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Original Research Article

Enhancing understanding of Embryology through POGIL: An Innovative Approach

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ABSTRACT

Background: Many research studies have revealed that traditional teaching methods in higher education do not completely meets the students' educational needs and have led to several initiatives. One of these initiatives is Process Oriented, Guided-Inquiry Learning (POGIL) which helps the students to develop the skills they need to be successful in medical careers. The aim of the present study is to introduce POGIL technique for improvement in students' understanding of the core concepts in embryology and enhance high order thinking skills.
Methods: The study was conducted on 100 students of MBBS Phase I in GIMS, Greater Noida, UP, India. The POGIL technique was implemented in two sessions, one is on the development of Gastrointestinal & Genitourinary system and another is on the development of cardiovascular system. The effectiveness of POGIL was assessed by MCQ test. The learner satisfaction was taken on Likert scale and perceptions of the faculty were taken by one-to-one interview.
Results: The mean marks scored by POGIL group was (6.78±1.98) on development of GIT and GUT in session 1 and (5.5±1.41) on the development of CVS in session 2. Improvement in score was observed in both sessions in comparison to traditional teaching method but was statistically significant in session 2 only.
Conclusions: A majority of the students felt that POGIL technique had overall beneficial effect on their learning process and the group dynamics. They started to take ownership of their learning whereas a few students felt that the activity was not useful in improving their academic performance. Faculty were fairly satisfied with this innovative technique. The use of the POGIL is newer approaches which actively engages the students and promote them to be lifelong learner.
KEY WORDS: POGIL, Traditional teaching method, Embryology models, Academic performance, Medical education.

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BACKGROUND

The learner in higher education should get more opportunities to accomplish the knowledge and skills required to be successful in this increasingly vibrant environment. In the past few years, the National Medical council (NMC) is focusing

on the development of well-rounded skills among medical students, giving emphasis to make our students fast learner, critical thinker, and problem solver. Students are expected to be proficient in communication, teamwork, time management, and self- assessment [1]. In traditional teacher-centred learning, the majority of time is spent on one way communication by teacher with little student-teacher interaction, and almost no student-student communication.

Hence to promote students' involvement in classroom and engage them in the learning process, many newer active teaching-learning strategies are being employed. The active teaching learning approaches, such as Problem-Based Learning (PBL), Team-Based Learning (TBL), Case-Based Learning (CBL), and Process-Oriented Guided Inquiry Learning (POGIL) are increasingly utilized. PBL presents students with real-world problems, encouraging them to research and develop solutions collaboratively [2, 3]. TBL involves students working in teams on assignments, fostering peer learning and collaboration [4]. Case-Based Learning uses detailed case studies to apply theoretical concepts to practical scenarios, enhancing analytical skills [5, 6]. POGIL guides students through structured activities, allowing them to discover concepts in which the tools and processes include learning teams, guided inquiry activities, critical and analytical thinking, problem solving [7]. In POGIL, students learn in a group of 4 or 5 students (process-oriented), explore the model or case on the knowledge being told by the lecture and resources provided by the facilitator through a series of questions (exploration). These questions help them to build concept by inspiring them to think critically about the model, which helps them to define objectives, under the supervision of a facilitator (guided enquiry). This is followed by application of the gained knowledge, and finally reflection and self-assessment [8]. POGIL was first implemented in General chemistry course [9] but recently has been implemented in different streams like, Emergency Medicine, Psychology, Anatomy & Physiology and Nursing course. [10-13]. This approach may be superior because it incorporates the essential characteristics of the other alternative non-traditional teaching methods like guided-inquiry-based, problem-based learning, with each activity starting with a context-rich problem and collaborative learning via teams. Involvement of students as collaborators of knowledge make the learning deeper and discourage superficial acquisition of information with less applicability in the future.

POGIL has been implemented in a wide variety of ways depending on the institutional culture, class size, the nature of facilities, and instructor's preferences. As the concept building in human embryology is the most difficult among the 1st year MBBS students, the application of innovative teaching learning method POGIL, may improve their critical and analytical thinking power to understand the human development and basis of congenital malformations. Hence, this study is planned to introduce POGIL as a teaching-learning technique for better understanding of the core concepts of embryology and enhance their analytical ability to solve high order thinking skill questions.

MATERIALS AND METHODS

The project was undertaken as part of Advance Course in Medical Education (ACME) at CMC, Ludhiana, India. The study commenced after approval from the GIMS Scientific Research Committee and GIMS-Ethics Committee. The study was conducted on 100 MBBS Phase 1 students. All students, who were present during the conduction of the two sessions, were enrolled in the study. The students who were absent in any of the sessions of a particular module were excluded.

The students were divided into 4 batches (A, B, C, D) of 25 students each. Two batches followed the POGIL session (POGIL group) and the other two acted as control (control group) in first session and vice-versa in the next session. One facilitator was assigned to each group.

Following steps were followed for introduction and conduction of POGIL sessions:

Sensitization of Faculty, planning of sessions & validation of feedback questionnaire:

The faculty of the department were sensitized about POGIL teaching-learning method. In the departmental meetings, the topics for POGIL sessions were decided, study materials were collected for the students and assessment in the

form of MCQs was finalized after brainstorming. MCQs for both sessions were validated with the subject experts.

A sensitization session for the students was organized on POGIL teaching-learning technique. The students were then asked to give consent for participating in the study.

The POGIL study was planned on two topics in embryology, to be conducted in two sessions:

Session 1- Gastrointestinal system and genitourinary system

Session 2- Cardiovascular system

The feedback questionnaire for satisfaction survey of students and faculty was validated by peers and guide during ACME sessions, and also by faculty of Medical Education Unit of the institute.

Conduction of POGIL Sessions

Session 1:

Didactic Lecture in large group was delivered on Gastrointestinal (GIT) and Genitourinary system (GUT) by the principal investigator covering learning objectives and contents. For small group session, Group A and B were taught by POGIL technique and Group C and D by traditional teaching method. The control group was taught using readymade embryology models available in the department. The facilitator explained them the concept of embryology by showing them these models. The POGIL group was provided with study materials and was asked to prepare embryology models within one week. The facilitator also guided them on team dynamics and in planning to make 3 D models for better concept building and to understand basis of congenital malformations. Students were given enough time and opportunities to ask and clarify their doubts they had till the end of the sessions. After 1 week, the POGIL group presented their self-made embryology model in large group. All the groups were assessed through Multiple Choice Questions and short answer questions.

Session 2:

Lecture in large group was conducted on cardiovascular system (CVS). Group C and D were assigned for the POGIL teaching-learning technique and Group A and B were taught by traditional teaching method using ready made embryology models available in the department. The same method was followed again as in session 1.

After completing both the sessions, the students were asked to complete the Learner satisfaction survey. The questionnaire had two types of items, 08 items were close ended and were marked on 05 point Likert Scale ranging from "Strongly disagree", "Disagree", "Neutral", "Agree", "Strongly agree". Three questions were open ended questions on their perception towards role of facilitator, hindrance factors and suggestions for improvement.

Faculty feedback was obtained through One-to-one interviews, using pre-defined open-ended questions as follows: "What are your viewpoints on the POGIL sessions?" "What is the best part of these sessions?" "How can it be improved further?"

DATA ANALYSIS

Quantitative analysis **-** Statistical analysis was performed using the Microsoft Excel and SPSS Vs 26. The scores of the test were recorded and compared in both groups. The mean and standard deviation of marks obtained was calculated and scores in the 2 methods were compared using Mann Whitney U test. A $p<0.05$ was taken as statistically significant.

From the responses of feedback questionnaire, the satisfaction index for each item was calculated using the following formula [14]-

$$\frac{[(n_1 * 1) + (n_2 * 2) + (n_4 * 4) + (n_5 * 5)] * 20}{(n_1 + n_2 + n_4 + n_5)}$$

Where n is the total number of students gaining the score mentioned in the subscript for that particular item, for example

n1=number of participants who had opted for Strongly Disagree n2= number of participants who had opted for Disagree

n4= number of participants who had opted for Agree

n5= number of participants who had opted for Strongly Agree.

Qualitative Analysis **-** To record the perceptions of the students, open-ended questions on POGIL

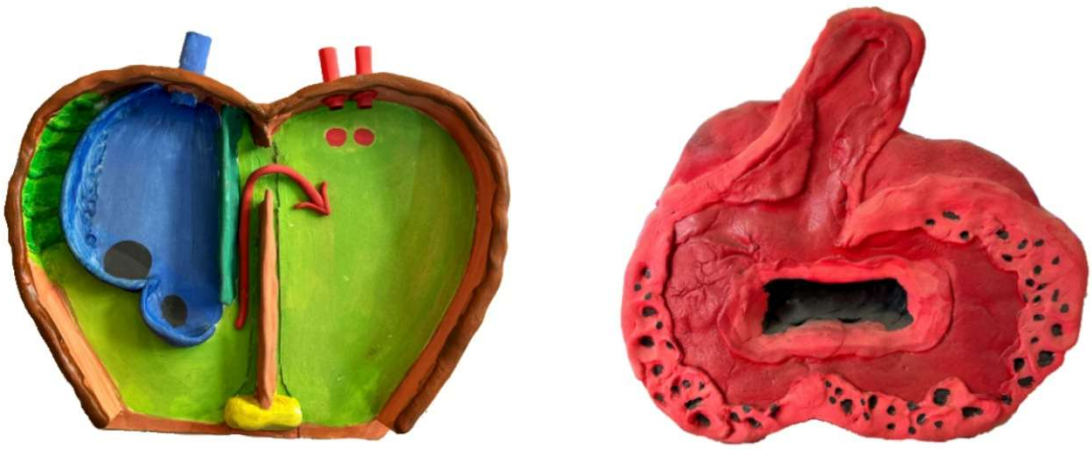
sessions were also asked using Google Forms. For the qualitative analysis, the responses to the open- ended questions were reviewed and thematically analyzed by two of the investigators. Final agreement was reached after thorough discussions between them. The findings were clustered in groups: perceptions about POGIL sessions and facilitators, factors that hinder the sessions and suggestions for improvement. Faculty perceptions were obtained through one-to-one interviews.

RESULTS

DEVELOPMENT OF GASTRO INTESTINAL SYSTEM

DEVELOPMENT OF GENITOURINARY SYSTEM

Fig. 1: Shows the models created by students on the development of the gastrointestinal tract (GIT) and genitourinary tract (GUT) during Session 1. Figure 2 depicts the embryology models made on the development of the cardiovascular system (CVS) during Session 2.



INTERATRIAL SEPTA *INTERVENTRICULAR SEPTA*

Fig. 2: Models prepared by the POGIL batch on the development of CVS.

Out of total 100 MBBS Phase I students, 93 students had participated in the study & the rest, being absent during the module implementation were excluded. Five faculty members were part of the study. In session 1 (development of Gastrointestinal and Genitourinary system), Batch A and B followed the POGIL teaching-learning technique, studied the topic in details in group and prepared embryology models with clay. Fig 1 shows the models made by the students in session 1. Figure 2 depicts the embryology models on the development of CVS made by Batch C & D.

Mean marks scored by POGIL group and tradition teaching group in session 1 & 2 are given in Table 1. The marks scored by the POGIL group in both sessions were higher than the marks scored by the traditional teaching group. Statistically significant difference in the marks was observed in session 2.

Table 1: Marks obtained in Session 1 (Development of GIT & GUT) and session 2 (Development of CVS) by POGIL group and traditional teaching group. (The scores are compared using Mann Whitney U Test. The significance level was set at P< 0.05).

Topic	Marks obtained (MM=10)		P value
	(Group A & B)	(Group C & D)	
Session 1	POGIL group (mean± SD)	Traditional teaching group (mean± SD)	0.19
	6.78 ± 1.98	6.15 ± 2.2	
Session 2	Traditional teaching group	POGIL group	0.003*
	4.52 ± 1.41	5.5 ± 1.41	

The satisfaction index (1-100) was calculated for each item of the feedback questionnaire (Table 2). The minimum satisfaction index was 86 for item 4, which specified that students developed the interest to solve other problems in embryology after the POGIL sessions. A maximum satisfaction index obtained 90 for item 7, which stated that the POGIL sessions were well organized by the facilitator.

The response to the open ended questions (Table 3), students stated that facilitators helped them during sessions and they learned a lot during these sessions which were difficult to learn from book by reading. They are concerned about the time devoted during these sessions and half-hearted involvement of some group members. They suggested that the time slot should be provided for making models during college hours and all students should be

Table 2: Feedback response of 93 students and Satisfaction Index (SI) of each item. (Scores are determined as follows: Strongly Disagree-1, Disagree-2, Neutral-3, Agree-4, Strongly agree - 5).

S. N.	Question	1	2	3	4	5	SI
1	The knowledge gained in POGIL, sessions were highly relevant.	1	0	11	45	36	88
2	By applying POGIL technique, I am better able to correlate the knowledge of embryology.	0	0	11	48	34	88
3	I understand in better way, the anatomical basis of congenital malformations, after POGIL sessions	1	0	12	46	34	88
4	I developed the interest to solve other problems in embryology after the POGIL sessions.	1	3	14	42	33	86
5	The session has inspired me to read more about the embryology topics for myself.	1	0	17	43	32	88
6	This module has enhanced my ability to organise and plan my approach towards understanding embryology problems:	1	1	14	42	35	88
7	The POGIL sessions were organised very well by the facilitator.	1	0	16	36	40	90
8	POGIL is an effective teaching-learning tool	0	7	10	43	33	88

Table 3: Response of students to the open-ended questions.

Open-ended questions –	Themes that emerged from the analysis of students' responses	Few verbatim quotations of students supporting the themes
How the facilitators helped you in your learning during POGIL sessions?	Helpful Guide by the side	*"They helped lot in the sessions, I learned lots during these sessions which I found difficult to learn from book by reading."*
		"Our facilitators guided us in selecting the best concept out of the topic which could be represented well with the models. They also guided us throughout the model-making process."
		"Created interest in me..."
		"Doubt solving, Concept clarity."
What hindered the learning process during the POGIL sessions?	Time management Uninterested group members Lack of coordination among group members	*"Model making was slightly time consuming, sometimes the focus shifted on merely making the model as a work of art rather than understanding the anatomy behind it, which is why I believe that it is important to label the diagrams as well so that we know what we have made."*
		"Not everyone in my team was as enthusiastic as me and others."
		"We couldn't discuss properly with each other because of different hostels and also couldn't coordinate properly.....Hostel timings were also a major issue."
		"It was very difficult to convert the given diagrams into 3D format."
How could this POGIL session be improved further?	Smaller group More frequent sessions Peer teaching can be added More time for doubt clearing	*"Time slot for making models could be provided during college hours and all students could be encouraged to participate more actively in model making. I think that the option of making online 3d models could also be explored if feasible."*
		"Should be held at frequent intervals and for a wider spectrum of topics."
		"Smaller group for model making."
		"Increased doubt clearing sessions."
		"After models are made they could be distributed among groups randomly to be explained. So that all teams have knowledge of all topics."

encouraged to participate more actively in model making.

The faculty insight on POGIL session was obtained by one to one talk. The faculty viewpoints were inspiring. They opined that POGIL sessions should be further extended to include more topics in anatomy but simultaneously they said that conducting these sessions were time consuming. The facilitators expressed their views like "*I would like to take this type of session on the other sections of anatomy"* and " *I feel making embryology models by students are innovative*." Some faculty suggested that POGIL session can be improved by involving a larger number of facilitators and making smaller groups. According to them, some students are very active and have creative ideas, while some do not actively participate in the whole process. Most of the Faculty members felt that a group should have students with varying academic performance and educational background.

DISCUSSION

The main educational goal of the present study is to look into the progression in learning curve of medical students after implementation of POGIL learning technique. In the present study, POGIL teaching was applied in the embryology section of Anatomy and designed to compare its benefits compared to traditional teaching-learning method. The aim is also to see the feasibility and acceptability of the POGIL technique by teachers and students.

The assessment was done to measure the contents of memory, and also see comprehension, analysis, synthesis and evaluation of the given topics. The marks scored by the POGIL group in session 2 was significantly higher (P value-0.003) than the marks scored by the traditional teaching group while in session 1, the average marks scored by POGIL group was higher but P value (0.19) was not significant. The 3-D imagination of development of GIT & GUT (session 1) is less complex as compared to the development of CVS (session 2). This may be the reason of better understanding of GIT & GUT and non-significant difference in performance of both groups in session 1. Chase et al, 2013, noted positive trend in favour of POGIL technique but there was no change in students' grades, retaining power, attitude towards the subject [8]. A study conducted in the second half of a two-semester course of anatomy and physiology, score of MCQs rose from a mean of 68% to 88% and the number of students scoring low grades was also halved in the first two semesters [12]. Studies conducted in emergency medicine, experimental psychology lab and fundamental course in nursing also confirmed that students using the POGIL materials performed significantly better on achievement tests than students not using them [10,11,13]. According to Soltis R et al, on implementation of POGIL strategy, performance on questions requiring higher-level thinking skills was significantly improved, whereas performance on the direct questions remain unchanged [15]. It was noted in a multi-institutional study of organic chemistry course, that the percentage of unsuccessful students in lecture-based courses was double as compared to the POGIL based courses [16]. POGIL is an effective reinforcement tool and is good teaching methodology for low achievers because they gain knowledge and confidence by working in a team [17].

Student perception on the POGIL teaching learning technique was collected using a wide variety of questions on Likert-scale ratings and free response to open-ended questions. Largely, response of students was positive regarding it. The satisfaction index scores for most of the questionnaire were above 80. Students were particularly satisfied with the well-organized sessions led by the facilitator. However, the questionnaire regarding their interest in solving other problems in embryology after the POGIL sessions showed a lower satisfaction level (SI-86). This lower satisfaction could be attributed to perceived time constraints or the minimal emphasis placed on embryology in university exams. In response to the open ended questions students stated that facilitators guided them in model making, clarifying their doubts, and tried to spark interest in the subject among learners. It generated interest in them and they also recommended planning this type of sessions more frequently and for wider spectrum of topics. Students also suggested to explore online 3D models as they felt that it will enhance their learning. But at the same time, some students also

mentioned that during these sessions, all students didn't participate actively and model making was perceived as time consuming. Sometimes the focus shifted on merely making the model as a work of art rather than understanding the underlying anatomy behind it. Student satisfaction with the POGIL method was high, and most students perceived the value of this form of instruction [12]. Student's feedback was positive for the POGIL teaching learning technique. They indicated that the course provided significant increase in opportunity to learn from their classmates and helped them realize the benefit of group studies. They also opined that class exercises were helpful as it provided relevant applications of concepts, kept students engaged throughout class [15,17].

The faculty viewpoints on POGIL sessions were encouraging and they felt that POGIL technique should be further extended to include more topics of anatomy. They felt that conducting these sessions is time consuming putting more burden on the faculties. This problem can be tackled by involving a larger number of facilitators (senior students) so more attention can be given to individual students and they will participate actively. Anthony Chase stated that implementation of POGIL had minor impact on students' score, attitude toward chemistry, and self-efficacy. However, it has enhanced students' perseverance as well as their attitude toward the learning environments provided in the course [8]. Student satisfaction with this method was high, and most students perceived the value of this form of instruction [12]. The use of the POGIL strategy increased student overall performance on examinations, improved higher-level thinking skills, and provided an interactive class setting [9]. Student attrition was lower, learning improved and have more positive attitudes about the course and the instructors [18].

CONCLUSION

Student centred learning strategies are becoming more common in medical science education as the number of reports expressed its favourable results. The execution of the POGIL teaching technique had also an overall beneficial effect on student learning process and the group dynamics. The MCQ score of low achievers was better after POGIL sessions and performance of students on questions, requiring higher-order thinking skills such as application and analysis, was also improved. Students expressed that their problem solving and critical thinking skills improved after the POGIL sessions. Although the implementation of POGIL is challenging task with minimal faculties, future efforts should be made to improve group effectiveness by providing a structured introduction on how to manage group work effectively, special attention to low scorer students in each group and implementation of a peer evaluation system. The study is limited by sample size is small and single batch. Additionally, due to reduced duration of 1st MBBS course, limitation of time is a major constraint.

The study is limited by a small sample size of 100 students and the reduced duration of the 1st MBBS course, making time a major constraint as model making is time consuming. Variations in enthusiasm and commitment among team members affected participation. At times, the focus shifted from understanding anatomy to artistic presentation, potentially compromising conceptual clarity.

Ethics statement: Ethical approval was granted by the GIMS/IEC-ECR/1224/Inst./UP/2019 via letter no. GIMS/IEC/2022/11 dated 28.04.2022.

Abbreviations

POGIL – Process Oriented, Guided-Inquiry Learning

NMC – National Medical Council

PBL – Project Based Learning

TBL – Team Based Learning

CBL – Case Based Learning

CVS – Cardio Vascular System

GIT – Gastro Intestinal Tract

GUT- Genito Urinary Tract

Competing Interest: No financial and non-financial competing interests.

Authors' contributions: All the authors contributed equally in conceiving and writing.

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