feedback, abstract conceptualization for knowledge synthesis, and adaptive repetitive training for active experimentation. This

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integrated design helps address existing gaps in the literature, particularly regarding the insufficient investigation of procedural skill retention and analysis of multi-dimensional learner satisfaction.

As an initial application of this cyclical framework to BLS virtual simulation training, our study seeks to comprehensively evaluate its impact on clinical skill acquisition, procedural proficiency, and learner satisfaction within an integrated assessment model. These findings offer preliminary insights into the interplay between theoretical knowledge and practical skill development in medical education, while also contributing empirical evidence to support the adoption of innovative pedagogical approaches. Furthermore, this research proposes a novel instructional strategy for simulation-based medical training, with potential implications for curriculum design and skill assessment.

Materials and Methods

Research Subjects

A total of 527 undergraduate students participated in BLS training conducted by the simulation medical teaching and research department as research subjects. They were divided into a traditional teaching group (control group, 264 students) and a virtual simulation teaching group based on Kolb's experiential learning model (hereafter referred to as the Kolb-vs teaching group, ie, observation group, 263 students,) which all trained in the second half of 2024. The control group received traditional teaching methods, while the observation group was taught using the virtual simulation teaching model based on Kolb's experiential learning model. Questionnaires were disseminated via Wenjuanxing, a digital platform designed for survey collection. A total of 388 valid responses were obtained, with 199 emanating from the control group and 188 from the observation group (the observation group questionnaire also includes a satisfaction survey). Data was organized and analyzed using WPS and IBM SPSS 27.0.

Survey Methods and Evaluation Indicators

Operation Examination

Organize the operation exam that strictly scores and records the same exam content for students in two groups according to the same evaluation criteria. The details is shown in Table 1.

Table 1 Guidelines for Scoring Practical Skills Operations

Items	Rules	Points
1	Confirm the safety of the environment	3
2	Tap and shout to assess patient consciousness	5
3	Activate the emergency response system, call 120, and locate an AED	5
4	Remove the patient's clothing	5
5	Correctly check the carotid pulse	5
6	Simultaneously assess for effective breathing, with a judgment time of 5–10 seconds	5
7	Place the patient in a supine position on a hard surface	5
8	Begin chest compression immediately, with proper hand positioning	6
9	Compression rate of 100–120 compression per minute	6
10	Compression depth of 5–6 cm	6
11	Clear oral and nasal obstructions	6
12	Open the airway	5

(*Continued*)

Table 1 (Continued).

Items	Rules	Points
13	Mouth-to-mouth ventilation	5
14	Ventilation tidal volume of 400–600 mL, with visible chest rise during operation	6
15	Perform CPR at a compression-to-ventilation ratio of 30:2	4
16	Complete a total of 5 cycles	4
17	Observe the patient during press	3
18	Assess for successful resuscitation after 5 cycles	4
19	Verify spontaneous breathing and pulse return, indicating resuscitation effective	4
20	Organize equipment and prepare for further life support treatment at the hospital	3
21	Demonstrate humane care and perform operations smoothly and accurately	5

Self-Assessment

Drawing from relevant studies and actual teaching practices,[12,13] self-assessment indicators were developed across four dimensions: knowledge mastery, skill mastery, application ability, and error correction ability. The same questionnaire was administered to both groups, utilizing a percentage-based scoring system (1–100 points). Higher scores reflected a more positive self-evaluation by students regarding their learning outcomes.

Course Satisfaction

Based on established research and the specific conditions of the teaching environment, course satisfaction indicators were designed.[14,15] The observation group received a questionnaire structured around three primary indicators, as outlined in Table 2. Each indicator was measured using a 5-point Likert scale (1–5), with the total score serving as a metric for overall satisfaction. Higher scores indicated greater satisfaction with the teaching process.

Kolb Virtual Simulation Teaching Method

Kolb's experiential learning cycle, proposed by American scholar David Kolb built upon the experiential learning theories of Dewey, Lewin and Piaget, is an innovative learning model which consists of four stages: concrete experience, reflective observation, abstract conceptualization, and active experimentation,[16] emphasizing the enhancement of learning outcomes through cyclical learning. Concrete experience serves as the starting point of learning, where students engage in practical activities to gain initial experience, laying the foundation for theoretical understanding. The stage of reflective observation facilitates students' critical analysis of theoretical principles and practical challenges, thereby enabling them to explore potential strategies for professional enhancement and problem resolution. Abstract conceptualization transforms experiences and reflections into systematic theoretical knowledge, enabling students to grasp

Table 2 Dimensions and Secondary Indicators of Teaching Satisfaction

Course Experience	Ability to adapt to the course pace Satisfaction with classroom atmosphere
Teaching Quality	Good communication among students Teacher-student interactions are effective The teacher is flexible and up-to-date
Learning Outcomes and Support	Ability to use learning materials for review Content with teaching resources and support Satisfaction with the course content

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underlying patterns and methodologies. Finally, active experimentation applies theory to new situations, verifying learning outcomes and solving practical problems, thereby consolidating knowledge. This model combines practice and reflection to enhance students' cognitive depth, and improve learning motivation and efficiency.

This teaching session focuses on BLS. The reference textbooks include: Clinical Skills Operation Guide for Chinese Medical Students (3rd Edition) edited by Chen Hong,[17] Practical Clinical Basic Skills Operation Standard Tutorial edited by Wang Heng and Wang Jinian.[18] Both the control and simulation groups were taught by similar teaching experience teachers, with a total teaching duration of four sessions. The teaching equipment included the Laerdal Anne half-body manikin and the SimMan 3G high-fidelity simulator (equipped with a computer and large screen display) for AED training.

Control Group

The control group received traditional teaching methods for BLS training. At first, teachers followed the curriculum standards to explain the theoretical knowledge related to BLS operations[19] and demonstrated the correct procedures. Common misconceptions and key points in BLS operations were emphasized during the instruction. Subsequently, students were divided into small groups to practice on the Laerdal Anne half-body manikins. During this process, each student performed the procedures independently while observing others' operations. Teachers provided real-time guidance to ensure that every student thoroughly understood and mastered the techniques, thereby improving their operational accuracy and clinical application skills.

Observation Group

Teachers in the observation group implemented instruction based on Kolb's experiential learning model integrated with virtual simulation, strictly adhering to the curriculum standards. Prior to the teaching session, instructors provided an overview of foundational theoretical knowledge, demonstrated procedural steps, and emphasized key points to ensure students gained a preliminary understanding of virtual simulation teaching. Subsequently, the teaching process was carried out in accordance with the Kolb-vs teaching workflow, as illustrated in Figure 1, Kolb-vs teaching consists of concrete experience (group BLS practice with Anne simulator), proactive practice, reflective observation (complex scenarios with SimMan 3G simulator for peer feedback and performance analysis), and abstract conceptualization (Q&A, theory integration, and key points summary). This cyclic framework integrates hands-on simulation with theoretical reflection to enhance medical students' practical skills in basic life support through iterative learning. The modified and designed virtual simulation cases for emergency techniques in case 2 are as follows,[20,21] as shown in Table 3 (Note: To better demonstrate clinical scenarios, in-hospital tools were used during the operation, but the procedures still followed out-of-hospital basic life support protocols).

The course focuses on helping students comprehensively master the operational skills of BLS and the underlying theoretical knowledge through Kolb's experiential learning model. During the concrete experience phase, students participate in a relatively simple case simulations to gain an intuitive understanding of the BLS operational procedures, accumulating practical experience that lays the foundation for deeper learning. In the reflective observation phase,

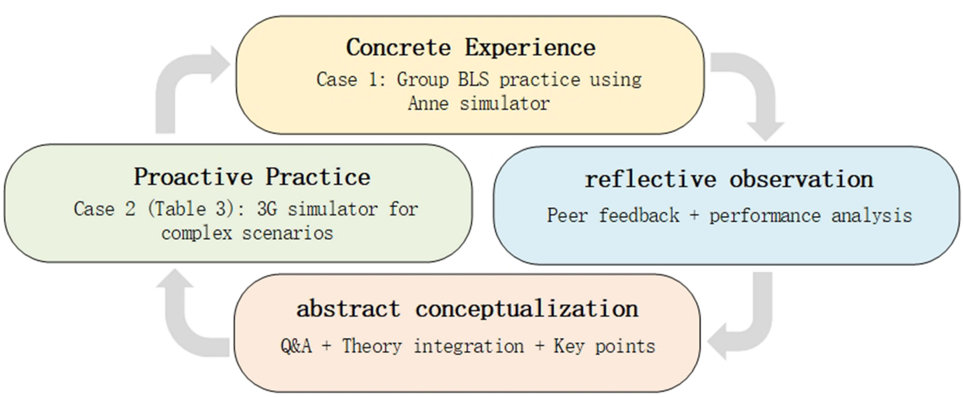

Figure 1 Kolb virtual simulation teaching process.

Table 3 Virtual Simulation Teaching Basic Life Support Cases

Scenario/ Time	Monitor Display	Patient (Simulated) Condition	Student Intervention	Instructor Action
Scenario 1: Normal	Heart Rate: 87 Respiratory Rate: 19 Blood Pressure: 128/78 Oxygen Saturation: 97% Peripheral Temperature: 36.1°C	Normal		Switch to the next state
Scenario 2: Patient Collapse	Heart Rate: 0 Respiratory Rate: None Blood Pressure: None Oxygen Saturation: Unmeasurable	Ventricular FibrillationEyelid State: Closed Right Pupil Size: Dilated Left Pupil Size: DilatedSound: Painful Screaming	Assess patient consciousness Call for help Locate AED (verbalize) Remove clothing	Prompt whether emergency medication is needed
Scenario 3: Collapsed State	Heart Rate: 0 Respiratory Rate: None Blood Pressure: None Oxygen Saturation: Unmeasurable	Ventricular FibrillationEyelid State: Closed Right Pupil Size: Dilated Left Pupil Size: DilatedCarotid Pulse: Absent	Check carotid pulse Place on a hard surfacePerform chest compressions Clear airway Maintain open airwayProvide mouth-to-mouth resuscitation Perform 5 cycles of CPR	Observe the student's performance for standardization and decide whether to switch to the next state
Scenario 3: Return to Normal	Heart Rate: 109 Respiratory Rate: 15 Blood Pressure: 127/70 Oxygen Saturation: 99% Peripheral Temperature: 36.1°C Chest Rise: 15	Normal breathing and heartbeat restored Pulse return to normal	Organize equipment provide humane care	

students review their simulation performance details, identify areas for improvement, and participate in group discussions as well as peer feedback sessions to explore issues and share solutions, thereby deepening their understanding of the principles and logic underlying the procedures. In the abstract conceptualization phase, teachers guide students to integrate practical experience with theoretical knowledge, summarizing key concepts to help students more comprehensively grasp the essential points of BLS operations and emergency response strategies. Finally, in the active experimentation phase, students apply the refined skills and theoretical knowledge to new and relatively complex virtual simulation cases, consolidating their learning outcomes through repeated practice and adjustments.[22] Throughout the teaching process, students emphasize a guided approach, avoiding one-way instruction, providing timely feedback and support to stimulate students' active learning abilities and foster teamwork awareness.

Results

Practical Exam Scores

Comparing the practical skill operation exam scores of the two groups (excluding unqualified results), the observation group demonstrated significantly higher scores than the control group, with a statistically significant difference (P <0.01).

Questionnaire Information

We distributed the questionnaires to the control group and the observation group, respectively. The questionnaire for the control group included only self-assessment, while the observation group's questionnaire contained both self-assessment and emotional evaluation. The control group yielded 199 valid responses, with a response rate of 75.4%, whereas the observation group produced 188 valid responses, with a response rate of 71.4%.

In terms of self-assessment, the data from both groups met the criteria for normal distribution, and the differences were statistically significant (P<0.01). Additionally, the questionnaire demonstrated high reliability and validity, with a Cronbach's Alpha coefficient of 0.902, a KMO value of 0.861, and Bartlett's test of sphericity yielding a value of 1003.452 (P <0.01). These results indicate that the scale is both reliable and valid.

Discussion

The observation group exhibited significantly superior performance in practical skill assessments (Table 4, t=3.33, P<0.01, d=0.29), which supports existing evidence regarding the effectiveness of virtual simulation for skill acquisition. These findings are consistent with the meta-analysis conducted by McGaghie et al, which revealed that simulation-based training combined with deliberate practice outperforms traditional methods in terms of skill retention and application.[2] Notably, the observation group demonstrated more consistent performance with lower score variability, indicating not only enhanced operational competence but also more uniform learning outcomes. This finding corroborates the results of Jabaay et al, who found that medical students trained through simulation achieved higher procedural accuracy in basic life support (BLS) tasks.[23]

These results suggest that Kolb's experiential learning model may enhance skill retention, particularly through its dual emphasis on hands-on simulation and reflective observation. This finding extends the principle established by Weller et al, which states that repetitive simulation training with timely feedback improves the mastery of emergency skills.[24]

As shown in Table 5, the observation group outperformed the control group across all four dimensions of learning outcomes, highlighting the advantages of Kolb-VS teaching in improving student learning effectiveness.

Table 4 Comparison of Final Exam Scores

Group	N	Points (Mean ± SD)
Control Group	264	87.29±6.44
Experimental Group	263	89.07±5.84
t		3.33
p		<0.01
d		0.29

Table 5 Self-Evaluation Comparison

Group	Knowledge Mastery (Mean ± SD)	Skill Proficiency (Mean ± SD)	Practical Application Ability (Mean ± SD)	Error Correction Ability (Mean ± SD)
Control Group (N=199)	92.69±6.53	92.48±6.43	92.27±6.76	92.41±7.13
Experimental Group (N=188)	94.44±6.62	94.77±6.24	94.11±6.66	94.47±6.46
t	2.62	3.56	2.70	2.96
p	<0.01	<0.01	<0.01	<0.01
d	0.27	0.36	0.27	0.30

Regarding knowledge mastery, the observation group's scores (t = 2.62, P<0.01, d=0.27) reflect the benefits of integrating theory and practice in Kolb-VS teaching. This approach enables students to more intuitively understand and grasp key concepts related to BLS, a finding that resonates with Konak et al. The study noted that Kolb's model enhances conceptual understanding through "active experimentation" in virtual environments.[16]

For skill mastery, the observation group's scores were significantly higher than those of the control group (t = 3.56, P<0.01, d=0.36). This result can be attributed to repeated simulation exercises and immediate feedback, mirroring the findings of Wijnen-Meijer et al. The research demonstrated that linking real-world cases with simulation via Kolb's cycle improves clinical reasoning.[22]

Concerning practical application ability, Kolb-VS teaching introduced dynamic scenarios (eg, transitioning from a non-responsive patient to one with restored vital signs). This allows students to make real-time decisions in emergency situations and apply theoretical knowledge flexibly in practice, thereby enhancing their application skills (t=2.70, P<0.01, d=0.27). The finding aligns with Tivener & Gloe (2015), which observed that high-fidelity simulation enhances learners' confidence in dynamic decision-making during CPR scenarios.[12]

On the aspect of error correction ability, the self-reflection and experience summary sections of Kolb-VS teaching effectively help students correct operational errors (t=2.96, P<0.01, d=0.30). This finding is corroborated by Davitadze's (2022) research.[25] The study effectively implemented Kolb's reflective observation and abstract conceptualization phases, which participants engaged in post-simulation debriefing for medical scenarios (SIMBA's Adrenal Course), systematically analyzing experiences to develop conceptual understanding and reinforce clinical competencies.

Overall, Kolb-VS teaching excels particularly in skill mastery and practical application, comprehensively improving students' practical abilities and clinical thinking.

Table 6 illustrates that the Kolb-VS approach facilitates dynamic adjustments to instructional content and pacing based on student progression, thereby overcoming the rigidity of traditional teaching models. Notably, 93.12% of students reported satisfaction with this adaptability, a finding consistent with Akella's (2016) seminal research.[26] The study emphasized that personalized learning frameworks grounded in Kolb's experiential theory significantly enhance student engagement and satisfaction by addressing diverse learning styles.

The high satisfaction ratings for classroom atmosphere further reflect the strengthened teacher-student rapport fostered by Kolb-VS teaching pedagogy. As a core strength, interactivity achieved exceptional scores in both peer-to-peer and instructor-student interactions. This finding aligns with Frenay et al,[27] which emphasized that interactive learning environments integrating experiential cycles promote collaborative communication and knowledge co-construction among learners.

The integrated support system of Kolb-VS teaching enables students to identify and address learning challenges, leading to tangible improvements in team collaboration and academic performance. Additionally, the approach receives

Table 6 Satisfaction Survey

Group	Satisfaction Distribution (%)					Points
	Very Dissatisfied	Dissatisfied	Neutral	Satisfied	Very Satisfied	
Ability to adapt to the course pace	1 (0.53%)	2 (1.06%)	10 (5.29%)	71 (37.57%)	105 (55.56%)	4.47±0.69
Satisfaction with classroom atmosphere	–	1 (0.53%)	7 (3.70%)	64 (33.86%)	117 (61.90%)	4.57±0.60
Good communication among students	–	2 (1.06%)	5 (2.65%)	56 (29.63%)	126 (66.67%)	4.62±0.59
Teacher-student interactions	-	1 (0.53%)	9 (4.76%)	50 (26.46%)	129 (68.25%)	4.62±0.60
Teacher flexibility and up-to-date	-	1 (0.53%)	9 (4.76%)	49 (25.93%)	130 (68.78%)	4.63±0.60
Ability to use learning materials	1 (0.53%)	3 (1.59%)	11 (5.82%)	73 (38.62%)	101 (53.44%)	4.43±0.71
Teaching resources and support	-	1 (0.53%)	11 (5.82%)	55 (29.10%)	122 (64.55%)	4.58±0.63
Satisfaction with course content	-	1 (0.53%)	7 (3.70%)	60 (31.75%)	121 (64.02%)	4.59±0.59

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acclaim for its resource infrastructure, including robust learning materials and logically structured course design. These elements resonate with McGaghie et al's foundational principles,[28] which underscored that effective simulation-based education relies on well-organized content and abundant resources to facilitate deep learning experiences.

Regarding student motivation, 94.71% of respondents reported satisfaction or high satisfaction with the course content. The integration of real-world scenarios and diversified teaching strategies in Kolb-VS instruction effectively ignites learning enthusiasm, building on Barrie et al's research.[29] Their study demonstrated that embedding practical, authentic examples in medical education significantly enhances student motivation and knowledge retention through contextualized learning.

Limitations and Optimization Measures

Although Kolb virtual simulation teaching has achieved positive results overall, there is still room for improvement. As shown in Table 4, the operation scores of the observation group were significantly higher than those of the control group, but the distribution of scores still showed fluctuations, and some students failed to achieve high scores. Feedback from teachers indicated that key skills such as chest compression depth, frequency, and tidal volume control during artificial respiration were the main factors contributing to score variability. Since BLS is a critical skill that every medical professional should master, the observation group's average score not exceeding 90 suggests that further refinement of skills is needed.

In Table 5, although the observation group's average score for knowledge mastery was higher than that of the control group, the difference was relatively small, and the standard deviation was large, indicating that some students remained at a superficial level of knowledge retention and struggled to integrate theory with practice. The improvement in practical application ability was only 1.84 points compared to the control group, suggesting that students still lack adaptability in dynamic or complex scenarios, particularly when facing emergencies or multitasking situations. For example, instructors noted that some students failed to quickly recognize subtle changes in patients' vital signs, which lead to miss optimal intervention opportunities.

In Table 6, despite the overall high satisfaction in emotional evaluation, certain areas require attention. Specifically, 6.88% of students rated the course pace as average or unsatisfactory, which implies that some students may not have fully adapted to this new teaching approach. Teacher-student interaction received lower ratings compared to peer interaction, indicating potential communication barriers between instructors and students. Some students perceived instructors as lacking proficiency in the new teaching method. Additionally, the utilization of learning resources was rated slightly lower than other dimensions, with 1.59% expressing dissatisfaction and 5.82% rating it as average. This reflects that some students found the content of learning materials inadequate for post-class review, limiting their ability to consolidate and understand knowledge. Furthermore, 6.35% of students rated course support and resource design as average or unsatisfactory, pointing to unmet expectations regarding resource accessibility or suitability. Lastly, 4.23% of students felt the course did not meet their expectations in terms of engagement, revealing a need for improvements in course design to better capture students' attention and stimulate interest.

To address specific issues identified in exam operations, learning outcomes, and emotional assessments, the following targeted optimization measures can be implemented:

Improve the Stability and Accuracy of Operational Performance

To reduce score fluctuations (standard deviation of 5.84), specialized training for key skills should be strengthened. For example, during the active experimentation phase, real-time feedback on compression depth and frequency can be provided through intelligent simulation devices and allow students to adjust their techniques during training. For students with weaker performance, personalized supplementary teaching plans,[30] such as additional practice time and individual tutoring, can help address skill deficiencies, ensuring high performance in both standardized and complex scenarios.

Comprehensive Improvement of Learning Outcomes

To address the limited depth and breadth of knowledge mastery (for example, only a 1.75-point increase in knowledge mastery), cases based on clinical scenarios can be multidisciplinary, such as combining emergency surgery with basic medical knowledge to strengthen the connection between theory and practice, thus strengthening the connection between theory and practice. To enhance the flexibility of application ability (only a 1.84-point increase), dynamic scenario simulations, For instance, multi-task emergency response or rapid decision-making scenarios, can be introduced to help students develop adaptability in complex or emergent situations. To improve error correction ability, self-check mechanisms can be incorporated during the reflective observation phase that allow students to independently identify and correct errors after completing operations, summarizing lessons learned to further enhance learning outcomes and practical skills.

Improving Course Engagement and Learning Resource Utilization

For the 4.23% of students who rated course interest as average or unsatisfactory, course design can be made more engaging by introducing challenge tasks, virtual patient interactions, and team competitions to attract more active participation. To enhance engagement for the 4.23% of students who rated course interest as average or unsatisfactory, the course design could incorporate challenge-based tasks, virtual patient interaction scenarios, and competitive team activities to foster active participation. Regarding the suboptimal utilization of learning resources, the optimization strategy could involve the integration of online and offline materials, supplemented with concise video tutorials and interactive learning components. The establishment of mobile friendly platforms would further improve resource accessibility and enhance the overall quality of digital materials.[25] In response to the limited resource adaptability identified by certain students, periodic surveys can be conducted to gather feedback, which would facilitate timely updates and modifications to the learning materials.

Enhancing Classroom Atmosphere and Interaction

The ratings of classroom atmosphere (4.23%) and teacher-student interaction (5.29%) could be addressed through the implementation of role-playing activities with active instructor participation. This approach would enhance both peer-to-peer and student-teacher interactions.[27] The incorporation of role assignment and task coordination training within team-based tasks would improve students' communication efficiency and task execution capabilities, thereby establishing a solid foundation for future clinical teamwork. Furthermore, teachers should dedicate additional efforts to lesson preparation, focusing on the mastery of emerging technologies and innovative teaching methodologies.

Conclusion

This study investigated the application effectiveness of an integrated approach combining Kolb's experiential learning model with virtual simulation in practical skills training for medical undergraduates. The results demonstrated that this integrated model, which merges the learning cycle of concrete experience, reflective observation, abstract conceptualization, and active experimentation with the high-fidelity and interactive features of virtual simulation technology, significantly enhanced students' practical operation performance, depth of knowledge acquisition, practical application abilities, and error correction capabilities. In particular in high-demand areas such as basic life support, the approach allowed students to integrate knowledge and skills within dynamic scenarios, thus strengthening their emergency decision-making and clinical thinking abilities.

Future research will focus on verifying the model's effectiveness for other medical skills (eg, surgical operations, clinical diagnosis) and adapting it to different student levels (junior students, interns). We will also explore its application in low-resource settings, addressing the challenge of high-cost virtual simulation technology. Longitudinal studies will track long-term skill retention and clinical performance, while multi-institutional trials will validate its effectiveness across diverse contexts. Additionally, we will optimize scenario design, develop personalized training programs with feedback mechanisms, and improve learning resources to enhance adaptability.

In conclusion, the integrated model based on Kolb's experiential learning model and virtual simulation teaching provides important theoretical guidance and practical inspiration for medical education reform. It not only significantly improves students' learning outcomes, but also lays a solid foundation for their future clinical practice. With the continuous development of technology and teaching methods, this model has broad application prospects in the field of medical education. However, in order to promote its wider application, more in-depth research is needed on its generalizability and long-term effectiveness in the future, as well as continuous optimization and improvement.

Ethics Approval and Consent to Participate

The study aligns with China's Regulations on the Management of Medical Education (2017) and the Ethical Review Measures for Biomedical Research Involving Human Subjects (2016), which permit educational innovation projects to proceed without additional ethics approval when using routine teaching methods and datanonymized assessments.

All participants (medical undergraduates) provided oral or written informed consent prior to enrollment. The consent process specifies the purpose of the research, voluntary participation, confidentiality (data anonymization).

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Disclosure

The authors declare no conflicts of interest in this work.

References

1. Nara N, Beppu M, Tohda S, Suzuki T. The introduction and effectiveness of simulation based learning in medical education. *Intern Med*. 2009;48(17):1515–1519. doi:10.2169/internalmedicine.48.2373
2. McGaghie WC, Issenberg SB, Cohen ER, Barsuk JH, Wayne DB. Does simulation-based medical education with deliberate practice yield better results than traditional clinical education? A meta-analytic comparative review of the evidence. *Acad Med*. 2011;86(6):706–711. doi:10.1097/ACM.0b013e318217e119
3. Cortés RC, Jiménez FJ, Moreno GG, París MA, Ruiz FM, Cruz AC. Impact of the forgetting curve on cognitive skills in basic life support. *JETT*. 2024;15(3):99–111.
4. Cruz AC, Caño EP, Cruz DC, Suárez IS, Piedra MÁM, Ruiz FMP. Comparative analysis of advanced and immediate life support acquisition degree. *Revista Española de Educación Médica*. 2021;2(2):101–115.
5. Saad R, Favarato MHS, de Paiva EF, Nunes MDPT. Medical student skill retention after cardiopulmonary resuscitation training: a cross-sectional simulation study. *Simulation Healthcare*. 2019;14(6):351–358. doi:10.1097/SIH.0000000000000383
6. Braslow A, Brennan RT, Newman MM, Bircher NG, Batcheller AM, Kaye W. CPR training without an instructor: development and evaluation of a video self-instructional system for effective performance of cardiopulmonary resuscitation. *Resuscitation*. 1997;34(3):207–220. doi:10.1016/S0300-9572(97)01096-4
7. Chien CY, Fang SY, Tsai LH, et al. Traditional versus blended CPR training program: a randomized controlled non-inferiority study. *Sci Rep*. 2020;10(1):10032. doi:10.1038/s41598-020-67193-1
8. Roppolo LP, Heymann R, Pepe P, et al. A randomized controlled trial comparing traditional training in cardiopulmonary resuscitation (CPR) to self-directed CPR learning in first year medical students: the two-person CPR study. *Resuscitation*. 2011;82(3):319–325. doi:10.1016/j.resuscitation.2010.10.025
9. Gu W, Yue X. The dilemma of improving teaching feedback and its reconstruction in practice. *Journal of Teacher Education*. 2024;11(4):106–113.
10. Morris TH. Experiential learning–a systematic review and revision of Kolb's model. *Interactive Learning Environ*. 2020;28(8):1064–1077. doi:10.1080/10494820.2019.1570279
11. Bergsteiner H, Avery GC, Neumann R. Kolb's experiential learning model: critique from a modelling perspective. *Stud Continuing Educ*. 2010;32(1):29–46. doi:10.1080/01580370903534355
12. Tivener KA, Gloe DS. The effect of high-fidelity cardiopulmonary resuscitation (CPR) simulation on athletic training student knowledge, confidence, emotions, and experiences. *Athletic Training Educ*. 2015;10(2):103–112. doi:10.4085/1002103
13. Reeves NE, Waite MC, Tuttle N, Bialocerkowski A. Simulated patient contributions to enhancing exercise physiology student clinical assessment skills. *Adv Simulation*. 2019;15(4):1–10.
14. Pekrun R, Goetz T, Frenzel AC, Barchfeld P, Perry RP. Measuring emotions in students' learning and performance. The achievement emotions questionnaire. *Contemp Educ Psychol*. 2011;36(1):36–48. doi:10.1016/j.cedpsych.2010.10.002
15. Duffy MC, Lajoie SP, Pekrun R, Lachapelle K. Emotions in medical education: examining the validity of the medical emotion scale (MES) across authentic medical learning environments. *Learn Instruction*. 2020;70(11):101–150. doi:10.1016/j.learninstruc.2018.07.001
16. Konak A, Clark TK, Nasereddin M. Using Kolb's experiential learning cycle to improve student learning in virtual computer laboratories. *Comput Educ*. 2014;72(4):11–22. doi:10.1016/j.compedu.2013.10.013
17. Baoguo J, Hong C. *Guidelines for Clinical Skills Operation of Chinese Medical Students*. Beijing: People's Health Publishing House; 2020:36–41.
18. Heng W, Jinian W. *Practical Clinical Basic Skills Operation Standard Tutorial*. Anhui: Anhui Science and Technology Press; 2019:391–394.
19. Spooner BB, Fallaha JF, Kocierz L, Smith CM, Smith SCL, Perkins GD. An evaluation of objective feedback in basic life support (BLS) training. *Resuscitation*. 2007;73(3):417–424. doi:10.1016/j.resuscitation.2006.10.017
20. Thoureen TL, Scott SB. *Emergency Medicine Simulation Workbook: A Tool for Bringing the Curriculum to Life*. Beijing: Science Press; 2022:23–28.
21. Guanchao J, Lexuan L. *Collection of Clinical Medical Scenario Simulation Teaching Plans*. Beijing: People's Health Publishing House; 2022:264–279.
22. Wijnen-Meijer M, Brandhuber T, Schneider A, Berberat PO. Implementing Kolb´s experiential learning cycle by linking real experience, case-based discussion and simulation. *J Med Educ Curricular Develop*. 2022;12(9):205–221.

23. Jabaay MJ, Marotta DA, Aita SL, et al. Medical simulation-based learning outcomes in pre-clinical medical education. *Cureus*. 2020;12 (12):11875–11887.
24. Weller JM, Nestel D, Marshall SD, Brooks PM, Conn JJ. Simulation in clinical teaching and learning. *Med J Aust*. 2012;196(9):594. doi:10.5694/mja10.11474
25. Davitadze M, Ooi E, Ng CY, et al. SIMBA: using Kolb's learning theory in simulation-based learning to improve participants. *Confidence BMC Med Educ*. 2022;22(1):116. doi:10.1186/s12909-022-03176-2
26. Akella D. Learning together: kolb's experiential theory and its application. *J Manag Organization*. 2010;16(1):100–112. doi:10.5172/jmo.16.1.100
27. Frenay S, Eddy SL, McDonough M, et al. Active learning increases student performance in science, engineering, and mathematics. *Proc Natl Acad Sci*. 2014;111(23):8410–8415. doi:10.1073/pnas.1319030111
28. McGaghie WC, Issenberg SB, Petrusa ER, et al. A critical review of simulation-based medical education research: 2003–2009. *Med Educ*. 2010;44 (1):50–63. doi:10.1111/j.1365-2923.2009.03547.x
29. Barrie M, Socha JJ, Mansour L, Patterson ES. Mixed reality in medical education: a narrative literature review. *Proceedings of the International Symposium on Human Factors and Ergonomics in Health Care*. 2019;8(1):28–32. doi:10.1177/2327857919081006
30. Lesch H, Johnson E, Peters J, Cenda´n JC. VR simulation leads to enhanced procedural confidence for surgical trainees. *J Surg Educ*. 2020;77 (1):213–218. doi:10.1016/j.jsurg.2019.08.008