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An Effective Use of POGIL in Improving Academic Performance of Students and Their Approach in Organic Chemistry

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ABSTRACT

Organic Chemistry is perceived to be one of the most challenging of undergraduate science courses, and attrition from this course may impact decisions about pursuing a professional or academic career in the biomedical and related sciences. POGIL (Process Oriented Guided Inquiry Learning) is a collaborative learning technique that employs guided inquiry within a cyclic system of exploration, concept invention, and application. This action research explores students' academic performance on a unit of organic chemistry work taught using POGIL, in addition to the effect of POGIL on their academic performance and confidence. Research suggests that chemistry students who are strategic help seekers may outperform those students who avoid seeking help and that encouraging self-regulated learning behaviors can benefit academically at-risk students. In the current study, we present the results of action research conducted in an Organic Chemistry classroom over the course of three semesters. Results suggest that encouraging academic help seeking, a type of self-regulated learning, improves student outcomes. The academic performance was measured using a summative assessment at the end of the study whilst academic confidence was measured using test designed questionnaire. Final test result suggested a varied academic performance, whilst tests of significance indicated an improved level of academic confidence among the students involved. It is hoped that this study will serve as a platform for the use of more student-centered pedagogies in chemistry.

INTRODUCTION

While many students enter college with the intention to major in science or mathematics, a large percentage exits these disciplines during the early college years. Moreover, attrition rates of students from these disciplines have been disproportionately high relative. Surprisingly, research has indicated that students leaving science and mathematics fields are not necessarily weaker academically; rather, a disproportionately “able” or academically successful group of students leaves these disciplines.

Various factors are known to contribute to what has been termed the “leaky pipeline” of science and mathematics undergraduates, including a competitive classroom atmosphere and poor quality teaching. In some cases, loss of interest and subsequent attrition may be related to negative academic experiences, such as earning poor grades, negative experiences with teaching assistants or lab instructors, and minimal or poor contact with professors of particular interest, however, are how negative experiences with Chemistry courses, especially Organic Chemistry, play a key role in discouraging students from persisting in premedical studies. Beliefs students hold about their own intelligence (Dweck & Leggett, 1988) lead some who perform poorly in Organic Chemistry toward self-blame due to a belief that their failure stems from a lack of ability (entity beliefs about intelligence) rather than a limited background in science (incremental beliefs about intelligence).

Learners have demonstrated longstanding difficulties interconverting and interconnecting chemical knowledge through microscopic, macroscopic and symbolic forms; many studies have documented students’ difficulties and tried to suggest solutions. The issue has also been considered across a variety of contexts, Students in India for instance, have been found to have difficulty with organic chemistry in general, and tend to either perform poorly on, or to all out avoid organic chemistry questions on state examinations. Indeed, the numerous difficulties that learners encounter with organic chemistry have promoted a plethora of suggested methods to improve pedagogical efficiency.

Two research questions with respective, corresponding hypotheses are addressed in this study:

1. How do students perform at the end of a unit of organic chemistry taught using POGIL?

2. What is the effect of POGIL on the academic confidence of students during a unit of organic chemistry?

Whilst being a student an unexpected hurdle came in the form of organic chemistry at the advanced level. The corresponding author found it challenging to link concepts from one reaction to another and particularly to follow the stepwise procedures, (i.e. reaction mechanisms), through which reactions progressed. This was caused by my inability at the time to visualize the formation of the molecular intermediates and final products of organic chemical reactions which also made it challenging to mentally create or manipulate the organic molecules that I studied from textbooks or encountered on assessment questions. As a result, it was difficult to grasp the underpinning concepts involved in organic chemistry. In my present practice as a Chemistry teacher to 16 to 18 years old boys, I have found that my students also have similar concerns regarding organic chemistry as I did when I was a student. This has led to some challenges in keeping my students confident in their ability when studying organic chemistry and has certainly caused them to relay their lack of confidence in the soundness of their oral and written responses to organic chemistry problems. These experiences have further retarded their motivation to pursue organic chemistry related work. My students' performance though, mirrors a wider issue. It has reported that students' performance generally ranged from moderate to poor in organic chemistry questions ranked from knowledge to analysis on Bloom's taxonomy

The students under discussion make up a class of almost 50 third year level, ranges in age from 20–21 years old. Based on the previous end of term results and a tacit knowledge of the students, this group may be considered to be a class of mixed ability. The members of the group had previously been observed to relate well to each other, perhaps as a result of being in the same class for the last six years. As a group too, this class was very curious and routinely tried to find relationships, (often inventing new scientific hypotheses in response), between their personal experiences, topics covered during chemistry class and new science areas that they had read about independently. To respond to these complaints and concerns surrounding student performance in organic chemistry in previous years, molecular model building sets were used in an attempt to concretize abstract images so that students could better describe and manipulate them. Students were able to develop and use their own explanations of the molecular structures, their behaviour, and their reactions. Once students developed their explanations after exploring the topics themselves, their complaints were observed to decrease significantly. Additionally, they also appeared to be more determined and confident to seek solutions to organic chemistry assessment questions. Process Oriented Guided Inquiry Learning (POGIL throughout this paper), as a collaborative learning strategy, was thought able to extend the advantages of molecular modeling as it can provide the concrete experiences that could help these students to learn organic chemistry better. POGIL may aid in this respect by allowing the learner to build their own methods of approach to organic chemistry in order to develop their own understandings.

The Problem

The challenge being faced in this study can be summarized as follows:

1. The students' ability to conceptualize processes happening at the molecular level in organic chemistry reactions.

2. The students' ability to manipulate and use organic chemistry concepts that they learn within new situations.

The students' academic confidence levels in organic chemistry

The need for the Study

A unit of organic chemistry was taught to students in the third year level, using POGIL. The study measured the post-unit academic performance of the students and the impact of POGIL on their academic confidence

REVIEW OF THE RELEVANT LITERATURE

It is difficult to neatly divide organic chemistry concepts into discrete topics in the same way as might be possible in other areas where topics show little conceptual overlap. Within organic chemistry, the academic performance of students may not be at its best if there are gaps for the students in previously covered topics. Additionally, for students to learn and manipulate concepts in reaction mechanisms, various forms of reaction modeling may be an irreplaceable tool. This is important, given that it has been found that, "Chemists cannot talk to each other without the use of drawings", itself a form of modelling as is to the representation of the concepts in organic reactions via equations and mechanisms. If students are to learn and manipulate concepts in reaction mechanisms, various forms of reaction modelling may be an irreplaceable tool. Therefore, in the teaching and learning of organic chemistry opportunities for concept invention and development may prove useful.

POGIL, similar to Problem Based Learning (PBL) and Peer-Led Team Learning (PLTL), is built on a platform of social constructivism. “Learning awakens a variety of internal developmental processes that are able to operate only when the [student] is interacting with people in his environment and with his peers”. This implies that with social-constructivist strategies such as POGIL, knowledge is something between the individual and a community or a group, and is aided by cooperative social interactions.

Furthermore, “observations of students working together have found that peer-to-peer interactions may be even more facilitative for active meaning-making than teacher-student interactions, given the shared perspectives and life experiences”. Within the knowledge-constructions of inquiry-learning “knowledge is not transmitted directly from the teacher to the student, but is actively developed by the student.

Moreover, studies have also indicated that attempting to solve real world problems whilst engaged with peers has increased students’ self-efficacy and motivation. Further inquiry was needed to better develop scientific knowledge and that it was also necessary for the understanding and application of scientific concepts and methods. By extrapolation, POGIL’s ability to allow students to apply content knowledge while trying to solve real world problems through peer collaboration suggests that it may be used/employed/able to develop cognitive skills across the hierarchy of Bloom’s Taxonomy (Kuhn, Black, Keselman, & Kaplan, 2000) and so affect academic performance as reflected by students’ grades.

POGIL hinges on a cycle of exploration, concept invention and application. The exploration phase may be critical in constructing personal knowledge through an active process guided and facilitated by the teacher. Within this project, group work used in POGIL also provided a more realistic setting for the limited material that was available for the execution of the study. The POGIL Project that was co-funded by the US National Science Foundation, the Toyota USA Foundation, the US Department of Education, and the Hach Scientific Foundation, reported that the implementation of a POGIL approach in general chemistry led to examination results that indicated significant shifts in student performance from lower scores to higher scores, and did so uniformly across low- through high- achieving students. Moreover, when one of three general chemistry lectures each week was replaced with a peer-led team learning session using POGIL materials, it was found that the students who attended the group learning sessions achieved a higher average score on the common examinations (The POGIL Project, 2012-2014). POGIL employs structured chemistry exercises given to and carried out by, students. The students operate in groups to work through the steps outlined in the exercises in order to formulate their own understanding of the topic. As their understanding of the topic develops, students should be better able to solve new problems which may fall anywhere in the hierarchy of cognitive skills and therefore impact their academic performance. Academic performance outcomes may be categorized by students' grades. Students' grades obtained across various cognitive levels after implementing POGIL were used to reflect the academic performance of the students in this study.

These self-managed groups of students follow a learning cycle in each exercise involving POGIL. The learning cycle used is as follows:

Exploration: In this phase, the students interrogate the information in the given exercises through discussion within their groups. This may lower the degree of uncertainty in students since the teacher provides the inquiry questions and procedures. This stage may therefore impact upon the academic confidence of students. POGIL provides a process for exploration which is needed to address difficulties students have in mentally forming chemistry concepts. The exercises therefore may involve the making of observations, the analysis of results or data, or even the design of an experiment. Students are to generate hypotheses and test them in order to explain and understand the information. In this phase of exploration, each exercise should work harmoniously with others to meet specific learning objectives.

Concept Invention: In this phase, the students describe or explain the observations made whilst exploring. The concepts are concretized when each group reports their findings from the exercises to the entire class allowing further discussion which is moderated by the teacher. Reports can be submitted by having a representative present the findings of individual groups, or groups may simultaneously place their findings on the class' chalk or white board so that their results can be interrogated by the entire class. After the students have constructed and expressed their own understandings, conventional related terminology is introduced by the teacher.

Application: This phase of the learning cycle requires deductive reasoning skills since it relates the general concepts derived in the previous phase to new situations. Application to new situations builds learner confidence and provides the opportunity to solve real world problems. Noteworthy is that "application" in this context, encompasses possible analyses, syntheses and evaluations which may arise and is not confined to the third place of "application" in the hierarchy of Bloom's taxonomy.

The POGIL learning cycle stated above is similar to Bloom's Taxonomy since there is a combination of content learning with process skills. Therefore, there are implications of using POGIL on the cognitive, affective and psychomotor skills of students. This may be reflected in better performance in examinations assessing these aspects of student learning. Additionally, students are able to reflect on their learning process through the activities and discussions that are a formal part of each POGIL session. Moreover, the interactivity and communication skills of students are challenged as they are required to communicate scientific ideas whilst working in groups. POGIL also helps students to develop competencies in decision making as they formulate hypotheses.

POGIL can also impact students' confidence to study organic chemistry. Academic confidence is subsumed in the concept of self-efficacy. Self-efficacy can be defined "as people's judgments of their capabilities to organize and execute courses of action required to obtain designated types of performance"

POGIL can promote such self-efficacy since students are engaged primarily in concept invention which helps them to facilitate/promote their own understandings. Hence, if students can discuss their performance on tasks associated with their self-efficacy whilst pursuing academic goals, then we can have a measure of their academic confidence.

Academic confidence was found by Sander and Sanders (2005) to cluster around the following factors:

Studying, Understanding, Verbalizing, Clarifying and Attendance.

The degree of student agreement with the positively-skewed statements related to the above mentioned factors suggests the levels of academic confidence of the students involved in this study. Academic confidence scores as evidenced by responses to the questionnaire do not necessarily predict academic performance; however academic performance may affect academic confidence (Sander & Sanders, 2005). POGIL too has shown the ability to improve student confidence.

MATERIALS AND METHODS

This study is action-research. Action-research's primary aim is to use systematic methods to make improvements within educational settings by solving noted problems. Though action-research is able to incorporate elements from quantitative and/or qualitative research, this study collects numerical data for both research questions one and two and performs analyses primarily through statistical means. Simply described, qualitative research is naturalistic, inductive, emergent, and seeks to capture participants' constructed worldviews usually through text-based methods. Alternatively, quantitative research is deductive and primarily considers/deciphers the relationships between variables through statistical analysis of numerical data

The study can be described as having a quasi-experimental design since the participating upper-six class was not randomly chosen. Randomization is not always an appropriate option, especially in cases like this where only a small group is available for implementation of the intervention. Additionally, there is only one upper-six chemistry class at the college where the study was carried out. Hence, there could be no control group and there is an inability to say that results were not influenced by factors unattributed to the intervention. The lack of a control group however, eliminated the possibility of any unethical, biased treatment of classes through the application of an intervention which could be potentially beneficial or harmful to the treatment group, whilst being denied to the control group (Cook & Campbell, 1979; Thyer, 2012). The study also does not require the identities of students to be divulged and so protects any sensitive information that may arise.

To answer the questions, study design was used. The intervention was made at the beginning of the organic chemistry module and scores relating to the students' previous performance in organic chemistry were unavailable, hence the choice of a post-test only design. As a result, there is no means of comparing the effectiveness of the strategy used to previous organic chemistry work pursued by these students; that is, any changes in academic performance are not necessarily attributable to the POGIL intervention. However, the students' performance in the post-test was qualitatively discussed against their academic scores from the previous end of term examinations to get some indication of how well they were proceeding through the curriculum.

Research Plan

The study was conducted over a two weeks period. The students were briefed on the details of the study and informed of their assigned group roles during the week before the commencement of the intervention.

The unit of work consisted of eight lessons:

1. **Carbon compounds and homologous series**. Students identify the various families of organic compounds called homologous series, and the general formulae which define them.

2. **Nomenclature of organic compounds.** Students develop their own system of naming organic molecules before they are introduced formally to standard rules for naming the compounds within various homologous series of organic compounds.

3. **Isomerism.** Students identify and illustrate different types of monomers using two- and three-dimensional models.

4. **Movement of electrons in organic molecules and types of reagents.** Students describe the behaviour of electrons in different molecules in order to classify the molecules as electrophiles and nucleophiles.

5. **Hybridization and physical properties of alkanes and alkenes**. Students attempt to illustrate hybridization and the effect it has on the shapes, and hence the properties, of molecules.

6. **Reactions of alkanes and alkenes**. Students use drama and molecular models to describe substitution vs. addition reactions among other types of reactions undergone by alkanes and alkenes.

7. **Naming of alcohols.** Students name and classify alcohols as primary, secondary, and tertiary.

8. **Reactions of alcohols**. Students discuss the oxidation of the different classes of alcohols.

9. **Spectroscopy:** Problem solving

Each lesson consisted of activity sheets comprising a combination of multiple choice questions, structured questions, and free response questions. Many of the related activities involved the drawing of two dimensional representations of molecules, and the building of three dimensional representations of the same. The advantages of this Pedagogy were discussed with the class, in a few words, in order to reduce the confusion from some of the students on exposure to the POGIL method which is completely different from traditional method of lecturing adopted by teachers in India.

The size of the groups should ideally be restricted to three or four members. Larger groups may result in less focused exploration whilst smaller groups tend to have richer exchanges. However, a larger number of groups may require additional teachers present to facilitate the POGIL process for some of the clusters with the teacher intervening only where and when needed. Hence, with a greater number of groups the demand for teacher intervention may increase. The composition of any group can include a high and low performing student and students of various ethnicities. The groups were formed randomly. In classrooms with male and female students, gender differences can also be considered when putting the groups together. To support the team building process and to encourage the student participation and accountability, specific roles are also assigned to the members of a group and these can be rotated from lesson to lesson. These roles are as follows

The Manager: This student has the responsibility of keeping the group on the task and seeks to assure that each member of the group participates and understands the content.

The Recorder: This student prepares a report of the group's findings. The report must be compiled through consultation with the other group members.

The Strategy Analyst: This student has the task of reflecting on the group's performance and identifies its strong and weak points.

Similarly to the recorder, this role is done in consultation with the other group members. There is a greater demand on the metacognitive skills of this student since he or she must reflect on the learning process, which is just as important as reflecting on the content.

The Spokesperson: This student is responsible for communicating the findings of the group to the class.

The unit and final assessment comprised questions which fell into the knowledge, understanding, application, and analysis categories of Bloom's. Students were also required to develop a concept map as the unit of work progressed to reflect their maturing understandings of how each topic within the unit related to the others.

The student's insight or their opinion about the advantages or shortcomings of POGIL were understood with the help of survey based on Likert scale to gather data reflective of students' academic confidence, both before, and at the conclusion of the study. Questionnaires with positively skewed questions were outlined on the basis of Likert scale with not just yes or no type response but the freedom has been given to students to put forward their opinion. The questionnaire to measure academic confidence was distributed at the start of the first day of the intervention and at the end of the intervention after the final assessment. The summative academic test was administered as an instrument after the completion of the unit.

For this purpose, 11 questions were drafted and specific format has been prepared as follows. Students were asked to rate each question from 1 to 5, where "1 = strongly disagree" and "5 = strongly agree".

Strongly disagree
Disagree
Neutral
Agree
Strongly agree

Question sheets were prepared to keep in mind the learning objectives of course design. The various components of POGIL tool were taken into consideration while preparing question papers which includes aptitude skill based questions, organic chemistry model making which will explore student talent, critical thinking based questions which will test conceptual thinking ability of student, exercise on spectroscopy problems solving.

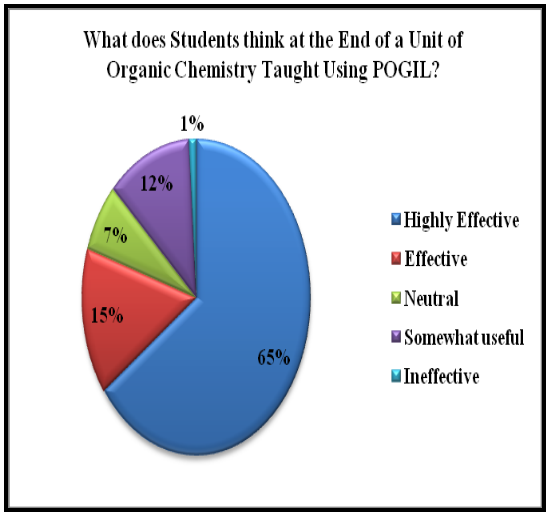
The main objective of this test conducted is

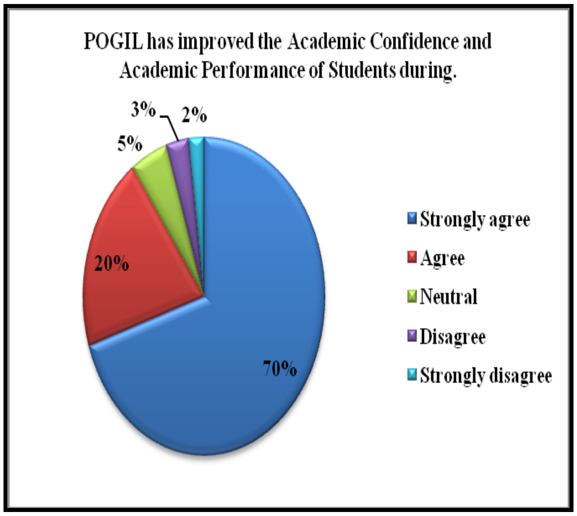
1. To see the approach of students from traditional lecture pedagogy to POGIL.
2. To encourage the group learning activities
3. Effectiveness of the cooperative learning methods
4. Opinion towards blooms' Taxonomy i.e. knowledge, understanding and application
5. To develop effective interaction sessions in terms of Question Answer in the classroom help in solving various doubts.
6. Help in building self confidence and cultivating healthy independent work atmosphere
7. To investigate overall impact of this new tool i.e. POGIL

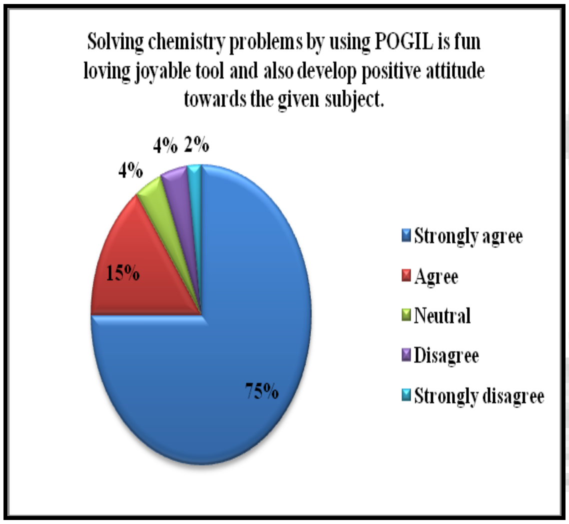
RESULTS AND DISCUSSION

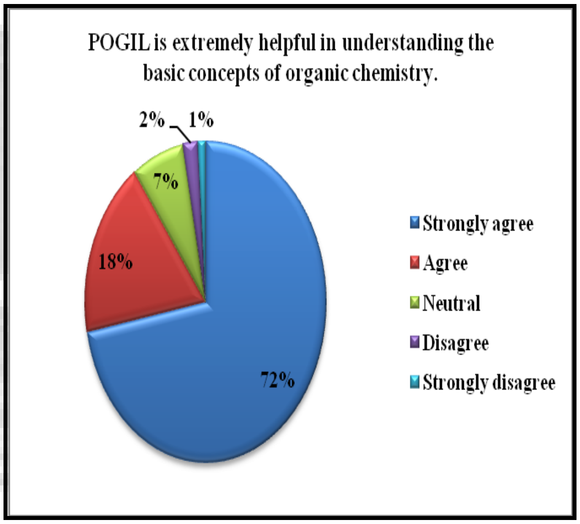
All the 50 Students actively participated in this post designed study to analyze the overall impact of this POGIL on the students. Most of the students established that this pedagogy required effective communication, good coordinating skills and cooperative attitude. Also, many students highlighted self-regulated learning and academic help seeking behaviour after doing this novel learning method and at the same time they have discussed this with all other college students. The effort level was significantly high in this pedagogy and also the challenge level was equally tough but in spite of this student never considered this as a burden but only as a motivational factor and help seeking activities.

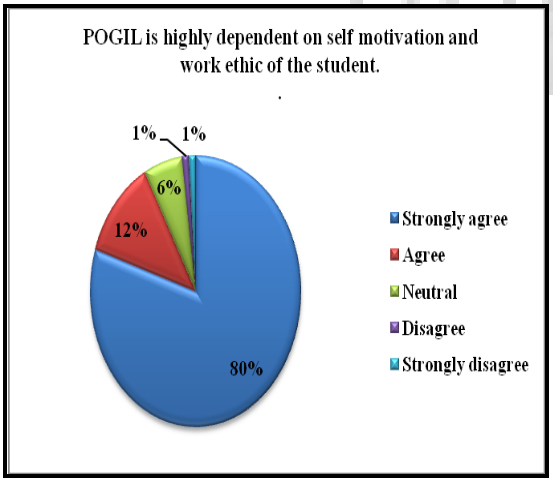
At the end of this study test, students showed a drastic change in their academic performance at the end of an organic chemistry unit of work taught using POGIL thus this helped them in a positive way to improve their academic confidence. The final outcome of this conducted test is expressed in the terms of pie charts given as follows:

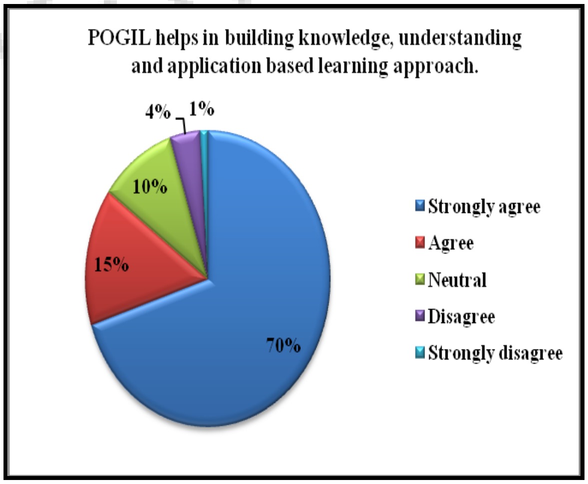

What does Students think at the End of a Unit of Organic Chemistry Taught Using POGIL?
1%
12%
7%
15%
65%
Highly Effective
Effective
Neutral
Somewhat useful
Ineffective

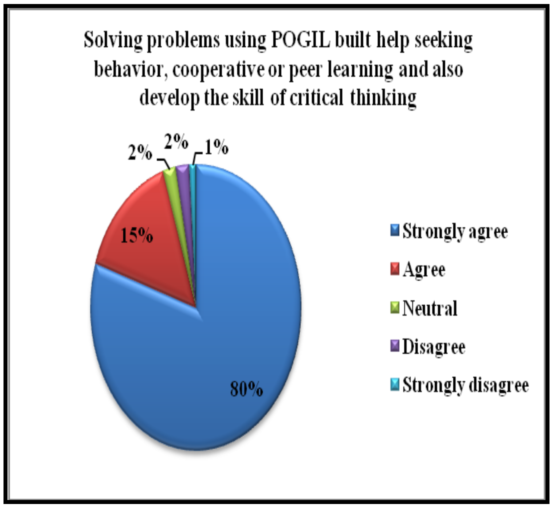

POGIL has improved the Academic Confidence and Academic Performance of Students during.
3%
2%
5%
20%
70%
Strongly agree
Agree
Neutral
Disagree
Strongly disagree

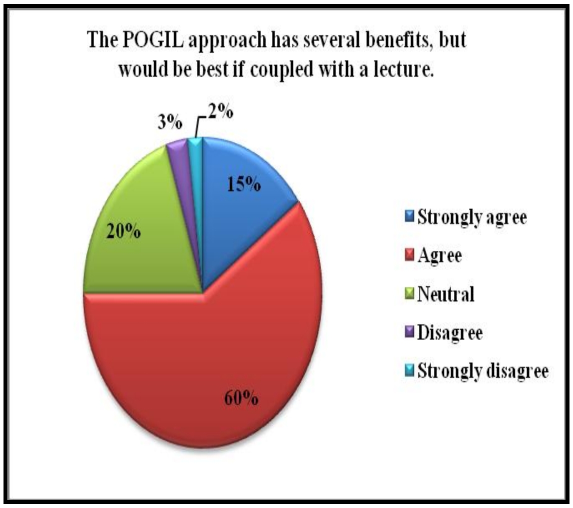

Solving chemistry problems by using POGIL is fun loving joyable tool and also develop positive attitude towards the given subject.
4%
2%
4%
15%
75%
Strongly agree
Agree
Neutral
Disagree
Strongly disagree

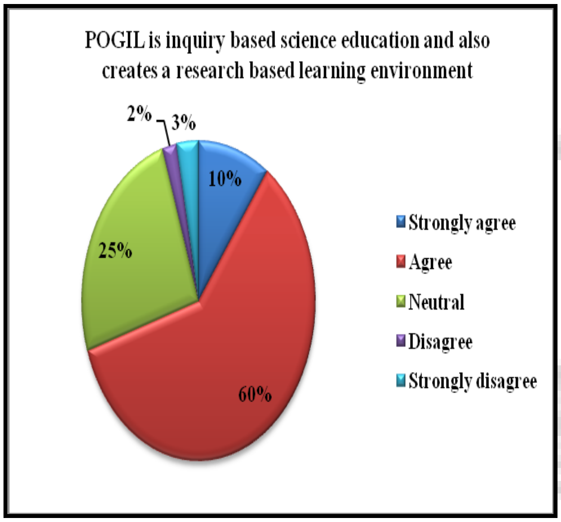

POGIL is extremely helpful in understanding the basic concepts of organic chemistry.
2%
1%
7%
18%
72%
Strongly agree
Agree
Neutral
Disagree
Strongly disagree

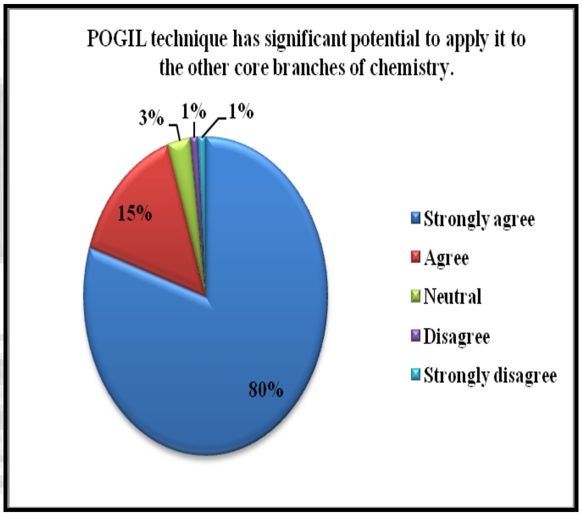

POGIL is highly dependent on self motivation and work ethic of the student.
1%
1%
6%
12%
80%
Strongly agree
Agree
Neutral
Disagree
Strongly disagree


POGIL helps in building knowledge, understanding and application based learning approach.
4%
1%
10%
15%
70%
Strongly agree
Agree
Neutral
Disagree
Strongly disagree









Thus above survey shows that POGIL offers remarkable potential to improve academic performance and confidence of student. It also cultivates motivation amongst the students which facilitate them in deeper learning. It develops group learning activity among the students. POGIL generates the tremendous interest about the subject which was found to be quite difficult and tough in learning using traditional teaching methods.

Using the POGIL method, the students are guided through a course that is focused on concepts. POGIL uses new situations to which students must apply learned concepts and against which information may be analyzed and products synthesized. If students find the concepts difficult to apply, exploration can be used to map a way to a solution and hence also serve as a reinforcement of studied material. The use of POGIL is suited to help develop the target to students' academic achievement and confidence in organic chemistry. It also seems especially useful given that it supports, in this class, natural curiosity, inquisitiveness, tendency to invent solutions, and to work collaboratively with their peers. The use of POGIL within this study necessitated moving away from the usual “one behind the other” arrangement of desks found in many classrooms, to multiple circular arrangements that could better promote and facilitate group work. This arrangement improved the teacher’s physical access to students, and assisted the teacher in focusing on, and assessing students’ understanding through direct observation of the group discussions of individual groups. This was advantageous to other forms of assessment that would not have allowed the teacher to be aware of all the steps within a given reaction mechanism that students would have personally formulated whilst developing their own understandings.

CONCLUSION

Process-oriented guided-inquiry learning 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 student-centered methodology and structure that are consistent with the way people learn and achieve these outcomes. The goal of POGIL is to help students, simultaneously master discipline content and develop essential learning skills. This module explains the relationship between three primary components of POGIL: cooperative learning, guided inquiry, and metacognition. It also offers advice on implementing POGIL in the classroom and provides evidence that POGIL instruction produces better understanding and higher grades compared with traditional lecture-style methods. Studies reveal that traditional teaching methods in higher education are no longer meeting students’ educational needs. This has led to several reform initiatives. Some of these initiatives focus on changing the curriculum and course content; others seek to utilize computer-based multimedia technology for instruction and some promote more student involvement in class in order to engage students in learning.

POGIL is built on this research base, sharing the key premise that most students learn best when they are actively engaged in analyzing data, models, or examples and when they are discussing ideas; when they are working together in self-managed teams to understand concepts and solve problems; when they are reflecting on what they have learned and thinking about how to improve performance; and when they are interacting with an instructor who serves as a guide or facilitator of learning rather than as a source of information. To support this research-based learning environment, POGIL utilizes self-managed learning teams, guided-inquiry materials based on the learning cycle, and metacognition.

When they first hear about POGIL, many instructors are intrigued by the approach and can see its advantages, but they are concerned that the pace at which the material is covered will be significantly slower in a POGIL course than for a lecture-based course. Our experience is that, this is not a problem. One way to measure this is to compare the standardized exam performance of students who learned using POGIL instruction, comparing the average outcomes against those of students from the same institution who experienced a traditional approach. Such comparisons show that students experiencing POGIL instructions scored higher on these examinations than students in traditional classes in both general chemistry and organic chemistry. It is inspiring that in evaluating POGIL at Stony Brook, instructors said, **this is the way to teach! And many students responded, more time for workshops and less time for lectures!**

There are a number of student-centered instructional techniques that can be effective for achieving valid learning goals in the classroom. POGIL differs from other approaches in its use and design of distinct classroom materials. Three characteristics of POGIL materials are as follows:

- POGIL materials are designed for use with self-managed teams that interact with the instructor as a facilitator of learning rather than as a source of information.

- POGIL materials guide students through an exploration to construct understanding.

- POGIL materials use discipline content to facilitate the development of higher-level thinking skills and the ability to learn and apply knowledge in new contexts.

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REFERENCES

1. Douglas, E. P., & Chiu, C. Process-oriented Guided Inquiry Learning in Engineering.Procedia - Social and Behavioral Sciences, 2012: 56(0): 253-257.
2. Farrell, J. J., Moog, R. S., & Spencer, J. N. A guided-inquiry general chemistry course. Journal of Chemical Education. 1999: 76(4): 570.
3. Myers, T., Monypenny, R., & Trevathan, J. Overcoming the glassy-eyed nod: An application of process-oriented guided inquiry learning techniques in Information technology. Journal of Learning Design. 2012: 5(1), 12-22.
4. Zimmerman, B. J., & Martinez-Pons, M. Development of a structured interview for assessing student use of self-regulated learning strategies. American Educational Research Journal. 1986: *23*(4): 614-628.
5. Gosser, D. K., & Roth, V. The workshop chemistry project: Peer-led team learning. Journal of Chemical Education.1998: 75(2): 185-187.
6. Karabenick, S. A. Seeking help in large college classes: A person-centered approach. Contemporary Educational Psychology. 2003: 28(1): 37-58.
7. Phillips, K. E., & Grose-Fifer, J. A performance enhanced interactive learning workshop model as a supplement for organic chemistry instruction. Journal of College Science Teaching: 2011: 40(3): 90-98.
8. Sander, P., & Sanders, L. Measuring confidence in academic study: A summary report. Electronic Journal of Research in Educational Psychology and Psychopedagogy. 2005. 1(1):1-17.
9. The POGIL Project. 2012-2014. Effectiveness of POGIL. Available from https://pogil.org/about/effectiveness
10. Sirhan, G. Learning difficulties in chemistry: An overview. Journal of Turkish Science Education. 2007: 4(2): 2-20.
11. Tsarpalis, G. Using PARSEL modules to contextualizing the states-of-matter approach (SOMA) to introductory chemistry. Science Education International. 2008: *19*(3): 323-330.
12. Hanson, D., & Wolfskill, T. Process workshops - A new model for instruction. Journal of Chemical Education. 2000:77(1):120