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# Implementing Process-Oriented Guided Inquiry Learning in an Undergraduate Physical Chemistry Class: A Survey of Student Perception and Attitudes

**Marazban Kotwal*** **and Abhilasha Jain**

*Department of Chemistry, St. Xavier's College (Autonomous), 5, Mahapalika Marg, MUMBAI – 400 001, **INDIA**

Email: marazban.kotwal@xaviers.edu

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## ABSTRACT

*Process-Oriented Guided Inquiry Learning (POGIL) is a student-centered, pedagogic strategy that has been used effectively in science classrooms in several colleges and universities, especially in USA. This approach is built on the ground breaking research work in the areas of cognitive development, cooperative learning, and instructional design by several researchers. Process-oriented, guided-inquiry learning (POGIL) is an active learning method based on learning cycle paradigm which is consistent with research on how students learn as described by Novak's human constructivism theory. This paper presents a case study of the authors' experience using the POGIL method in a Physical Chemistry course involving spectroscopy. The POGIL activity, initially, familiarized students with several terms and laws governing spectroscopy and hence set a ground for them to construct knowledge about energies involved in several allowed transitions and decipher the structure of spectra obtained as a consequence with the help of critical thinking questions and finally helped them to extrapolate the knowledge constructed to several applications of spectroscopy. The students were actively engaged in classroom and interacted with the instructor without inhibitions to tackle critical thinking questions. In this paper we describe our approach to using POGIL and discuss student perceptions regarding the same, which was obtained from the students in the form of a survey based on a Likert type scale. The conclusions of this research throws open a plethora of avenues for future implementation of POGIL in Chemistry in the Indian context.*

**Keywords:** Chemical Education Research, Inquiry based Learning, Guided Inquiry Learning, Active Learning, Student-centered Learning, POGIL.

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## INTRODUCTION

A traditional lecture in Chemistry education focuses on transmission of information. This indicates to the students that learning means making a record of (note-taking) and repeating (memorizing) what the instructor says [1]. However it is a common knowledge amongst academia that lecture presentation, in its most passive forms, is not effective in helping students to recall presented material at a later time. Exclusive use of lecture-method is useful for a small fraction of students who already possess mature metacognitive abilities and hence this method leaves a sizeable section of students behind. Teaching practices in these critical chemistry courses are changing slowly because few chemistry faculty members have formal training in education. They teach as they were taught, using lectures and modelling problem solving by example. This mode of chemistry instruction is strongly "teacher-centred" with a primary relationship between teacher and content [2]. Student success in college chemistry courses can be increased by replacing content laden lectures with team based learning that promotes concept understanding and skill development. Process Oriented Guided Inquiry Learning (POGIL) is one of the techniques for improving chemistry instruction. POGIL provides a teaching strategy and a philosophy of learning that enables chemistry faculty members to transition from a model of transmitting knowledge from teacher to student to a developmental model of student-centred instruction [3].

POGIL is an instructional model that has been used to achieve the goal of improving student learning. POGIL is a strategy in which students work in small groups with individual roles to ensure that all students are fully engaged in the learning process and uses guided inquiry as the basis for many of the carefully designed materials that students use, to guide them to construct new knowledge. POGIL is based on the constructivist theory of learning [4].

Major tenets of POGIL are that learning is enhanced when students are

→ actively engaged,

→ thinking,

→ analysing data, drawing conclusions, and constructing their own knowledge, and interacting socially by discussing ideas with their peers [5].

POGIL (Process Oriented Guided Inquiry Learning) is a type of learning based on the principle that students learn more when they construct their own understanding, rather than teaching by telling, POGIL instructors provide activities that guide students to discover concepts on their own. Students work in groups, encouraging them to discuss their findings with their peers. Not only do students learn the material better, but the very process of discovery teaches them to be better problem solvers [6]. A POGIL activity is built upon the framework of the Learning Cycle (LC), an approach that has been shown to be effective in teaching science [7, 8, 9].

The LC as applied here has three distinct stages:
i) Exploration,
ii) Concept Invention/Term Introduction, and
iii) Application.

In practical terms, a POGIL activity starts with a model or set of data that will serve to illustrate key features of the concepts to be presented. The activity requires students to answer questions leading them to explore the model or data. At this stage, students note important relationships in the data or key features of the model. Next, students are asked critical thinking questions leading them to form a generalized concept. In the initial stages, the vocabulary associated with the concept is introduced. Finally, application questions reinforce the concept and further enhance critical and creative thinking skills. In a POGIL classroom, students work cooperatively in small groups on the guided inquiry activities. To foster the interdependence necessary for successful cooperative learning, POGIL activities are challenging enough that most students find it difficult to complete them independently, but are appropriately targeted so that a group of students can work through them with only targeted intervention from an instructor [10, 11].

To aid the group process and to foster individual participation and accountability, roles are assigned to each group member. Thus, knowledge is personal and is constructed in the mind of the learner. This construction depends on the misconceptions, biases, prejudices, beliefs, likes, and dislikes of the learner.

This learning model, called constructivism, is one of the leading pedagogical paradigms for enhancing student learning. A POGIL learning activity engages students, promotes restructuring of information and knowledge, and helps students develop understanding by employing the learning cycle in guided inquiry activities. This sequence of exploration through application is generally more effective than traditional lecture method of learning and often used Problem-based learning [12-15]. Traditional lectures present the concepts, model how they are applied, and then provide further applications for students to work out on their own. Students are not guided in exploration or helped in developing their understanding. Problem-based learning requires students to work on large-scale applications with the objective that they will explore and develop an understanding of the concepts and fundamentals as they develop the problem solution. Facilitating group work increases and improves instructor-student interactions [16]. The students and the instructor interact more frequently through instructor observation, answering questions, and providing feedback. This interaction improves the instructor's assessment of the students' grasp of the material via the questions the students ask and how they manipulate the information as they move through the application questions. In turn, student inhibition is decreased and they are more willing to ask clarification questions and to free-think about the material. By the end of the course, most students indicated the POGIL format provided a positive learning environment.

Process skills are becoming increasingly important as our knowledge base expands, as society addresses interdisciplinary and more complicated problems, and as businesses seek technological developments on shorter and shorter time scales. Hence those with highly developed process skills like information processing, critical and analytical thinking, problem solving, communication skills, teamwork, management skills, and assessment skills will be most successful [17]. Industrial employers would like chemistry-trained employees whose education includes greater preparation in communication, team skills, relating applications to scientific principles, and problem solving, without sacrificing thorough preparation in basic science concepts and experimental skills" [18]. These skills therefore need to be included explicitly in college-level courses, not only to help students be successful in these courses but also to prepare them for the workplace and for life in general. POGIL pedagogy definitely encompasses these life-skills which is a must to improve employability of a student. This paper presents the results of POGIL pedagogy on a group of 51 students of T.Y.B.Sc. majoring in Chemistry at St. Xavier's College in a course of on Spectroscopy, a subdiscipline of Physical Chemistry.

## METHODLOGY

The POGIL sheets were developed keeping the learning objectives of the course in mind. Important components of POGIL activities which include a descriptive title, models for student exploration, critical thinking questions to promote concept development, exercises for practice, and problems to apply the concepts were included in every sheet. The Accelerator Model [19] and Grow's Staged Self-Directed Learning Model (SSDL) [20] both predict that an unproductive learning environment occurs when the level of self-directed learning and cognitive challenge is increased before students are ready. This was kept in mind by the authors while drafting the POGIL sheets. The rate of increase of self-directed learning and cognitive challenge was adjusted to the level of student readiness and hence progressively increased with time and adaptation indications from the students.

Initially, the benefits of this Pedagogy were announced to the class, briefly, to reduce the resistance from some of the students on exposure to the POGIL method which is completely different from traditional method of lecturing almost hundred percent adopted by teachers in India. To the author's surprise the students showed rapid adaptation for the method probably as it broke the monotony from traditional lectures and posed a challenge to students.

In each of the sessions of POGIL students were made to work co-operatively in small groups of three, randomly created in the beginning of the sessions. To create the interdependence between the members of a given group for successful co-operative learning, POGIL activities were designed to be challenging enough that most students find it difficult to complete them independently, but can work through them with only on targeted intervention from the teacher facilitating the POGIL session. To support the group process and to encourage participation from all and accountability, roles were assigned to each group member. The roles were: i) Chairperson – coordinated the activity and ensured that the group remain focussed on task, ii) secretary – kept a record of the group's progress and noted key concepts, iii) spokesperson – shared the group's results with the class. Roles were rotated every session so that students developed the distinctive skills of all roles.

The perception of the students towards the benefits of POGIL was fathomed with the help of a survey based on Likert Scale conducted by the authors using Google Forms. The link to Google Form having the survey questions were emailed to each and every student and were requested to fill it within a week. The students were assured about the survey being anonymous in nature. The Google form did not require them to reveal their identity and all their responses to the survey were automatically lodged in an excel sheet with a time stamp. Multiple forms filling by a given student was disabled to avoid students submitting the responses more than once. In the questionnaire students were asked to present their opinions regarding their attitude towards various aspects of the POGIL classroom model. The survey questionnaire was drafted on the basis of a five point Likert scale as Likert Scale items have the inherent **advantage** of not expecting a simple yes / no answer from the respondent, but rather allow for degrees of opinion, and even no opinion at all [21-22]. The format used for the questionnaire had 5 Likert items, and was scaled from 1 to 5 as follows:

- Strongly disagree
- Disagree
- Neither agree nor disagree
- Agree
- Strongly agree

There were 15 questions in the questionnaire. Some of the questions pertaining to student attitudes that helped to reach the conclusion of this survey touched upon the following facets of the pedagogy:

- The attitude towards going through a change in learning method from traditional lectures to POGIL.
- Improvement in quality of interaction in the classroom including opportunity to ask questions and clarify difficult points.
- Utility of the co-operative learning methodology.
- Perception of improvement in concept understanding.
- Perception of the satisfaction and improvement in self-confidence towards independent learning.
- Perception of improvement in the performance/ grades/ marks in the internal assessment due the POGIL model.
- Extra effort demanded by this method as perceived by students as an additional burden.
- Overall impact of the POGIL methodology.

## RESULTS AND DISCUSSION

Students found that POGIL activities required a more coordinated and cooperative approach than they had previously experienced in group work or on worksheets. In the first session, many of the groups adopted a completion-oriented approach by braking down the activities into sections, assigned sections to group members, and agreed to come back and share their answers. However they quickly discovered that unlike a traditional worksheet, breaking a POGIL activity into smaller pieces and finding the right formula or answer was not an effective way to complete the work because POGIL activity builds upon itself as it progresses – each question requires information from previous models and questions – and are designed to be challenging enough not to be completed by an individual in a timely fashion. The survey which was filled by 48 students via Google forms showed that all the students strongly agreed or agreed that they learned from POGIL sessions and surely preferred them over traditional classroom. About 59% of the students strongly agreed and 26% of the students agreed that the sessions improved their self-confidence towards independent learning (Figure 1, Figure 2). About 59% of the students strongly agreed and 26% of the students agreed that peer learning or co-operative learning which being an integrated part of POGIL pedagogy, is advantageous (Figure 3). Perception of improvement in the understanding towards concepts was shown by 89% of the students (strongly agreed and agreed) and the remaining 11% neither agreed nor disagreed giving an indifferent opinion (Figure 4). POGIL has been demonstrated to be effective in improving student retention and performance, which was indicated by more than about 80 % (Strongly agreed and agreed) of the students (Figure 5 and 6).

Students appreciated the fact that the challenge level was increased progressively with time in tandem with their adaptation to the methodology.

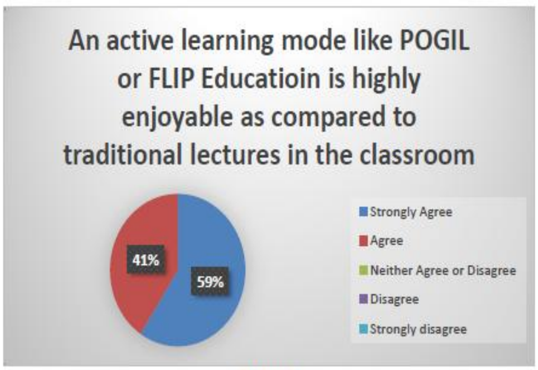

Figure 1

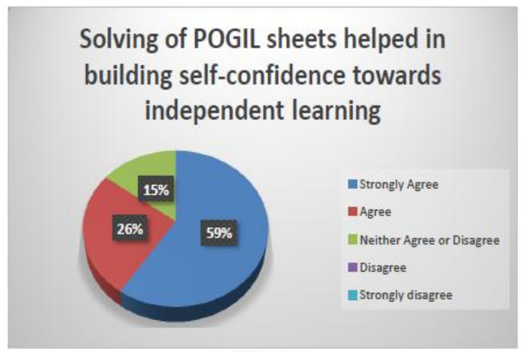

Figure 2

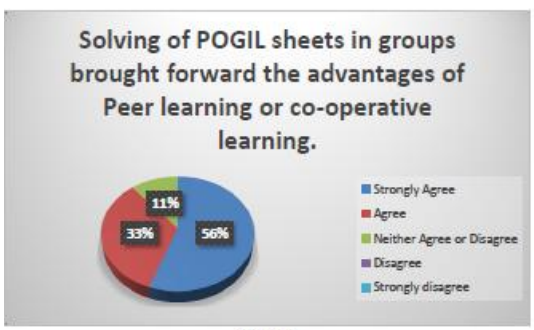

Figure 3

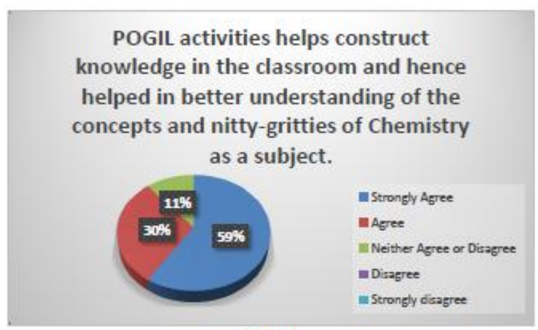

Figure 4

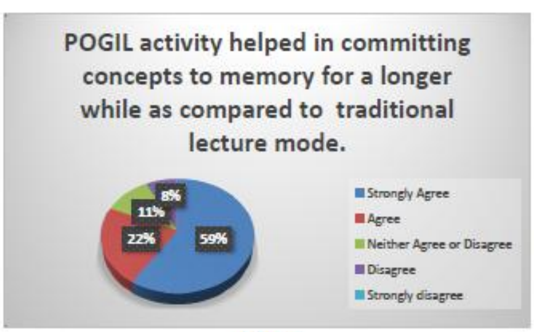

Figure 5

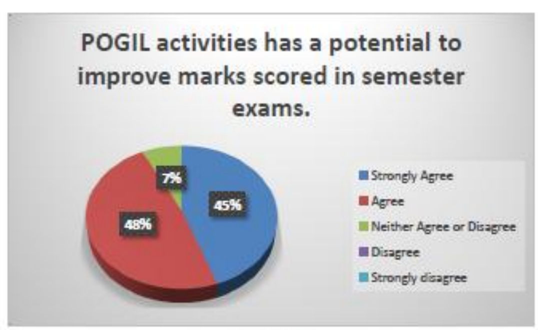

Figure 6

The results of the survey clearly indicate that POGIL offers tremendous potential to transform chemistry education by promoting deeper student learning, encouraging increased student responsibility for learning, developing process skills needed for employment, and increasing student satisfaction. The POGIL approach provides a manageable transition for chemistry faculty members to move from teacher and content-oriented instruction to more student-centred instruction.

## CONCLUSIONS

Process-oriented guided-inquiry learning (POGIL) is both a philosophy and a strategy for teaching and learning. It is a philosophy because it encompasses specific ideas about the nature of the learning process and the expected outcomes. It is a strategy because it provides a specific methodology and structure that are consistent with the way people learn and that lead to the desired outcomes. Much research exists to document that real understanding and learning requires active restructuring on the part of the learner. Restructuring involves integrating new knowledge with previous knowledge and beliefs, identifying and resolving contradictions, generalizing, making inferences, and posing and solving problems. This restructuring can be easily achieved through POGIL model of education.

## FUTURE SCOPE

In Indian scenario of mass tertiary education to practice POGIL will be a challenge, primarily due to large classrooms. Instituting POGIL in large classrooms does not have as long a history as its use in smaller classes. However keeping in mind several benefits of POGIL it is imperative to practice POGIL not only in Chemistry but any STEM (Science, Technology, Engineering and Math) courses, which are concept based courses. This can be achieved by the primary teacher of the course having assistance from a colleague or from students from senior classes as teaching assistants. Classroom civility issues can be addressed in large classes by using activities that are challenging but not overwhelming in order to keep students on task; recruiting enough facilitators so that a group may get help if they become frustrated and awarding participation points and credits to those who actively participate.

Another foreseeable problem that can arise in a large classes is that a small amount of content coverage will get sacrificed using POGIL. This problem can be partly solved by following a set schedule during the session and ensuring that the main concepts are covered. Students in large classes may be especially sceptical of any non-traditional teaching method. Hence it will be necessary to reinforce the rationale behind the POGIL method throughout the semester and not just in the beginning. However, the potential faculty using POGIL in large classrooms may be warned that some students will resist collaboration and guided inquiry at the beginning, but then appreciate POGIL after a few weeks. Whereas, some other students may realise the value of POGIL only after the course ends. The discussions through POGIL activities should infact lead to students understanding the importance of connecting with other students and forming study groups. To improve student learning, enthusiasm, and retention, especially in science, technology, engineering, and mathematics (STEM) areas, educators need developed a wide variety of approaches to engage students, enhance learning, and emphasise attitudes and skills in addition to knowledge.

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## AUTHORS' ADDRESSES

1. **Marazban Kotwal**
   Assistant Professor, Department of Chemistry,
   St. Xavier's College, 5, Mahapalika Marg, MUMBAI – 400 001
   marazban.kotwal@xaviers.edu, Phone No: 91-9821086871
2. **Abhilasha Jain**
   Assistant Professor, Department of Chemistry,
   St. Xavier's College, 5, Mahapalika Marg, MUMBAI – 400 001
   jainabhilasha5@gmail.com, Phone No: 91-7506270677