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Original Research

Effectiveness of Self-Directed Learning and Peer-Assisted Learning in Biochemistry in First-Year MBBS Students.

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Abstract

Background: Active learning strategies are important in competency-based medical education because they promote engagement, independent inquiry, and collaborative reasoning. Self-directed learning (SDL) and peer-assisted learning (PAL) are increasingly used in preclinical subjects such as Biochemistry, where students need support to connect abstract concepts with applied understanding. **Objectives:** To evaluate and compare SDL, PAL, and lecture-based teaching for academic performance and learning experience among first-year MBBS students in Biochemistry. **Methods:** This quasi-experimental study was conducted among 150 first-year MBBS students in the Department of Biochemistry. Students were equally allocated into SDL, PAL, and control groups. The SDL group received learning objectives and resources for independent study with faculty facilitation. The PAL group learned through peer-led subgroup discussions and presentations under faculty supervision. The control group received conventional lectures on the same topics. Knowledge was assessed using pre-test and post-test scores. Student perceptions were collected through structured five-point Likert-scale questionnaires. **Results:** Mean pre-test scores were 4.7 ± 1.3 , 4.5 ± 1.2 , and 4.2 ± 1.2 in the SDL, PAL, and control groups, respectively. Mean post-test scores improved to 6.5 ± 1.4 , 7.6 ± 1.6 , and 5.3 ± 1.2 , respectively. PAL showed the highest immediate academic gain, while SDL also produced better improvement than conventional teaching. Feedback showed that PAL improved understanding, participation, communication, teamwork, and confidence, whereas SDL encouraged learning-resource use and independent study. **Conclusion:** SDL and PAL are effective teaching-learning strategies for first-year MBBS Biochemistry. PAL produced superior immediate post-test performance and collaborative skill development, while SDL supported independent learning. A blended model integrating SDL, PAL, and focused faculty facilitation can strengthen student-centered learning.

Keywords: Self-directed learning; peer-assisted learning; Biochemistry; first-year MBBS; active learning; medical education; competency-based medical education.

Introduction

Undergraduate medical education has moved from a predominantly teacher-centered model to a competency-oriented framework that expects learners to acquire knowledge, skills, attitudes, and lifelong learning abilities. In India, the competency-based medical curriculum has emphasized outcome-based learning, early clinical exposure, integration, formative assessment, and active participation of students [1]. Although conventional lectures remain useful for introducing core content to large groups, exclusive dependence on didactic teaching restricts learner autonomy and reduces opportunities for application, reflection, and collaborative problem-solving [2]. This concern is particularly relevant in first-year MBBS education, where students enter a demanding learning environment and must adapt rapidly to the volume and complexity of biomedical sciences.

Biochemistry is a foundational subject for understanding metabolism, molecular mechanisms of disease, laboratory interpretation, nutrition, endocrinology, genetics, and pharmacological principles. However, many first-year students perceive Biochemistry as abstract because several concepts are taught before adequate clinical exposure. Student-centered strategies are therefore important to help learners connect biochemical pathways with diagnostic and therapeutic reasoning. Self-directed learning (SDL) is one such approach in which learners identify learning needs, set goals, select resources, complete learning activities, and evaluate progress. Systematic reviews have reported that SDL can improve knowledge acquisition and cognitive performance in health professions education when it is appropriately structured and facilitated [3,4]. It also supports curiosity, self-regulation, professional responsibility, and readiness for lifelong learning, which are key expectations from modern medical graduates [5-8].

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Peer-assisted learning (PAL) is another active learning approach in which students learn with and from peers through discussion, explanation, feedback, and shared problem-solving. PAL reduces the perceived distance between teacher and learner and creates a comfortable environment for asking questions. It also encourages communication, teamwork, leadership, and mutual accountability. Evidence from systematic reviews and meta-analyses shows that PAL can improve academic outcomes and is comparable with expert-led learning in selected educational contexts [9-11]. Student-as-teacher models further show that peer teaching benefits both tutors and learners by reinforcing content and promoting professional confidence [12].

Recent innovations in Biochemistry education have highlighted the value of active, team-based, and game-based learning for improving engagement and clinical integration [13,14]. Nevertheless, direct comparison of SDL and PAL with conventional teaching in first-year MBBS Biochemistry remains relevant because the effectiveness of these strategies depends on learner readiness, topic selection, faculty facilitation, and institutional context. The present study was conducted to evaluate the effectiveness of SDL and PAL in improving academic performance among first-year MBBS students in Biochemistry and to compare their perceived educational benefits with conventional lecture-based teaching. The objectives were to compare pre-test and post-test scores across SDL, PAL, and control groups and to assess student perceptions regarding SDL and PAL as teaching-learning methods.

Materials and Methods

Study design and setting: This quasi-experimental comparative study was conducted in the Department of Biochemistry, S.V. Medical College, Tirupati, among first-year MBBS students. The study was carried out over a period of 4-6 weeks. The design was selected to compare two active learning interventions, SDL and PAL, with conventional lecture-based teaching under routine academic conditions.

Study population and eligibility: All first-year MBBS students who were present during the study period and provided informed consent were considered eligible. Students who were absent during intervention sessions or either assessment session were excluded from analysis. Participation was voluntary, and confidentiality of individual responses was maintained. The study was conducted after obtaining institutional permission.

Sample size and grouping: A total enumeration approach was followed because the entire available first-year MBBS batch was considered for participation. A total of 150 students were finally included and divided equally into three groups of 50 each. Group A received SDL, Group B received PAL, and Group C served as the control group receiving conventional didactic lectures. Allocation was performed to maintain equal group size and comparability for educational exposure.

Intervention: The SDL group received clearly defined learning objectives on selected Biochemistry topics such as enzymes and carbohydrate metabolism. Recommended textbooks and online learning resources were shared, and students independently studied the assigned content. Faculty members acted as facilitators by guiding learning, clarifying doubts, and encouraging reflection. The PAL group was divided into small subgroups of 5-10 students. Each subgroup was assigned specific topics, and peer leaders facilitated discussion, explanation, and presentation. Faculty supervised the sessions and provided corrective feedback. The control group received conventional faculty-led lectures on the same topics. The intervention structure was aligned with established principles of SDL and PAL implementation [5,8,9,12].

Study tools and data collection: Knowledge was assessed using a pre-test before the intervention and a post-test immediately after completion of the sessions. The assessment included multiple-choice questions, short-answer questions, and case-based questions related to the selected Biochemistry topics. Student perceptions were collected using pre-validated structured questionnaires based on a five-point Likert scale. Separate feedback forms were used for SDL and PAL groups to assess understanding, resource use, interest, participation, teamwork, confidence, and reinforcement of learning.

Outcome measures and statistical analysis: The primary outcome was change in academic performance from pre-test to post-test scores. Secondary outcomes included student perception of SDL and PAL. Data were entered in Microsoft Excel and analyzed using SPSS version 15.0. Continuous variables were expressed as mean $\pm$ standard deviation, and categorical variables were expressed as frequency and percentage. Pre-test and post-test scores were compared using appropriate statistical tests. A p-value less than 0.05 was considered statistically significant.

Results

A total of 150 first-year MBBS students participated in the study. The students were equally distributed into the SDL group, PAL group, and control group, with 50 students in each group. The pre-test scores were numerically similar across the three groups, indicating comparable baseline knowledge before the educational intervention. After the intervention, all groups showed improvement in post-test scores, but the gain was greater in the active learning groups, especially the PAL group. The comparison of pre-test and post-test scores is shown in Table 1.

Table 1. Comparison of pre-test and post-test scores among SDL, PAL, and control groups

Group	Pre-test score, mean $\pm$ SD	Post-test score, mean $\pm$ SD	Mean gain	p-value
SDL (n=50)	4.7 $\pm$ 1.3	6.5 $\pm$ 1.4	1.8	<0.001
PAL (n=50)	4.5 $\pm$ 1.2	7.6 $\pm$ 1.6	3.1	<0.001
Control (n=50)	4.2 $\pm$ 1.2	5.3 $\pm$ 1.2	1.1	<0.001

The PAL group had the highest post-test score (7.6 $\pm$ 1.6), followed by the SDL group (6.5 $\pm$ 1.4) and the control group (5.3 $\pm$ 1.2). The mean gain was 3.1 in the PAL group, 1.8 in the SDL group, and 1.1 in the control group. These findings indicate that both active learning methods improved academic performance, with PAL producing the greatest immediate improvement in Biochemistry learning outcomes.

Student feedback regarding SDL showed mixed but important educational responses. A favorable response was highest for the statement that SDL encouraged the use of multiple learning resources, with 31 students (62.0%) selecting either strongly agree or agree. Twenty-three students (46.0%) reported that SDL helped them understand Biochemistry concepts better, and 21 students (42.0%) felt that SDL improved critical thinking and problem-solving skills. The detailed SDL feedback distribution is presented in Table 2.

Table 2. Student feedback on SDL using a five-point Likert scale

Statement	Strongly agree n (%)	Agree n (%)	Neutral n (%)	Disagree n (%)	Strongly disagree n (%)
SDL sessions helped me understand Biochemistry concepts better	11 (22.0)	12 (24.0)	8 (16.0)	10 (20.0)	9 (18.0)
SDL encouraged me to use multiple learning resources	15 (30.0)	16 (32.0)	8 (16.0)	5 (10.0)	6 (12.0)
SDL improved my critical thinking and problem-solving skills	10 (20.0)	11 (22.0)	10 (20.0)	9 (18.0)	10 (20.0)
SDL helped me manage my study time effectively	10 (20.0)	7 (14.0)	8 (16.0)	13 (26.0)	12 (24.0)
The guidance provided during SDL sessions was adequate	12 (24.0)	8 (16.0)	10 (20.0)	10 (20.0)	10 (20.0)
SDL increased my interest in Biochemistry	6 (12.0)	5 (10.0)	8 (16.0)	15 (30.0)	16 (32.0)

Student feedback regarding PAL was more consistently favorable. For improved understanding, learning from peers, and active participation, 30 students (60.0%) selected strongly agree or agree for each statement. Communication and teamwork skills were favorably rated by 31 students (62.0%), and the same proportion reported that teaching peers reinforced their own knowledge. The detailed PAL feedback distribution is shown in Table 3.

Table 3. Student feedback on PAL using a five-point Likert scale

Statement	Strongly agree n (%)	Agree n (%)	Neutral n (%)	Disagree n (%)	Strongly disagree n (%)
PAL sessions improved my understanding of Biochemistry topics	18 (36.0)	12 (24.0)	9 (18.0)	6 (12.0)	5 (10.0)
Learning from peers made complex topics easier to grasp	16 (32.0)	14 (28.0)	10 (20.0)	7 (14.0)	3 (6.0)
PAL encouraged active participation during learning	20 (40.0)	10 (20.0)	11 (22.0)	5 (10.0)	4 (8.0)
PAL improved my communication and teamwork skills	19 (38.0)	12 (24.0)	12 (24.0)	4 (8.0)	3 (6.0)
Teaching peers helped reinforce my own knowledge	18 (36.0)	13 (26.0)	8 (16.0)	5 (10.0)	6 (12.0)

Overall, the results suggest that SDL improved independent learning behaviour and use of learning resources, whereas PAL generated stronger immediate academic improvement and more favorable perceptions regarding interaction, teamwork, and confidence. The findings support the use of both strategies as complementary approaches in first-year Biochemistry teaching.

Discussion

The present study demonstrates that SDL and PAL are effective teaching-learning strategies for first-year MBBS students in Biochemistry. All three groups showed statistically significant improvement from pre-test to post-test scores, but the magnitude of gain was greater in the active learning groups than in the lecture-based control group. PAL produced the highest immediate post-test performance, followed by SDL. This pattern indicates that active student engagement, structured interaction, and learner responsibility contribute meaningfully to academic performance in preclinical Biochemistry.

The improvement observed in the SDL group is consistent with the educational premise that students learn more deeply when they assume responsibility for identifying learning needs, selecting resources, and organizing study plans. Previous systematic reviews have shown that SDL improves knowledge outcomes and cognitive performance when compared with traditional didactic learning [3,4]. In medical education, SDL also supports habits of inquiry, reflection, and lifelong learning, which are central to professional development [5]. The present findings also align with studies showing that structured SDL activities are feasible for first-year medical students and can improve learner engagement when clear objectives and faculty guidance are provided [6]. However, SDL feedback in this study was less uniformly favorable than PAL feedback, suggesting that student readiness, motivation, time management, and clarity of facilitation influence the student experience [7,8].

The higher gain in the PAL group can be explained by the collaborative nature of peer learning. Students often understand peer explanations easily because they are delivered in familiar language and at a similar cognitive level. PAL also creates a less intimidating learning space where students ask questions, clarify doubts, and participate actively. These findings are supported by systematic reviews and meta-analyses showing that PAL improves academic outcomes in medical education and can be a useful adjunct to conventional teaching [9,10]. Peer teaching also benefits student tutors because explaining content to others reinforces their own knowledge and develops communication skills [11,12]. In the present study, favorable responses for teamwork, active participation, and reinforcement of knowledge were consistently high in the PAL group.

The findings are particularly relevant to Biochemistry because the subject requires conceptual integration rather than rote memorization. Active learning strategies such as gamification, team learning, and clinically oriented group tasks have been shown to improve engagement and help students connect biochemical concepts with clinical reasoning [13,14]. The present study supports a blended approach in which conventional lectures introduce essential frameworks, SDL develops independent inquiry, and PAL strengthens collaborative understanding. For effective implementation, faculty should select appropriate topics, provide structured learning objectives, train peer leaders, monitor group discussions, and use formative assessment. Such integration can improve not only academic performance but also confidence, communication, and readiness for lifelong learning.

Limitations

This study had a quasi-experimental, single-institution design with a short intervention period. Long-term knowledge retention was not assessed. Peer teaching quality differed across subgroups despite faculty supervision. Student perception was measured using self-reported feedback, which is influenced by individual learning preference, confidence, and motivation. Randomized allocation details, blinding, topic-wise subgroup analysis, and control for topic difficulty were limited in routine academic settings.

Conclusion

Self-directed learning and peer-assisted learning improved academic performance among first-year MBBS students in Biochemistry. PAL produced the highest immediate post-test scores and received stronger favorable feedback for understanding, participation, teamwork, communication, and confidence. SDL encouraged students to use multiple learning resources and supported independent learning behaviour, although its success depends on learner readiness and faculty facilitation. Conventional lectures remain useful for structured content delivery, but they are insufficient as the only strategy for competency-oriented medical education. A blended model that combines focused lectures, structured SDL, supervised PAL, and formative faculty feedback can provide a balanced, student-centered approach for strengthening Biochemistry learning outcomes and learner engagement in routine undergraduate medical teaching.

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