Education Reform and Development, 2025, Volume 7, Issue 1
https://ojs.bbwpublisher.com/index.php/ERD
Online ISSN: 2652-5372
Print ISSN: 2652-5364

Research on the Application of Standardized Patient Robot Teaching in the Training of Medical Students' Reception Skills: GEE Analysis 2.0 Based on Generalized Estimation Equation

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Abstract: *Objective:* To improve the efficiency of TCM clinical teaching by standardizing patient robot application and clinical training and assessment. *Methods:* A total of 100 students majoring in traditional Chinese medicine who practiced in Zhongshan Hospital of Traditional Chinese Medicine from July 1, 2022 to June 30, 2023 were included in the study and randomly divided into teaching test group and traditional teaching control group. Traditional teaching takes teachers out for outpatient consultation, and the learning test group adds standardized patient robot training on the basis of traditional teaching. Traditional Chinese medicine (TCM) treatment and diagnosis assessment were conducted every 6 days for a total of 5 weeks. Using repeated measurement variance and generalized estimation equation, the intra-group and inter-group studies were conducted to analyze the difference of teaching achievement between the two groups. *Results:* The mean score of the control group was 62.19, and the standard deviation was 10.71, while the mean score of the experimental group was 69.19, and the parity difference was 16.45. According to the inter-group effect analysis, the significance *P*-value of different teaching groups was 0.000***, showing a significant level and there was a main effect. According to the generalized estimation equation analysis, the significance *P*-value of the gender item was 0.054. No significance was shown, OR 95% CI was (-2.445–0.054), and the *P*-value of group significance was 0.000***, showing significance at level, OR 95% CI was (5.797–8.356). The marginal effect of group was 7.08, and the marginal effect of gender was -1.21. *Conclusion:* The combination of high and new technologies such as artificial intelligence, deep learning and robot with modern medical teaching mode can promote the development of digitalization and technology in the field of modern medical education, and can be applied and promoted in the field of medical education.

Keywords: Standardized patient robot; Traditional Chinese medicine receiving; TCM diagnosis; TCM teaching

Online publication: February 10, 2025

1. Introduction

The cultivation of TCM receiving ability is an important and core issue of medical students' clinical ability [1].

The traditional teaching mode is a common form for medical students to accept clinical teaching. In this mode, medical students learn the knowledge and skills of diagnosis, treatment and nursing of clinical cases by following the guidance of doctors or senior doctors. The traditional teaching and training mode exerts importance on the practical operation and experience accumulation and focuses on cultivating students' practical operation ability and clinical thinking abilities, which can help students quickly adapt to practical clinical work. However, there are also some problems in the traditional teaching mode. First of all, due to the shortage of teachers, the schedule of students and teachers is contradictory, resulting in the uneven quality of teaching. Secondly, the traditional teaching mode pays attention to practical operation and experience accumulation but lacks a standardized training process, which is easy to cause differentiation among students. In addition, the number of students in the traditional teaching mode is relatively limited, which cannot meet the needs of large-scale medical education [2].

In view of the problems existing in the traditional teaching mode, modern medical education has gradually introduced a variety of new technologies and new methods to improve the teaching effect. The application of robot SP in the training of medical student's receiving ability is one of the innovative methods. Standardized patient robot (hereinafter referred to as SP robots) is designed by combining modern information engineering technology such as artificial intelligence, deep learning, voice interaction and robots with clinical thinking of TCM diagnostics. It is a robot that can simulate doctor-patient voice interaction dialogue. Through the application of SP robot and clinical training and assessment, clinical teaching efficiency can be improved, and a teaching model with extensibility and normalization can be formed to solve the problems such as uneven teaching ability in the current training model, the large cost of traditional standardized patient training, difficult to expand disease types, and differences in the role ability of patients in actual teaching, and difficulty in maintaining repeatability. Finally, cultivate a group of excellent medical students with clinical reception ability to promote the development of medical education to information, digitalization, standardization and science and technology [1,3,4].

2. Data collection

A total of 100 students majoring in traditional Chinese medicine who practiced in Zhongshan Hospital of Traditional Chinese Medicine from July 1, 2022, to June 30, 2023, were included in the study and randomly divided into two groups, 50 in the teaching test group and 50 in the traditional teaching control group. In the outpatient teaching group of TCM internal medicine, the study will select 5 certified teachers who have 3 years of experience in teaching medical students.

2.1. Research process

(1) Experimental group procedure

The teaching group consisted of 10 people/group, and the follow-up test was carried out for 5 weeks in total. The baseline assessment of the receiving ability of the subjects was carried out on the first day, and the simulated SP robot was used for 30 minutes of training every week. Every 2 people followed the teacher out of the clinic according to the assigned list, and the number of cases per person per day was no less than 20, and the teacher was changed according to the assigned list the next week. More than one cycle was carried out every 6 days, and the final ability evaluation was carried out on the fifth weekend.

(2) Control group procedure

The traditional control group consisted of 10 people/group, and the follow-up test was carried out for 5 weeks in total. On the first day, a baseline assessment was carried out on the receiving ability of the

subjects. Every 2 people followed the teachers out of the clinic according to the assigned list, and the number of patients per person was no less than 20 cases per day. More than once every 6 days, the final ability evaluation was carried out at the end of the fifth week. The above is taken as a cycle every 2 months, and a total of 5 cycles are carried out. Data statistics are carried out after all cycles.

2.2. Data statistics

The collected data is checked for missing values, and the collected continuous data is normalized to eliminate dimensional differences between different variables. The group classification data of gender, experimental group and control group were treated with dummy variables, and the data were labeled for identification and differentiation in data analysis and visualization. The statistical method of repeated measurement variance was used to compare the differences within and between groups. The scores of the first week, the second week, the third week, the fourth week and the fifth week were taken as the intra-group variables, and the intra-group effect analysis was conducted to analyze whether there were significant differences in the repeated measurement data. The group variables and gender of the experimental group and control group were taken as the inter-group variables, and different weeks were taken as the time observation points to analyze whether there were significant differences in different levels of inter-group items [5].

To evaluate the differences between the teaching experimental group and the traditional teaching group. Taking the ability evaluation score of continuous data as the dependent variable (Y variable), the generalized estimation equation (GEE) was used to analyze the repeated measurement data to explore the influence of gender and group on ability evaluation and to evaluate the differences between different groups and gender in ability evaluation [6].

3. Research results

3.1. Descriptive statistical analysis

A total of 500 students' performance data were collected in this study, and no outlier appeared in the data. There were 250 cases in the experimental group and 250 cases in the control group, of which 215 were male students, accounting for 43%, and 285 were female students, accounting for 57% (**Table 1**). Through the classification, summary and descriptive analysis of the scores of the students (**Table 2** and **Table 3**), it can be seen from the above table that the average score of the control group is 62.19, the standard deviation is 10.71, the minimum value is 41, and the maximum value is 82. The average score of the experimental group was 69.19, the parity difference was 16.45, the minimum value was 39, and the maximum value was 95.

Table 1. Results of frequency analysis

Name	Options	Frequency	Percentage (%)	Cumulative percentage (%)
Gender	Female	285	57	57
	Male	215	43	100
Group	Control group	250	50	50
	Experimental group	250	50	100
Total		500	100	100

Table 2. Classification and summary analysis of grades and scores

Title	Item	Group		Summary
		Control group	Test group	
Grade scores	n	250.00	250.00	500.00
	Average	62.19	69.19	65.69
	Standard deviation	10.71	16.45	14.30
	Mean ± standard deviation	62.188 ± 10.714	69.192 ± 16.446	65.690 ± 14.302
	Sum	15547.00	17298.00	32845.00
	Minimum	41.00	39.00	39.00
	Maximum	82.00	95.00	95.00

Table 3. Summary table of results for different weeks

Headings	Item	Groups		Summary
		0	1	
Week 1	n	50	50	100
	Mean ± standard deviation	47.000 ± 5.696	48.560 ± 5.628	47.780 ± 5.688
Week 2	n	50	50	100
	Mean ± standard deviation	56.680 ± 3.673	56.960 ± 5.206	56.820 ± 4.484
Week 3	n	50	50	100
	Mean ± standard deviation	62.780 ± 3.125	66.440 ± 5.163	64.610 ± 4.627
Week 4	n	50	50	100
	Mean ± standard deviation	67.780 ± 3.086	82.960 ± 3.194	75.370 ± 8.243
Week 5	n	50	50	100
	Mean ± standard deviation	76.700 ± 2.140	91.040 ± 1.895	83.870 ± 7.481

3.2. Repeat measurement variance

The sphericity test results showed that the significance *P*-value was 0.000***, showing horizontal significance. If it failed to pass the sphericity test, it was necessary to adopt the correction result and adopt the Greenhouse-Geisler correction method (**Table 4**).

From the intra-group effect analysis, for the time point of the variable, the Greenhouse-Geissler correction method is used to obtain that the significance *P* value is 0.000****, which shows significance at the horizontal level and has a significant impact on the result, and there is a main effect. For the group of variables, using the Greenhouse-Geisler correction method, the analysis can obtain that the significance *P* value is 0.000****, showing a significant effect on the result at the level, and there is a main effect. For the gender of the variable, the Greenhouse-Geisler correction method is used to obtain that the *P* value of significance is 0.006****, which shows a significant effect on the result and has a significant effect[7] on the result. For the interaction term time point* group, the Greenhouse-Geisler correction method is used to obtain that the significance *P* value is 0.000****, showing a significant effect on the result at the level, and there is an interaction. For* gender of the interaction term time point, the Greenhouse-Geisler correction method is used to obtain that the significance *P* value is 0.322, showing no significance at the level, no significant impact on the result, and no interaction. For the interaction item group* gender, the Greenhouse-Geisler correction method is used to obtain that the *P-value* of significance is 0.044**, which shows significance at the level, has a significant impact on the result, and there is interaction[8]. For* group* gender at the time point of interaction terms, the Greenhouse-Geisler correction

method is used to obtain that the *P-value* of significance is 0.116, and there is no significance at the level, no significant impact on the result, and no interaction. See Table 5.

From the inter-group effect analysis, for the groups, from the results of the F-test analysis, the significance *P* value is 0.000***, showing significance on the level, has a significant impact on the results, there is a main effect. For the gender of the variable, it can be obtained from the analysis of the results of the F-test that the *P-value* of significance is 0.342, and there is no significance at the level, no significant impact on the results, and no main effect. For the interaction item group* gender, it can be obtained from the analysis of the results of the F-test that the *P-value* of significance is 0.491, and there is no significance at the level, no significant impact on the results, and no interaction. See Table 6.

Table 4. Repeated measurement methods Spherical test

In-body effect	Mochi Lai W	Approximate Chi-square	df	Salience	Epsilon		
					Greenhaus - Geissler	Sin Fidler	Lower LIMIT
Point in time	0.308	112.304	0	0.000***	0.658	0.692	0.25

Note: ***, **, and * represent significance levels of 1%, 5%, and 10%, respectively

Table 5. Analysis of in-group effects

Item		3 categories sum of squares	df	Mean square	*F*	*P*
Point in time	Assumed sphericity	80741.139	4	20185.285	2898.459	0.000***
	Greenhaus - Geissler	80741.139	2.632	30672.681	2898.459	0.000***
	Lower limit	80741.139	1	80741.139	2898.459	0.000***
Category	Assumed sphericity	717.709	1	717.709	103.058	0.000***
	Greenhouse-Geissler	717.709	0.658	1090.6	103.058	0.000***
	Lower limit	717.709	0.25	2870.837	103.058	0.000***
Gender	Assumed sphericity	67.246	1	67.246	9.656	0.002***
	Greenhouse-Geissler	67.246	0.658	102.184	9.656	0.006***
	Lower limit	67.246	0.25	268.984	9.656	0.023**
Point in time* Group _	Assumed sphericity	5070.356	4	1267.589	182.016	0.000***
	Greenhouse-Geissler	5070.356	2.632	1926.173	182.016	0.000***
	Lower limit	5070.356	1	5070.356	182.016	0.000***
Point in time * Gender	Assumed sphericity	32.357	4	8.089	1.162	0.327
	Greenhouse-Geissler	32.357	2.632	12.292	1.162	0.322
	Lower limit	32.357	1	32.357	1.162	0.282
Category * Gender	Assumed sphericity	33.017	1	33.017	4.741	0.030**
	Greenhaus - Geissler	33.017	0.658	50.171	4.741	0.044**
	Lower limit	33.017	0.25	132.067	4.741	0.062*
Point in time * Group * Gender	Assumed sphericity	56.741	4	14.185	2.037	0.089*
	Greenhouse-Geissler	56.741	2.632	21.555	2.037	0.116
	Lower limit	56.741	1	56.741	2.037	0.154
Residual (point in time)	Assumed sphericity	2674.232	384	6.964		NaN
	Greenhouse-Geissler	2674.232	252.705	10.582		NaN
	Lower limit	2674.232	96	27.857		NaN

Note: ***, **, and * represent significance levels of 1%, 5%, and 10%, respectively

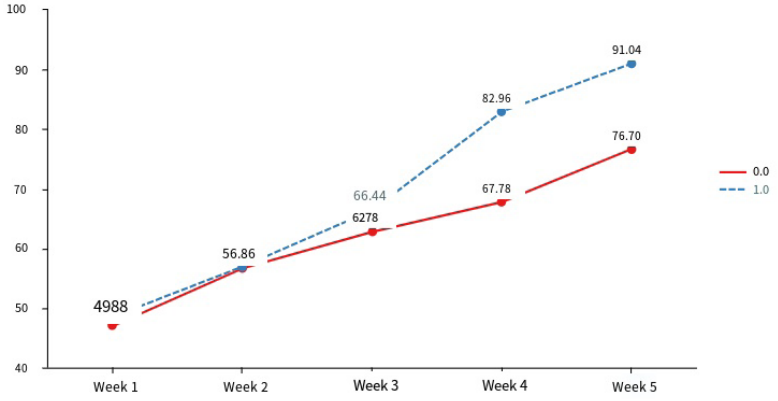

Figure 1. Plot of estimated marginal mean values for experimental and control groups.

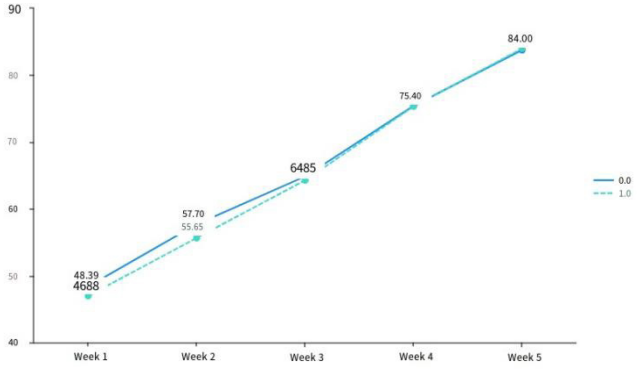

Figure 2. Estimated marginal mean for gender.

3.3. Generalized estimation equation results

As can be seen from the generalized estimation parameter estimation table, the significance *P*-value of the gender item is 0.054, showing no significance, OR 95% CI is (-2.445–0.054). The *P*-value of the significance of the group item was 0.000***, showing significance at the level, OR 95%CI was (5.797–8.356). The marginal effect of group was 7.08, and the marginal effect of gender was -1.21, as shown in **Table 7** and **Table 8**.

Table 7. Parameter estimation table of generalized estimation equation

Parameters	Coefficient	Standard error	Wald	*P*	Lower 95% confidence interval	95% upper confidence interval
Const	62.672	0.571	12057.038	0.000***	61.554	63.791
Gender	-1.211	0.629	3.702	0.054	-2.445	0.023
Group	7.077	0.653	117.507	0.000***	5.797	8.356

Table 8. Results of marginal effect analysis of generalized estimation equation

	Marginal effect dy/dx	Standard Error	*z*	*p*	95% CI
Groups	7.08	0.65	10.84	0	5.797–8.356
Sex	-1.21	0.630	-1.92	0.054	-2.445–0.023

4. Discussion

From the data on teaching methods in different groups, it was found that the scores of the experimental group and the control group were significantly different. The summary score of the experimental group was higher than that of the control group, and the standard deviation score of the control group was less variable, while the standard deviation score of the experimental group was larger. From the first week, the score of the control group was 62.188 ± 10.714, and that of the experimental group was 69.192 ± 16.446. There was no significant difference between the two groups. In the fifth week, the score of the control group was 76.700 ± 2.140, and the score of the experimental group was 91.040 ± 1.895. The students' score changes were improved under the standardized patient robot training mode.

From the analysis of the inter-group effect, it was found that gender had no effect on the whole teaching model, and there was a major effect on different teaching groups with or without standardized patient robot training mode, which was statistically significant. In terms of group * gender, the *P*-value of significance was 0.491, which had no statistical significance and no interaction. In the model analysis, the influence of confounding factors is excluded, and the differences in scores brought by teaching in different groups are clarified. From the marginal benefit chart (**Figure 1**), with the addition of standardized patient robot training, it can be seen that from the second week, the scores of the two groups began to show a large gap. Standardized patient robot training helps students to be helpful in TCM diagnosis and evaluation. According to the generalized estimation equation, the scores of the groups have statistical significance. According to the data from **Table 8**, the test group can improve by 7.07 points compared with the control group.

In this study, we used the robot SP to train medical students' reception ability. The experimental results show that robot SP has a remarkable effect on the training of medical students receiving ability. First of all, robot SP can provide highly realistic clinical scenes, so that medical students can be trained in a more realistic scene. This helps to improve medical students' practical operation ability and clinical thinking ability. Secondly, the robot SP can interact intelligently according to medical students' responses, providing timely feedback and guidance to medical students. This helps to correct the wrong operation and thinking of medical students and also enables medical students to better understand and master the essentials of clinical operation. In addition, the robot SP can also simulate different conditions and patient reactions, so that medical students can be exposed to more kinds of conditions and patient reactions, and improve their resilience and practical operation experience. Finally, the robot SP can record the medical students' treatment process for follow-up evaluation and improvement. This helps medical students better understand their shortcomings and areas that need improvement so that they can better train for the next step of receiving patients [9–14].

The application of robot SP in the receiving ability training of medical students is an innovative practice in the field of medical education. The expansion of the number of SP diseases is to better simulate the real medical scene so that medical students can face more diseases in the receiving process to better exercise clinical ability. In the process of expanding the number of SP diseases, it is necessary to take into account the diversity and complexity of the diseases, avoiding too simple or too complicated situations to ensure the effectiveness of the training effect.

In the traditional education of medical students, there are often differences in the level and teaching quality of doctors, which leads to the uneven training quality of medical students. The application of robot SP in the training of medical students' receiving ability can realize the standardization and homogenization of training. First of all, the speech recognition technology and speech synthesis technology of robot SP can ensure that the performance of robot SP is consistent in different training scenarios to achieve the homogenization of teaching

quality. Secondly, robot SP can train medical students according to standardized processes and standardized operation requirements, so as to achieve standardization of training. In this way, whether in different training scenarios or in different teaching of doctors, robot SP can ensure that medical students receive the same training content and training quality, thus improving the training quality and training efficiency of medical students [15].

In addition, the robot SP can also record and analyze the training process of medical students, to realize the monitoring and evaluation of the training process of medical students. Through the data analysis of the training process of medical students, the problems and deficiencies in the receiving process of medical students can be found, to carry out targeted training and improvement. In this way, the robot SP can not only realize the standardization and homogenization of the training of medical students, but also through data analysis and monitoring, constantly optimize the training content and training effect, and improve the training quality and clinical ability of medical students.

Funding

(1) Municipal Health Bureau, "A Study of the Application of Robotic SP in the Training of Medical Students' Reception Skills (Project No.: 2022A020465);
(2) Zhongshan Science and Technology Bureau, "Popularisation of Artificial Intelligence Chinese Medicine Diagnosis and Treatment Robot Achievements and Construction of Chinese Medicine Characteristic Science Popularisation Demonstration Base" (Project No.: 2023B2025);
(3) Education and Teaching Research Project of the Clinical Education Research Association of the Society for Higher Education in Chinese Medicine, "A Study on the Application of Robotic SP in the Development of Medical Students' Reception Skills and Clinical Thinking" (Project No.: 2023-006).

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