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Reform and Exploration of the Flipped Classroom in Practical Teaching of Plaster Fixation

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Abstract: Plaster fixation is a basic clinical skill of considerable importance in orthopedics and in emergency medicine. Conventional teaching tends to focus too much on theory, to provide little actual practice, to rush the in-class part of instruction, and to neglect mastery after class. The present work applies the flipped classroom idea to the teaching of plaster fixation, proposes a hybrid method combining "online self-directed preview—offline handling of material-on internalization—post-class consolidation or improvement", and looks at its teaching value. *Methods*: Fifty postgraduate trainees (in surgery) were chosen and randomly assigned to one of two groups (intervention or control). For the intervention group, flipped classroom methods were used, whereas the control group got traditional instruction. Among the indicators considered for evaluation are theoretical scores from tests, scores of standardized practical skills, and results of the teaching satisfaction questionnaire—all of which are used to assess teaching outcomes. *Results*: Following the teaching intervention, each group showed a definite improvement (of statistical significance) with regard to theoretical scores, practical skill scores, and satisfaction with teaching scores, which should be evaluated in relation to pre-intervention values. As far as improvement is concerned, each of the indicators studied appears to show much more marked progress in the intervention group than in the control group, with a statistically significant difference between groups ($P<0.05$). *Conclusion*: The flipped classroom model seems well suited to increasing theoretical learning among surgical postgraduates and to improving their ability to perform standardized plaster procedures, to reason clinically and to avoid risks—and to do so more efficiently than under traditional instruction. Such results help establish an empirical foundation for pedagogical reform of clinical skills training in medicine.

Keywords: Flipped classroom; Plaster fixation; Clinical skills; Practical teaching; Teaching reform; Orthopedic teaching

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1. Introduction

Clinical skill training for medical students is one of the main pillars of medical education and has a direct bearing on both physicians' competence and the safety of patients [1–3]. Plaster fixation—a basic method of treating fractures or joint injuries conservatively or of immobilizing limbs after orthopedic surgery—has several advantages: it is simple to apply, gives dependable fixation, and is broadly applicable. Such an elementary clinical skill is vital for all three types of practitioner (orthopedist, trauma surgeon, emergency physician). Its standardization has a major influence upon the quality of fracture reduction, upon limb edema and its control, and upon complication rates—all of which affect prognosis [4–5].

At present, most domestic medical schools teach clinical skills by means of a conventional model—centralized theory classes, one-time demonstrations in class, and imitation exercises by students. Various inadequacies of this model emerge with regard to plaster fixation training: there is no prior study (before class) of anatomy or of therapeutic and contra-indicative factors; the amount of time available for in-class teaching is limited,

the teaching process is burdened by rushed demonstrations by instructors, too little contact between teachers and students, and slow correction of individual errors; after class, no good means of review or consolidation are available. As a result, the students' theoretical learning tends to be shallow, their procedures uncertain, their risk sense underdeveloped, and their clinical reasoning weak—all of which complicate attainment of the standards of modern clinical practice [6–8].

The flipped classroom—by reorganizing the instructional process—moves knowledge transmission into the pre-class phase, puts knowledge internalization under the heading of class time, and allows for competency growth after class as well. With such an arrangement, learners study independently (using digital tools) prior to class, while class hours are given over to applied work, to problem-oriented discussion, to tailored help and to feedback, thus transforming passive learning into active inquiry [9–11]. This method coincides with the logic of clinical teaching, can contribute positively to both conceptual understanding and technical skill, and has been shown to be useful in a variety of medical practice contexts [12–15].

2. Participants and methods

2.1. Participants

Of the available methods of sampling, convenience sampling was used to choose 50 postgraduate surgery students who were registered at the First Affiliated Hospital of the University of South China between September 2023 and September 2025.

Inclusion criteria: (1) postgraduate students whose major is surgery; (2) capacity—physical or mental—to be fully involved in either kind of teaching (online or face-to-face); (3) voluntary participation with signed consent.

Exclusion criteria: (1) failure to finish the whole teaching/assessment procedure; (2) prior membership—either actual or potential—in such teaching studies. (3) missing information or absence of follow-up; (4) engagement—during the intervention—in another comparable teaching study; (5) noncompliance with the planned learning tasks.

A third-party researcher used a random number method to divide the subjects into an intervention group (n = 25) and a control group (n = 25). Among those assigned to the intervention group, there were 23 males and 2 females, averaging 24.3 ± 1.47 years of age, whereas the control group had 19 males and 6 females,

averaging 24.7 ± 1.68 years of age. Baseline characteristics for both groups were not significantly different (P>0.05), which confirms their comparability. Each of the two groups was taught entirely by the same team of senior orthopedic physicians.

2.2. Methods

2.2.1. Teaching material and textbook

The standardized residency training textbook called Orthopedics was accepted as the uniform teaching blueprint. The total amount of teaching time—whether for one or both groups—was fixed at 2 class hours; the content was alike.

2.2.2. Group receiving intervention (Flipped classroom model)

The idea of a three-stage closed-loop teaching method is proposed: "pre-class independent learning (online)—in-class work with actual examples or discussion (to fix ideas)—post-class online reinforcement or expansion."

(1) Pre-class online self-directed learning: Each instructor made available certain learning items on the teaching platform—namely, anatomical facts about plaster fixation, conditions calling for or against it, steps of operation, means of complication avoidance or treatment, standard video demonstrations, and selected case histories. The students worked on the material alone and noted any questions they had.

(2) With regard to class hands-on work and discussion: The instructors held a centralized question-and-answer time, gave standard demonstrations with detailed, sequential explanations; students worked in small groups, and each received one-on-one help from an instructor in correcting errors. Risk-related points were discussed—often in connection with actual cases—to improve clinical reasoning.

(3) After-class consolidation and improvement: Review items as well as self-test questions were made available by the platform; individual reports—on actual performance—were prepared and handed in, so the whole learning cycle is completed.

2.2.3. Control group (Standard teaching method)

The control group was subjected to the standard teaching process—"centralized theoretical lecture (in class)+uniform on-site illustration+group imitative practice"—without prior online preview of the class material, without pre-class questions or post-class digital summaries. The length of each class and the content taught were not changed from what they were for the intervention group.

2.3. Outcome measures

A unified theoretical examination and a model-oriented practical skills assessment were given both before the course and one week after it had been completed, as well as a questionnaire on teaching satisfaction. All the assessments—whether of knowledge or of attitude—were scored independently by physicians not linked to the teaching to eliminate bias due to subjectivity.

(1) Theoretical performance: A 20-item single-choice test (total score 100) has been used for a complete assessment of each student's knowledge of basic theory, namely of anatomy as it applies to plaster fixation, of indications, of complications, and of the operative principle.

(2) With regard to practical skill performance: A standardized scoring rubric was used, assigning marks to eight items—preparation of the materials, positioning of the patient, maintenance of fracture alignment,

handling of the plaster mold, specification of the fixation zone, control of tightness, avoidance of complications, and doctor-patient humanistic communication. The total score is 100 points.

(3) Teaching satisfaction: A standardized questionnaire for evaluating teaching satisfaction was used, which included five separate dimensions—self-directed learning efficiency, in-class hands-on work, gain in clinical competence, practical value of the course, and instructor teaching quality—totaling 15 items. A 5-point Likert-type scale was applied (1 = very dissatisfied, 2 = dissatisfied, 3 = basically satisfied, 4 = satisfied, 5 = very satisfied), with overall scores reflecting higher satisfaction when they are larger. Scores of satisfaction were obtained for both groups at baseline (before the teaching) and one week post-teaching in order to compare satisfaction pre- and post-intervention.

2.4. Statistical methods

The data were double-entered and verified by means of Excel, and statistical work was done with SPSS 26.0. Quantitative variables are reported as means ± standard deviations (Mean ± SD). For each subject, pre- and post-teaching scores and satisfaction were compared internally using paired-samples t-tests. To avoid a misleading influence of initial values, between-group analysis of improvement (post-treatment minus pre-treatment) was carried out via independent-samples t-tests for all indicators. Categorical data are given as frequencies or proportions, and intergroup differences are analyzed using the chi-square (x^2) test. A P-value<0.05 is taken to indicate statistical significance.

3. Result

3.1. Comparison of theoretical examination scores between the two groups before and after the teaching intervention

With regard to the theoretical score before the intervention, the group receiving it had significantly higher values than the control group (P<0.01). After the intervention, both groups improved markedly in their scores (P<0.001), and—with regard to theoretical content—the post-teaching score of the intervention group was clearly superior to that of the control group (a statistically significant between-group difference, P<0.05), as shown in **Table 1**. This supports the claim that the flipped classroom model helps greatly in raising student performance.

Table 1. Comparison of theoretical scores before and after teaching between two groups (Mean ± SD, points, n=25)

Group	Initial Theoretical Score	Post-Teaching Theoretical Score	Intra-group *t* value	Intra-group *P* value
Intervention Group	79.64±2.97	86.72±2.46	3.74	.000
Control Group	75.12±2.88	81.12±2.59	7.230	.000
Inter-group *t* value	2.14	-	-	-
Inter-group *P* value	0.038	-	-	-

3.2. Comparison of operation scores between the two groups before and after the teaching intervention

Baseline data reveal a statistically significant difference in operation scores between the two groups (P<0.01).

Following the teaching intervention, both groups improved markedly—as compared with baseline—in their operation scores (each $P<0.001$). Moreover, the group receiving the intervention obtained significantly higher scores than the control group in terms of operations performed, with an actual and statistically significant between-group difference ($P<0.05$), as stated in **Table 2**. Such results point to the value of the flipped classroom method for raising the standard of students' practical work and for enabling them to cope well with special fixation cases in actual clinical situations.

Table 2. Comparison of practical scores before and after teaching between two groups (Mean ± SD, points, n=25)

Group	Initial Practical Score	Post-Teaching Practical Score	Intra-group *t* value	Intra-group *P* value
Intervention Group	79.48±2.73	92.96±1.79	22.56	.000
Control Group	71.80±2.78	84.92±2.34	18.33	.000
Inter-group *t* value	2.31	-	-	-
Inter-group *P* value	0.025	-	-	-

3.3. Comparison of teaching satisfaction scores between the two groups

With regard to baseline data, a statistically significant difference is apparent between the two groups in terms of satisfaction ($P<0.01$). Following the teaching intervention, each group has a marked improvement in satisfaction scores (both $P<0.001$). Moreover, the satisfaction level of the intervention group comes out significantly higher than that of the control group post-intervention—this too is a statistically significant group difference ($P<0.01$), as shown in **Table 3**. Such results support the claim that the flipped classroom gives students more autonomy in setting their own pace of study, and thus encourages both initiative and a better classroom atmosphere. At the same time, if one avoids too much theoretical repetition and instead offers help tailored to each learner's needs, the teacher may find it easier to be precise and efficient in teaching, which helps to raise the students' satisfaction with the whole course.

Table 3. Comparison of teaching satisfaction scores between two groups (Mean ± SD, points, n=25)

Group	Initial Satisfaction Score	Post-Teaching Satisfaction Score	Intra-group *t* value	Intra-group *P* value
Intervention Group	175.84±6.77	207.76±4.94	18.82	.000
Control Group	165.92±5.75	184.28±5.29	10.86	.000
Inter-group *t* value	3.57	-	-	-
Inter-group *P* value	0.001	-	-	-

4. Discussion

The basic aim of clinical skills teaching is to encourage—or even to help achieve—a well-ordered application of theory in such areas as operation, reasoning about cases, and risk avoidance [16–18]. Even though the plaster cast immobilization process seems straightforward from the standpoint of workflow, it brings together many complex competencies, such as anatomical knowledge, fracture evaluation, correct positioning of the patient, tension evaluation, and prevention of complications [19–20]. The model known traditionally as "classroom

lecture with one-time centralized demonstration" is not adequate for a full treatment of competency building. A large proportion of class time goes to theoretical material of general interest, whereas practice (in any form) or correction of errors—on an individual basis—are treated only briefly, and the teaching resources used inefficiently as a result.

This paper reports on an attempt to apply the flipped classroom model to instruction about plaster cast immobilization. It was found that the group receiving flipped classroom teaching achieved much more favorable results across all three main indicators—scores on theoretical tests, ratings of standardized hands-on work, and of teaching satisfaction—relative to the control group (which had been taught by means of the conventional method). Such findings support the claim that the flipped classroom is especially appropriate for teaching practical orthopedic skills such as plastercast immobilization and for raising the level of clinical skill training.

4.1. The flipped classroom restructures the teaching process to achieve efficient internalization of knowledge

Among traditional methods of teaching, the lecture—as a form of theory-based instruction—takes up most of class time, leaving little room for practical work or for one-to-one guidance. By contrast, in the flipped classroom model, the basic theoretical content is brought forward to the pre-class stage, so that each student may go at his or her own speed, watch instructional videos again and again, and identify questions in advance. With such pre-class preparation, the limited time available in class may be used fully for practical work, for focused error correction, and for case-based analysis—an arrangement that greatly improves efficiency and mastery [21]. The present investigation shows that the intervention group obtained notably higher operation scores than the control group, which supports the view that pre-class study combined with in-class reinforcement is especially suitable for teaching skills.

4.2. The flipped classroom strengthens clinical reasoning and enhances standardized operational competence

Instruction on plaster cast immobilization must not be limited to teaching the "how to do it", but must also help clarify "why it is done, when it is needed, and how to prevent complications." If students prepare cases before class and engage constructively—with problems in mind—in class discussion, the flipped classroom offers a means of working toward an optimal immobilization plan (taking fracture type, swelling level, and limb perfusion into account) and of strengthening their reasoning about indications, risks, and emergency measures [22–23]. Such a method avoids rote copying and actually encourages the change from "knowing how to act" to "understanding clinical practice."

4.3. The flipped classroom enhances self-directed learning ability and improves the teaching–learning experience

The flipped classroom changes the role of students from passive listeners into active learners. With it comes the opportunity to regulate one's own study time, to re-read complex material as often as needed, or to ask questions early—all of which encourage much more serious and sustained learning. At the same time, the teacher moves away from the role of "knowledge transmitter" to that of guide, error analyst, and helper, thus gaining a more precise grasp of individual difficulties and of teaching needs [24–25]. From the standpoint of this study, the intervention group expressed markedly higher satisfaction, which suggests that the model is well

adapted to graduate-level education and may be worth expanding in many contexts.

4.4. Limitations and future directions

There are several limitations to this study. The number of subjects studied is not very large, and the work was confined to one institution. Most of the assessment tools used were summative and periodic in nature; no extended follow-up was made of either operational efficiency (in actual practice) or the prevention of complications (in realistic situations). With regard to future work, one might think about increasing the size of the sample. With regard to multicenter controlled trials and to a wide range of indicators—such as long-term clinical follow-up, blinded review of standardized operation videos, and simulated trauma situations—there is room for continuing improvement of the standardized setup of the flipped classroom as applied to clinical skills teaching. Moreover, this approach seems adaptable to other essential clinical skill modules, namely surgical dressing change, knot-tying under aseptic conditions, puncture work, or emergency care techniques.

5. Conclusion

Using the flipped classroom model for the practical teaching of plaster cast immobilization—as part of an orthopedic curriculum—seems very likely to lead to substantial gains in theoretical understanding, in properly standardized immobilization techniques, and in student satisfaction with the course, as well as to more autonomous study habits and to the formation of an integrated (not fragmentary) clinical reasoning system.

Teaching effectiveness taken as a whole is clearly better than that of the standard lecture-demonstration model. Such an approach makes the educational process more efficient, gives a rational account of classroom time usage, and lays stress upon practice (as opposed to theory), thus meeting many of the needs of reform in present-day clinical skill training and offering substantial room for development in clinical teaching.

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Authors’ contributions

Study design, data analysis and collection, paper writing, and paper submission: Jun-Cheng Cui
Consultation, data collection and analysis: Zhou Hu
Data collection: Mai Chen
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Research guidance and paper revision: Li Zeng

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