Comparative Analysis of Traditional Instruction and POGIL: A Student-Centered Learning Approach in Civil Engineering

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Abstract

Students in the twenty-first century need to think creatively, collaborate creatively with others, and use innovation in their daily lives. This means that students have to equip themselves to develop creative solutions to the many problems and challenges that they may face. Still many educational institutions are following the traditional teacher - centered approach predominantly which is inappropriate to develop the twenty-first century skills among the students. The conventional method of teaching, which emphasises memorization and standardised testing through lectures, rote learning, and memorization, may impede the development of critical thinking, problem solving, and creative thinking skills that are essential in everyday life. In addition, the conventional teaching methods can be monotonous and inflexible, which can cause students to lose interest and motivation in their studies. To make students more attentive in class, students centered approach need to be implemented.

Variety of instructional strategies are in practice to engage the students in learning, to enhance student learning, and also to provide opportunity for students to reflect on their learning. One such student-centered instructional strategy is Process Oriented Guided Inquiry Learning (POGIL). This active learning strategy aims to engage students in the learning process through guided inquiry. This paper describes implementation of process-oriented guided inquiry learning in an engineering classroom in one of our civil engineering subject for cognitive lesson. The POGIL strategy divided into five phases namely Exploration, Concept Invention, Application, Reflection and Extension. In this student-centered approach, the teacher's job is to facilitate learning by encouraging students to apply what they've learned to solve more difficult problems or scenarios that are connected to the subject, which helps them to gain deeper comprehension of the material. This allows students to actively comprehend the material and gives them the chance to practise and develop critical thinking, communication, and teamwork skills. This study project involved two classes of UG students. The POGIL was introduced for only one batch which consists 48 students. The other batch is taught using the conventional approach. In this study, the learners' performance was evaluated and data was gathered from them via a questionnaire. Based on the data collected, the efficacy of the POGIL is evaluated through comparative analysis using statistical test. The comparative analysis shows that students who exposed to POGIL had significantly higher mean scores in engagement than students exposed to traditional instruction. The result indicates notable distinctions in how the two groups perceive their respective learning outcomes, as well as insights into the differences, similarities, and relationships between various groups.

Introduction

In recent years, researchers in the field of higher education have become increasingly interested in assessing traditional instruction practices and modifying them towards more student-

centered and active instructional approaches [1]. The most of the accrediting organizations have recommended the use of more active instructional methods in higher education to improve the quality of education [9], [11], [14]. Student-centered and active instructional methods lead to greater achievement from the viewpoint of student learning outcomes when compared to traditional [2], [12], [19]. The active learning courses provide better support for student success and conceptual understanding compared to traditional lectures across STEM disciplines [8], [10], [17].

In the traditional teaching method, the teacher becomes the focal point at the front of the room and this conveys an implicit message of power, with the teacher having the entitlement to speak, whereas the students listen in a passive and non-participatory manner [20]. The higher-education (HE) institutions, supporting active and learner-centred pedagogies, more-flexible learning spaces need to be created [6].

Process Oriented Guided Inquiry Learning (POGIL) is a student-centered, active learning pedagogy that aims to engage students in the learning process through guided inquiry. POGIL was developed in the late 1990s and implemented in teaching chemistry [15], [16]. Then it gained popularity in various educational settings, particularly in science, technology, engineering, and mathematics (STEM) disciplines [5], [18]. POGIL is an evidence-based, student-centered pedagogy that develops both content knowledge and process skills such as communication, critical thinking, problem solving, and teamwork [3], [4]. Research studies generally find that students in POGIL classes have better learning outcomes [7], [13].

This learning method has emerged as a transformative pedagogical approach in higher education, especially in the field of engineering education. In the ever-evolving field of civil engineering, where applying theoretical knowledge to practical problems is critical, POGIL provides an organised, yet adaptable framework that encourages critical thinking, active learning, and teamwork in solving problems. POGIL shifts the focus from traditional lecture-based instruction to student-centered, inquiry-driven learning experiences

Civil Engineering education faces the challenge of preparing students not only with a solid theoretical foundation but also with the practical skills and problem-solving abilities essential for success in the profession. POGIL addresses this challenge by engaging students in authentic, hands-on experiences where they actively explore complex concepts, analyze data, and work collaboratively to solve real-world engineering problems. By immersing students in inquiry-based activities, POGIL fosters a deeper understanding of fundamental principles while simultaneously honing essential skills such as teamwork, communication, and critical analysis.

This paper aims to explore the application of POGIL in Civil Engineering education, examining its effectiveness in enhancing student learning outcomes, promoting engagement and collaboration, and preparing future engineers to tackle the challenges of the 21st century. Two student batches of Civil Engineering (UG degree) were examined in our study. The POGIL was introduced in one batch to teach the Mechanics of solids subject which consists 48 students. A traditional approach was applied to the other batch which consists 36 students.

Methodology

In this research work the effect of POGIL compared to traditional teaching methods. The methodology is carefully planned and executed as per the flow chart.

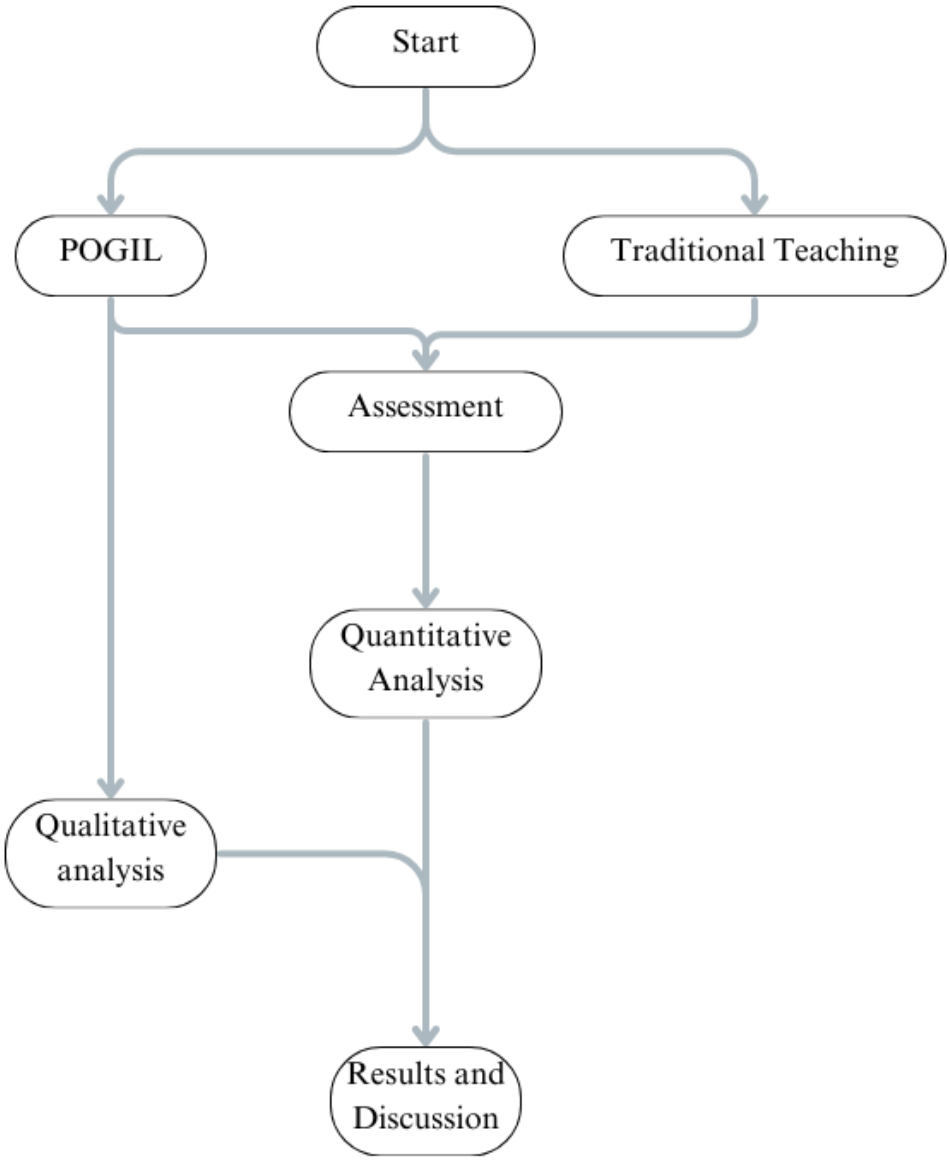

Figure 1. Methodology Flow chart

Process-Oriented Guided Inquiry Learning (POGIL) was implemented in one of the batches, and careful planning of various factors was focused for successful execution. Initially, suitable topics for POGIL activities were chosen. Then, student groups were framed with 3–4 members for collaborative work during POGIL activities. Then the designed POGIL activities were distributed to the students to engage them in active learning, collaboration, and inquiry. This method is implemented for a batch of 46 students. On the other hand, the traditional method of teaching was implemented for the another batch. The students strength for the traditional method was 38.

Then two formative assessments were conducted with the same questions for both batches to measure the performance of the students. Based on the assessment results, a quantitative analysis was performed to determine the effectiveness of one method over another. This comparative study provided the efficacy of POGIL

In qualitative analysis, a questionnaire with a 5-point Likert scale was developed to gather feedback on students' experiences on learning through the POGIL method. This data was collected from the students who have undergone the POGIL method. Finally, the results of the qualitative and quantitative analyses are expressed in detail.

In POGIL, the role of Teacher/Professor /Instructor is as facilitator. They involved to guide and support student discussion.

Elements of POGIL

Here the elements of POGIL is emphasizing the implementation of POGIL in one of the Civil engineering subject namely Mechanics of Solids in the Third semester.

Small Group Work: The entire batch of students divided into small groups. Each group consist 3-4 students to actively engage in the learning process.

Guided Inquiry: Instead of traditional lecture-style teaching, students explore concepts under the guidance of the teacher with the help of designed materials that guide their inquiry. These materials contain models, data, and questions designed in Mechanics of Solids, which help students to construct their own understanding.

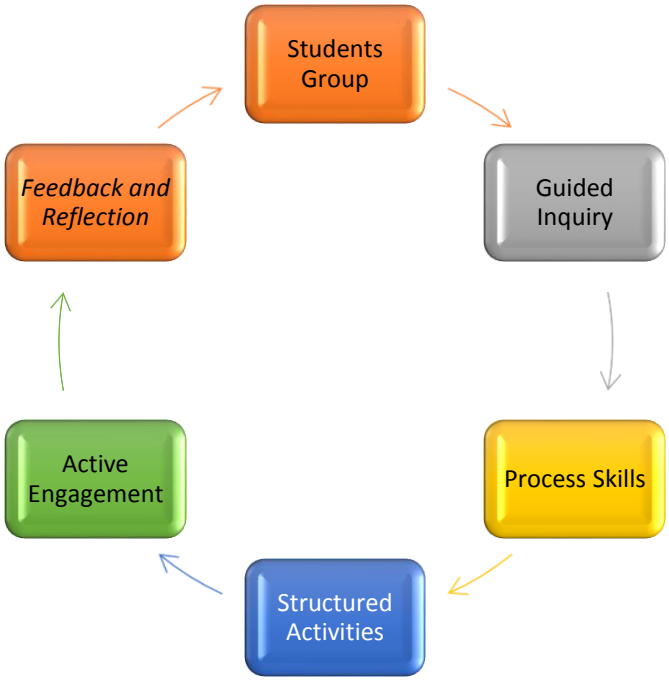

Figure 2. Elements of POGIL

Process Skills: POGIL focuses on developing process skills such as critical thinking, problem-solving, collaboration, and communication. Students learn how to think like scientists or

professionals in the field by engaging in the process of inquiry. The elements of POGIL is shown in figure 2.

Structured Activities: Based on the input given by the teachers student started to involve in activities. Activities are structured to encourage students to construct their own understanding by handling with new concepts and learning through collaboration.

Active Engagement: Students are actively engaged in constructing their own knowledge rather than passively receiving information.

Feedback and Reflection: Finally the feedback received from the students on their work and are encouraged to reflect on their learning process and outcomes.

Phases of Learning Cycle in both POGIL and Traditional

The table 1 shows the lesson plan which implemented for the traditional teaching which consist 5E namely Engage, Explore, Explain, Evaluate and Elaborate. This table also showing the various phases in POGIL

Table 1. Phases of Traditional & POGIL

Traditional Method - Lesson Plan Phases (5E)	POGIL Implementation Phases	What it does?
Engage	Exploration	Brainstorm. Access prior knowledge
Explore	Concept Invention	Discuss and analyse the information provided,
Explain	Application	Apply newly developed understanding to new contexts
Evaluate	Reflection	Students articulate and discuss their conclusions
Elaborate	Extension	Connects the concepts to the life beyond the classroom. Apply learning to new situation

In POGIL, the instructional process is divided into several phases to guide students through their learning journey. The phases in a POGIL activity generally include:

Exploration:

Introduction to the topic or concept. Students are presented with materials such as models, diagrams, data, or readings that provoke their curiosity and initiate the learning process.

Initial exploration of the content and the posing of key questions that encourage students to begin thinking about the subject matter.

Concept Invention:

Guided inquiry where students collaboratively work together to delve deeper into the topic. They discuss and analyze the information provided, attempting to make connections and develop a conceptual understanding.

Students propose and test hypotheses, attempting to develop their understanding of the concept by answering thought-provoking questions. Figure 3 shows the POGIL phases which implemented in this study.

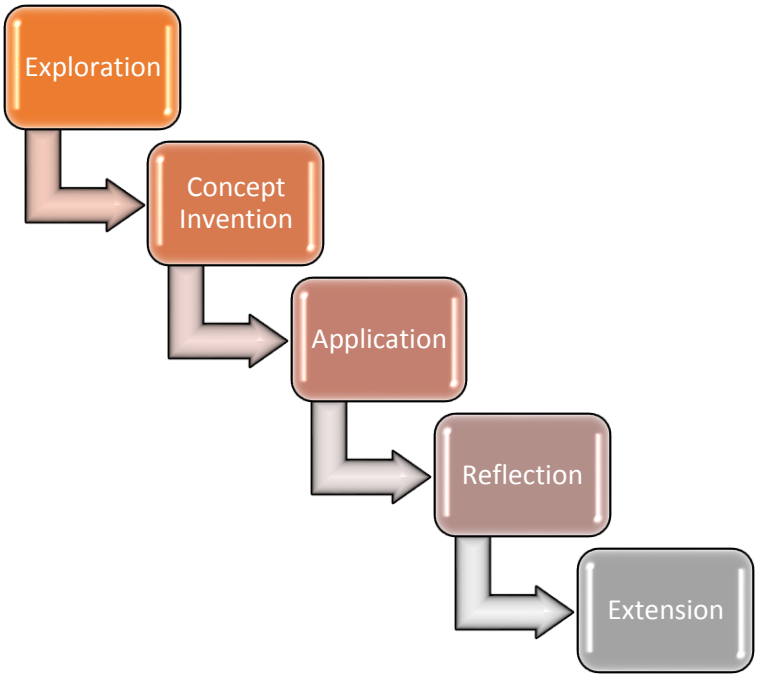

Figure 3. Phases of POGIL

Application:

Application of the newly developed understanding to new contexts or scenarios. Students use their learning to solve problems or analyze real-world situations related to the concept.

Reflection:

Discussion and reflection on what has been learned. Students articulate and discuss their conclusions, often through group discussions or presentations.

Reflecting on the learning process itself, considering what worked well, what was challenging, and how they might apply their learning in other contexts.

Extension:

Students may be encouraged to apply their understanding to further complex problems or scenarios related to the concept, deepening their knowledge and critical thinking skills.

These phases are structured to guide students through the process of constructing their understanding of a concept, fostering active engagement, collaboration, and critical thinking.

The instructor's role is more of a facilitator, guiding and supporting students as they progress through these phases rather than delivering direct content.

Result and Discussion

As per the university norms, we used to conduct two formative assessments per semester. This subject taken for the implementation contains five units. Two units were covered during formative assessment I (FA I), and the remaining were covered in formative assessment II (FA II). The students' performance on the formative assessments were measured. Figure 4 and Table 2 show the results of the students' performance on both assessments.

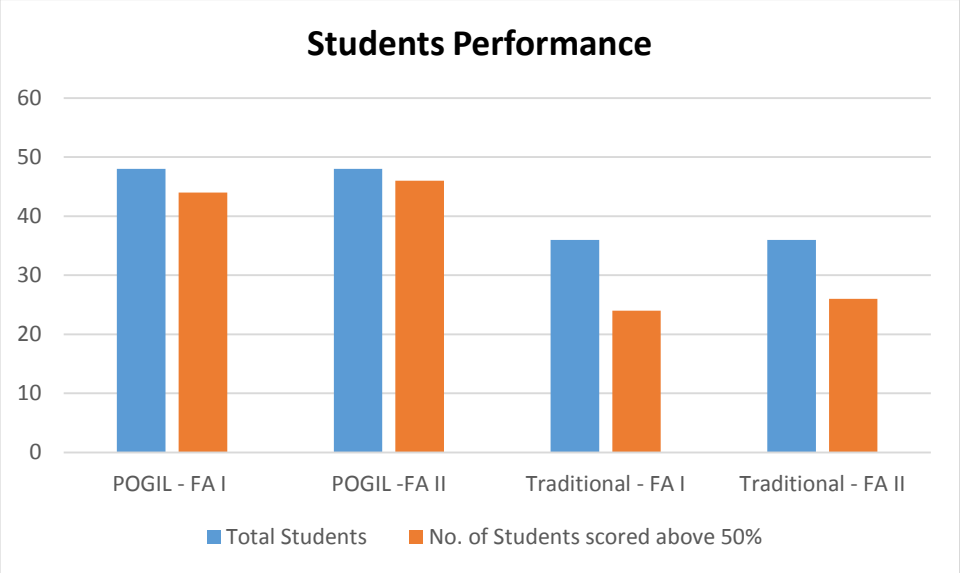

Figure 4. Students performance in formative assessment

Table 2. Performance of Students in FA- I and FA-II

	POGIL - FA I	**POGIL -FA II**	**Traditional - FA I**	**Traditional - FA II**
Total Students	48	48	36	36
No. of Students scored above 50% marks	44	46	24	26
Percentage of Students scored above 50% marks.	91.67	95.83	66.67	72.22

The results of Formative Assessments I and II show that the students who learned through POGIL performed better in the assessments. The percentage of students scoring above 50% marks is 91.67% for the POGIL batch, whereas 66.67% for the traditional batch for formative assessment I. But for FA II, the percentage of students scoring above 50% marks is 95.83% for the POGIL batch, whereas it is 72.22% for the traditional batch. The results of this evaluation have shown that students who learned through POGIL performed better than those who received traditional instruction. With POGIL, the specified learning outcomes are more successfully attained.

Similarly, the mean mark of the POGIL batch in FAI is 74.85, while the traditional batch's mean mark is 59.6. Likewise, for FA II, the traditional batch mean mark is 63.5, while the POGIL batch mean mark is 78.2.

Qualitative Analysis

As POGIL is an important student centered learning method, qualitative data have been collected to assess feedback about this method, especially to gather students experiences and perceptions. A questionnaire was designed to collect qualitative data from the students who have participated in POGIL for learning. A total of 10 questions were framed. The first five questions were focused on the POGIL method. The next three questions were used to assess the effectiveness of the POGIL methodology in the civil engineering discipline. The final two questions were framed to assess the teacher / instructor who was involved in the process. The aim of this qualitative analysis is to gather qualitative insights from students, especially their experiences, perceptions, and attitudes regarding Process Oriented Guided Inquiry Learning in Civil Engineering education. They were asked to respond to each statement on a 5-point Likert scale, indicating the level of agreement or disagreement.

Table 3. Questionnaire used for qualitative analysis

S.No.	Questions	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1	POGIL exercises aided in your understanding of difficult concepts	96 %	04%	-	-	-
2	POGIL exercises improved your ability to solve problems	92%	08%	-	-	-
3	POGIL Activities promoted involvement and active participation	88%	12%	-	-	-
4	Activities facilitated collaboration with peers	96%	04%	-	-	-
5	Activities made learning more enjoyable	90%	06%	04%	-	-
6	Activities improved my performance in courses	90%	10%	-	-	-

7	Activities increased my confidence in applying engineering principles to real-world problems	88%	08%	04%	-	-
8	Activities motivated me to explore topics beyond the classroom	92%	08%	-	-	-
9	Class Teacher gave challenging activities to make us think	90%	10%	-	-	-
10	Class Teacher guided us and clarified the doubts when necessary	94%	06%	-	-	-

Challenges observed

Group formation

Initially, while making a group, students were allowed to randomly pick the persons to form group which could not achieve the outcome, due to lack of skill of the group. The teacher helped to modify the group persons and performed again to achieve desired outcome.

Time Allocation

A period contains 50 minutes of duration. The 50 minute time allotted for this POGIL method is not sufficient. So whenever the POGIL activities are introduced, the time duration is increased to one hour and 40 minutes. That is, two consecutive periods are allotted.

Conclusion

The POGIL is one of the student centered learning method which prioritizes the needs, interests, and abilities of individual students, aiming to make learning more personalized, engaging, and meaningful. Encouraging active participation, collaboration, and hands-on experiences rather than passive learning. Allowing students to take more responsibility for their learning by setting goals, making choices, and managing their own progress. Providing varied resources, technologies, and learning opportunities to support diverse learning styles and preferences. Teachers take on the role of facilitators, guiding and supporting students in their learning journey rather than being the sole source of knowledge. Assessment methods are used to evaluate the understanding, progress, and skills acquired by the students, rather than just test performance. Ultimately this POGIL create an environment where students are more motivated, engaged, and able to apply their learning in real-life situations.

The application of POGIL in Civil Engineering education is particularly advantageous due to the interdisciplinary nature of the field. Civil engineers are tasked with designing, constructing, and maintaining infrastructure systems that impact society on various levels, from transportation and urban development to environmental sustainability and public health. POGIL provides a platform for integrating diverse subject areas within Civil Engineering,

allowing students to explore the interconnectedness of concepts across disciplines and develop holistic problem-solving strategies.

The results of qualitative and quantitative analysis showing that the implementation of POGIL in Civil Engineering education is much effective than the traditional. This method aligns with the evolving demands of the engineering profession. In an increasingly complex and rapidly changing world, engineers are required to adapt to new technologies, address emerging challenges, and collaborate across disciplines to find innovative solutions. POGIL cultivates the skills and mindset necessary for lifelong learning and professional growth, empowering students to become adaptable, creative, and reflective practitioners.

Overall, POGIL is a versatile and effective instructional approach that can benefit students and educators across a wide range of disciplines. POGIL represents an innovative approach to teaching and learning that challenges traditional instructional methods, by promoting active learning, collaboration, and critical thinking. The principles and strategies of POGIL can be applied in diverse educational settings, making it a valuable tool for educators across disciplines. This study has shown that active learning approaches like POGIL can lead to better student outcomes, including improved retention rates, higher achievement levels, and increased student satisfaction. By providing students with engaging and interactive learning experiences, POGIL contributes to their overall success and well-being.

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