Original Article

Transforming Learning with 'MedMorph': A Structural Game Model in Undergraduate Medical Education

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Abstract

Background: Conventional anatomy teaching, which can rely on lectures and cadaveric dissections, is likely to encourage passive learning and minimal interaction. As the trend towards active, student-centered learning gains momentum, game-based and multimodal strategies are being considered to enhance knowledge acquisition, retention, and motivation. The MedMorph structural game model was developed to combine embodied cognition, collaboration, and interactive learning with medical education; thus, the purpose of this study was to measure the effectiveness of the MedMorph structural game model in advancing students' immediate knowledge and their attitudes toward its educational usefulness. **Material and Methods:** It was a cross-sectional study involving 50 first-year MBBS students as the intervention group. Pre-test measures were conducted before the intervention, and an after-test was administered immediately after the MedMorph activity. The quantitative data analysis used paired t-tests and effect sizes, whereas qualitative feedback was collected through questionnaires and structured focus group discussions. **Results:** The difference between post-test and pre-test performance was large, with a p-value of < 0.001 and a large effect size, indicating significant learner gains. The qualitative evidence showed that students were interested in the new approach as it was interactive and better than traditional lectures. They focused more on clearer conceptualization of anatomical structures, improved visualization, and enhanced teamwork. Certain issues regarding timing and initial reluctance were also observed, but did not outweigh the positive results. **Conclusion:** Student engagement and learning improvement were greatly enhanced by using the MedMorph structural game model. It has been successfully implemented in anatomy classes, but more study is required on its retention over time and extent.

Keywords: Medical students, structural game model, gamification, key concepts, Anatomy education, MedMorph.

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Introduction

Anatomy has remained a fundamental theme in medical training and the basis of clinical knowledge, diagnostic reasoning, and surgical competence. Despite its centrality, anatomy is considered a challenging topic by students, requiring them to memorize extensive factual data and complex structural relationships. Conventional methods like didactic lectures and textbook training, which may be effective at delivering material, are often denounced as passive, cramming, and incapable of instilling insightful concepts.[1] In turn, learners can find it difficult to put their knowledge into meaningful structures, which can create gaps in understanding that can complicate clinical practice in the future. In recent years, medical educators have begun to realize the constraints of traditional pedagogies and have actively sought active-learning methods and strategies that can engage students more effectively and ensure long-term retention and transfer of knowledge to clinical practice.[2]

Active learning, in general, as a teaching technique that involves learners in the process of conceptualizing knowledge through meaningful action, has received strong empirical support in the teaching of medical and health sciences. Active methods such as problem-based learning, case-based discussions, and simulations have been found to improve learning, critical thinking, and teamwork compared to lectures. These practices focus on participation, interaction, and feedback, which are important aspects of deeper learning. Nevertheless, this is not easily applicable to the implementation of such strategies in the anatomy context.[3] The generosity of material, its abstractness, and space, and the time constraints of a busily timetabled curriculum can restrict the amount of active learning applied. Although cadaveric dissection has traditionally offered a demonstrative, hands-on, and immersive teaching method, due to resource limitations, ethical concerns, and time restrictions, most programs have cut dissection time, substituting it with prosections, models, or computer-based solutions. The change has necessitated a need for new techniques that can emulate some of the advantages of practical learning while remaining pragmatic and scalable.[4] Game-based learning and

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gamification have become potential solutions in this context. Game-based learning incorporates the concepts of play, competition, and rules in learning environments; it is based on the motivation, interest, and memorability of the information being learned. Board games, quizzes, and computer simulations have been used in medical education to teach everything from pharmacology and physiology to clinical reasoning.[5] According to meta-analyses, these interventions typically yield small to medium effects on learning outcomes, accompanied by increases in student satisfaction and engagement. However, most current approaches have shortcomings, despite their promise. Digital games might not provide opportunities for social interaction and embodied learning, whereas small-scale board games cannot be as complex as anatomical relationships are. So, a search is underway for models that not only engage students but also enable them to feel anatomy in a more dynamic and integrative manner.[6]

Conceptual models such as multimodal learning and embodied cognition can help explain why novel methods may be especially useful in the anatomy field. Multimodal learning implies that the encoding of information across various sensory modalities, including visual, acoustic, and kinesthetic, results in more vivid memory encoding and contributes to retrieval.[7] Embodied cognition emphasizes the body's role in developing thought, and argues that physical activity, gestures, and spatial performance may shore up abstract ideas. Such views are particularly useful in anatomy, where spatial logic and structural interactions are key to comprehension. For example, students who physically interact with the positions of body parts or pretend to emulate the workings of body systems are not only memorising but also internalising connections in a manner that can promote subsequent recall and use. The combination of these principles into a structured, game-based approach can potentially bridge the divide between abstract and practical knowledge.[8] The MedMorph structural game model has been developed in response to these educational issues and theoretical knowledge gaps. Although MedMorph is similar to digital quizzes or small-scale games, it involves large-group performances of anatomical structures and systems, with students playing different body parts. Learners play active roles in making and visualizing relationships through rules, tasks, and collaborative problem-solving, while at the same time competing and cooperating. Not only is it a multimodal learning system with active retrieval, immediate feedback, and social interaction, but it also provides a comprehensive system that covers both cognitive and motivational aspects of learning. Placing abstract material in the context of a memorable, embodied experience, MedMorph aims to make anatomy a little more comprehensible, enjoyable, and collaborative. Past studies have given promising data about game-based and embodied instruction in anatomy learning. Indicatively, research on quiz-based anatomy games has shown that they enhance short-term recall and student satisfaction. Luchi et al. also reported substantial learning improvements with board games focused on physiology,[9] and Chang et al. (2013) showed spatial recall improvement when teaching via gestures was compared with lectures.[10] Equally, Sivashankar et al. (2023) found that retention increased twice with enactment strategies compared with passive observation.[11] Most studies, including meta-analytic reviews such as those by Roberts and others (2022), report that gamification in education tends to yield moderate improvements in learning outcomes.[12] Although these findings are encouraging, they also highlight the variability of results and the need for models that consistently yield high and enduring effects. MedMorph is based on this evidence but uses a hierarchical combination of concepts to meet the demands of the particular anatomy; these concepts include, but are not limited to, embodiment, retrieval, feedback, and competition.

Motivation also plays a significant role in medical education. Students often consider anatomy one of the most difficult subjects due to its scope and the level of learning required. A lack of sufficient motivational factors will lead learners to rely on memorization rather than aiming to understand.[13] If the game-based approach includes elements of challenge, accomplishment, and social involvement, it has proven effective in increasing intrinsic motivation. Students will also be more open-minded when they enjoy learning, and will have a greater chance of being attentive, engaging actively, and storing knowledge in their long-term memory.[14] This is what MedMorph capitalizes on by ensuring that the environment it provides students is collaborative and competitive, and that students own the learning process. Another important factor is peer interaction, which enhances colleagues' understanding and support of ideas and further develops involvement. Although gamification and embodied learning are of growing interest, there are still several gaps in the literature. A lot of available research is small-scale, focuses more on digital platforms, or lacks robust statistical data on effectiveness. Not many interventions have attempted to combine embodied acting with formal rules and competition, especially in a large-group classroom setting.[15] Moreover, although anecdotal feedback tends to focus on pleasure, few studies have explicitly tested quantitative learning outcomes and qualitative perceptions within a single design. These gaps must be addressed to determine whether game-based models can transcend the hype and become useful instruments in the regulars of the medical curriculum.[16] The current research was thus aimed at assessing the effectiveness of the MedMorph structural game model as a novel teaching-learning tool for undergraduate medical learners. Particularly, it focused on evaluating the effects of model participation, including significant improvements in knowledge testing, as measured by pre- and post-tests, and whether students would find the experience engaging, memorable, and contributing to teamwork and the clarity of concepts. With a mixed-methods design that includes both quantitative and qualitative components, the research question measured the extent of learning gains and investigated the processes and student beliefs underlying them. This twofold attention offers a better insight into the way and reason within the context of why MedMorph could act as a pedagogical aid.

Finally, the significance of the current research is that it could contribute to the developing field of medical education by providing evidence that can be applied to a model that is both theoretically sound and practically applicable. When executed successfully, MedMorph might be a scalable initiative that furthers the purpose of anatomy teaching, aligns with the principles of active and embodied learning, and responds to students' calls for more engaging and meaningful education. By so doing, it can not only enhance immediate learning outcomes but also provide a basis for understanding and further preparation for clinical practice.

Materials and Methods

AA cross-sectional interventional study was done with 50 first-year MBBS students after an introductory lecture on the anatomy of the hip joint. All participants were given a baseline pre-test in the form of an Essay, worth 15 marks, to assess their factual knowledge. As soon as that, the structural game model activity of the MedMorph was introduced. In this exercise, the group of students who were interested and admitted voluntarily to participate in the game model-making were guided accordingly. They played the role of bones, ligaments, and the functional movement of the hip joint (Figure 1), and others observed, discussed them, and made their contributions under the supervision of the faculty. The structure game model was also intended to encourage active involvement, peer-to-peer learning, and enhanced memory of the anatomical concepts. The test was again administered to all students after the activity to assess post-intervention knowledge gain. Also, student feedback regarding the intervention was collected using a structured online questionnaire with closed- and open-ended questions. This was done through institutional ethics approval, and informed consent was taken from all subjects. The scores were input into the spreadsheet in Google, and the percentage was computed and statistically analysed.

Results

The quantitative study indicated a significant increase in the knowledge score. The fundamental pre-test score was 26.02 (SD = 12.75), but it rose to 41.66 (SD = 14.38) on the post-test. This was an average increment of 15.64 points. This was statistically significant, as a paired-samples t-test confirmed $t(149) = 15.45$, $p < 0.001$. The confidence interval (mean difference) of 95 or above was [13.65, 17.63]. It had a large educational impact, with an effect size of Cohen's $d = 1.27$. The effect size was also substantial ($dz = 0.81$, $t(149) = 9.97$, $p < 0.001$) even when the pre- and post-test scores were assumed to be zero-correlated.

The statistical results were supported by qualitative feedback. Students claimed that the MedMorph structural game model helped them learn more effectively, more engagingly, and easily than the lectures. The benefits of visualizing anatomical structures through enactment were described by many and included enhanced understanding of the concepts and collaboration. Only a few learners expressed hesitation at the beginning or about time constraints, but they recommended expanding the model to clinical settings to make it more applicable.

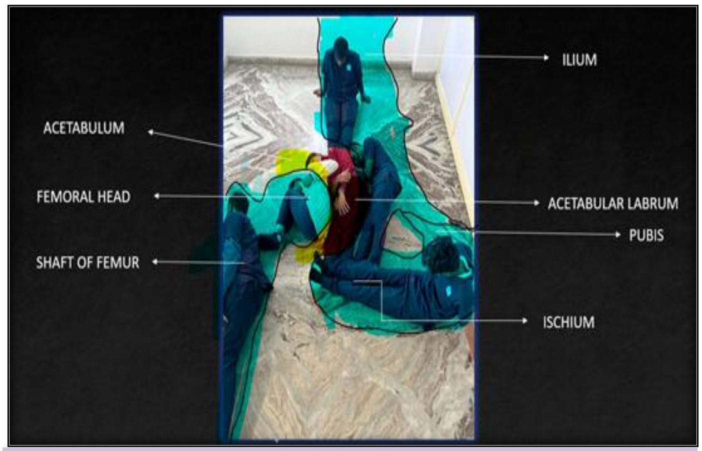

Figure 1: The "MedMorph" structural game model of Hip Joint

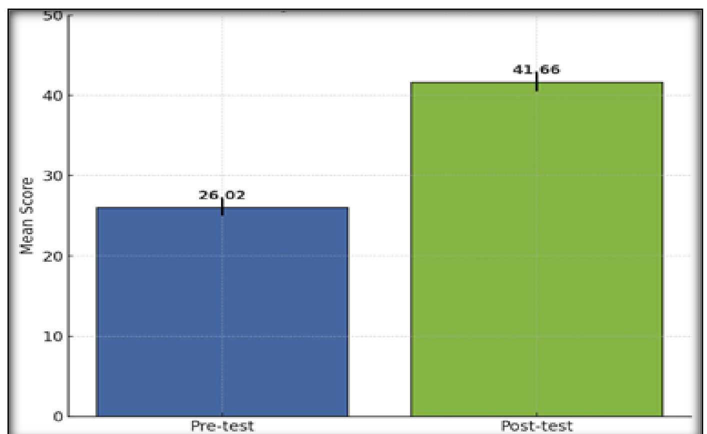

Figure 2: Comparative analysis of the pre and post-test percentage scores

Table 1: Comparison of Pre-test and Post-test Scores

Groups	Mean	N	Std. Deviation	Std. Error Mean	p-Value
Pre Test Scores	26.0200	50	12.75451	1.04140	<0.001
Post Test Scores	41.6600	50	14.38065	1.17418	

Discussion

The results presented in this paper clearly show that the MedMorph structural game model led to a drastic increase in students' knowledge and understanding. The average pre-test score of 26.02 (SD = 12.75) increased significantly to 41.66 (SD = 14.38) after the intervention, yielding a mean increase of 15.64. This was statistically significant, and a paired-samples t-test yielded $t(149) = 15.45$, $p < 0.001$, with a confidence interval for the mean difference of 13.65 to 17.63. The effect size was remarkably large (Cohen's $d = 1.27$), which is uncommon in educational interventions. The improvement was large even when the analysis was conducted under more conservative assumptions ($dz = 0.81$, $t(149) = 9.97$, $p < 0.001$), indicating the robustness of the results. In addition to the quantitative students, the MedMorph events were suggested as more interactive, engaging, and memorable than a typical lecture. Several stressed that the exercise helped them learn more about the relationships among various organs and tissues, encouraged cooperation, and facilitated group learning. However, some participants indicated they felt hesitant to participate and worried about how much time it would take. In general, the quantitative and qualitative results are rather convincing, as they allow practitioners and scholars to conclude that MedMorph is a robust pedagogical strategy that can lead to tangible educational outcomes.

The magnitude of the change realized at MedMorph suggests that the benefits extended beyond a significant educational step. Effect sizes of 0.8 or more in academic research could be regarded as large, and this means that the effect of 1.27 is unusually strong. Several theoretical accounts can explain this. The use of multimodal encoding is one such issue: students were not only listened to but also represented visually, acted out physically, and formed teams. According to cognitive theories, only when concepts are coded across various sensory and cognitive modalities is memory strengthened. The other learning tool is active retrieval and immediate feedback of the game. Retrieval practice is more effective at improving learning than exposure, whereas timely feedback has also been proven to correct misconceptions before they are internalized. Moreover, competition and social elements of the game must have increased motivation, distracted less, and stimulated further cognitive processing. Lastly, the kinesthetic practice of the anatomy's structural relationships could have offered benefits of spatial cueing and structural comprehension, which are less readily accomplished by any textual or purely auditory instructional method.

These results are complemented by qualitative feedback from students and provide further insight into the learning mechanisms. Students have consistently noted that lectures were less enjoyable, less engaging, and easier to forget than MedMorph. They reported that the implementation of anatomical relationships improved visualization of concepts, with knowledge becoming more concrete and easier to remember. Another issue raised by students is the importance of teamwork, which they emphasized as helpful to their learning through collaboration and peer explanations, making the process more enjoyable. These descriptions are more fitting in line with social learning theories, where social discussion and group performance add to the construction of knowledge. Remarkably, the students who were not eager to follow the unknown format at first or who expressed concerns regarding the duration devoted to the activity disclosed them, but tended to partially lose them as they realized the benefits of the model. Notably, disapproving remarks were more focused on logistical modifications than on any educational defects, and some students noted that the model would apply to clinical settings. It shows that the learners have recognized the importance of the approach and are willing to see it incorporated more widely into the curriculum.

The results of this research also align well with previous research on the use of game-based and other interactive learning strategies in medical research. An example is provided by Styn et al. (2023), who conducted a pre-post study in which learners used a tablet-based anatomy gross drawing game.[17] Still, Luchi et al. (2019) found the effect size of the physiology board games to be important. It is on this background that the effect size realized by MedMorph (dz = 1.27) is particularly strong. A meta-analysis by Roberts et al. found that, in general, gamification has moderate effects in education. MedMorph thus appears to be even better than expected for game-based interventions, probably due to its embodied and social character. Similar studies, including that of Hill et al. (2018), which found medium effects using game-based functional anatomy,[18] also indicate the benefit of the structured enactment provided by MedMorph. Embodied cognition studies also offer a second reason to support this: Chang et al. found that gesture-based teaching improves spatial memory,[10] whereas Sivashankar et al. found that enactment increases retention twice as much as passive viewing.[11] MedMorph is based on these principles, but with a more organized, team-oriented approach that would increase its impact. The risk of cognitive overload, as explained by cognitive load theory, is one of the issues commonly raised with interactive or game-based models. If many things are added during the process, learners might become overwhelmed and unable to assimilate the information. The qualitative reports of this study, however, indicate the opposite. The students, in general, perceived the anatomical relationships as clearer and easier to comprehend, without being chaotic or confusing. This implies that the MedMorph model induced germane, or schema-supportive, cognitive load, not any superfluous or supernumerary load. The so-called germane load, in accordance with the framework introduced by Cheon, J., and Grant, indeed promotes an ultimate understanding, but forces learners to engage in meaningful processing.[19] Although the immediate gains achieved in this research are remarkable, the issue of retention remains to be addressed. Neyemet al. (2025) reported that game-based anatomy sessions were rated lower after 6 weeks of retention without additional game use, using spaced-repetition techniques.[20] This suggests that MedMorph could be even more effective when integrated with post-training activities, periodic tests, or clinical practice to maintain knowledge in the long term.

The current study has several strengths that enhance its credibility. The pre-post intervention design, which assessed students at the beginning and after the intervention, helped control for individual differences, as each student served as their own control group. The fact that the t-test was large and the limits were both small suggests that we not only obtained statistically significant results, but the effect sizes and the conservative Sensitivity Analysis extend the findings that the gains were noteworthy even under pessimistic assumptions. Lastly, this is because of the mixed-methods approach implemented, i.e., quantitative test data are used alongside qualitative student feedback, which provides a more holistic perspective. The improvement may be seen as mere numbers, which is why student reflections would give reasons and ways in which the model was functioning, so that teachers can learn more of the mechanisms behind the observed improvements.

Meanwhile, certain limitations have to be taken into consideration. Of greatest importance, the research did not include a randomized control group, which limits the ability to draw causal inferences. When there is no comparison with another teaching strategy, it is hard to eliminate the possibility that the improvement was caused by repeated testing, maturation, or the newness of the experience. The measure taken of gains immediately following the intervention also implies that the data already obtained are more indicative of short-term memory, and that there is yet no conclusion as to the long-term retention. The study was also carried out at one institution, and thus it might not be generalizable to other settings or student groups. Measurement factors should also be taken into account. If the evaluation elements were closely linked to the content rehearsed in the MedMorph game, the gains may reflect test-specific learning rather than general conceptual knowledge. These restrictions indicate that one should be cautious when generalizing the results, but they do not dismiss the strong evidence of short-term positive consequences.

Notwithstanding these constraints, there are educational implications. The findings indicate that learning, motivation, and teamwork can be improved through organized, game-based interventions, such as MedMorph, when carefully integrated into the teaching reported in anatomy courses. Teachers who are considering adopting such models are encouraged to provide as much orientation to students as possible to reduce hesitation, ensure the right amount of time to eliminate the feeling of being under pressure, and organize sessions with clear goals and streamlined facilitation. The MedMorph can also be integrated into a larger pedagogical sequence, starting with preparatory reading, continuing with a structural game, and ending with debriefing and transfer assignments. This would consolidate the acquired information from the activity and implement it in clinical settings. Given that even students themselves are interested in the model's application in clinical contexts, MedMorph or other models may be scaled to case-based learning, procedural skills, and clinical reasoning, thereby widening their scope of application across various fields of medical education.

The challenge of identifying the limits of the research should be targeted in future research, which should also further explore the potential of structural game models. Stronger causal arguments and a conclusion on whether MedMorph has benefits or harms relative to existing techniques could be supported by randomized controlled trials comparing MedMorph with other active-learning methods. Longitudinal studies should also be conducted to test retention in the medium and long term and the transfer of knowledge to clinical reasoning and practice. The study of several institutions and various student groups would help gauge the general applicability of the findings. Investigations at the process level might also be very informative, such as quantifying amounts of cognitive load, attention, or even physiological signs of attention during MedMorph sessions. Lastly, research on the cost-effectiveness and logistics of large-scale implementation would be needed to inform broader curricular implementation directions.

Conclusion

As indicated in the present research, the MedMorph structural game model of teaching-learning is an innovative teaching-learning model that has high effectiveness in improving immediate knowledge acquisition and engaging students. The significance of the effect is immense, and the use of qualitative feedback regularly demonstrates that the model not only enhances factual knowledge but also clarity of concept, collaboration, and motivation within the team. The lack of a randomized control group and the scarcity of long-term follow-up limit the quality of causal inference and conclusions. Still, the overlap between quantitative and qualitative data provides overwhelming evidence of its teaching value. Notably, the students themselves expressed interest in applying the model across wider curricular and clinical settings, suggesting it is viable and acceptable. Future studies should investigate its effects on long-term retention, clinical reasoning, and cross-institutional generalizability. On balance, MedMorph is a possible pedagogical novelty that could enrich medical education through embodied, interactive, and student-centered learning.

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Conflicts of interest

There are no conflicts of interest.

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