Research Article

Implementation of Project-Based Learning (PtBL) as a Teaching–Learning Tool in Pharmacology for Phase II MBBS Students at a Medical College in Northeast India: A Prospective Interventional Study

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ABSTRACT

Background: Implementation of CBME has brought a paradigm shift in medical education. PtBL is an innovative teaching-learning method that encourages students to learn and apply knowledge, skills through an engaging experience.

Objectives: To implement PtBL as teaching–learning tool in Pharmacology for MBBS students; to determine its effectiveness in improving knowledge, critical understanding and collaborative skills.

Methods: This study was conducted over six months in Pharmacology Department, among 100 Phase-II MBBS students. After sensitization sessions for faculty and students, selected pharmacology topics were taught through interactive lectures. Students were then divided into 10 groups and assigned either poster-based or model-based projects under faculty facilitation. Topic-specific pre- and post-tests were administered using validated multiple-choice and short-answer questions. Feedback from students and facilitators was collected using structured questionnaires. Data were analysed descriptively; pre- and post-test scores were compared using paired/unpaired t-tests, $p<0.05$ was considered statistically significant.

Results: Across all topics, there was a statistically significant improvement in mean post-test scores compared with pre-test scores. Both models and posters were effective, with mean scores improving from pre-test scores; there was no significant difference between the two formats. Student feedback indicated that PtBL was engaging, improved critical thinking and problem-solving. 70% facilitators reported better retention and application of pharmacological concepts, although time and resource constraints were noted.

Conclusion: PtBL is an effective and feasible teaching–learning strategy for Pharmacology, enhancing knowledge, engagement, and collaborative skills. Integrating PtBL more widely into pharmacology may help bridge the gap between basic pharmacology and its clinical application.

Keywords: *Project-based learning, CBME, Pharmacology education, MBBS, Active learning.*

1. INTRODUCTION

Pharmacology occupies a central position in the undergraduate medical curriculum, providing the foundation for rational prescribing and safe drug use in clinical practice. However, students frequently perceive pharmacology as a vast, fact-heavy discipline that is difficult to understand and recall, especially when taught predominantly through didactic lectures. Traditional lecture based learning (LBL) may promote passive reception of information and short-term memorization rather than conceptual integration and application of knowledge to patient care [1, 2, 3].

Contemporary educational frameworks in health professions emphasize learner-centered, active pedagogies that foster critical thinking, clinical reasoning, and self-directed learning. Among these, project-based learning (PtBL) is characterized by student engagement in extended, authentic tasks or projects that require

them to investigate questions, solve problems, and create tangible products, often working in groups under faculty guidance. In medical and health professions education, PtBL has been adapted to support integration of basic and clinical sciences, enhance research skills, and promote higher-order cognitive and professional competencies [1, 3, 4].

Evidence from health professions and biomedical education suggests that PtBL can improve academic performance, deepen conceptual understanding, and increase student motivation. A literature review of PtBL in health professions education reported positive effects on knowledge acquisition, skills development, and learner satisfaction across diverse contexts. In a recent study among medical students, project-based and simulation-based approaches were shown to enhance research competence and academic outcomes. Within pharmacology specifically, the use of project- or task-based strategies, including model building and poster preparation, has been associated with improved examination scores, better retention, and high levels of student satisfaction [1, 4, 5].

In India, undergraduate pharmacology teaching has traditionally relied on lectures and practical exercises centered on prescription writing, charts, and demonstrations. Given the evolving competencies expected from Indian Medical Graduates, including problem-solving, communication, teamwork, and lifelong learning, there is a need to integrate structured active learning strategies such as PtBL into the pharmacology curriculum. Prior work from a South Indian medical college demonstrated that project-based learning using posters and models significantly improved pharmacology learning and were well received by students. However, there is limited published evidence from Northeast India, and contextual factors such as resource constraints and faculty readiness may influence implementation and outcomes [1, 2, 3]. PtBL emphasizes active engagement, critical thinking, and collaborative learning, which are core competencies for medical professionals. By focusing on essential pharmacological topics and engaging students in the development of educational products such as posters and models, PtBL has the potential to enhance understanding of drug mechanisms, therapeutic applications, and adverse effect profiles, while simultaneously strengthening communication and teamwork skills. Generating local evidence on PtBL in Pharmacology will support informed curricular decisions under the competency-based medical education framework in India. Hence, this study was undertaken to implement and evaluate the effectiveness of project-based learning as a teaching–learning tool in Pharmacology for Phase II MBBS students with the objectives to sensitize faculty members and students regarding PtBL in Pharmacology, to implement PtBL as a teaching-learning tool in Pharmacology and to determine the effectiveness of PtBL in improving students' knowledge, skills and engagement.

2. MATERIALS & METHODS

2.1 Study Setting and Design

This was a prospective interventional study conducted in the Department of Pharmacology, Jorhat Medical College, Assam, India, over a period of six months. The department conducts regular theory and practical sessions for Phase II MBBS students under the competency-based undergraduate medical curriculum.

2.2 Participants

All 100 Phase II MBBS students enrolled in Pharmacology during the study period were invited to participate. Inclusion criteria were regular attendance in Pharmacology classes and willingness to provide informed consent. Students who were absent for either the pre-test or post-test related to their project topic were excluded from the respective analysis.

2.3 Ethical Consideration

The study protocol was reviewed and approved by the Institutional Ethics Committee (H) (SMEJ/JMCH/MEU/841/Pt-III/2023/4603).

Written informed consent was obtained from all participants. Confidentiality and anonymity were maintained by assigning unique codes to student responses and feedback forms, and participation or non-participation had no bearing on internal assessment or summative evaluation.

2.4 Sensitization of Faculty and Students

Prior to implementation, faculty members in the Department of Pharmacology participated in a

sensitization session conducted by the Department of Medical Education on the principles and process of project-based learning, including setting clear learning outcomes, facilitating group work, and providing constructive feedback. Similarly, an orientation session was held for students to introduce the concept of PtBL, outline expectations, explain assessment methods, & clarify timelines [1. 4, 6].

2.5 Selection of Topics and Instructional Phase

Core pharmacological topics from the "must-know" area of the Phase II MBBS syllabus were identified, ensuring relevance to future clinical practice and suitability for visualization through models or posters. The topics included were acid peptic disease, bronchial asthma, glaucoma, opioid analgesics, receptors, antidepressants, antihypertensive drugs, local anaesthetics, oral antidiabetic drugs and antiparkinsonian drugs. These topics were first covered through interactive lectures using audiovisual aids and clinical vignettes, with emphasis on mechanisms of action, therapeutic uses, adverse effects, and contraindications.

2.6 Group Formation and Project Allocation

Students were divided into 10 groups of approximately 10 students each, ensuring a mix of academic performance levels and gender to promote peer learning and inclusivity. Each group was assigned one pharmacological topic and one mode of project:

- Model-based projects (5 groups): Acid peptic disease, Bronchial asthma, Glaucoma, Opioids, Receptors.
- Poster-based projects (5 groups): Antidepressants, Antihypertensive drugs, Local anaesthetics, Oral antidiabetic drugs, Antiparkinsonian drugs.

Each group was assigned a faculty facilitator responsible for guiding topic exploration, monitoring progress, and helping resolve any conceptual or logistical difficulties. Facilitators were advised to promote student autonomy while providing timely feedback [1, 2].

2.7 Nature of Projects

Model-based projects involved the design and construction of three-dimensional models illustrating relevant physiological or pathophysiological processes, mechanisms of drug action, or drug delivery systems e.g. models of gastric acid secretion and H2 blockers, receptor subtypes and signal transduction, or airway changes in asthma and the effects of bronchodilators [2, 6]

Poster-based projects required groups to design structured, visually coherent posters that presented key concepts, drug classifications, mechanisms, therapeutic uses, adverse effect profiles, and clinical pearls for the assigned topic. Evidence-based information from standard pharmacology textbooks and current guidelines was encouraged [1, 2].

Students were given a defined timeline to conceptualize, prepare, and finalize their projects, during which they could consult faculty facilitators during allocated hours.

2.8 Assessment Tools

2.8.1. Knowlwdge assessment

For each topic, a structured questionnaire was developed, comprising a combination of multiple-choice questions (MCQs) and short-answer questions mapped to pre-specified learning objectives. The questionnaires were content-validated by senior Pharmacology faculty and pilot-tested for clarity.

Students completed a topic-specific pre-test before commencing project work. On the day of project presentation, the same set of questions was administered as a post-test. Scores were recorded as mean ± standard deviation (Mean ± SD).

2.8.2 Feedback Questionnaires

Student feedback was collected using a pre-designed, anonymous questionnaire with Likert-scale items assessing perceived usefulness of PtBL in understanding pharmacological concepts, impact on critical thinking and problem-solving skills, improvement in teamwork and communication skills, level of engagement and enjoyment, perceived challenges (time constraints, resources, group dynamics).

Facilitators completed a separate feedback form capturing perceptions of student engagement, conceptual understanding, feasibility of implementation, and challenges faced.

2.9 Data Management and Statistical Analysis

Data from pre- and post-tests, and feedback forms were entered into Microsoft Excel. Continuous variables (test scores) were expressed as mean ± SD. Paired comparisons of pre- and post-test scores for each topic were conducted using paired t-test with $p < 0.05$ considered statistically significant. For comparison of overall learning gains between model- and poster-based projects, mean pre- and post-test scores for each format were compared using unpaired t-test with $p < 0.05$ indicating a significant difference.

3. RESULTS & DISCUSSION

3.1 Participant Characteristics

All 100 Phase II MBBS students participated in the PtBL sessions and completed the assigned projects. Complete pre- and post-test data were available for all 10 groups, and the response rate for student feedback questionnaires exceeded 90%.

3.2 Topic-wise Pre- and Post-Test Scores

Across all topics, students demonstrated significant improvement in knowledge following participation in project-based learning. Mean pre-test and post-test scores for each topic are summarized in Table 1.

Table 1: Comparison of pre- and post-tests of individual model and poster

Topic	Type of project	Pre-test	Post-Test	p-value
Acid peptic disease	Model	2.8±1.1	4.3±1.2	<0.05/Sig
Bronchial Asthma	Model	3.3±1.9	5.6±1.7	
Glaucoma	Model	2.8±2.0	4.9±1.9	
Opioids	Model	2.1±1.1	3.2±0.9	
Receptors	Model	4.6±0.9	6.0±0.9	
Antidepressants	Poster	2.0±1.4	4.1±1.4	
Antihypertensive drugs	Poster	4.4±1.6	6.2±1.4	
Local Anaesthetics	Poster	3.1±1.2	5.5±1.5	
Oral Antidiabetic drugs	Poster	3.9±2.0	5.5±2.0	
Antiparkinsonian drugs	Poster	2.4±1.8	4.8±1.9	

These results indicate that engagement in project-based tasks, whether via models or posters, led to meaningful gains in topic-specific pharmacology knowledge.

3.3 Comparison of Models and Posters

When aggregated by project type, both model-based and poster-based formats yielded substantial learning gains (Table 2).

Table 2: Comparison of models and posters.

ns = Not significant.

The difference in post-test performance between model- and poster-based projects was not statistically significant ($p = 0.51$), indicating that both formats were similarly effective in improving learning outcomes.

3.4 Students‘ Feedback

Student perceptions of PtBL were predominantly positive:

- Eighty five percent (85%) agreed or strongly agreed that PtBL was engaging and effective in reinforcing pharmacological concepts.
- Eighty percent (80%) reported that participation in projects improved their critical thinking and problem-solving skills.
- Seventy five percent (75%) felt that teamwork during PtBL enhanced their communication and collaboration, although some reported difficulties in coordinating schedules and task distribution.

Ninety percent (90%) appreciated the support and guidance provided by faculty facilitators.

3.5 Facilitator Feedback

Faculty facilitators observed:

- Increased student participation and enthusiasm during project preparation and presentations.
- More in-depth discussions of mechanisms, indications, and rational drug use compared with conventional lecture sessions.
- Better retention and application of pharmacological concepts among students, as reflected in discussions and post-test performance; approximately 70% of facilitators explicitly noted improved conceptual grasp.

However, facilitators also highlighted challenges e.g. time constraints within the existing timetable to adequately supervise projects in addition to routine teaching responsibilities, limited availability of materials and institutional funds for constructing elaborate models, particularly in a resource-constrained, government medical college setting. Despite these challenges,

facilitators expressed willingness to continue and expand PtBL in the Pharmacology curriculum with appropriate institutional support.

3.6 Discussion

3.6.1 Principal findings

This prospective interventional study demonstrated that implementing project-based learning in Pharmacology for Phase II MBBS students significantly improved topic-specific knowledge, as evidenced by higher post-test scores across all ten topics. There was no significant difference in learning gains between model-based and poster-based projects, indicating that both formats can be used effectively to promote active learning. Students and faculty reported high levels of engagement and perceived benefits for understanding, critical thinking, and teamwork, although challenges related to time and resources were identified.

3.6.2 Comparison with Existing Literature

The results of this study corroborate published evidence supporting PtBL and related active methodologies in Pharmacology and broader medical education. A study from a South Indian medical college that utilized poster and model projects in Pharmacology reported significant improvements in immediate post-test scores for both project types, high proportions of students achieving ≥50% marks, and strong student endorsement of the approach. Our findings of significant pre- to post-test improvements and comparable effectiveness of posters and models are in line with these observations [2].

Beyond Pharmacology, adapted project-based and problem-based learning strategies in physiology and other basic sciences have been shown to enhance understanding of complex concepts and promote student satisfaction. A literature review of PtBL in health professions education concluded that PtBL can positively influence knowledge, skills, and attitudes, particularly when projects are well aligned with curricular outcomes and adequately supported by faculty. More recent work in medical education has shown that project-based and simulation-based strategies can strengthen research competencies and academic performance, further underscoring the versatility of PtBL in fostering higher-order learning [4, 5, 6].

While most Pharmacology education research has focused on problem-based learning (PBL) rather than PtBL, meta-analyses have shown that PBL can lead to higher examination scores, better thinking skills, and increased student satisfaction compared with traditional lecture-based methods in undergraduate pharmacology. Our study adds to this body of evidence by highlighting that project-based approaches, which often integrate elements of self-directed inquiry, teamwork, and product creation, also produce significant learning gains and are well accepted by students [3].

3.6.3 Possible Explanations and Educational Implications

Several mechanisms may underlie the positive impact of PtBL observed in this study. Students involved in designing models or posters must process and reorganize pharmacological information, which promotes deeper semantic encoding and retention compared with passive listening. Models and well-designed posters enable visualization of abstract processes such as receptor interactions, signal transduction, or disease pathophysiology, helping learners form integrated mental models that support application to clinical scenarios.

Collaborative learning through working in groups encourages peer teaching, negotiation of meaning, and distributed problem-solving, which have been linked to improved understanding and social learning outcomes in health professions education. Regular interactions with faculty facilitators also provide opportunities for clarification, correction of misconceptions, and scaffolding of higher-order thinking skills.

These features are aligned with constructivist theories of learning and with competency-based medical education's emphasis on learner-centered, outcome-oriented design. Incorporating PtBL into Pharmacology teaching can therefore support not only knowledge outcomes but also generic competencies such as communication, collaboration, and self-directed learning that are essential for future clinicians.

In practical terms, PtBL can be integrated into the Pharmacology curriculum in ways as follows:

- Replacing a subset of didactic lectures with project-based sessions on selected "must-know" topics.
- Using PtBL as a capstone activity for thematic modules (example autonomic pharmacology, cardiovascular pharmacology).
- Linking projects with early clinical exposure by focusing on common clinical conditions and real-world prescribing challenges.

Our experience suggests that both posters and models are effective, but institutions may choose formats based on available resources, time, and assessment strategies.

3.6.4 Strengths and Challenges of Implementation

A key strength of this study is its comprehensive, topic-wise evaluation of PtBL in a full Phase II MBBS cohort within a government medical college in Northeast India, a region under-represented in medical education research. The study also combines objective learning outcomes (pre- and post-test scores) with subjective feedback from both students and facilitators, providing a multidimensional view of effectiveness and feasibility.

However, implementation was not without challenges. Time constraints were a recurrent concern, both for students balancing multiple subjects and for faculty managing project supervision alongside regular teaching and administrative responsibilities. Similar challenges related to faculty workload and time allocation have been highlighted in previous PtBL implementations, particularly in resource-limited settings. Limited access to materials and funds for constructing models also posed difficulties, suggesting a need for institutional support, creative use of low-cost resources, and possibly shared repositories of reusable models.

Despite these constraints, the positive reception and measurable learning gains observed in this study indicate that PtBL can be successfully implemented even in relatively resource-constrained environments when careful planning, faculty development and administrative backing are present. This is consistent with recent work showing that PtBL can be adapted effectively to low-resource medical education contexts when faculty receive targeted training and structured implementation frameworks.

3.6.5 Limitations

This study has several limitations. First, it used a single-group pre- and post-test design without a parallel control group receiving only traditional lectures, which limits causal inference regarding the relative superiority of PtBL over traditional Lecture-Based Learning. Second, assessment focused on short-term knowledge gains; we did not evaluate long-term retention or performance in summative examinations or clinical settings, although prior studies suggest that active learning methods can enhance long-term outcomes. Third, the study was conducted in a single institution with one batch of students, which may limit generalizability to other contexts. Finally, feedback instruments relied on self-report and may be subject to social desirability bias.

3.6.6 Future Directions

Future research could address these limitations by using controlled or crossover designs comparing PtBL with traditional lectures, assessing long-term retention and clinical performance, and exploring objective measures of skills such as communication, teamwork, and problem-solving. Multi-institutional studies would help determine the scalability and generalizability of PtBL in pharmacology across diverse educational and resource settings. Integration of PtBL with other active methodologies, such as simulation-based learning and flipped classrooms could also be explored.

4. CONCLUSION

Project-based learning is a feasible and effective teaching–learning strategy for Phase II MBBS Pharmacology in a government medical college in Northeast India. Implementation of poster- and model-based projects on core pharmacological topics led to significant improvements in topic-specific knowledge, with no significant difference in learning outcomes between the two formats. Students and facilitators perceived PtBL as engaging and beneficial for understanding,

critical thinking and teamwork, despite challenges related to time and resources.

Incorporating PtBL more widely into the Pharmacology curriculum may help bridge the gap between theoretical knowledge and clinical application, foster essential professional competencies, and align teaching practices with the goals of competency-based medical education. Institutional commitment to faculty development, timetable planning and basic material support will be essential for sustainable integration and scaling of PtBL in Pharmacology and other basic medical sciences.

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CONFLICT OF INTEREST

We wish to confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

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ETHICAL INFORMATION

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