Original Research Article

EVALUATION OF HANDS-ON ANATOMICAL MODELLING FOR TEACHING THE FIBROUS CAPSULE OF THE ELBOW JOINT AMONG FIRST-YEAR MBBS STUDENTS

Deepa C[1], Ramesh P[2], Balaji K[3], Kalyani T[4]

[1]Associate Professor, the Department of Anatomy, Swamy Vivekanandha Medical College Hospital and Research Institute, Tiruchengode, Tamil Nadu.
[2]Professor, Department of Anatomy, The Oxford Medical College Hospital and Research Centre, Bangalore, Karnataka.
[3]Assistant Professor, Department of Anatomy, Swamy Vivekanandha Medical College Hospital and Research Institute, Tiruchengode, Tamil Nadu.
[4]Assistant Professor, Department of Anatomy, Noida International Institute of Medical Sciences, Greater Noida, Uttar Pradesh.

Corresponding Author: Dr Deepa C, Associate Professor, the Department of Anatomy, Swamy Vivekanandha Medical College Hospital and Research Institute, Tiruchengode, Tamil Nadu.
Email ID: drdeepac85@gmail.com

ABSTRACT

Background: A sound understanding of three-dimensional anatomical relationships is fundamental to learning gross anatomy and clinical medicine. Traditional seminar-based teaching is often associated with passive learning and may not be sufficient to learn the complexity of anatomical structures such as the fibrous capsule of the elbow joint. Active learning strategies involving students in the construction of anatomical models may enhance spatial understanding and acquisition of knowledge. The objective is to compare the effectiveness of practical anatomical modelling to enhance the conceptual understanding and academic performance of first year MBBS students on the fibrous capsule of elbow joint over the conventional teaching method through seminars. **Materials and Methods:** An educational practice evaluation was conducted among 100 first-year MBBS students attending a scheduled gross anatomy practical class. Students were divided into two equal groups (n = 50 each) according to institutional roll numbers. One group received conventional seminar-based teaching, while the other participated in a hands-on anatomical modelling activity using articulated elbow bones and modelling dough. Immediate learning outcomes were assessed using a structured short-answer question with a predefined 3-mark rubric. The assessment tool was reviewed for content validity by three senior anatomy faculty members. Student perceptions of conceptual understanding were assessed using a structured questionnaire. Group differences were analysed using the independent-samples t-test and Pearson Chi-square test; Cohen's d and 95% confidence intervals were also calculated. **Results:** Students in the hands-on anatomical modelling group had higher assessment scores than those who received conventional seminar-based teaching (2.85 ± 0.30 vs. 1.72 ± 0.65; mean difference = 1.13, 95% CI = 0.93–1.33; $p < 0.001$). The between-group difference demonstrated a very large effect size (Cohen's d = 2.23). All students in the hands-on modelling group (100%) reported clear conceptual understanding compared with 30% of students in the seminar group ($\chi^2 = 53.85$, $p < 0.001$). **Conclusion:** Hands-on anatomical modelling significantly improved short-term knowledge acquisition and perceived conceptual understanding over traditional seminar-based instruction. Structured tactile learning activities in undergraduate anatomy teaching can improve understanding of complex anatomical structures and supplement traditional teaching methods.

Keywords: Active learning, Hands-on modelling, Medical education, Anatomy teaching, spatial learning, Elbow joint.

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INTRODUCTION

Gross anatomy is a core component of undergraduate medical education and the structural basis for understanding physiology, pathology, clinical examination, diagnostic imaging and surgical practice. Competent medical graduates must have a sound knowledge of gross anatomy to apply anatomical principles in clinical decision-making and patient care. But anatomy education has changed substantially in the last few decades with decreased curricular time, increased student numbers, a lack of cadaveric resources and the advent of modern teaching methods. Such challenges have prompted educators to embrace learner-centred instructional strategies that advocate active engagement and meaningful learning, as opposed to passive acquisition of factual knowledge.[1-3]

Acquiring an accurate three-dimensional understanding of anatomically complex structures is one of the major challenges faced by first-year

medical students. Traditional lecture and seminar-based teaching methods rely mainly on verbal explanations, textbook illustrations and 2D images which might not be enough to help spatial visualisation. Although these methods are effective in conveying theoretical information, they often do not allow students to actively build mental representations of complex anatomical relationships. Thus, students often struggle with concepts such as joint capsules, ligamentous attachments, fascial planes, and other structures that require advanced spatial reasoning.[3-5]

Active learning strategies have been consistently shown through educational research to improve student engagement, conceptual understanding, critical thinking and academic performance when compared to traditional passive instructional approaches. Active learning encourages the active participation of the learners in the process of education through discussion, problem solving, collaborative learning and model building. These strategies use visual, tactile and kinesthetic experiences to engage deeper cognitive processing, leading to long-term retention and meaningful learning. A landmark meta-analysis by Freeman et al. found that active learning results in significantly improved examination performance and reduced failure rates in science, technology, engineering and mathematics disciplines.[1] Comparable findings have been reported in anatomy education where learner-centred instructional methods have consistently demonstrated superior educational outcomes over traditional didactic teaching.[3-6]

Practical, anatomical modelling is a student-centred approach that allows students to actively construct anatomical structures using simple and inexpensive materials. Anatomical model building helps students to identify anatomical landmarks, understand three-dimensional spatial relationships, and integrate theoretical knowledge with practical understanding. Manipulation of anatomical models is a multimodal sensory process that supports spatial cognition, a prerequisite for the mastery of gross anatomy. Furthermore, collaborative model construction supports active engagement, immediate feedback, peer-supported learning and self-guided exploration, all of which enhance conceptual understanding and knowledge retention.[4-8]

The instructional topic of the present study was the fibrous capsule of the elbow joint as it is considered one of the more difficult anatomical structures for novice learners. Its attachments are complex and require integration of multiple bony landmarks and an appreciation of its complex three-dimensional orientation. Students often find it difficult to memorise the exact attachments and spatial orientation of the capsule in routine anatomy practicals, even after attending conventional seminars. The subject may therefore be best taught through active model construction, which can be an effective means of improving spatial understanding beyond traditional seminar-based instruction. While many studies have demonstrated the educational benefits of active learning, simulation and 3D visualisation in anatomy education, there are relatively few studies that have specifically evaluated low-cost hands-on anatomical modelling with readily available materials such as modelling dough in routine undergraduate practical classes. Such teaching approaches are especially appealing to medical colleges in resource-constrained settings, as they do not demand much infrastructure and encourage experiential learning and active student participation.[3-4,7-8] Therefore, the present study was undertaken to compare the effectiveness of hands-on anatomical modelling and conventional seminar method of teaching in terms of conceptual clarity and immediate academic performance of first year MBBS students on the topic of fibrous capsule of elbow joint. We hypothesized that students in the hands-on anatomical modelling session would obtain significantly higher assessment scores and demonstrate greater perceived conceptual understanding compared to students receiving traditional seminar-based instruction.

MATERIALS AND METHODS

Educational Practice Evaluation: An educational practice evaluation was conducted to assess students' immediate learning outcomes and perceptions following two approaches to teaching the fibrous capsule of the elbow joint during a routine undergraduate gross anatomy practical session.

Study Setting and participants: The study was carried out in the Department of Anatomy, Swamy Vivekanandha Medical College Hospital and Research Institute,Tiruchengode, Tamilnadu, India during the year 2026 as part of the routine undergraduate gross anatomy practical curriculum. One hundred first-year MBBS students attending the scheduled practical session participated in the teaching activity.

Group Allocation

Participants were allocated into two equal groups (n = 50 each) according to their institutional roll numbers.

Group A (Seminar Group): Roll numbers 1–50

Group B (Hands-on Modelling Group): Roll numbers 51–100

Allocation was based on the existing institutional roll-number sequence rather than individual randomisation.

Educational Intervention

Conventional Seminar-Based Teaching (Group A)

A seminar on the fibrous capsule of the elbow joint was conducted for Group A students in the conventional way. The same faculty took the session through PowerPoint presentations, labelled anatomical diagrams and verbal explanation. The fibrous capsule was described with emphasis on its anatomical attachments, boundaries and functional significance. The seminar was about 20 minutes.

Hands-On Anatomical Modelling (Group B)

Students in Group B participated in a structured hands-on anatomical modelling session of similar duration. The faculty member first showed the attachments of the fibrous capsule using articulated elbow bones and commercially available modelling dough. The demonstration highlighted the anatomical limits, points of attachment, and the three-dimensional orientation of the capsule.

After the demonstration, each student individually reconstructed the fibrous capsule using modelling dough on articulated elbow bones under faculty supervision. During the activity, students identified the relevant anatomical landmarks and reproduced the capsular attachments with immediate feedback from the instructor. The total instructional time was approximately 20 minutes, ensuring comparable teaching duration between both groups.

Assessment of Learning Outcomes: Immediate learning outcomes were assessed following the teaching session using a structured short-answer question with a maximum score of three marks. A predefined marking rubric was used, with one mark awarded for each correctly identified anatomical component. The assessment tool and marking rubric had been reviewed by three senior anatomy faculty members for content validity before implementation.

Students' perception about conceptual understanding was assessed immediately after the teaching session by means of a structured questionnaire with a dichotomous ("Yes/No") response to the question whether the teaching method helped them to clearly understand the fibrous capsule of the elbow joint.

Statistical Analysis: Data were entered into Microsoft Excel and analysed with Jamovi (Version 2.7.38). Continuous variables were expressed as mean ± standard deviation (SD) and categorical variables as frequencies and percentages. The mean assessment scores were compared between the two groups using an independent-samples t-test. A Pearson Chi-square test was used to compare the proportions of students reporting clear conceptual understanding. The magnitude of the between-group difference was expressed using Cohen's d, and the mean difference between groups was reported with its corresponding 95% confidence interval (CI). A two-tailed p value of <0.05 was considered statistically significant.

RESULTS

Participant Flow

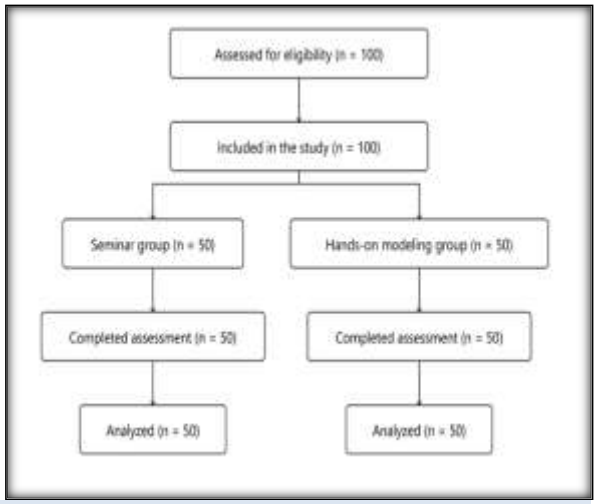

Figure 1: Flow of participants through the study

Academic Performance: Students who participated in the hands-on anatomical modelling session demonstrated significantly better academic performance than those who received conventional seminar-based teaching. The mean assessment score was higher in the hands-on modelling group than in the seminar group (2.85 ± 0.30 vs. 1.72 ± 0.65). In contrast, the seminar group earned a mean score of 1.72 ± 0.65. The mean difference between the groups was 1.13 marks (95% CI: 0.93–1.33) and was statistically significant ($p < 0.001$). The hands-on modelling group demonstrated a very large between-group effect (Cohen's $d = 2.23$).

Table 1: Comparison of Post-Teaching Assessment Scores

Variable	Seminar Group (n=50)	Hands-on Modelling Group (n=50)	Mean Difference (95% CI)	p value
Assessment score (Mean ± SD)	1.72 ± 0.65	2.85 ± 0.30	1.13 (0.93–1.33)	<0.001

Student Perception of Conceptual Understanding

Students who participated in the hands-on anatomical modelling session had significantly improved conceptual understanding of the fibrous capsule compared to students who attended the conventional seminar. All students in the hands-on modelling group (100%) reported that the teaching method facilitated a clear understanding of the anatomical topic, whereas only 30% of students in the seminar group reported similar understanding. The difference between groups was statistically significant (Pearson $\chi^2 = 53.85$, $p < 0.001$).

Table 2: Student Perception of Conceptual Understanding

Response	Seminar Group n (%)	Hands-on Modelling Group n (%)
Yes	15 (30)	50 (100)
No	35 (70)	0 (0)
Test		Value
Pearson χ^2		53.85
p value		<0.001

Magnitude of the Educational Effect: The effect size analysis revealed a Cohen's d of 2.23 which indicates a very large educational effect of the hands-on anatomical modelling activity compared with conventional seminar-based teaching. Moreover, the 95% confidence interval for the mean difference does not contain zero which provides evidence of the statistical significance of the observed difference.

DISCUSSION

This educational evaluation compared two approaches to teaching the fibrous capsule of the elbow joint during a routine undergraduate anatomy practical session. Students who participated in the hands-on modelling activity obtained higher immediate assessment scores and reported greater perceived conceptual understanding than students who received conventional seminar-based teaching. The findings suggest that adopting structured tactile learning activities in routine anatomy practical sessions may enhance students' understanding of anatomically complex structures.

The substantially higher assessment scores obtained in the hands-on modelling group suggest that active involvement in model building resulted in greater immediate knowledge acquisition than traditional seminar-based instruction. The large effect size (Cohen's d = 2.23) indicates that the educational benefit was not only statistically significant but also of practical importance. These results align with the growing evidence that active learning strategies enhance student performance by promoting meaningful engagement with learning material rather than passive reception of information.[7,8] Recent systematic reviews further show that interactive and technology-enhanced approaches to anatomy education improve knowledge acquisition and learner engagement compared to conventional instructional methods.[11,12]

Gross anatomy requires students to comprehend complex three-dimensional relationships that are often difficult to visualize from two-dimensional drawings alone. Traditional seminars are good for conveying facts, but may not facilitate the development of the spatial reasoning skills needed to understand complex anatomical structures. The educational practice evaluation employed in the present study is consistent with constructivist learning theory, which posits that learners actively construct knowledge through meaningful experiences. Students physically constructed the fibrous capsule, integrating prior anatomical knowledge with new spatial information, which facilitated deeper conceptual understanding.

The present findings are consistent with previous research on learner-centred and spatially oriented approaches to anatomy education. Estai and Bunt reported that learner-centred teaching strategies can enhance engagement and knowledge acquisition in anatomy education,[3] while Yammine and Violato demonstrated benefits of three-dimensional visualisation for anatomical learning.[4] More recent systematic reviews and meta-analyses of immersive and interactive anatomy teaching modalities have also reported favourable effects on anatomical knowledge.[11,12] Although these studies evaluated educational approaches different from the low-cost physical modelling used in the present evaluation, collectively they support the value of actively engaging learners with three-dimensional anatomical relationships.

Notably, in the current study all students in the hands-on modelling group reported clear understanding of the fibrous capsule following the teaching session, compared to less than 1/3 of students in the seminar group reporting similar confidence. Increased confidence may enhance motivation for future learning and support application of anatomical knowledge in future clinical training, although learner perception does not directly equate to objective competence. The present study supports the educational relevance of the intervention by demonstrating the correlation between subjective perception and objective assessment scores.

One of the strengths of the present teaching approach is its simplicity and practicality. Unlike expensive simulation technologies or sophisticated three-dimensional visualisation systems, anatomical modelling using articulated bones and commercially available modelling dough requires minimal financial resources and can be readily incorporated into routine practical sessions. This may make the approach particularly useful in resource-constrained educational settings.

The study has a number of limitations. Firstly, the study was done in one institution among one cohort of first year MBBS students which may limit the generalizability of the findings to other educational institutions. Second, the participants were allocated by institutional roll numbers and not by individual randomisation, which may have introduced selection bias. Third, assessment was limited to immediate post intervention knowledge acquisition and long-term retention of anatomical knowledge was not assessed. Finally, student perception was measured with a simple structured questionnaire rather than a validated multidimensional learner evaluation tool and knowledge was assessed with a single structured short answer question. Future studies should employ validated assessment tools, evaluate long-term knowledge retention and include multicentre cohorts to strengthen the evidence base for hands-on anatomical modelling in anatomy education.

CONCLUSION

The findings of this educational practice evaluation suggest that hands-on anatomical modelling could be a beneficial complement to traditional seminar-based teaching for learning complex gross anatomical

structures. Given the simplicity, low cost and ease of implementation, hands-on anatomical modelling may be a feasible teaching strategy for routine undergraduate anatomy practical sessions, particularly topics that require three-dimensional spatial visualisation.

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