The Role of Virtual Simulation Experimental Teaching in Cultivating Clinical Thinking Ability for Resident Standardized Training Physicians

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Abstract: Objective: This study aims to investigate the impact of virtual simulation experimental teaching on the development of clinical thinking ability among resident standardized training physicians. Methods: Forty-six trainees undergoing resident physicians standardized training in the emergency department of our hospital in 2022 served as the control group and received traditional teaching methods; whereas forty-eight trainees undergoing resident physicians standardized training in the emergency department of our hospital in 2023 formed the study group, and they completed emergency virtual simulation experimental teaching prior to their departmental rotations. The two groups were compared in terms of assessment scores, learning motivation (evaluated using the Active Learning State Scale), clinical thinking ability, and teaching evaluations. Results: At the time of completion of their rotations, the study group exhibited higher theoretical and practical scores, scores across five items in the Active Learning State Scale, and evaluations across six teaching aspects compared to the control group ($P<0.05$). At the end of their rotations, both groups demonstrated higher scores in clinical thinking ability for three items and the overall score compared to their scores at the beginning of the rotations ($P<0.05$), with the study group surpassing the control group ($P<0.05$). Conclusion: Virtual simulation experimental teaching in the cultivation of clinical thinking ability among resident training physicians can enhance trainees' enthusiasm for learning, improve their clinical thinking ability, and elevate their theoretical knowledge and practical skills.
***Keywords*:** virtual simulation experimental teaching, emergency department, resident training physicians, clinical thinking ability

1. Introduction

The emergency department (ED) is a crucial clinical department and an important stage in the standardized training of resident physicians. Patients in the ED present with a wide range of conditions, often severe, rapidly changing, and psychologically distressing. The management of ED patients requires strong clinical competence due to the complexity, fast pace, intensity, and high risk involved [1]. In clinical teaching in emergency medicine, traditional theoretical teaching focusing on system-based or single-disease teaching is insufficient for guiding students in managing complex and urgent cases. There is a need to emphasize the cultivation of innovative thinking such as holistic thinking, layered thinking, and feasibility thinking [2]. In traditional residency training, outdated teaching methods and limited opportunities for practical experience result in poor teaching effectiveness, failure to improve students' practical skills, and the inability to foster clinical thinking [3]. In recent years, virtual simulation experimental teaching has been introduced into residency training to address issues such as the lack of interactivity in traditional teaching and the lack of experiential learning in practical projects. Some studies suggest that innovative teaching methods, utilizing virtual reality technology, can provide students with various virtual training environments, enhancing their sense of participation, promoting active learning, and stimulating creative thinking [4]. In our hospital, among resident physicians undergoing standardized training rotations in the ED in 2023, the use of virtual simulation experimental teaching showed promising results. This report presents our findings.

2. Objects and Methods

2.1 Study Subjects

94 trainees who underwent standardized residency training rotations in the emergency department of our hospital from January 2022 to December 2023 were included in the study. Inclusion criteria were as follows: ① No adverse records during the training period; ② Age not less than 18 years old; ③ Willingness to cooperate with all investigations. Exclusion criteria were as follows: ① Failure to complete the training; ② Attendance issues during the training period; ③ Systematic learning of relevant knowledge before entering the department. The trainees included in the study were divided into two groups, the control group ($n=46$) and the study group ($n=48$), based on the duration of their training. There were no statistically significant differences in the general characteristics of the trainees between the two groups ($P>0.05$), as shown in Table 1.

Table 1. Comparison of General Characteristics between the Two Groups of Trainees

Group	*n*	Sex (Male/ Female, n)	Age (years)	Education (Bachelor's/ Master's, n)	Theoretical Score upon Entry (points)	Practical Score upon Entry (points)
Study Group	48	21/27	23.81±2.17	11/37	53.52±3.74	51.08±4.17
Control Group	46	24/22	24.07±2.35	12/34	54.28±4.46	51.74±4.56
x^2/ t		0.668	0.558	0.128	0.897	0.733
P		0.414	0.578	0.721	0.372	0.466

2.2 Methods

Control Group: Traditional Teaching Method.Trainees in the control group received instruction through traditional teaching methods. Teachers explained emergency-related knowledge to students in the classroom setting and led them in batches to the emergency outpatient department and wards to learn clinical skills such as patient history taking, auxiliary examination, disease diagnosis, and basic emergency treatment.

Study Group: Virtual Simulation Experimental Teaching.The specific steps of virtual simulation experimental teaching were as follows: (1) Preparations before Teaching:The teaching utilized the virtual simulation experimental teaching platform "Emergency Simulation Practice Course for Trauma Patients based on Intelligent Simulation Standardized Patients (ESP)," developed in collaboration between the Clinical College of Guilin Medical University and Shanghai Dream Road Company. Teachers led students in learning how to use the virtual simulation experimental platform and relevant theoretical knowledge related to emergency care, providing timely clarification to ensure students mastered the use of the teaching platform. (2) Construction of Teaching Framework:A virtual simulation teaching system was built based on the BOPPPS teaching framework, including steps such as Introduction (Introducing the topic), Objectives (Teaching objectives), Pre-assessment, Participatory Learning, Post-assessment, and Reflective Report. (3) Implementation Steps: ① Introduction: One month before entering the department, teachers opened student learning accounts and posted notifications in WeChat groups about completing the "Emergency Simulation Practice Course for Trauma Patients based on Intelligent Simulation Standardized Patients (ESP)" exercise. ② Objective Setting: One week before entering the department, students were guided to understand teaching objectives, key knowledge points, and learning directions. ③ Pre-assessment: Three days before entering the department, teachers logged into the virtual simulation experimental teaching platform to understand students' learning progress and assess their mastery of emergency-related knowledge and current level of clinical thinking ability. ④ Participatory Learning: During the course, students accessed the virtual simulation experimental platform to complete related virtual and simulated training exercises, obtaining scores from the virtual simulation experimental system. After training, discussions were held on the teaching platform, encouraging students to raise questions and express their opinions. Real clinical cases were also discussed to guide students in discussing treatment methods and key points to note. Teachers observed and collected information on students' performance during rotations, providing commendation to those who performed well. ⑤ Post-assessment: Before completing the rotation, students completed the exit assessment according to the requirements of the standardized residency training teaching outline developed by the base institution. The results were recorded, analyzed, and discussed. ⑥ Conclusion: Within one week after completing the rotation, students were required to submit reflective reports. The reports assessed their self-learning situation, summarized personal gains, and analyzed areas for improvement. Teachers provided comments after reviewing the reports, acknowledging achievements and offering guidance on areas for improvement. Additionally, teachers could provide online answers to student questions through the discussion module of the teaching platform.

2.3 Observation Indicators

(1) Assessment Scores: At the end of the rotation, students were assessed, with the assessment comprising theoretical knowledge and practical operation components. The theoretical assessment was conducted through written exams with questions uniformly provided by the teaching base. The practical assessment was conducted through simulated exercises, with the content and related standards determined by the teaching and research office and evaluated by two teachers. The final result was the average of the evaluations. (2) Learning Motivation: At the end of the rotation, the Clinical Active Learning State Scale (ALS) [5] was distributed to both groups of students to evaluate their learning motivation. The ALS includes 21 items covering learning motivation, learning objectives, deep learning, control of learning, and solid learning, each rated on a 5-point scale (1-5 points), with a maximum score of 105 points. A higher score indicates higher learning motivation.(3) Clinical Thinking Ability: At the beginning and end of the rotation, the Clinical Thinking Ability Assessment Scale [6] was distributed to both groups of students to evaluate their clinical thinking ability. The scale includes 24 items covering critical

thinking (6 items), systemic thinking (11 items), and evidence-based thinking abilities (7 items), each rated on a 5-point scale (1-5 points), with a maximum score of 120 points. A higher score indicates stronger thinking ability.(4) Teaching Evaluation: At the end of the rotation, a self-made teaching evaluation form was distributed to students, with evaluation items including "ability to improve self-learning, ability to stimulate learning interest, deepening understanding of knowledge, improvement of professional skills, ability to enhance problem-solving skills, and good teaching effectiveness." Each item had two options, "agree" and "disagree," and students responded with a checkmark (√).

2.4 Statistical Methods

Data were analyzed using SPSS 22.0 software. Descriptive statistics were used to describe continuous data with mean ($\bar{x} \pm s$), and t-tests were employed for comparisons. Categorical data were described using counts [n (%)] and analyzed using x^2 test. A significance level of $P<0.05$ was considered statistically significant.

3. Results

3.1 Comparison of Assessment Scores at the End of the Rotation

The theoretical and practical assessment scores of the study group were higher than those of the control group at the end of the rotation ($P<0.05$), as shown in Table 2.

Table 2. Comparison of Assessment Scores at the End of the Rotation ($\bar{x} \pm s$, points)

Group	*n*	Theoretical Score	Practical Score
Study Group	48	90.27±3.41	91.75±3.69
Control Group	46	84.65±4.07	85.17±4.31
t		7.268	7.962
P		< 0.001	< 0.001

3.2 Comparison of ALS Scores between the Two Groups

The scores for all five items in the ALS were higher in the study group than in the control group (P<0.05), as shown in Table 3.

Table 3. Comparison of ALS Scores between the Two Groups ($\bar{x} \pm s$, points)

Group	*n*	Learning Motivation	Learning Objectives	Deep Learning	Control of Learning	Solid Learning
Study Group	48	15.40±2.34	14.25±2.81	13.81±2.13	12.52±2.69	12.58±2.32
Control Group	46	12.07±2.79	10.39±3.02	10.35±2.67	9.91±2.07	9.76±3.14
t		6.280	6.419	6.960	5.256	4.967
P		< 0.001	< 0.001	< 0.001	< 0.001	< 0.001

3.3 Comparison of Clinical Thinking Ability between the Two Groups

At the end of the rotation, the scores for three items of clinical thinking ability and the total score were higher in both groups compared to the scores at the beginning of the rotation ($P<0.05$). Additionally, the scores for all four items were higher in the study group than in the control group ($P<0.05$), as shown in Table 4.

Table 4. Comparison of Clinical Thinking Ability between the Two Groups ($\bar{x} \pm s$, points)

Group	*n*	Critical Thinking		Systemic Thinking		Evidence-based Thinking		Total Score	
		Beginning	End of Rotation	Beginning	End of Rotation	Beginning	End of Rotation	Beginning	End of Rotation
Study Group	48	18.02±2.86	23.29±4.15*	31.50±4.76	40.33±5.61*	18.73±3.09	23.27±4.15*	68.25±7.91	86.90±9.26*
Control Group	46	18.26±3.08	20.41±3.48*	32.15±5.31	36.65±4.73*	18.54±2.62	20.59±3.93*	68.96±8.58	77.65±8.21*
t		0.392	3.638	0.625	3.431	0.321	3.212	0.417	5.116
P		0.696	< 0.001	0.533	0.001	0.749	0.002	0.677	< 0.001

Note: *$P<0.05$ compared to the beginning of the rotation within the same group.

3.4 Comparison of Students' Evaluation of Teaching between the Two Groups

The study group rated all six aspects of teaching higher than the control group (*P*<0.05), as shown in Table 5.

Table 5. Comparison of Students' Evaluation of Teaching between the Two Groups [n (%)]

Evaluation Item	Study Group (*n*=48)		Control Group (*n*=46)		x^2	*P*
	Agree	Disagree	Agree	Disagree		
Improving self-learning ability	42 (87.50)	6 (12.50)	31 (67.39)	15 (32.61)	5.475	0.019
Stimulating learning interest	43 (89.58)	5 (10.42)	31 (67.39)	15 (32.61)		
Deepening understanding of knowledge	43 (89.58)	5 (10.42)	29 (67.39)	17 (32.61)	6.907	0.009
Improving professional skills	44 (91.67)	4 (8.33)	31 (67.39)	15 (32.61)	8.583	0.003
Enhancing problem-solving skills	41 (85.42)	7 (14.58)	27 (58.70)	19 (41.30)	8.382	0.004
Good teaching effectiveness	44 (91.67)	4 (8.33)	32 (69.57)	14 (30.43)	7.411	0.006

4. Discussion

4.1 Virtual simulation experimental teaching can enhance the learning enthusiasm of resident physicians during their rotation in the emergency department and improve their performance at the end of the rotation

The purpose of resident physician standardized training is to help medical students become familiar with clinical processes, master relevant operational skills, and acquire diagnostic and therapeutic capabilities. In traditional teaching, knowledge is primarily imparted through one-way lectures by teachers, and residents passively receive information. This approach lacks interaction between teachers and students, fails to stimulate students' motivation and enthusiasm for learning, and results in inadequate mastery of the knowledge imparted. Furthermore, due to limitations in teaching resources, time, and conditions, most residents often only observe operational procedures, with limited opportunities for hands-on practice, leading to poor practical skills [7]. Therefore, it is necessary to adjust traditional teaching methods to improve the effectiveness of teaching for resident physicians.In this study, the study group scored higher in all aspects of the ALS, as well as in theoretical and practical assessment scores at the end of the rotation compared to the control group. This suggests that the teaching model used in this study can enhance the learning enthusiasm of resident physicians and improve teaching effectiveness. The virtual simulation experimental teaching can present abstract knowledge in vivid and realistic visualizations, allowing students to immerse themselves and gain real experiences, thereby stimulating proactive learning [8]. Introducing typical cases and raising related questions can motivate students to explore knowledge actively. Setting learning objectives and conducting pre-tests can help students understand their starting point in learning, thus promoting proactive learning. Encouraging students to express their opinions and engaging them in discussions can enliven the learning atmosphere and maximize their subjective initiative [9]. Moreover, virtual simulation experimental teaching, through heuristic learning, can deepen students' understanding and mastery of knowledge points. The use of "virtual patients" and repeated practice in virtual environments can address the disconnection between theory and practice in traditional teaching, effectively improving students' operational skills [10].

4.2 Virtual simulation experimental teaching can enhance the clinical thinking ability of resident standardized training physicians

Clinical thinking ability is the capability of physicians to fully integrate various aspects of information related to patients' conditions, thereby making differential diagnoses, formulating diagnostic and treatment plans, and appropriately addressing issues. The cultivation of this ability is crucial in medical education and serves as an important criterion for assessing whether physicians are competent in their positions [11]. In this study, the study group showed a significant increase in scores for three aspects of clinical thinking ability as well as the total score at the end of the rotation compared to the control group, indicating that the teaching method used in this study can enhance students' clinical thinking ability. In traditional teaching models, clinical thinking courses are lacking, and there is a gap between theoretical learning and practice, making it difficult for students to transition their thinking and hindering the cultivation of clinical thinking. However, virtual simulation experiments can guide students to think actively and engage in interactive exercises to help them develop clinical diagnostic thinking. In addition, participatory learning encourages students to ask questions, answer others' doubts, and boldly question. This interaction and collision of ideas among students helps to unearth their thinking abilities [12]. Furthermore, this teaching model encourages students to continually explore and actively resolve issues during learning. Writing reflective reports allows students to recognize their strengths and areas for improvement, leading to deeper learning [13].

4.3 Virtual simulation experimental teaching can enhance resident trainees' acceptance of teaching

The results in Table 5 show that the study group's evaluation of teaching across six aspects is higher compared to the control group, which is similar to the findings of Zhang et al. [14]. Several reasons could explain this outcome. Firstly, virtual simulation experimental teaching transcends the limitations of time and space, allowing students to complete experimental courses autonomously using their smartphones at any time. This not only reduces the time spent on learning but also enhances the effectiveness of learning [15]. Secondly, virtual simulation technology promotes the realism of clinical practice, enabling students to get closer to clinical scenarios. Moreover, it emphasizes the development of problem-solving skills, gradually boosting students' confidence in learning and giving them a sense of achievement.

In summary, the application of virtual simulation experimental teaching in resident standardized training physicians can stimulate their subjective initiative, enhance clinical thinking ability, and improve their performance in assessments.

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