Process Oriented Guided Inquiry Learning in Introductory Computer Science

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Abstract

Process Oriented Guided Inquiry Learning (POGIL) is an evidence-based, student-centered pedagogy that focuses on the simultaneous development of both content knowledge and process skills. Students work in learning teams completing classroom activities designed to help them collaboratively construct an understanding of key concepts. POGIL activities use learning cycles in which teams begin with a model and collectively answer questions that guide students to explore the model, invent their own understanding of key concepts, and then apply that understanding to other contexts. The instructor is not a lecturer but serves as an active facilitator who observes student teams, interacts to address problems, and leads classroom discussion as needed. Research studies have generally found that students in POGIL classrooms have better learning outcomes than students in traditional classrooms.

The 2017 NSF IUSE IntroCS-POGIL project seeks to expand the use and evidence of POGIL in Introductory Computer Science by studying how faculty implement POGIL in introductory CS courses and the factors that affect faculty implementation and student outcomes. In its first year, the project supported 13 CS faculty from seven institutions as they adopted POGIL by providing professional development, curriculum resources, and regular mentoring by experienced POGIL instructors. All 13 instructors plan to continue to use POGIL in their IntroCS courses.

Introduction

Process Oriented Guided Inquiry Learning (POGIL) is a pedagogy that organizes students in learning teams to develop both content knowledge and process skills (e.g. problem solving, teamwork, and written/oral communication). Compared to most other active learning strategies, POGIL is more explicitly constructive because of the way its activities are designed and facilitated. POGIL uses an explore-invent-apply learning cycle [1] by incorporating models (e.g., figures, tables, equations, code snippets) and a sequence of carefully designed questions that guide students to explore the models, invent key concepts, and apply their new understanding [2]. The models and critical thinking questions must be robust and well-aligned, and distinguish POGIL from simply having students complete worksheets in small groups [3,4].

In a POGIL classroom, self-managed teams of 3-4 students work together and discuss problems to improve understanding for all team members. At the same time, instructors purposefully help students to develop process skills such as critical thinking, information processing, problem solving, and teamwork. The instructor’s role shifts from disseminator of information (“sage on the stage”) to facilitator of learning (“guide on the side”), who continually assesses how and when to offer additional guidance as the teams work [5]. In small classes or labs, the instructor can carefully assign and monitor teams; in large lecture halls, teams may self-identify (based on proximity) and use tools (e.g., clickers) to facilitate interactions between teams and the instructor. For all students, and particularly those from underrepresented groups, teams can provide academic, emotional, and language support.
POGIL was originally implemented in college general chemistry courses, where it was found both to improve student performance and significantly decrease failing grades and withdrawals [e.g. 2,3]. Hanson [5] summarizes the student outcomes generally described in the literature: (1) attrition is lower for POGIL than for traditional courses; (2) content mastery is greater than for traditional instruction; (3) students prefer POGIL over traditional methods; (4) students have more positive attitudes about the course and the instructors; and (5) learning skills appear to improve during the course. POGIL has been used across many STEM and non-STEM disciplines including engineering [6], mathematics [7], and environmental health [8].

POGIL is especially appropriate for CS because it emphasizes process skills, and thus shifts student attention away from language syntax and towards conceptual understanding. For example, a POGIL activity might guide students through the problem-solving process of writing a loop by posing questions about its intended behavior, rather than emphasizing where the parentheses and braces need to go. The IntroCS-POGIL project focuses on introductory CS courses because they enroll the most students and have the biggest impact on retention; involve the most instructors and thus the largest potential community; and have the most diverse pool of existing POGIL activities.

IntroCS-POGIL Objectives & Activities

The 2017 NSF IUSE IntroCS-POGIL project has four objectives:

*Objective I: Refine and validate POGIL activities for IntroCS courses.* Several sets of IntroCS-POGIL activities (in Java and Python) have been developed. Each activity has an instructor’s guide with learning objectives and some preparation and facilitation notes.

*Objective II: Provide ongoing support for IntroCS faculty who adopt POGIL.* Each year, we recruit teams of new instructors from multiple institutions to attend POGIL training workshops and implement POGIL in their IntroCS courses. These instructors attend the standard three-day POGIL training workshop and an extra day of CS-specific sessions. Instructors are connected to experienced POGIL instructors who serve as mentors throughout their first semester teaching with POGIL. Instructors complete reflective teaching logs and are invited to a one-day mid-year meeting.

*Objectives III and IV: Assess factors that affect faculty adoption and persistence with POGIL and assess the impact of using POGIL on student outcomes.* These research objectives involve a variety of data sources, including qualitative, semi-structured interviews at the end of a POGIL course, faculty and student surveys, and student learning measures.

IntroCS-POGIL Outcomes

During the first year of the IntroCS-POGIL project, four instructors took part in a Spring 2017 pilot implementation while nine instructors participated in the full implementation in Fall 2017. The nine instructors participated in a four-day POGIL training (including the extra CS-specific day) in Summer 2017 and met regularly with an experienced POGIL instructor (mentor) and two other new POGIL instructors.
In interviews at the end of their semesters, all instructors from both semesters were very positive about implementing POGIL in their classes. All the instructors adopted at least eight POGIL activities and plan to continue to use POGIL, with some planning to make modifications in the activities they use. Instructors in both semesters chose to participate in the project primarily because they were interested in making their classes more student-centered and felt the opportunity to have access to developed materials and training was too good an opportunity to turn down.

The Fall 2017 instructors came from a wide variety of institutions, including community colleges, private liberal arts colleges, public four-year colleges and R1 universities. They were all interested in discovering if POGIL would work in their specific classroom settings with their student population. Some combined lectures and labs, some flipped their classrooms, while others retained their own lectures and had teaching assistants facilitate the POGIL activities. That all found POGIL useful and are planning to continue using POGIL activities is an early indicator of POGIL’s ability to be used in diverse settings.

The biggest difficulty Fall 2017 instructors reported while implementing POGIL was flipping the traditional model of having students read/be lectured about the material and then doing activities to help their understanding of the materials.

Reflecting on their perceptions of POGIL’s impact on their students, Fall 2017 instructors all felt that their students were more engaged in a POGIL classroom. POGIL, they felt, made both the class and the teaching more interactive. However, the instructors had different perceptions about when the groups worked best. One instructor found the groups worked best with those who had already been exposed, while another instructor felt the groups worked best when stronger students were matched with other students which provided opportunities for the groups to clarify misconceptions, dig deeper and explore. Other instructors felt the groups worked well for all the students.

Fall 2017 instructor perceptions on the impact of doing POGIL on student achievement varied greatly. One instructor felt that compared to the previous semester when POGIL was not used, that there was no impact on A and F students but POGIL helped C and D students become B and C students. Another felt that academically the students did marginally better than previous semesters, but since this was only the first semester they had done POGIL, they wanted to see more data before they drew any conclusions. Another instructor felt POGIL helped students retain and share knowledge. Because of POGIL, the instructor felt students retain the knowledge longer but they still forget the knowledge. Other instructors didn’t see any academic impact or felt it was too soon to see an academic impact. However, one instructor had fewer A, B and C students and more withdrawals and failures when POGIL was introduced, although they felt that the time the course was offered may have had an impact.

Conclusions

This executive summary paper has described the motivation, objectives, activities, and outcomes for an NSF project focused on POGIL in introductory computer science courses. The IntroCS-POGIL project is a large-scale study of how faculty implement POGIL in introductory CS
courses and the factors that affect faculty implementation and student outcomes. Preliminary findings from the first year of the project demonstrate that POGIL can be adopted for IntroCS courses at a wide variety of institutions. All instructors in the project thus far plan to continue to use POGIL activities in their courses, but not enough data has been collected to draw conclusions on POGIL’s impact on students.

The IntroCS-POGIL project will continue to explore some promising future directions:

- Measuring introductory computer science student learning across multiple institutions and programming languages, with an emphasis on process skills integral to computer science.
- Integrating technology into activities and using a learning management system or tools like Jupyter Notebooks, which can combine text, live code, and other content.
- Several new professional development workshops for faculty that focus on:
  - Writing and sequencing effective questions in an activity.
  - Identifying cultural bias and making activities more culturally relevant.
  - Using patterns for activities and classroom facilitation.

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