Medical Education

Effectiveness and perceptions of MBBS students about process-oriented guided inquiry learning in biochemistry

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ABSTRACT

Background. On reviewing our teaching methods through students' feedback, we realized they were dissatisfied with the present teaching methodology of lectures in terms of knowledge retention and problem-solving. This issue was addressed using student-centred and cooperative learning methodology, i.e. process-oriented guided inquiry learning (POGIL) where pre-designed questions guide students to enquire concepts, with reflection writing exercise helping students to strengthen their concepts. This study analysed the effectiveness and perceptions of POGIL sessions conducted after lectures.

Methods. The study was approved by the institutional ethical committee. A total of 42 (7 groups; each group with 6 members of high, low and average achievers) consented and POGIL-sensitized MBBS phase I students were part of the study. One-hour POGIL sessions were conducted a week after lecturing with reading material. Pre-, post- and retention test multiple-choice questions (MCQs) were administered for assessment of effectiveness and a close-ended questionnaire for recording perception.

Results. Post-test and retention test MCQ scores were statistically higher than pre-test scores both in all participants and low achievers ($p<0.05$). Around 60% of the students felt that the POGIL activities and working in teams helped them to understand concepts. Reflection analysis revealed the best and least understood concept and students came up with memory aids to remember complex metabolic regulation.

Conclusion. POGIL might be a promising reinforcement strategy to lectures in biochemistry and preferred tool to address the issue of low achievers in the class.

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INTRODUCTION

Higher education in medical profession expects us to impart the knowledge and skills needed to provide the best patient care, plan for preventive healthcare strategies and be successful in an increasingly dynamic environment.[1] To achieve this, it is essential to recognize that education has content and process as

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components, and often the process is not given adequate attention. Hence, the process skills become increasingly important as our knowledge base expands.[2] In 2014, Vanishree *et al.*[3] obtained feedback regarding the biochemistry curriculum at the J.N. Medical College (JNMC). Most students were dissatisfied with the techniques used for knowledge retention and the few misconceptions that arose during lectures.[3] Hence, we felt that our teaching–learning methodology should be process-oriented.

Problem-based learning and team-based learning have the weakness of expecting content to be learnt by a novice and require extensive facilitation.[4] Case-based learning is enquiry-oriented, but students work in groups over a case. Here again, the facilitator plays a major role.[5] Process-oriented guided inquiry learning (POGIL) is an active learning approach that was pioneered in chemistry. POGIL is team learning with a set of 4 or 5 students (process-oriented) exploring a model (e.g. a graph, a table of data, or cases) through a series of questions (exploration). These questions help students develop an understanding of the concept by encouraging them to think critically about the model, followed by understanding of the concept, which helps them define objectives, under the guidance of a facilitator (guided enquiry). Students explore the module or case on the knowledge being imparted by the lecture and resources provided by the facilitator. This is followed by application of the gained knowledge, and finally reflection and self-assessment.[6] Reflecting and self-assessment help students strengthen their strengths and weaken their weaknesses.

Purpose and research questions

The current teaching strategies in biochemistry are more focused on traditional lectures where students are not involved; hence, this disengages students from the learning process causing the information to be forgotten quickly. POGIL is a self-managed, student-centred learning cycle, which focuses on core concepts, and encourages attainment of higher levels of cognitive domain. Hence, we assessed the effectiveness and perception of POGIL as a reinforcement tool to lectures in biochemistry.

METHODS

Study design

Forty-two students of MBBS phase-I were included after approval of the Ethical Clearance Committee, JNMC, Belagavi, Karnataka, India. The study was conducted in the Department of Biochemistry from October 2015 to March 2016. The study involved a preparatory phase (POGIL modules preparation) and three POGIL sessions after the lecture.

Preparation of modules for POGIL

Three modules were prepared by the faculty of biochemistry after the faculty was sensitized and trained to conduct POGIL

sessions. Pre-validated multiple-choice questions (MCQs) were set to study the effectiveness of POGIL.

Conduct of POGIL sessions

Students were selected from the 2015–2016 batch based on their performance in the first internal assessment. Seven groups, each with 6 students were made (1–2 high achievers, 2 low achievers and 2–3 average students). After obtaining informed consent, students were sensitized to the POGIL methodology. To begin with, traditional lecturing was done, followed by providing reading material to the 42 selected students. Seven days were given to them to read the material and discuss among the teams. On the day of the POGIL sessions, students were given a pre-test and then all the students were divided to be in their respective teams and were guided by the facilitator for all the seven teams. POGIL activities were meant to be completed by small groups of 5–6 students/group working collaboratively. Each session was designed to be completed within the 1-hour class. To make process skill acquisition more effective and explicit, each student was assigned one of three roles to play within the group. The leader was responsible for keeping the entire group on time and task and make sure that all were participating equally in the discussion. The recorder or scribe was the official record-keeper of the group whose worksheet was examined by the instructor/facilitator to check student progress. The reporter was the official spokesperson of the group who ensured that he/she understood consensus answers for each question and could communicate that answer to the rest of the group members. The teams with students and their specified roles were to work on modules, with the help of questions framed by the subject expert, define their learning area, their objectives (under the guidance of facilitator), then apply their acquired knowledge to a set of cases or problems, and finally, they self-assessed and reflected on their learning outcomes (questionnaire was provided). This was followed by the post-test. MCQ-based assessment of the students was done to test retention of gained knowledge, after a week on the same topic. Finally, after all the three modules, the perceptions of students regarding POGIL were recorded with the help of a questionnaire.

Details of POGIL sessions

Three different sessions of POGIL on carbohydrate metabolism such as glycolysis, metabolic and hormonal control in glycolysis and gluconeogenesis and exploring the citric acid cycle were conducted. During these sessions, students were divided into groups as discussed earlier and then session material was provided by the facilitator. Session material included:

1. Pre-test MCQs
2. Learning objectives (2–3)
3. Questions (8–10) which were framed on the basis of known to unknown and help to achieve objectives and understand concepts (exploration step)
4. Worksheet for solving the questions and problems with the help of provided reading material which was taken from 2–3 textbooks of biochemistry, think-pair-share among the group and facilitators (guided enquiry)
5. Self-assessment sheet to know the best understood and least or not understood concepts
6. Reflection writing sheet
7. Post-test MCQs.

Each POGIL session contained numerous models that the

Box 1. Process-oriented guided inquiry learning (POGIL) session on exploring the citric acid cycle

1. Pre-test multiple-choice questions on citric acid cycle ($n=10$)
2. Learning objectives: At the end of this session student should be able to
   a. Build specific knowledge to understand the citric acid cycle.
   b. Develop their ability to transfer their knowledge from one context to another by applying prior knowledge of regulation to this new pathway.
   c. Understand the net reaction of citric acid cycle.
3. Questions ($n=10$) were framed from known to unknown. For example:
   i. What do you mean by the Gibbs free energy change?
   ii. Locate the ΔG values in your book for the reaction of the citric acid cycle. What are the far from equilibrium and near equilibrium reactions in the citric acid cycle?
   iii. Discuss the regulation of isocitrate dehydrogenase and explain why the effector NAD^+ and ADP make sense.
   iv. It is often said that the citric acid cycle functions catalytically. How does it resemble a catalyst (recall the definition of catalyst)?
   v. Where are the oxidative reactions in the citric acid cycle? The oxidative reactions in the citric acid cycle that involve NAD^+ are different from those that involve FAD. How are they different?
4. Work sheet for solving the questions and problems.
5. Self-assessment sheet.
6. Reflection writing sheet.
7. Post-test multiple choice questions ($n=10$).

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students explored through a series of critical thinking questions. For example, if the POGIL session was on 'exploring the citric acid cycle', then students were provided with reading material containing flowcharts, diagrams and illustrations from the textbooks. The students were allowed to read the material for a week before the session. On the day of the POGIL session as mentioned earlier, whole material for the session (Box 1) was provided.

Statistical analysis

Results were expressed as mean (SD). Paired *t*-test was used to compare pre- and post-mean scores. Statistical analysis was done using SPSS version 16 (Trial) software. Percentage distribution was used to summarize the categorical outcomes. The statistical significance level was set at $p<0.05$.

RESULTS

A total of 42 students were enrolled randomly in this study. The student performance based on their mean scores in pre- and post-test (minimum score was '0' and maximum '10') was compared. The mean (SD) score of the students before the POGIL session (pre-test) was 5 (1.74), with scores ranging from 2 to 9 and after the POGIL session (post-test) was 9.3 (1.26), with scores ranging from 5 to 10. The effectiveness of the POGIL session (Fig. 1a), assessed by comparing the students' performance before and after the POGIL session, showed significant improvement in the scores ($p<0.001$). The long-term effectiveness of the POGIL session (Fig. 1b) showed a mean (SD) score of 7.4 (1.89), and there was also considerable improvement in the scores in comparison to the pre-test ($p=0.017$).
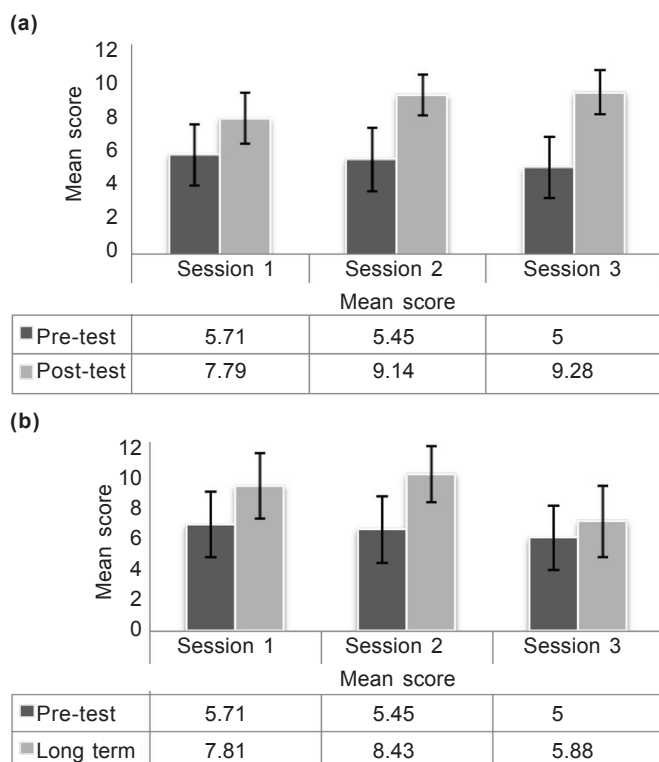
The impact of POGIL on student performance was assessed

(a)

Mean score			
	Session 1	Session 2	Session 3
■ Pre-test	5.71	5.45	5
■ Post-test	7.79	9.14	9.28

(b)

Mean score			
	Session 1	Session 2	Session 3
■ Pre-test	5.71	5.45	5
■ Long term	7.81	8.43	5.88

Fɪɢ 1. Effectiveness of process-oriented guided inquiry learning (POGIL) sessions. (a) Short-term effectiveness of POGIL sessions. Comparison of students' performance based on pre- and post-test scores. Scores of all three POGIL sessions were compared. Data showed significant improvement in the post-test scores (p<0.001). Each bar shows the mean (SD). (b) Long-term effectiveness of POGIL sessions. Comparison of students' performance based on pre- and long-term test scores. Scores of all three POGIL sessions were compared. Data showed significant improvement in the long-term test scores (p=0.017). Each bar shows the mean (SD)

TABLE I. Comparison of increase in mean scores of all participants and low achievers

Participants	Pre- and post-comparison	Pre- and retention comparison
All learners	9.9 (3.49)	5.7 (3.50)
Low achievers	8.8 (2.48)	4.9 (3.31)

by comparing the total score of all three sessions. The total score of post-test and retention test was not only increased in all participants but also low achievers group with respect to the pre-test score (Fig. 2). The mean (SD) score between the pre-test and post-test was increased up to 9.9 (3.49) in all participants. In low achievers the increase in score was 8.8 (2.48). The mean increase in score between the pre-test and retention test was 5.7 and 4.9 in all participants and low achievers, respectively (Table I).

Around 60% of students said that POGIL activities and working in a team helped them to understand concepts of biochemistry to a great extent (score of 5). Only 38% of students felt that lectures helped them to understand the concepts better. Textbooks were not at all or little helpful to understand the concepts by 40% of students. POGIL activities also made them confident and self-directed learners (Table II). Reflection
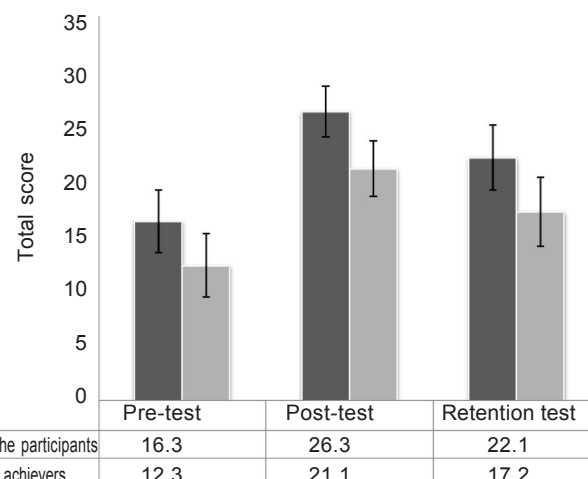

	Pre-test	Post-test	Retention test
■ All the participants	16.3	26.3	22.1
■ Low achievers	12.3	21.1	17.2

Fɪɢ 2. Impact of process-oriented guided inquiry learning (POGIL) on all participants and low achievers. Comparison of total multiple-choice question scores of post- and retention test to the pre-test between all participants and low achievers were done. The total score of post-test and retention test was increased in all participants and also in low achievers with respect to the pre-test score. Each bar shows the mean (SD)

analysis revealed the best and least understood concepts and students came up with memory aids to remember complex metabolic regulations (Table III).

DISCUSSION

Our study shows that POGIL, a student-centred approach,[7] might be an effective and suitable teaching method for 1st year MBBS students studying biochemistry. The current teaching strategies in biochemistry are didactic lectures and tutorials where students cannot critically think and analyse. This disengages students from the process of learning and they quickly forget the information. To address this issue, we evaluated both short-term and long-term effectiveness of POGIL on students' performance. The performance of students undertaking POGIL was significantly better compared to the lecture class. These findings were in accordance with a meta-analysis by Walker and Warfa[8] showing improvement in student achievement outcomes by POGIL pedagogy. The short-term effectiveness of POGIL was significantly improved not only in all participants but also in low achievers. For the long-term effectiveness of POGIL, we compared the retention test score with pre-test score which also showed considerable improvement in all participants and in low achievers. Hence, POGIL is a good strategy to address students' concern regarding long-term retention of the subject. Cooperative learning, think-pair-share strategy and guided enquiry learning are pivotal components of POGIL, which creates a positive attitude of students towards biochemistry and its concepts.

More than 60% of students felt confident of understanding the concepts in biochemistry after participating in POGIL and working with peers as a team. Our findings corroborate those of Balasubramaniam[9] regarding students learning, i.e. they learn better when they are actively engaged in the structured learning format during the sessions, which improved their concept construction and understanding.

Students' reflections on topics in POGIL sessions revealed the most understood and least understood concept with memory aid to retain the concept learnt for a longer time. After

TABLE II. Perception regarding process-oriented guided inquiry learning (POGIL) sessions

Item	Rating				
	Great deal	A lot	Somewhat	Little	Not at all
My understanding of the concept and vocabulary of biochemistry improved with					
Activities provided by POGIL	63.75	30	3.75	2.5	0
Working with peers in POGIL	52.5	40	2.5	5	0
Pre-assignment reading material of POGIL	25.64	33.33	38.46	2.56	0
Lectures	37.5	25	27.5	5	5
Textbooks	7.5	7.5	45	15	25
To what extent did you become					
Confident, to talk about concepts of biochemistry	37.8	43.73	10.12	2.5	2.5
Good communicator, when in a team	55	28	10	5	2
Self-directed learner and self-reflector	30.68	32	33.28	3.66	0

Results expressed in percentage with respect to the grading system

TABLE III. Narration and outcome of 'reflections on topics' in process-oriented guided inquiry learning (POGIL) sessions by students

Narration of self-reflection	Outcome of reflection analysis
What happened during the POGIL sessions	*What next*
Almost all the students, reflected the 'most understood' and 'least understood' concept in all the three sessions. Most of them reflected how these concepts will help them in future. Few of them gave a memory aid which will help them to retain the concept learnt for a longer time.	We were contented to know that students got to know the concepts better and could come up with a memory aid to remember the concept learnt. We need to evaluate and reconstruct our POGIL sessions on the concepts being least understood and also incorporate new activities/ questions, which will help them think, apply and retain knowledge.

comprehensive analysis of students' self-reflection, we need to reconstruct our POGIL sessions on the least understood concept and also incorporate new activities or questions, which will help them think, apply and retain knowledge. Elements of cooperative learning in groups,[10,11] namely learning by mutual support, collaborate skills, interdependence, individual responsibility and self-assessment, are positively created by POGIL activities.

In the present scenario of medical education in India, lectures cannot be abandoned completely in biochemistry as concepts have to be introduced by subject experts. However, retention of the gained knowledge is a big issue; hence, active learning strategies have to be introduced in Indian medical colleges so that learning becomes interesting and fruitful. The new foundation course has introduced attitude and communication competencies modules, and reflection writing and self-assessment are part of these modules, and also coincidently POGIL emphasizes on reflection writing and self-assessment. Hence, POGIL can be a part of teaching–learning methodology in the government and some private colleges where the student number is large.

Despite the limitation of the small sample size, constraints of time and faculty, our study findings are pertinent because the results reflect students' responses in various aspects of POGIL. Most students felt that POGIL sessions changed them into self-directed learners. Based on our and previous reports,[9,12,13] we suggest that POGIL might be a promising reinforcement tool for lectures in biochemistry and can be a good tool to address issues concerning low achievers.

Conclusion

POGIL is an effective reinforcement tool for lectures as well as for retention of subject knowledge. It is a good teaching methodology for low achievers because they gain knowledge and confidence by working in a team.

Conflicts of interest. None declared

REFERENCES

1 Greiner AC, Knebel E. Recommendations for reform. In: *Health Professions Education: A Bridge to Quality*. Chapter 6. Washington (DC):National Academies Press (US); 2003.

2 Jaffe L, Gibson R, D'Amico M. Process oriented guided inquiry learning: A natural fit for occupational therapy education. Georgia Regents University. Available at *www.gru.edu/mcg/academic-affairs/edi/documents/jaffe4.pdf* (accessed on 28 Oct 2015).

3 Vanishree B, Rekha N, Somannavar Manjunath S, Sonoli Smita S. The perception of MBBS interns towards biochemistry curriculum in a South Indian medical college. *Natl J Integr Res Med* 2016;**7:**82–6.

4 Hausfather S. Content and process in constructivist teacher education 2002. Maryville University. Available at *http://blogs.maryville.edu/shausfather/vita/content-process* (accessed on 1 Nov 2015).

5 Thistlethwaite JE, Davies D, Ekeocha S, Kidd JM, MacDougall C, Matthews P, *et al.* The effectiveness of case-based learning in health professional education. A BEME systematic review: BEME guide no. 23. *Med Teach* 2012;**34:e**421–e444.

6 Chase A, Pakhira D, Marilyne S. Implementing process-oriented, guided-inquiry learning for the first time: Adaptations and short-term impacts on students' attitude and performance. *J Chem Educ* 2013;**90:**409–16.

7 Eberlein T, Kampmeier J, Minderhout V, Moog RS, Platt T, Varma-Nelson P, *et al.* Pedagogies of engagement in science: A comparison of PBL, POGIL, and PLTL. *Biochem Mol Biol Educ* 2008;**36:**262–73.

8 Walker L, Warfa AM. Process oriented guided inquiry learning (POGIL®) marginally effects student achievement measures but substantially increases the odds of passing a course. *PLoS One* 2017;**12:e**0186203.

9 Balasubramaniam G. Process oriented guided inquiry learning as an innovative teaching method in clinical biochemistry: Piloting of the process. *Educ Med J* 2015;**7:**e60–e63.

10 Johnson DW, Johnson RT, Smith KA. *Cooperative learning: Increasing college faculty instructional productivity*. Washington, DC:The George Washington University, Graduate School of Education and Human Development; 1991.

11 Hanson D. *Instructor's guide to process oriented guided inquiry learning*. Lisle, IL:Pacific Crest; 2013.

12 Minderhout V, Loertscher J. Lecture-free biochemistry: A process oriented guided inquiry approach. *Biochem Mol Biol Educ* 2007;**35:**172–80.

13 Hale D, Mullen LG. Designing process-oriented guided-inquiry activities: A new innovation for marketing class. *Market Educ Rev* 2009;**19:**73–80.