

Learning Gains of Process Oriented Guided Inquiry Learning in an Online Course Setting

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Abstract: There is substantial evidence that student-centred learning activities foster the evolution of higher-order skills, such as critical thinking and problem-solving. Process Oriented Guided Inquiry Learning (POGIL) approach is one such student-centred instructional approach that is mainly focused on improving student's content mastery and learning skills such as information communication, critical thinking, problem-solving and metacognition. Currently, POGIL has been mostly implemented in traditional classroom settings, where all participants are physically present. However, advances in online learning technologies have increased the popularity of online courses. Our study aims to implement and evaluate the effectiveness of POGIL in improving the overall student performance in an online course setting. We also present a meta-analysis on POGIL implementation and its effectiveness in different course settings. We implemented a POGIL approach in two completely online courses from the Health Information Management (HIM) program, M200 (Database Design for HIM) and M220 (Health informatics for Decision Support). We integrated POGIL practices into the course redesign of these HIM courses considering the core philosophy of POGIL - students learn through the process of performing activities that aid in developing critical thinking skills - the teacher, in this method, does not instruct, but rather facilitates guided inquiry. The lecture slides and videos were updated with POGIL activities and updates to the educational content, by removing the introduction of new concepts, and replacing them by background information that was required to do the POGIL activities. The modified content was implemented in Summer and Fall semesters of 2018. To evaluate the effectiveness of the POGIL, we compared the student academic performance (grades in the course assessments) of HIM M-200 course before (all semesters of 2017 and spring of 2018) and after POGIL implementation (Summer and Fall semesters of 2018). We used the Wilcoxon rank sum test to compare the performance of the student's pre and post-implementation. The results of the analysis showed that there is a statistically significant difference (p -value = 0.03) in the academic performance of the students before and after implementation. These different implementation under two contexts have been discussed and evaluated under the results.

Keywords: process oriented guided inquiry learning, POGIL, online courses, student-centred, instructional approach

1. Introduction

Online college courses are a rapidly growing feature of higher education. The number of students taking at least one online course in USA is now over 6.7 million in 2017. One out of three students now take at least one course online during their college career, and that share has increased threefold over the past decade (Allen and Seaman 2013). According to Allen and Seaman (2017) study, of all students taking at least one online class, almost half (48%) are taking only online classes. Online education tools are changing the way not only students learn but also their expectations towards how they could be taught efficiently. "Flexible delivery" is a common term used by the majority of the tertiary institutions to introduce off-campus teaching. Online technologies have benefits in terms of flexibility to deliver the courses and learning materials, facilitates collaboration within students, and subject administration. Amidst a multitude of versatile technologies, education practitioners pose the question of how to employ the technologies to enable a rich, engaging learning experience for the students. From the literature reviewed, as the solution, we found out that the acquisition of critical thinking and problem-solving skills can be improved through the implementation of collaborative inquiry-based learning (Duran & Dökme, 2016; Espinosa, Monterola, & Punzalan, 2013; Kowalczyk & Leggett, 2005; Miri, David, & Uri, 2007; Styron, 2014; Wartono, Hudha, & Batlolona, 2018), in which the learning process is emphasized on developing metacognitive skills, such as building some solution, testing the solution, and evaluating the results (Schraw, Crippen, & Hartley, 2006). Through the activity that involves the students in scientific investigation, they are expected to construct their knowledge independently by connecting the new knowledge with the prior knowledge (Fay, Grove, Towns, & Bretz, 2007).

Problem-solving and critical analysis are educational milestones that can be achieved by student engagement and the development of process skills (Kruger & Soltis et al., 2015). Learning methods have revolutionized from lecturer-concentrated to student-focused in the contemporary era, where “Active learning” has the ring of the slogan; and “Passive learning” is an oxymoron (Marchese 1998). Process Oriented Guided Inquiry Learning (POGIL) is one such strategy of active (dynamic) learning where the instructor portrays the role of a facilitator, and students are accountable for their comprehension as well as learning. In this class, the instructor doesn't lecture rather students work in groups or teams, typically of four students, on specially planned activities accompanying a learning cycle paradigm including worksheets completion containing background material, critical thinking questions to develop fundamentals and application exercises that utilize the concepts derived in the critical analysis phase (Elliot P. Douglas, 2012). Initially, widely adapted and practiced only in the chemistry curriculum but today POGIL has application in nearly all major disciplines viz. Engineering, Organic Chemistry, Marketing, Nursing, Computer Science, Online Information Technology, Anatomy & Physiology, Pharmacology, Physiological Psychology, Pharmaceutical Sciences & Information Literacy. Existing POGIL techniques were tested for teaching chemistry in a traditional context (Farrell, Moog, & Spencer, 1999; Moog & Spencer, 2008). However, most of the studies still address a situation where the teacher and the student are physically present. Therefore, implementing the results of such studies in an environment where interaction happens majorly online was not successful. (i.e., no face-to-face interaction between the tutor, students, and students themselves).

Encouraging results were generated by Myer et al. (2012) when he adapted POGIL methodology in Information Technology (IT) classes. Myers's et al. (2012) study spanned two years, which consisted of two subjects (networking and databases). The study noted a significant improvement in students' problem-solving abilities, interpersonal skills, and learning outcomes. POGIL was found beneficial by over 85% of the surveyed students for their studies. The outcomes focused not only on developing content mastery or emphasis on core concepts through student construction of their reason, but also enhancing essential process skills such as data processing, oral and written communication, problem-solving, critical thinking, meta-cognition and assessment fostering improved outcomes exclusively when deep learning is to be accomplished (Erl C. Villagonzalo, 2014). Being an instructional strategy to recognize the learning outcomes, the notable aspect of POGIL implementation is its ability to be independent of a specific course outcome. It reinforces accountability among groups generating peer-driven outcomes in comparison to instructor-driven (Myers & Trevathen et al., 2013). Several studies have mentioned that students working together found peer-peer interactions to be more beneficial for active learning than teacher-student interactions alone.

Additionally, the majority of students recognized that being actively engaged in class and interacting with others is an essential part of gaining understanding and retention of knowledge. However, one research study cited that it was unclear that learning outcomes were possibly due to several other factors like cooperative learning, active learning, student mental constructivism & indirect factors like regular study due to POGIL. A clear demarcation for one factor being responsible was not justifiable (Vanags & Pammer et al.). However, despite the proposed advantages of POGIL in these diversified disciplines, there is a paucity of research in the overall effects of POGIL on student performance. Hence our paper entails a meta-analysis on the adoption, implementation and efficiency of POGIL in improving student's performance in different educational disciplines and also details about an actual implementation and learning gains of POGIL in an online course environment. Furthermore, results indicates that implementation of POGIL in a single subject do not yield as much results as when we implemented in a different context with alternate subjects.

2. Methodology

2.1 Meta-Analysis

2.1.1 Data sources and search strategy

Journal articles published during the period 2008-2017 were searched electronically through the primary databases such as PubMed, Ovid, and Science Direct. Keywords such as ‘POGIL Assessment’ and ‘POGIL Methodology’ were searched. After collating all the material of the related literature, another round of search was conducted using the reference list found in the literature yielded by the electronic search.

2.1.2 Search results

Initial Screening:

The initial screening yielded 536 abstracts published between 2000 and 2017 that were related to POGIL. The abstracts were read and judged about the POGIL implementation, the methodology used, assessment and their outcomes achieved outcomes, which further resulted in the selection of 60 abstracts out of which 30 abstracts were excluded.

Screening based on methodology and assessment of the outcomes:

In the second stage, the studies were screened according to the methodology. Experimental studies including the pre-test, post-test, review studies, post-test case studies only were included. After this stage, only 14 articles met the inclusion criteria

2.1.3 Application of Inclusion and Exclusion criteria

Inclusion criteria

- Studies were eligible for inclusion in the meta-analysis if they conformed with the following criteria
- If the studies had a properly defined methodology for conducting the POGIL Assessments. (peer reviewed)
- All original articles, reviews were included.
- Articles having POGIL implemented in multi-disciplinary domains were considered.

Exclusion Criteria

- Articles involving active learning methodologies apart from POGIL were excluded.

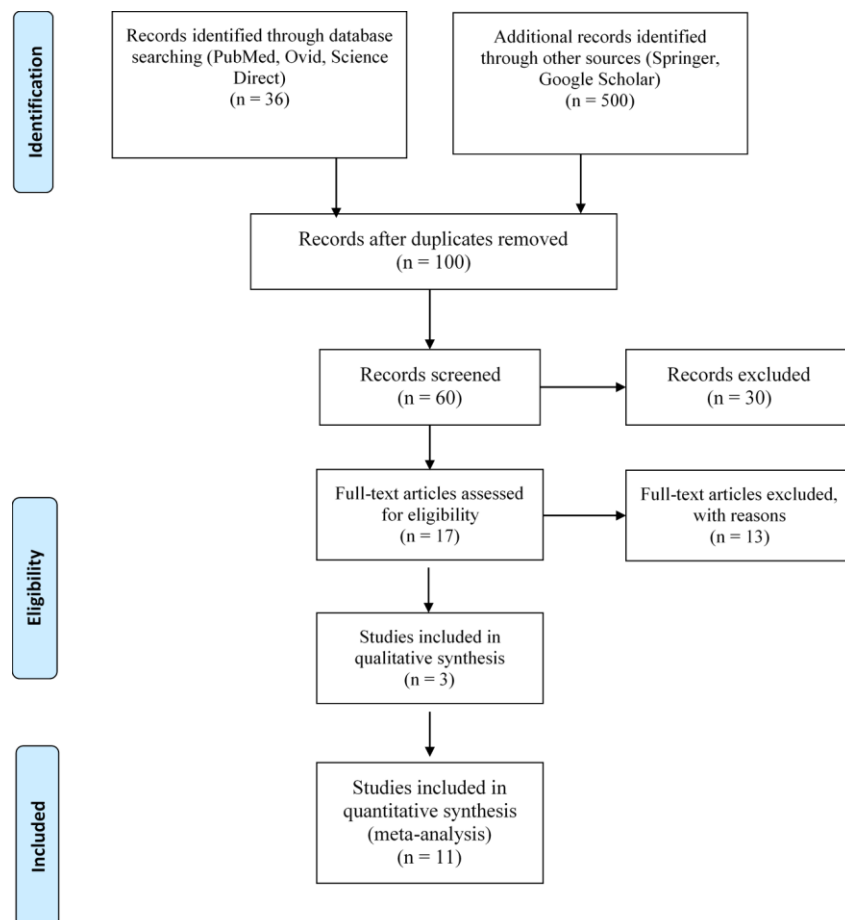


Figure 1: Prisma diagram

1.2. Our POGIL implementation context and methodology

At IUPUI's HIM program, we have taken multiple approaches such as active learning, problem-based learning, experiential learning, and inquiry learning, to involve the undergraduate students in the learning process. These methods are mainly aimed at engaging students in their learning process and are executed under the POGIL implementation. Two courses from the HIM program - M200 - Database design for HIM and M220 - Health Informatics for Decision Support were selected and the core philosophy of POGIL - that students learn through the process of performing activities - that is, by doing, rather than by instruction from a teacher. The teacher, in this case, only facilitates guided learning. The two courses selected for the study contain around 40 students, and already encompass active learning strategies like group discussion and virtual labs in their curriculum. Considering the core philosophy of POGIL, we integrated POGIL practices into the course redesign of these HIM courses - students learn through the process of performing activities that aid in developing critical thinking skills - the teacher, in this method, not only instruct but rather facilitates guided inquiry. The lecture slides and videos were updated with POGIL activities and updates to the educational content, by removing the introduction of new concepts, and replacing them by background information that was required to do the POGIL activities. The modified content was implemented in Summer and Fall semesters of 2018.

The two HIM courses provide didactic content on the Canvas learning management system (LMS) in the form of lecture slides and video recordings. This content gives background information required to synthesize the new concept that the students are expected to develop and understand using the POGIL pedagogy. POGIL implementation began by dividing the class into groups of 3-4, with each member playing the roles of iTrainee and rTrainee. The iTrainee is asked to create a set of tasks on the Canvas LMS, based on the concept that will be discussed based on materials, information from the lecture, and the instructor. The iTrainee, after finishing the task he created, requests the rest of the group - the rTrainees - to complete the task. After completion, the rTrainees and iTrainee will be able to compare their work with each other. The iTrainee will also similarly have to play the role of a rTrainee when other members of his/her group make inquiries and propose new tasks to the group. This method facilitates an intragroup system of learning by doing tasks, as per the POGIL system.

For a sample POGIL activity, an assignment from the HIM M220 course is chosen and modified into a group work. It requires students to identify data/information and knowledge from the EHR data on a patient's dashboard and use it to help in creating clinical decision support rules. Here, an iTrainee is instructed to search for a patient in the EHR system and tag the data as information or knowledge. He posts the same on the Canvas LMS with specific instructions for the rTrainees to complete this task. The students would then compete and collaborate with each other to discover new approaches to finishing this task and of using the EHR system, which would have been difficult in a traditional didactic setting.

Sample POGIL task: Here is the process that an iTrainee follows to reach a patient record and tag data, information, or knowledge. In this POGIL activity, the iTrainee has to gain a process skill that has *three planned concepts* relevant for the basics of clinical decision support systems.

- The process skills of finding a patient record helps articulate the concept of identifiers to search and identify a patient. Doing this activity by themselves would help the students to understand the various parameters in the search function, and the most efficient way to articulate these parameters to complete the task, unlike in a didactic setting which would only entail a lecture about the UI of the EHR.
- The skills of opening the vitals section of a patient record helps articulate the concept of forms in the OpenMRS EHR. Data can be captured through multiple forms, and the vitals form is the most important in the EHR workflow. The students need to be able to distinguish between demographics, formulate questions and learn the concept of forms in their knowledge construction to be able to finish this task.
- This step develops the skill of looking through the vitals data and by processing the data extract information, which when drawn inferences from, creates knowledge from it - for instance, height and weight are used to calculate BMI and when BMI is higher than 25, condition of the patient is overweight.

The iTrainee might sometimes not have understood these concepts and create an incomplete question on the Canvas LMS for the remaining group members to perform a task. The rTrainees would approach this task in their own way and compare it with others, enabling a discussion around the most efficient way to perform the task, which might differ from the iTrainee's initial intention. Improvements in understanding and formulating tasks and questions was seen within 2 weeks in both the trainees.

Student engagement was measured by using learning analytics and survey instrument from the Canvas LMS. The survey is based on the National Survey of Student Engagement (Kuh, 2003) and the Student Engagement Instrument (Appleton, 2012). It contained 22 questions under four engagement components and an interview about the student's experience with POGIL. The results of the analysis of the survey and interviews have been reported elsewhere.

3. Assessment

2.2 Meta-Analysis

Out of 14 articles selected for review and analysis, a majority, i.e., 11 articles performed a quantitative analysis while two articles used a qualitative methodology and 1 study used a mixed methodology approach for analysis. POGIL was implemented in various domains viz Bachelor of Pharmacy, Biochemistry, Online IT, Information Literacy, Computer Science, Pharmaceutical Sciences, Nursing, Marketing, Introductory Anatomy & Physiology, Engineering, Organic Chemistry, Chemistry, Introductory Psychology. POGIL activities were conducted in class in 13 studies, whereas one research study implemented POGIL in an online Information Technology class (Myers & Trevathan). Ezeala 2013, Soltis et al., 2015, Vanags (2012) & Gale (2015) conducted a pre- & posttest analysis, Soltis et al. evaluated GPA, Gale assessed summative scores and applied Non-directional & paired t-test, One-way ANOVA, Kruskal Wallis Test, Tukey's HSD test.

Murray conducted an assessment based on post activity skill, exams, and surveys and further calculating Mean and S.D whereas Roller (2015) considered the final grades by conducting quizzes, examinations, analyzing results by computing Mean, percentage and application of Mann Whitney test. Similarly, Mullen and Hale (2009) & Brown 2010 too assessed mean final grades and conducted quizzes (formative), thereby calculating average scores in percentage & using two-tailed T-test respectively.

Douglas et al. conducted the research using mixed methodology (Interview and final course grades) analyzing probability. Villagonzalo had a very different approach and utilized a tool ParNoMA2 for assessment and calculated ANCOVA, frequency, and Levene's test for Homogeneity. Only a single study was conducted online and was survey based providing analysis using percentages.

Qualitative analysis was conducted by Mitchell & Hiatt assessed effectiveness of POGIL based on questionnaires.

Table 1: Review of meta-analysis

Author	No. of subjects involved	Courses	Assessment	Interpretation of results	Conclusion
Ezeala	42	Second year Bachelor of Pharmacy	Pre- & Post-Test analysis	Mean Pre- & Post-test scores, paired sample t-test at $p < 0.01$, average normalized gain > 0.30 based on Hake's Criteria was considered significant.	POGIL, by computer simulations, produced significant learning gains in student's understanding of pharmacology.
Murray	26 (Fall 2009), 13 (spring 2010)	Biochemistry	Post activity skill Exercise, Exams, Survey	Average score & SD	Student satisfaction observed when dealing with the primary literature.
Myers & Trevathan	122	Third-year online Information Technology	Survey	Percentage (Majority found blogging & social media use interesting)	Students were receptive to the online teaching environment. Online technologies were conducive to

Saptarshi Purkayastha et al.

Author	No. of subjects involved	Courses	Assessment	Interpretation of results	Conclusion
					promote engagement and build a student-centred community.
Mitchell & Hiatt	9	Information Literacy	Qualitative analysis	Questionnaires' to learn database search, discuss the experience as a group, problem diagramming, learn to design research questions.	Student satisfaction towards POGIL was documented. The active teaching methodology was preferable for technical aspects of the course but not discussion or issue centred topics.
Kussmaul	-	Computer Science	Average grades, Interviews, Activity reports	-	Students initially were uncertain but later satisfied by process skills acquired & concept mastery
Soltis et. al	112 (2011 class), 111 (2012 class), 111(2013 class)	Pharmaceutical Sciences	GPA Evaluation (Mean and S. D, Range) Pre-& Post test	One - way ANOVA, Tukey's HSD post hoc test, Kruskal Wallis test.	Positive shift in grade and improved performance distribution and students. Overall students supported POGIL methodology for learning.
Roller	Experimental – 25 Control – 25	Nursing	Final grades – 2 exams, two quizzes, final exam, concept map & ATi grades	Mean, the maximum & minimum percentage of the final grade and ATi nursing national exam grades using Mann Whitney. The test was not statistically significant.	Mean final grade of POGIL group was higher.
Mullen & Hale	Section A – 22 students (Lecture) Section B- 22 students (POGIL)	Marketing	Quiz Final grades	Average percentage	POGIL class had less absenteeism and better performance, but final grades had no significant difference.

Saptarshi Purkayastha et al.

Author	No. of subjects involved	Courses	Assessment	Interpretation of results	Conclusion
Brown	Lecture based – 25 (spring 2008), POGIL – 18(fall 2008), 31 (spring 2009), 17 (fall 2009)	Introductory Anatomy & Physiology	Mean Final course grades evaluated by four formative quizzes	Two-tailed t-test at $p < 0.05$	Grade distribution was striking where D/F rate fell, and A/B rate rose. Student satisfaction and perception were recorded.
Douglas & Chiu	Control – 217 students Treatment – 98 & 96 students (2 groups)	Engineering	Interview questions, final course grades (mixed methods)	$P < 0.05$	Goal to reverse the pedagogical roles of the instructor and the student achieved, but student satisfaction was lacking.
Gale	22	Organic chemistry	Pre and Post-test questionnaires, summative scores	Non-directional t-test was used to compare the means.	Students showed a varied academic performance at the end of organic chemistry with a general overall class decrease in the mean score.
Villagonzalo	41	Chemistry	20 multiple choice items to assess students conceptual understanding using ParNoMA2	Analysis of Covariance, percentage, and frequency, Levene's test for homogeneity	POGIL method is better in enhancing students' level of performance & academic performance with higher mean scores as compared to the control.
Vanags	354 undergraduate students	Introductory psychology	Pretest, posttest, and follow-up quizzes.	ANOVA	POGIL approaches to teaching can produce improved long-term learning outcomes for students even when less experienced teaching assistants do the teaching
Rege & Sheikh	50, Third-year level students	Organic Chemistry	Post-test analysis with 11 positively skewed questions based on Likert scale, summative academic test	Pie charts, summary statistics	POGIL offered remarkable potential to improve academic performance and confidence of the candidates facilitating deeper learning

4.Results

2.3 Meta-Analysis

Upon collection of the data from each article Standard Deviation, Standard Error, and mean for both the Control and Experimental studies were calculated. Power analysis for each study population was performed in order to understand the statistical significance of each study. The Alpha value for this analysis was selected as 0.05, which indicates the error rate that we are willing to accept. The calculated effect size for this study was found to be 0.5. In general practice, 0.5 is used as it indicates moderate to a significant difference in the calculation of power.

From the four different types of power analysis, our study falls under Post-hoc power analysis where we are trying to compute the power based on the given Alpha, N (sample size) and ES (Effect Size) values. The sample size of each study greatly influenced the power analysis value. With N = 13 (given .05 alpha), the study has the power of 0.562 whereas, with N = 112, the study has the power of 0.999. After calculating the power analysis for each study sample, the values were found to be in the range of 0.562 – 0.999.

Apart from the above calculation, there is a discrepancy in the evaluation method of each study which restricts its application to other studies. For example, in Hale & Mullen (2009) paper, no assessment of understanding was conducted for the control group, whereas the POGIL treatment group was assessed. The assessment of the traditional lecture group would have proved more basis for comparison. Moreover, the study size of the treatment group was found to be smaller than the control group. All the results show treatment group to have gained less percentage when compared to the POGIL group, which can be attributed to the unequal size of the study population.

In the paper by Roller (2015), the most significant limitation was that the participants were not randomly assigned between the two groups. Undertaking the discrepancy in sample distributing the significance of this study cannot be considered beneficial. The accurate assessment of the study can only be considered when the knowledge and skills of the same student are tested. Though the power analysis gave good value, the results from the study are not very significant.

There are some papers which were mainly focusing on the particular implementation of POGIL method. For example, Fiji (2013) paper talks about the integration of POGIL with computer simulation software in a pharmacy setting. This method cannot be generalized to other areas or subject as it is not necessarily essential to have computer simulation software in every subject. Hence this method of implementation can only be restricted to the courses which have simulation exercises. As Soltis et al., the paper also focuses on the implementation of the POGIL implementation in pharmaceutical studies, it was mainly focusing on Pharmacokinetic and Pharmacodynamic studies. Whereas the pharmaceutical studies also include other areas of focus such as Chemistry, Biostatistics, Anatomy & Physiology. Though the title of the paper says pharmaceutical sciences, it was mainly focusing on just two areas out of all. Hence this method of evaluation may not provide significant results when implemented in other areas of Pharmacy. Apart from this, Rege's paper focuses on understanding its implementation for effective learning of Organic Chemistry. Though this paper presents results on the improvement of student's confidence and Academic performance, it did not necessarily talk about gaining in-depth Organic Chemistry concepts. Although it talks about how helpful it was in understanding the basic concepts but does not provide evidence of improvement, this provides less evidence for its actual significance in improving Organic Chemistry learning. In one paper by Sen (2016), the study was more specific to understanding how POGIL methodology can improve the student's misconception. Though this study was conducted only in Electrochemistry focus, the literature review provides evidence to conduct this type of research with alternative students as well as other subjects.

Though the power calculations gave us the range of values showing the effect of each study was purely due to the differences in the effect size of each study population. Based on the above review, we can conclude that the results of the implementation of POGIL in different settings were dissimilar. As there is not enough evidence of its implementation in the general setting to be successful, we can infer that POGIL implementation was not very impactful.

2.4 Our POGIL implementation

To study the effectiveness of the POGIL implementation in our online courses, we compared the student academic performance (grades in the course assessments) of HIM M-200 course before (all semesters of 2017 and spring of 2018) and after POGIL implementation (Summer and Fall semesters of 2018). The sample size(N) of the pre and post implementation phase was 42 and 37, respectively. The effect size was 0.355, and the power of the study was 47.4%. We used the Wilcoxon rank sum test to compare the performance of the student's pre and post-implementation. The results of the analysis showed that there is a statistically significant difference (p -value of 0.03) with a mean difference of $\pm 4\%$ in the academic performance of the students before and after implementation.

3. Conclusion

POGIL implementation in various courses reveals the methodology employed, and assessment was done using different parameters. POGIL implementation among the students facilitates them in deep learning. The implementation and assessment methodology of POGIL in various settings is different and differed with the type of study population taken into consideration. In some studies, there was an improvement in conceptual knowledge, whereas others presented the advancement in interpersonal skills. Overall, no two studies have either taken the same type of methodology or assessment so we cannot talk about its overall impact on a general setting. However, in our online course setting, there is an improvement in overall academic performance of students after POGIL implementation. Students show diverse academic performance at the end of work taught using POGIL. The success rate of POGIL differs from the methodology used and other factors like a response from students. Initially, POGIL is new and needs basic awareness programs for students and faculty for effective implementation.

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