ORIGINAL ARTICLE

Effects of Mastery-Based and Traditional Learning Models on Scientific Knowledge and Practical Skills in Neurosurgery

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Abstract

Background: The mastery learning model (MLM) is an active learning approach that enhances students' scientific knowledge and practical skills in surgical technology (ST). Given that more than half of the courses in this field are clinical, full mastery of the material can significantly improve practical learning. To date, no study has investigated the impact of MLM on neurosurgery education. Mastery learning is a teaching method in which students must achieve a predetermined level of mastery in each unit before progressing to the next. The present study aimed to assess and compare the effects of MLM and the traditional learning model (TLM) on the development of neurosurgical knowledge and related practical skills in ST students in Hamadan, Iran.

Methods: This semi-experimental study employed a pre-test–post-test two-group design. The study population consisted of 32 operating room students from Hamadan University of Medical Sciences, recruited through census sampling. A pre-designed questionnaire (for assessing neurosurgical knowledge) and a checklist (for evaluating practical skills) were validated using CVR and CVI indices. Data were analyzed using SPSS v.16, employing the paired t-test, the Kolmogorov–Smirnov test for normality, the Wilcoxon test, and the Mann–Whitney test.

Results: The mean scores of neurosurgical practical skills increased significantly ($P<0.05$) in post-test ST students (26.44±5.01) compared to the pre-test (18.91±3.85). Similarly, neurosurgical knowledge scores increased significantly ($P<0.05$) in the post-test (48.38±5.21) compared to the pre-test (34.69±8.85).

Conclusion: Both neurosurgical knowledge and practical skills in ST students can be substantially improved through the use of MLM. This model is recommended as an effective alternative to TLM for neurosurgery education.

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Introduction

Due to the rapid innovation of modern surgical technologies and approaches, surgical technology (ST) experts and students must continuously update their competencies. Among these requirements, acquiring new scientific knowledge while simultaneously adapting to various practical surgical skills presents a particular challenge. In neurosurgery, in particular, both scientific knowledge and related practical skills must be enhanced to ensure effective participation in surgical procedures.[1]

Thus, proper training in surgical interventions is a critical component of education for ST students. The studies have shown that in this context, operating room students sometimes lack sufficient skills to perform tasks despite having high levels of theoretical knowledge.[2] Unfortunately, in some areas, students have not yet reached the level required to perform the assigned activities.[3] It is also possible that certain complications encountered by patients arise from the lack of experience and skills among students and operating room personnel.[1]

Cochran and colleagues demonstrated that ST students often lack adequate practical skills, even when possessing high levels of scientific knowledge.[2] Similarly, Gattinger et al. reported a substantial gap between the clinical abilities of ST graduates and the optimal competencies required for operational procedures.[3] Under such circumstances, the likelihood of life-threatening medical errors increases.

Various learning methods are applied in medical and paramedical schools to train competent students in surgical and therapeutic procedures.[4] However, the absence of modern educational curricula remains a major obstacle to the advancement of medical education.[5] Many medical and paramedical courses are still taught passively, with minimal student engagement.[6] Such approaches result in indirect student participation, academic fatigue, low productivity, and rapid forgetting of acquired knowledge.[7] In contrast, student-centered methods are associated with significantly higher levels of learning compared to traditional learning models (TLM).[8] Educational psychologists emphasize that each student should be directly involved in the learning process and guided according to their innate abilities to achieve academic progress.[9] As Benjamin Bloom reported, students can attain successful and highly efficient performance through time-intensive, high-quality education.[10] Accordingly, various learning theories have been proposed based on individual learner characteristics, leading to the development of new educational models.

Mastery learning models (MLM) were developed by Benjamin Bloom, James Black, and John Croll.[11] According to John Croll's theory, the time required for complete learning is a critical factor that varies for each individual.[12] Therefore, MLM is designed to accommodate the time learners need to achieve mastery. In this model, progression to the next stage of education occurs only after the learner attains at least 95% of the relevant score on the previous assessment.[13] The MLM consists of several stages: defining educational objectives, conducting initial assessments, determining mastery levels, implementing training courses, performing formative evaluations, providing corrective instruction, and carrying out cumulative evaluations.[14] This approach prevents the excessive advancement of one group of students and the lagging behind of another group, a problem commonly observed in traditional educational systems.[5]

Studies have investigated the impact of the mastery learning model (MLM) on learners' knowledge acquisition and skill development across various fields.[15, 16] Shekari Kashani demonstrated that teaching chemistry concepts to high school students using MLM led to academic progress and fostered a positive attitude toward learning.[17] The effect of MLM on surgical skills, such as cholecystectomy and catheterization in ICU settings, among surgical residents has also been examined, showing that this method reduces medical errors during cholecystectomy and decreases bleeding and infection in the ICU.[18, 19] Another study on medical students indicated that learning to mastery positively influenced thoracentesis skills among internal medicine residents.[20] Similarly, MLM was found effective in teaching cardiopulmonary resuscitation (CPR) skills to medical students.[21] Ben Bassat reported that MLM improved nursing students' knowledge and skills in conducting patient physical examinations.[18] Tang showed that MLM had a positive effect on primary care education among nurses.[19] Although MLM is recognized as a time-consuming educational approach,[13] its benefits—such as accelerated acquisition of scientific knowledge and enhancement of practical skills—have been documented in diverse areas, including high school chemistry,[9] cholecystectomy and ICU catheterization among surgical residents,[14-16] thoracentesis skills,[16] CPR,[17] nursing physical examination,[18] and primary care education in nurses.[19]

Based on the evidence above, this teaching method may enhance both the acquisition of knowledge and the development of practical skills among operating room students, particularly for skills that require extended time, repetition, and hands-on practice. Among these, neurosurgical skills are especially important. Neurosurgery is a highly specialized and technically demanding field, and mastery of both its theoretical knowledge and practical skills is essential for every neurosurgery student.

Neurosurgery is a medical specialty focused on the surgical treatment of nervous system pathologies and traumas. Today, various neurosurgical approaches, along with advanced surgical equipment, have been developed, increasing the complexity of this field for ST students. Neurosurgical procedures are particularly challenging due to the small operative field, the high density of vessels and nerve fibers, strict aseptic requirements, and the overall sensitivity of the procedures. Consequently, both surgeons and their assistants, including ST students, are required to develop practical skills alongside their scientific knowledge rapidly.

Given that ST graduates often lack sufficient practical skills in neurosurgery due to inadequate training and suboptimal educational methods, implementing innovative teaching approaches may enhance the quality of neurosurgical education. Therefore, the present study aimed to investigate the effects of the Mastery Learning Model (MLM) on the development of practical skills and scientific knowledge in neurosurgery among ST students, compared to the Traditional Learning Model (TLM).

Methods

This semi-experimental study was conducted among students affiliated with Hamedan University of Medical Sciences (Hamedan, Iran), using a census method. Participants were assessed in pre-test and post-test groups between February 16, 2019, and March 19, 2020. The study aimed to investigate the potential benefits of the Mastery Learning Model (MLM) in improving neurosurgery-related scientific knowledge and practical skills among ST students.

Following initial sample collection, four individuals were excluded, resulting in a final sample of 32 ST students, representing the entire class. Inclusion criteria required participants to have no prior experience in neurosurgery and to attend all scheduled learning sessions. Four additional individuals were excluded due to either unwillingness to participate or failure to attend one of the training sessions.

Tools/Instruments: Data were collected using a pre-designed questionnaire and a checklist to assess neurosurgery-related scientific knowledge and practical skills, respectively. The Neurosurgery Knowledge Assessment Questionnaire was specifically developed for neurosurgery assistants and comprised 34 questions across six domains. Responses were recorded on a Likert scale with options: "Correct," "Incorrect," and "Not Sure," scored as 2, 0, and 1, respectively.

The neurosurgery skills assessment checklist was designed based on the standard Direct Observation of Procedural Skills (DOPS) index and included seven main items. Performance was scored using a Likert scale with the following options: "Less Than Expected" (1), "Borderline Limit" (2), "Within the Expected" (4), "More Than Expected" (5), and "No Comment" (3). Both tools were researcher-developed, validated, and used to systematically evaluate the theoretical knowledge and practical skills of ST students in neurosurgery.

Data Collection Methods: Content validity was employed to ensure the appropriateness of the questionnaire and checklist. Both instruments were thoroughly reviewed and revised by 15 experts affiliated with Hamedan University of Medical Sciences, including faculty members, ST instructors, ST students, neurosurgeons, and neurosurgery assistants, using the Content Validity Ratio (CVR) and Content Validity Index (CVI) indices. From an initial pool of 64 items, 34 questions were selected for further consideration. The mean CVR and CVI values for the final questionnaire were 0.497 and 0.946, respectively.

To assess reliability, the Cronbach's alpha method was applied, yielding mean scores of 0.934 for the questionnaire and 0.893 for the checklist. The reliability of the DOPS checklist has also been previously reported as 0.94 at Zahedan University of Medical Sciences, confirming its consistency for evaluating practical skills.

After explaining the study's objectives to the ST students, informed consent was obtained from all participants. Subsequently, the students were randomly assigned into two groups using a random number generator: the test group (n=16) and the control group (n=16). In the control group, neurosurgery education was delivered by faculty instructors using the Traditional Learning Model (TLM). In contrast, the test group received neurosurgery instruction based on the Mastery Learning Model (MLM), covering the following topics: "Neuroanatomy," "Neuropathology," "Neurosurgery Equipment," "Neurosurgery Diagnostic Procedures," "Blood Management and Suturing," and "Neurosurgical Care." Educational sessions were conducted through a combination of lectures, group discussions, and PowerPoint presentations.

Eight sessions, each lasting at least two hours, were conducted over eight weeks. During this time, the necessary practical neurosurgery skills were taught to the ST students in the test group, as outlined in the checklist, using both practical demonstrations and observational methods. Upon completion of the training, the neurosurgery knowledge assessment questionnaire was administered, and practical skills were evaluated by the researcher using direct observation during operations for both the control and test groups. The control group also received practical skills training through presentations based on the TLM. At the end of the training period, the examiner completed the checklist again for both groups to assess skill acquisition.

Data analysis: The collected data were analyzed using SPSS v.16. Statistical methods employed included the paired t-test, the Kolmogorov-Smirnov test for normality, the Wilcoxon test, and the Mann-Whitney test.

Ethical Considerations

This research was approved by the Ethics Committee of Hamadan University of Medical

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Results

The mean age of ST students was 22.3 years in the test group and 22.18 years in the control group. Of the participants, 46.9% (n=15) were male and 53.1% (n=17) were female (Table 1).

The mean neurosurgery knowledge score in male ST students increased significantly from 37.33±8.34 before training to 46.27±6.90 after training (P=0.006). In female ST students, the score also increased from 40.65±8.68 before training to 44.41±5.14 after training, although this change was not statistically significant (P=0.1) (Table 2). The effect size for the difference between pre- and post-training neurosurgery knowledge scores, calculated using Cohen's d and Hedges' correction, was 0.825 and 0.803, respectively, indicating a substantial effect.

The mean score of practical neurosurgery skills in male ST students increased significantly from 18.53±3.62 before training to 26.8±5.18 after training (P<0.001). Female ST students also showed a significant improvement in practical skills, from 19.24±4.13 pre-training to 26.12±4.99 post-training (P<0.001).

Regarding the individual items of the questionnaire, significant differences (P=0.01) were observed between pre- and post-MLM education scores for all items except for "Bleeding Management and Suturing" and "Neurosurgical Cares." The overall mean score of practical skills increased significantly after MLM training from 18.91±3.85 to 26.44±5.01 (P<0.05) (Table 3).

In the test group, the mean neurosurgery knowledge score increased significantly from 34.69±8.85 before MLM training to 48.38±5.21 after training (P<0.05). All five sub-items of neurosurgery knowledge showed significant improvement (P<0.05) after MLM education, except for "Bleeding Management and Suturing" (Table 4). The effect size for the total neurosurgery knowledge score in the test group, calculated using Cohen's d and Hedges' correction, was 0.695 and 0.678, respectively, indicating a strong effect of MLM training on knowledge improvement.

The total neurosurgery knowledge score following MLM was significantly higher in the test group compared to the control group (P<0.05), indicating that MLM was more effective than TLM in enhancing neurosurgery knowledge in ST students. Similarly, neurosurgery skill scores increased significantly (P<0.05) in both the control and test groups after MLM training compared to pre-training scores. As shown in Table 3, the mean neurosurgery skill scores improved significantly in both groups following MLM instruction. Moreover, the mean score of neurosurgery skills in the test group was significantly higher than that of the control group (P<0.05), demonstrating that MLM was more effective than TLM in improving practical neurosurgery skills in ST students (Table 4).

Table 1: Data frequency based on the gender in both groups of control and test.

	Groups		Total
	Control	Test	
Male	7 (21.9%)	8 (25%)	46.9%
Females	9 (28.1%)	8 (25%)	53.1%
Total	16 (50%)	16 (50%)	

Table 2: Mean and score of scientific knowledge and practical skills of surgical technologist students in neurosurgery according to gender.

	Scientific Knowledge of Neurosurgery				Practical Skills of Neurosurgery			
	Before Learning	After Learning	*t*	P value	Before Learning	After Learning	*t*	P value
Male	37.33±8.34	46.27±6.90	3.19	0.006	18.53±3.62	26.8±5.18	6.34	0.000
Female	40.65±8.68	44.41±5.14	1.74	0.1	19.24±4.13	26.12±4.99	5.63	0.000

Table 3: Mean score of practical skills of neurosurgery based on the learning and groups.

	Based on the Learning		Based on the Groups	
	Before Learning	After Learning	Control	Test
Mean Score	18.91±3.85	26.44±5.01	22.69±3.4	30.19±3.22
Score Limits (Min-Max)	7-35		-	
z-value	4.94		4.146	
P value	0.000		0.000	

Table 4: Mean score of scientific knowledge and practical skills of neurosurgery before and after training in control and test groups.

		Control Group				Test Group			
		Before Learning	After Learning	t*	P value	Before Learning	After Learning	t*	P value
Scientific knowledge of neurosurgery	Neuroanatomy	8.19±2.07	8.25±2.11	0.65	0.58	6.75±2.79	9.06±1.87	3.078	0.008
	Neuropathology	7.06±1.61	6.94±1.61	1	0.31	3.38±2.55	7.56±0.81	3.526	0.000
	Neurosurgery Diagnostic Procedures	1.19±0.91	1.19±0.91	0.000	1	0.62±0.5	1.44±0.72	2.829	0.005
	Neurosurgery Equipment	9.75±2.43	10±2.3	1.732	0.104	9.5±2.98	12.31±2.35	3.28	0.005
	Blood Management and Suturing	8.88±1.45	8.44±1.41	2.07	0.03	8±3.05	8.62±1.54	0.365	0.715
	Neurosurgical Care	8.44±1.71	7.38±2.06	2.638	0.01	6.44±3.44	9.38±2.65	2.443	0.027
	Total Score	43.50±5.62	42.19±5.19	2.78	0.01	34.69±8.85	48.38±5.21	5.951	0.000
Practical Skills of Neurosurgery		19.56±3.03	22.69±3.4	9.54	0.000	18.25±4.53	30.19±3.22	16.162	0.000

* To test the items and total scores of neurosurgery knowledge, the paired t-test was used at 95% confidence level. However, the Wilcoxon test was used (non-normality of the data) for assessment of neuropathology, Neurosurgery diagnostic procedures, and Blood management and suturing.

Discussion

Since MLM emphasizes providing sufficient time for each student to achieve complete learning, the total neurosurgery knowledge score in the test group increased considerably compared to both the control group and pre-education scores. In this context, Davrajoo et al. reported that MLM could significantly improve algebra scores in high school students.[20] Similarly, Kashani et al., in a semi-experimental study examining the effect of MLM on chemistry courses, concluded that this model significantly enhanced students' performance, attitude, and intrinsic motivation. In other words, MLM can effectively improve both academic performance and motivation. Although these studies were conducted in high schools, they confirm the positive effects of MLM on the learning process.[17] Furthermore, Benbassat et al. demonstrated that MLM is an effective strategy for enhancing both the scientific knowledge and practical skills of nursing students, enabling them to achieve all advanced stages of physical examination under instructor supervision.[18] These findings are consistent with the present study, highlighting the potential of MLM to improve scientific knowledge among students.

The results of this study also demonstrated that the total practical skills score in the test group was considerably higher than in the control group. These findings suggest that MLM can effectively enhance the level of practical skills in neurosurgery. In line with this, Dari et al. concluded that the application of MLM could improve performance and practical skills in nursing students.[22] Based on these results, the MLM educational method appears particularly useful in clinical activities, as it provides students with more opportunities to develop functional skills and clinical competence. Sharif et al. investigated the effects of MLM on clinical competence in ST students. They found that the total clinical competence score in the MLM-trained group was higher than in the TLM-trained control group.[23] Similarly, Benbassat et al. assessed the effects of MLM on learning hemodialysis catheter placement in urology assistants, reporting that this method enhanced clinical practical skills while reducing medical complications.[18] Additionally, Butter et al. conducted a study comparing TLM- and MLM-trained medical students in standard cardiac auscultation techniques. They found that students trained with MLM achieved higher scores than those trained with TLM.[24] In another study, Wayne and colleagues evaluated the impact of MLM on thoracentesis skills among 40 internal medicine residents, demonstrating that 93% of the residents could perform the procedure with high mastery.[25]

One of the primary reasons for the positive effects of MLM on students' learning is that it allows sufficient time for mastering both scientific knowledge and practical skills at high levels. A study by Zinda Jas et al. on laparoscopic hernia repair, conducted with 50 general surgery residents, showed that patients treated by residents trained in MLM experienced fewer complications, including peritoneal rupture, urinary retention, and seroma.[26] Similarly, Tang and colleagues reported that clinical nursing competence, including scientific knowledge, skills, cooperation, and professional development, improved significantly with the MLM approach.[19] In addition, Cummins et al. concluded that MLM had a substantial impact on cognitive learning in midwifery students,[27] and Rahmani et al. demonstrated that MLM enhanced both cognitive and functional learning in nursing students.[28] Based on the findings of the present study, it can be concluded that the MLM method provides students with sufficient time for in-depth learning, thereby enhancing their ability to acquire and accelerate scientific knowledge and practical skills in neurosurgery.

Among the limitations of this study, it is worth noting that MLM is time-consuming, requiring considerable instructor effort for training, and students may initially find it challenging to adapt to this method. Furthermore, the study period for each student was limited, restricting the possibility of allocating additional training time.

Limitation

Initially, students found it challenging to adapt to MLM because it is time-consuming and requires each student to achieve mastery before progressing to the next stage. However, as students' knowledge and skills improved over time, this challenge was effectively overcome.

Recommendation

Teaching should be designed and implemented according to the predominant learning styles of students. Given that operating room topics require clear examples and repeated practical exposure, methods such as MLM should be emphasized. Providing an environment where students can repeatedly practice and encounter realistic scenarios will help them acquire deeper knowledge and more proficient professional skills. Further studies with larger sample sizes and across other clinical fields are recommended to validate and extend these findings.

Conclusion

In our country, due to the limited number of neurosurgeries, students cannot gain exposure to all surgical procedures at the bedside. Therefore, educational methods that significantly enhance the learning rate are necessary. The Mastery Learning Model (MLM) can effectively accelerate both the scientific knowledge and practical skills of surgical technology (ST) students in neurosurgery. The authors believe that this type of education can lead to the graduation of more competent students and, consequently, reduce the incidence of complications and medical errors.

Considering that the MLM improved both knowledge and skills in neurosurgery among operating room students, it is suggested that this educational model be extended to other surgical fields, such as orthopedic surgery, maxillofacial surgery, and gastroenterology.

Authors' Contribution

All authors contributed significantly throughout the study, including conceptualization, study design, execution, data collection, analysis, and interpretation. They also participated in drafting and revising the manuscript and approved the final version for publication.

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Data Availability Statement

Upon reasonable request, the corresponding author can provide the datasets analyzed during this study.

Conflict of Interest

None declared.

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