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ORIGINAL ARTICLE

Sequential Multiple Classes for Improving Learning Skills Among Undergraduate Medical Students in Pharmacology: A Prospective Interventional Study

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ABSTRACT

Background: *Pharmacology plays a vital role in building rational prescribing skills, yet students frequently find it difficult to translate theoretical knowledge into clinical practice. Even though active, student-centered methods can enhance learning, there is limited evidence regarding adaptive sequential teaching in Bangladesh. This research compared the cognitive learning outcomes of sequential multiple classes against conventional teaching among undergraduate medical students studying pharmacology.* ***Methods & Materials:*** *A prospective interventional study was carried out involving fourth-year MBBS students from four medical colleges in Bangladesh. Students were assigned to either conventional or sequential multiple online classes, and later intervention sessions were tailored based on identified learning gaps and feedback. Learning outcomes were measured through pre-, post-, and supplementary post-tests grounded in the revised Bloom's taxonomy, while perceptions were evaluated using a five-point Likert scale. The data were analyzed with suitable statistical tests, and a p-value of less than 0.05 was regarded as significant.* ***Results:*** *Participation in the pre-test was greater in the intervention group (83.33% vs. 55.0%, p<0.05), whereas attendance and post-test participation were similar between the two groups. Significant improvement was seen in both groups across all cognitive domains (p<0.01), and post-test scores were higher in the intervention group (18.02±0.17 vs. 14.44±0.36, p<0.01). The intervention group likewise had higher supplementary post-test scores (10.71±0.22 vs. 8.42±0.35, p<0.01), with the exception of applying. Favorable perceptions were reported by both groups, with the conventional group showing a higher overall score (45.95±4.13 vs. 43.05±6.78, p<0.01).* ***Conclusion:*** *Sequential multiple classes led to better cognitive outcomes than conventional teaching and were received positively, supporting their promise as an adaptive approach to pharmacology teaching.*

Keywords: *Sequential multiple classes, Pharmacology education, Active learning, Cognitive learning, Competency-based teaching, Undergraduate medical students.*

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INTRODUCTION

Pharmacology plays a vital role in undergraduate medical education, offering the foundation for comprehending how drugs work, their therapeutic applications, adverse reactions, and the principles of rational prescribing. Nevertheless, students frequently encounter challenges when translating theoretical concepts into clinical decision-making. Inadequate undergraduate pharmacology education has been associated with insufficient prescribing knowledge and prescribing errors among junior physicians [1,2].

Traditional lecture-based instruction primarily focuses on transmitting information, while modern medical education encourages active, integrated, and student-centered learning. Team-based and other active-learning approaches have enhanced performance, satisfaction, engagement, and learning outcomes in pharmacology [3-5]. Combining medicinal chemistry with pharmacology and pharmacotherapeutics could further reinforce conceptual understanding and link basic science to clinical practice [6,7].

Learning is most effective when it advances from rote memorization toward more advanced cognitive abilities. The revised Bloom's taxonomy provides a framework for progressing from lower- to higher-order cognitive processes, including remembering, understanding, applying, analyzing, evaluating, and creating [8].

The growing adoption of online and blended education has opened up further possibilities for learning that is both flexible and interactive. Blended learning methods have proven effective with large and varied groups of undergraduates, which indicates that instruction can be organized to meet the needs of different learners while still preserving educational quality [9]. A study conducted in Bangladesh on e-learning within pharmacology practical classes found that integrating e-learning contributed to more active involvement of postgraduate medical students in practical teaching and aided their learning [10]. These results indicate that e-learning may serve as a valuable supplementary method for enhancing student participation and engagement in pharmacology education.

In Bangladesh, while e-learning and active teaching methods have been investigated in pharmacology education, there is scarce evidence regarding sequential, adaptive teaching models that rely on students' assessed competency gaps to adjust later

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sessions. Therefore, this study compared the cognitive learning outcomes and students' perceptions of sequential multiple classes with conventional teaching among undergraduate medical students in pharmacology.

METHODS & MATERIALS

Study design and setting: A prospective interventional study was conducted from February 2020 to July 2021 under the Department of Pharmacology, Bangabandhu Sheikh Mujib Medical University (BSMMU), Dhaka, Bangladesh. The study included fourth-year MBBS students from four randomly selected medical colleges in Bangladesh. Four medical colleges were selected for participation. Two colleges constituted the control group and two constituted the intervention group. A total of 202 eligible fourth-year MBBS students were included, comprising 100 students in the control group and 102 students in the intervention group.

The control group comprised fourth-year students from M Abdur Rahim Medical College, Dinajpur, and Mugda Medical College, Dhaka, where the selected Pharmacology and Therapeutics content was delivered through conventional online classes. The intervention group comprised fourth-year students from Sheikh Hasina Medical College, Jamalpur, and Shaheed Syed Nazrul Islam Medical College, Kishoreganj, where the selected content was delivered through sequential multiple online classes.

Development of teaching materials: Teaching materials were developed according to the learning objectives of the Bangladesh Medical and Dental Council (BMDC) curriculum for Pharmacology and Therapeutics. Assessment materials were designed according to the revised Bloom's taxonomy, covering six cognitive domains: remembering, understanding, applying, analyzing, evaluating, and creating.

Semi-structured questionnaires containing open- and closed-ended questions were developed to assess students' competency in these six cognitive domains. The teaching materials and assessment questionnaires were reviewed through discussions with the heads of the Pharmacology departments of the participating medical colleges before implementation.

Intervention: sequential multiple classes: Students in the intervention group received the selected Pharmacology and Therapeutics content through four sequential online teaching sessions. The content of subsequent sessions was modified according to the competency gaps identified after preceding sessions. Before each subsequent session, students' learning gaps were assessed using a semi-structured questionnaire. A brief discussion of approximately 15 minutes was also conducted to identify students' perceived learning difficulties and needs. In addition, two online focus group discussions, each involving approximately 7–10 students from the intervention colleges, were conducted to explore students' learning needs and preferred teaching approaches.

The findings from the competency assessments, student discussions, and focus group discussions were used to modify the content and teaching strategies of the subsequent sessions. Thus, the intervention followed a sequential process in which assessment findings and students' feedback informed subsequent teaching.

Control: conventional classes: Students in the control group received the same selected Pharmacology and Therapeutics content through conventional online lecture-based classes. The teaching was delivered without the sequential modification of subsequent sessions based on competency-gap assessment and student feedback.

As the study was conducted during the COVID-19 pandemic, teaching was delivered through online videoconferencing platforms, and assessments were conducted electronically.

Participation and attendance: Students who participated in the pre-test, attended the scheduled teaching sessions, and participated in the post-test were recorded separately. An attendee was defined as a student who attended the respective class, whereas a participant was defined as a student who completed the respective assessment. In the control group, 100 students were considered for participation, while 102 students were included in the intervention group. Participation in the pre-test, attendance at classes, and participation in the post-test among attendees were recorded for both groups.

Assessment of learning outcomes: Learning outcomes were assessed using pre-test, post-test, and supplementary post-test questionnaires. The pre-test was conducted before delivery of the selected teaching content to assess baseline cognitive performance. The post-test was conducted after completion of the teaching sessions to assess immediate learning achievement. Both the pre-test and post-test assessed the six cognitive domains of the revised Bloom's taxonomy: remembering, understanding, applying, analyzing, evaluating, and creating.

A supplementary post-test was also administered using an additional questionnaire. This assessment was included because the online learning environment and similarity between the initial pre-test and post-test could potentially influence students' performance. The supplementary assessment used a different distribution of marks across the six cognitive domains and was used to further assess students' cognitive learning outcomes.

Assessment of students' perceptions: Students' perceptions of the teaching approaches were assessed using a structured five-point Likert-scale questionnaire. The questionnaire assessed suitability of the teaching session, appropriateness according to learning objectives and learning needs, appropriateness for Pharmacology and Therapeutics lectures, synchronization with class duration, satisfaction with the teaching method, interactivity, support for active learning, contribution to rational prescribing, and overall satisfaction.

Responses were summarized to obtain individual domain scores and a total perception score. Higher scores indicated more favorable perceptions of the respective teaching approach.

Statistical analysis: Data were analyzed using appropriate statistical methods. Continuous variables were presented as mean ± standard error of the mean (SEM) or mean ± standard deviation (SD), as appropriate. Within-group differences between pre-test and post-test scores were assessed using the paired t-test, while comparisons of scores between the control and intervention groups were performed using the unpaired t-test. Differences in participation and attendance proportions between groups were assessed using the two-proportion Z-test.

A p-value <0.05 was considered statistically significant, while $p<0.01$ was considered highly statistically significant.

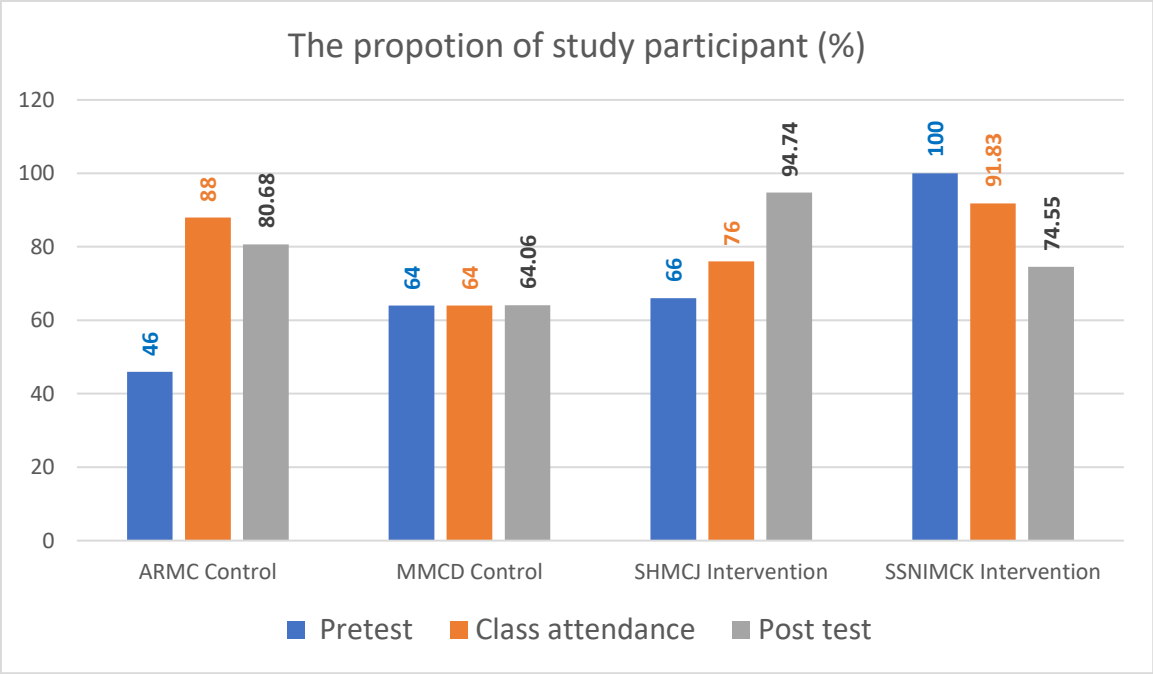
Ethical considerations: Ethical approval was obtained from the appropriate Institutional Review Board of Bangabandhu Sheikh Mujib Medical University. Participation was voluntary, and informed consent was obtained from the participating students. Students were informed about the purpose and procedures of the study, and confidentiality of the collected information was maintained. The study was conducted in accordance with accepted ethical principles for research involving human participants.

RESULTS

Figure 1 present the participation and attendance of a total of 202 students from four medical colleges, comprising 100 students in the control group and 102 students in the intervention group. Pre-test participation was higher in the intervention group (85/102, 83.33%) than in the control group (55/100, 55.0%), showing a statistically significant difference ($p<0.05$). Overall

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class attendance was 76/100 (76.0%) in the control group and 85.75/102 (84.07%) in the intervention group, with no statistically significant difference (p>0.05). Among attendees, post-test participation was 56/76 (73.68%) in the control group and 71.6/85.75 (83.50%) in the intervention group; this difference was also not statistically significant (p>0.05).



ARMC: *M Abdur Rahim Medical College, Dinajpur;* ***MMCD:*** *Mugda Medical College, Dhaka;* ***SHMCJ:*** *Sheikh Hasina Medical College, Jamalpur;* ***SSNIMCK:*** *Shaheed Syed Nazrul Islam Medical College, Kishoreganj*

Figure 1: The proportion of study participant in both control and intervention group

Table I shows the comparison of pre-test cognitive domain scores between the control and intervention groups. The mean total pre-test score was 5.66 ± 0.79 in the control group and 6.41 ± 0.43 in the intervention group, out of a maximum of 20 marks. Although the intervention group had a higher overall mean score, the difference was not statistically significant (p>0.05). Similarly, no statistically significant differences were observed between the groups in any individual cognitive domain, including remembering, understanding, applying, analyzing, evaluating, and creating (p>0.05 for all). These findings indicate that the two groups had comparable baseline cognitive performance before the intervention.

Table I: Comparison of pre-test scores between control and intervention groups

Cognitive domain	Maximum marks	Control group Mean ± SEM	Intervention group Mean ± SEM	p-value
Remembering	5	2.25 ± 0.25	2.62 ± 0.15	>0.05
Understanding	3	0.97 ± 0.14	0.86 ± 0.07	>0.05
Applying	3	0.81 ± 0.16	1.20 ± 0.12	>0.05
Analyzing	3	0.86 ± 0.17	1.22 ± 0.11	>0.05
Evaluating	4	0.48 ± 0.11	0.27 ± 0.07	>0.05
Creating	2	0.30 ± 0.07	0.24 ± 0.05	>0.05
Total	20	5.66 ± 0.79	6.41 ± 0.43	>0.05

Table II shows a significant improvement in cognitive domain scores from pre-test to post-test in both study groups. In the control group, the mean total score increased from 5.66 ± 0.79 to 14.44 ± 0.36 out of 20 marks (p<0.01). Similarly, in the intervention group, the mean total score increased from 6.41 ± 0.43 to 18.02 ± 0.17 (p<0.01). Significant improvements were observed across all six cognitive domains—remembering, understanding, applying, analyzing, evaluating, and creating—in both groups (p<0.01 for all). The intervention group demonstrated a greater increase in overall cognitive performance compared with the control group.

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Table II: Pre-test and post-test scores within each study group

Cognitive domain	Maximum marks	Control: Pre-test Mean ± SEM	Control: Post-test Mean ± SEM	p	Intervention: Pre-test Mean ± SEM	Intervention: Post-test Mean ± SEM	p
Remembering	5	2.25 ± 0.25	4.24 ± 0.08	<0.01	2.62 ± 0.15	4.80 ± 0.04	<0.01
Understanding	3	0.97 ± 0.14	2.69 ± 0.06	<0.01	0.86 ± 0.07	2.95 ± 0.02	<0.01
Applying	3	0.81 ± 0.16	2.32 ± 0.09	<0.01	1.20 ± 0.12	2.54 ± 0.06	<0.01
Analyzing	3	0.86 ± 0.17	2.38 ± 0.10	<0.01	1.22 ± 0.11	2.97 ± 0.03	<0.01
Evaluating	4	0.48 ± 0.11	1.70 ± 0.11	<0.01	0.27 ± 0.07	3.14 ± 0.08	<0.01
Creating	2	0.30 ± 0.07	1.10 ± 0.07	<0.01	0.24 ± 0.05	1.61 ± 0.04	<0.01
Total	20	5.66 ± 0.79	14.44 ± 0.36	<0.01	6.41 ± 0.43	18.02 ± 0.17	<0.01

SEM = Standard Error of Mean.

Table III shows that the intervention group achieved significantly higher post-test scores than the control group across all cognitive domains. The mean total score was 18.02 ± 0.17 in the intervention group compared with 14.44 ± 0.36 in the control group, with a statistically significant difference (p<0.01). Significant differences were also observed in remembering, understanding, analyzing, evaluating, and creating (p<0.01), while the applying domain showed a statistically significant difference (p<0.05). The largest difference between the groups was observed in the evaluating domain, where the mean score was 3.14 ± 0.08 in the intervention group compared with 1.70 ± 0.11 in the control group.

Table III: Comparison of post-test scores between control and intervention groups

Cognitive domain	Maximum marks	Control group Mean ± SEM	Intervention group Mean ± SEM	p-value
Remembering	5	4.24 ± 0.08	4.80 ± 0.04	<0.01
Understanding	3	2.69 ± 0.06	2.95 ± 0.02	<0.01
Applying	3	2.32 ± 0.09	2.54 ± 0.06	<0.05
Analyzing	3	2.38 ± 0.10	2.97 ± 0.03	<0.01
Evaluating	4	1.70 ± 0.11	3.14 ± 0.08	<0.01
Creating	2	1.10 ± 0.07	1.61 ± 0.04	<0.01
Total	20	14.44 ± 0.36	18.02 ± 0.17	<0.01

Table IV shows that the intervention group had a significantly higher mean total post-test score (10.71 ± 0.22) than the control group (8.42 ± 0.35) out of 15 marks (p<0.01). Significant differences were observed in remembering, understanding, analyzing, evaluating, and creating, with higher scores in the intervention group (p<0.05 or <0.01). However, in the applying domain, the control group had a higher mean score (1.10 ± 0.08) than the intervention group (0.73 ± 0.06), and this difference was statistically significant (p<0.01). Overall, the intervention group demonstrated better post-test cognitive performance.

Table IV: Comparison of supplementary post-test scores between groups

Cognitive domain	Maximum marks	Control group Mean ± SEM (n=50)	Intervention group Mean ± SEM (n=84)	p-value
Remembering	2.5	1.28 ± 0.09	2.38 ± 0.04	<0.01
Understanding	4	2.88 ± 0.17	3.27 ± 0.09	<0.05
Applying	1.5	1.10 ± 0.08	0.73 ± 0.06	<0.01
Analyzing	3	1.87 ± 0.11	2.23 ± 0.05	<0.01
Evaluating	2	0.63 ± 0.10	1.02 ± 0.08	<0.01
Creating	2	0.66 ± 0.11	1.08 ± 0.09	<0.01
Total	15	8.42 ± 0.35	10.71 ± 0.22	<0.01

The *Table V* shows that students in both groups reported generally positive perceptions of the teaching sessions. The mean total perception score was significantly higher in the control group using conventional classes (45.95 ± 4.13) than in the intervention group using sequential multiple classes (43.05 ± 6.78, p<0.01). Significant differences were observed regarding appropriateness according to learning objectives (p<0.01), learning needs, suitability for Pharmacology and Therapeutics lectures, satisfaction with the teaching method, interactivity, support for active learning, rational prescribing, and overall satisfaction (p<0.05). In contrast, no significant differences were observed in session suitability (p>0.05) or synchronization with class duration (p>0.05). Overall, both groups demonstrated favorable perceptions, although the conventional class group reported higher perception scores across most measured domains.

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Table V: Comparison of students' perceptions of the two teaching approaches

Students' perceptions	Control: Conventional classes Mean ± SD (n=65)	Intervention: Sequential multiple classes Mean ± SD (n=86)	p-value
Suitability of the session	4.46 ± 0.69	4.36 ± 0.84	>0.05
Appropriateness according to learning objectives	4.65 ± 0.60	4.28 ± 0.81	<0.01
Appropriateness according to learning needs	4.58 ± 0.58	4.30 ± 0.88	<0.05
Appropriateness for Pharmacology and Therapeutics lecture class	4.60 ± 0.77	4.33 ± 0.85	<0.05
Synchronization with class duration	4.22 ± 0.86	4.12 ± 1.11	>0.05
Satisfaction with teaching method	4.69 ± 0.56	4.27 ± 0.93	<0.01
Interactivity	4.71 ± 0.55	4.16 ± 0.99	<0.01
Helps active learning	4.66 ± 0.54	4.43 ± 0.78	<0.05
Helps rational prescribing	4.68 ± 0.53	4.43 ± 0.86	<0.05
Overall satisfaction	4.71 ± 0.52	4.47 ± 0.76	<0.05
Total perception score	45.95 ± 4.13	43.05 ± 6.78	<0.01

DISCUSSION

In this study, participation in the pre-test was notably greater in the intervention group compared with the control group (83.33% vs. 55.0%, p<0.05), whereas class attendance (84.07% vs. 76.0%) and post-test participation (83.50% vs. 73.68%) did not differ significantly. This study resembles an earlier one, which found that variations in lecture attendance patterns were not consistently linked to differences in medical students' academic and licensing examination performance [11]. These results imply that even though initial assessment participation may differ between groups, attendance and later assessment participation may stay similar across different teaching approaches.

In this study, baseline cognitive performance was similar between the control and intervention groups, with no significant differences in total or individual domain scores (p>0.05). This study aligns with earlier research, in which baseline assessments carried out prior to educational interventions demonstrated comparable pre-intervention performance across groups [12,13]. These results suggest that the groups were adequately comparable before the sequential teaching approach was implemented, which supports interpreting later changes as related to the intervention.

In this study, both groups exhibited notable improvement in every cognitive domain from pre-test to post-test (p<0.01), and the intervention group achieved a larger overall gain. This research resembles an earlier study that found better pharmacology learning after structured active-learning modules were used instead of conventional teaching [14]. Such results reinforce the value of learner-centered, structured teaching methods for enhancing cognitive outcomes.

In this study, the intervention group obtained notably higher post-test scores in every cognitive domain, especially in the area of evaluating. This study aligns with earlier research, in which flipped classroom instruction produced improved post-test results compared with conventional teaching [15]. The step-by-step assessment and feedback applied in this study might likewise have facilitated learning, in line with the idea of assessment for learning [8].

In this study, the intervention group obtained notably higher supplementary post-test scores across most cognitive domains and in the overall score, even though the control group did better in the application domain. This study aligns with an earlier one that showed active learning modules in pharmacology markedly enhanced students' post-test performance as well as their understanding, interaction, and self-learning [14,16]. Such results indicate that structured, learner-centered instruction can enhance overall cognitive learning outcomes.

In this study, both groups expressed positive perceptions, though the conventional class group achieved a higher overall perception score compared to the sequential multiple-class group (p<0.01). This study aligns with earlier research, which found that students held positive perceptions of pharmacology teaching and emphasized the value of suitable and practical instructional methods [17,18]. The results suggest that students accepted both approaches well.

In general, sequential multiple classes enhanced students' cognitive learning outcomes, whereas students viewed both sequential and conventional teaching approaches positively.

CONCLUSION

Delivering multiple classes in sequence, guided by competency-gap assessment, student feedback, and ongoing modification of teaching content, led to better immediate cognitive learning outcomes than conventional classes. Even though conventional classes earned higher perception scores, both approaches were viewed favorably. To confirm how effective this adaptive teaching approach is, further multicenter studies using randomized allocation, validated assessments, and longer follow-up are recommended.

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