POGIL in Computer Science: Faculty Motivation and Challenges

Aman Yadav
Michigan State University
East Lansing, MI, USA
ayadav@msu.edu

Chris Mayfield
James Madison University
Harrisonburg, VA, USA
mayfiecs@jmu.edu

Clif Kussmaul
Muhlenberg College
Allentown, PA, USA
clif@kussmaul.org

Helen H. Hu
Westminster College
Salt Lake City, UT, USA
hhu@westminstercollege.edu

ABSTRACT

Introductory computer science courses face multiple challenges, including a broad range of content, diverse teaching methods, and the need to help students develop skills such as problem solving, critical thinking, and teamwork. One evidence-based approach to address these challenges is Process Oriented Guided Inquiry Learning (POGIL), in which student teams work on classroom activities specifically designed to help them construct understanding and develop key skills. While POGIL has been widely used and studied in Chemistry and other STEM fields, much less is known about how it is used in Computer Science.

In this study, we examined how faculty adopt POGIL for the first time in introductory CS classrooms. Using qualitative in-depth interviews, we investigated why faculty chose to adopt POGIL and their concerns about using it. Our results suggest that faculty motivations to use POGIL centered around improving student outcomes, including their learning and engagement. However, faculty also had concerns about using POGIL, which ranged from how POGIL impacts the curriculum to logistical and institutional barriers. We discuss the implications of these findings with respect to faculty development and active learning pedagogies.

CCS CONCEPTS

• **Social and professional topics** → **Computer science education**;

KEYWORDS

Active Learning, Faculty Development, Qualitative Interviews

ACM Reference Format:

Aman Yadav, Clif Kussmaul, Chris Mayfield, and Helen H. Hu. 2019. POGIL in Computer Science: Faculty Motivation and Challenges. In *Proceedings of the 50th ACM Technical Symposium on Computer Science Education (SIGCSE '19), February 27–March 2, 2019, Minneapolis, MN, USA*. ACM, New York, NY, USA, 6 pages. <https://doi.org/10.1145/3287324.3287360>

Permission to make digital or hard copies of all or part of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. Copyrights for components of this work owned by others than ACM must be honored. Abstracting with credit is permitted. To copy otherwise, or republish, to post on servers or to redistribute to lists, requires prior specific permission and/or a fee. Request permissions from permissions@acm.org.

SIGCSE '19, February 27–March 2, 2019, Minneapolis, MN, USA

© 2019 Association for Computing Machinery.

ACM ISBN 978-1-4503-5890-3/19/2...\$15.00

<https://doi.org/10.1145/3287324.3287360>

1 INTRODUCTION

Introductory CS courses face a variety of challenges, whether in K-12 or in higher education. Many students have no prior exposure to the field, unlike nearly all students who take courses in mathematics and science. To succeed, CS students must develop a broad range of skills, such as teamwork, problem solving, and critical thinking, in addition to learning CS content. There are multiple approaches to teaching introductory CS (breadth-first, objects-first, etc.), and new languages, theories, tools, and practices are developed continually. CS faculty must spend time each year updating course content, reducing the time available to refine their pedagogical practices. Undergraduate CS faculty are usually trained as researchers, not educators, and are often unaware of effective teaching practices. The recent surge in CS enrollments exacerbates these challenges.

1.1 POGIL

A variety of evidence-based instructional practices have been developed and validated (e.g., [2], [15]). Many correspond to the ICAP model [1], which describes how learning increases as students shift from *passive*, to *active*, to *constructive* (creating their own understanding), to *interactive* (working with peers).

Process Oriented Guided Inquiry Learning (POGIL) is an evidence-based practice that is explicitly constructive and interactive. In a POGIL classroom, students work in teams of 3–4 on activities that are specifically designed to help guide student inquiry to construct their own understanding. At the same time, students develop process skills such as communication, teamwork, information processing, problem solving, and critical thinking. The instructor is not a lecturer or passive observer, but an active facilitator of student learning, who monitors progress, guides students to discuss insights and questions, and assists teams as needed. Prior work described POGIL in more detail, presented a sample activity (on stacks and queues) [12], and compared POGIL to other approaches (e.g., *Pair Programming*, *Peer Instruction*, and *Team-Based Learning*) [8]. A variety of POGIL activities for CS are listed at <http://cspogil.org>.

Numerous studies have examined the impact of POGIL (e.g., [3], [14], [16]). Most find that, compared to traditional approaches, attrition is lower, content mastery is greater, and students have more positive attitudes. After converting a CS1 course to POGIL, pass rates increased for female students but not males [9]. A POGIL CS Principles course increased student interest in taking additional CS courses [6]. In a software project course, POGIL helped students to understand the importance of communication in real projects [11].

1.2 Faculty Adoption

However, helping faculty to adopt evidence-based practices, including POGIL, can present significant challenges. A literature review on change in undergraduate STEM education [5] found that effective strategies for faculty professional development are aligned with or seek to change beliefs, involve long-term interventions (one semester or more), and approach education as a complex system. The review also identified two ineffective practices: top-down policy making, and simply making best practice materials available (e.g. on a website). In many cases, evidence-based strategies cannot be adopted directly, but must be adapted and customized for an institution, student population, and instructor.

For many faculty, it takes significant effort to shift from a familiar lecture-style to a POGIL-style classroom. Creating effective POGIL activities also requires significant effort, although other disciplines have found that activities, once written, can readily be adapted by other faculty. For example, a 2015 survey about faculty adoption of POGIL in CS identified several challenges, including lack of preparation time, availability of activities, and pressure to cover more content [7]. To help K-12 and college faculty adopt POGIL successfully, The POGIL Project (<https://pogil.org>) offers an extensive series of workshops on classroom facilitation, activity authoring, and related topics. However as suggested by the survey, literature review, and other research (e.g. [10]), many faculty who have adopted POGIL desire further training and mentoring beyond 1-day and 3-day workshops.

1.3 IntroCS POGIL Project

In response to these and other challenges, we have created a professional development program for CS faculty wishing to adopt POGIL in their introductory programming courses. Our *IntroCS POGIL* project seeks to improve faculty adoption and persistence with POGIL in three ways:

- **Materials:** Participants are given multiple collections of POGIL activities for CS1 in Java and Python with sample solutions and instructor guides.
- **Training:** A cohort of 10-15 participants attends a 3-day POGIL summer workshop, followed by a fourth day focused on CS pedagogy and individual course planning.
- **Support:** Participants are organized into teams of 2–4 faculty and each team has regular meetings with an experienced POGIL mentor to share questions, concerns, and insights.

In return, participants help the project to collect data, including student demographics, faculty and student interviews, surveys, learning assessments, and course outcomes.

This paper presents in-depth qualitative interview data from our first cohort of undergraduate faculty. The results complement and extend the literature on faculty motivation and challenges when adopting POGIL in computer science. In contrast to [7], which surveyed instructors who taught with POGIL for multiple years, our work focuses on faculty during their first year with POGIL. We study the impact of our professional development model (materials, training, and support) on faculty adoption and persistence. The specific examples that follow give further insight into how POGIL affects faculty teaching experiences and student outcomes in computer science.

2 METHODS

2.1 Participants

Twelve computer science faculty (seven female, five male) from the United States participated in the study. Based on Carnegie classification [4], ten faculty were from public institutions and two were from private institutions. One taught at a two year institution and the rest taught at four year institutions. Table 1 shows the demographic and university information for each participant.

All participating faculty were recruited via conference workshops and postings to the SIGCSE-members listserv to implement POGIL in introductory CS courses only (primarily CS1). As described in section 1.3, these faculty received collections of POGIL activities, attended summer workshops, and received mentoring on how to implement POGIL.

2.2 Data Collection and Analysis

Partway through their CS1 course, after faculty had implemented several POGIL activities, we invited them to participate in a qualitative interview. The purpose of the interview was to better understand their views about POGIL. Specifically, we wanted to get a picture of their motivation to use POGIL, how POGIL compared to the way they taught before, how their students responded to POGIL, and their concerns about using POGIL.

Each interview was conducted via phone or Google Hangouts and took an average of 22 minutes. The recorded interviews were transcribed, and the text files were imported into nVivo, a qualitative analysis software. The transcripts were read and analyzed by two researchers to see what themes and sub-themes emerged from the data. This bottom-up approach allowed us to maintain the primacy of the data rather than being influenced by our own preconceived notions of what it means to implement POGIL in CS1. In particular, we use an emergent coding method to identify the initial list of codes from the interview transcripts. The initial codes were combined and collapsed into conceptually-based themes, which represented faculty perspectives on implementing POGIL for the first time in their courses.

The analysis of the interviews revealed a number of themes related to faculty motivation to implement POGIL, challenges and issues they faced when implementing POGIL, and how their teaching practice changed as a result of using POGIL for the first time. Below we discuss these themes under two overarching categories: motivation for POGIL, and challenges/concerns when using POGIL.

3 MOTIVATION FOR POGIL

Faculty identified several reasons why they used POGIL that centered on improving student experience/outcomes, changing their teaching practices, and following other faculty recommendations.

3.1 Improving Student Experience/Outcomes

One sub-theme that emerged from the data was that faculty wanted to improve both the experience and learning of students in the CS1 course. One faculty, Christina, stated that:

I'm hoping it [POGIL] would be a better learning experience. They learn the concepts better and get better

Table 1: Participant Demographics

Name*	Gender	Level	Status	Size and Setting
Rachel	Female	4-year	Public	Large, primarily nonresidential
Matthew	Male	4-year	Private	Small, highly residential
John	Male	4-year	Public	Large, primarily residential
Olivia	Female	4-year	Public	Medium, primarily nonresidential
Pavitra	Female	4-year	Public	Medium, primarily nonresidential
Emily	Female	4-year	Public	Medium, primarily nonresidential
David	Male	4-year	Public	Large, primarily residential
Kathryn	Female	2-year	Public	Very large
Christina	Female	4-year	Private	Medium, highly residential
Jen	Female	4-year	Public	Large, highly residential
Jack	Male	4-year	Public	Large, primarily residential
Ray	Male	4-year	Public	Large, primarily residential

* The names used are pseudonyms to protect their identity.

performance in the class; better experience. Most importantly, they are also learning the concepts. We can't have fun without learning. I'm hoping it will help them get better learning experience.

Similarly, another faculty suggested that they wanted their students to get hands-on experience to help them have a good understanding, stating:

Mostly because I found especially the upper level computer science students don't get concepts as well, they are not conceptual thinkers; they are doers. Quite frankly, if it wasn't for computer science becoming a discipline, I probably wouldn't have got into academia because I tend to be more of active learner, too. I like hands-on; engineers are that way.

Faculty also believed that POGIL would help students retain the concepts better as they moved to more advanced courses. For example, Kathryn said:

One area I'm especially interested is retention. When we measure how well the students are doing at the end of the term, that's one thing. How well are the students doing? Let's see one term later when they come back after summer break, you know, how well they are doing.

3.2 Increasing Retention / Reducing Isolation

Christina also brought the idea of POGIL not only leading to better retention of material, but also better retention of students, stating:

Well, doing better and having better performance on the project. I'm hoping to see their better performance on the tasks. I'm hoping they have more retention in my class. They are really enjoying that. There's better retention from the CS1 to the next course. So those are the things. Better grades, perhaps—you know, fewer failing, fewer dropping.

Similarly, Olivia suggested that POGIL will have positive effects on the weaker students. She said:

We have such a high DWF rate. I decided it was worth trying something new to see if we can help the struggling students. So I decided to give it a try.

Faculty also hoped that, as a result of using POGIL, it would lead to more students coming to the class, as highlighted by Olivia:

One thing I am hoping to see it turn out a result in spring is that students start coming to class. Or when I say, 'Let's do the lab work,' and I'm hoping that this group activities are part of something that keeps them in the class and keeps them asking questions, and that improves their performances.

In addition, another motivation for faculty was to better engage their students during class as highlighted by Matthew:

I want people [to be] more engaged. In my upper division courses, I do get a lot of give-and-take with the students, even when I lecture. But in the 100-level courses, they often just sit there and maybe they're there, maybe they're somewhere else, you know what I mean? I don't get a whole lot of interaction. I do, but it's just up to your student, and that bothers me. You know, I tried some strategies to get other people to engage in questions so that it starts out and stuff, but it's not often. I want to get them all engaged in it. POGIL looks like a way to do that.

4 CHALLENGES/CONCERNS ABOUT POGIL

While faculty had various motivations to use POGIL, they also raised a number of concerns about implementing POGIL in their CS1 courses. These concerns were related to curricular issues, institutional challenges, student collaboration, and logistical problems. Below we discuss each of these sub-themes in detail.

4.1 Curricular Issues

Some themes emerged around faculty concerns related to how POGIL would support student learning in CS1. For example, faculty are concerned that active learning approaches like POGIL take more time than traditional lecture-based approaches. Matthew said:

The amount of time it takes to do POGIL is more than if you were just lecturing. So, there's always a concern about balancing active learning with actually covering the content.

Rachel also discussed how POGIL was time intensive:

The one problem that I have with it: it just takes a long time to implement. It takes a long time to do a POGIL activity. It takes the bare minimum of an hour to do a POGIL activity, and I am actually behind in my content—two weeks behind. Because of the implementation of POGIL, I'm already two weeks behind and that just makes me very, very nervous. . . Like I said, the greatest concern that I have right now, that is always putting an extra beat in my heart, is not being able to cover all the content that I have to, especially in this intro-to-programming class. They have to come up with a basic level of knowledge so that when they move into that second class, they have seen stuff and they have learned stuff and experienced stuff. I can't miss content; I can't skip it. It's critically important that they know it and that they feel confident with it.

The main concerns about lack of time to do POGIL was related to the pressure to cover content as highlighted by Pavitra:

I think the concern is usually time. I mean, we usually stress so much about being able to cover everything. You definitely have to get through everything. I think that is a major concern. I think it's just an additional set of activities that I'm doing. I mean, I've reduced the amount of time that I spend on slides. I usually now just show them the slides and tell them that it's there. But I think that's working on fine.

Some faculty also discussed that the POGIL activities themselves were time consuming, as Christina stated:

Well, one concern is I'd like to know. . . my class is one hour and forty minutes. It's not short, I have time, I'm interested to see can they finish the activity during my class time. Yesterday they had it; they had fun, telling you this is great; they really liked it. We didn't finish the whole activity because I am doing other things. It was the first class in this semester, and there's a few administrative things I had to do, make sure that they can get on the system because some freshmen never had their account. And yesterday was rushed. . . I am basically saying, the length of the activity, as soon as it is going to be run, perhaps if it is too long, remove some of it. I thought the first activity I did was long.

There were issues related to faculty themselves having the time needed to learn how to adapt their teaching to POGIL, as Christina stated:

But you know, it's time consuming. I'll spend more time on this. Because I need to learn what I am supposed to be doing, so I will try. I think time is the main thing. It is time learning some technology.

When it came to how POGIL related to their own curricula, faculty were concerned that the activities did not always match their own materials and they were adapting the materials for their own need. Matthew stated:

The other challenges would just be the availability of materials, available materials. You know, one of my

challenges is that I'm using a completely different set of tools and textbooks than the authors of materials. So, I have to be really strategic about where I can fit it in, and I'm doing things in a different order than they had, and things like that. In the repository, I mentioned earlier, there are second, third, elective types of courses with some materials that there's just not very many.

4.2 Classroom Space Challenges

Multiple faculty also suggested that their typical classrooms were not well suited to the collaborative nature of POGIL. This is highlighted by Jack:

It's a challenge to get four students together comfortably where they can see each other. We've got tables that seat three students going across. And we line through them up side-by-side, so it's essentially rows of . . . the classroom I've got six students per row, to my left and to my right. The tables the way they are, they've got a board in front of them, so you just can't sit on the other side of the table comfortably. That's been the biggest issue. Just the logistics of getting people moved around.

Similarly, Olivia suggested that her classroom is not set up to do POGIL, stating:

The biggest problem I have is that the classroom is not set up for it. The classroom is set up in traditional, all the seats and tables facing forward. And I'm having to rotate where each group meets, because quite honestly, some of the places I can't put them to work so much better. You know, in some cases, huddled with the computer between them, not really able to see each person well. So that's the biggest problem. We don't have any spare classroom we can move into temporarily, kind of thing.

The faculty's lack of experience in teaching POGIL might also have contributed to seeing how POGIL would work in classroom space, as suggested by David, who said:

So far, like I said, the one thing, I mean, the room was a problem on my first day. Despite having visited the room in advance and looking at it, you know, I had planned to rearrange the furniture. But I just, with my lack of experience I guess, I couldn't foresee how very crowded the room would become and having to reset it quickly before the next class. I was worried about making a bad impression for the colleague who had followed me. That's a little bit of concern, but thankfully that has been sort of solved.

4.3 Teamwork and Student Roles

Another issue faculty discussed was how to manage student roles given the collaborative nature of POGIL. In particular, faculty were concerned about the size of the group and how students would function within the group as highlighted by Emily, who said:

I'm struggling with how to manage your group, especially one group that has three or four people. So normally one out of three or four people always has free

riders. You know, some people just do all the work for others to follow along, you know. It's kind of frustrating. If I focus on that, then the classroom moves very slow. Eventually, I don't know, I just did it one time, instead of three or four people, I went back to two people a group. You know, [my institution] has a small class. We have around 20 students per class. I thought 2 people per group with 10 teams I can manage pretty well. If I have three or four people a group, I have around 6 or 7 teams, you know? And it becomes difficult to manage. Especially four people is very difficult to manage.

Given that students were working in teams, faculty also were concerned that not all students would contribute equally to the work. For example, Christina stated:

I also need to think about how to make sure that everybody is following their responsibility and roles. I am concerned about that one student actually taking lead and the others following. I want to make sure that doesn't happen. There's a tendency sometimes that someone with strong personality just takes lead and everyone say "yes, yes" and follows, without challenging them.

Another challenge is how to manage groups when some finished sooner than others, as stated by Christina:

I want to make sure I know how to handle well the various completion rate of the students in this class. Some of them finished earlier than others, and I need to be ready to give them more things. I mean, I need to think about how to handle that. I talked about before, when I just gave them labs, now I have to be slightly different with how to do that, because we just stop at different stages.

4.4 Institutional Challenges

Another theme that emerged was that faculty face institutional challenges when adopting new teaching approaches. This was mainly around how senior faculty were not open to changing what they have been doing. For example, Christina stated:

Well, you know, some faculty members are resistant to do something new. I don't know what exactly obstacle they think. They have to change the way things are accepted. Many of them are more senior faculty, they have a certain way of doing something. Or, maybe they believe in it, they believe what they are doing is successful, why try something new?

Similarly, Kathryn stated that faculty who have been at the institutions for a number of years were reluctant to do something new, stating:

What I found in our college is the forerunners. Some faculty members have been there since 20+ years, and they have their way of teaching and they like the way of teaching. There's no interest to change it.

One participant, David, also discussed that whether research or teaching was prioritized at the institution could be a barrier to faculty adopting POGIL. He stated:

[My University], at least the CS department here, you know, is not a research one school. Our incentives here are aligned with teaching. That makes POGIL sort of like a secure choice to be working on, for as far as my tenure-track position. If I were at a research position, like a tenure track professor at an R1 school, I am fairly certain that I will wait until after tenure to bother with POGIL, because my teaching would matter not at all and this takes, you know.

5 DISCUSSION

The interviews and emergent themes provide a rich description of some of the challenges faced by faculty who adopt POGIL and other similar approaches to teaching. Some of these challenges can be addressed in faculty workshops and mentoring, and thus have given us insights to improve this ongoing project.

Faculty worry about the time required to implement POGIL (section 4.1). This is a common concern raised in nearly every POGIL workshop, despite evidence of POGIL's effectiveness (e.g., [3], [14], [16]). When students truly understand key concepts and develop skills in teamwork, critical thinking, and problem solving, they become better learners, more able to learn new concepts and skills on their own.

Faculty also worry about the effort to adapt POGIL materials for their own courses. This highlights how materials created by faculty for their own classroom may require significant revision and refactoring to be readily adapted in other classrooms. The sets of POGIL materials provided in this project have instructor's guides that include learning objectives, sample answers, notes on pacing and discussion points, etc., but might benefit from more work to be more easily adapted by other faculty.

Faculty worry about interactions between POGIL and classroom layout (section 4.2). Faculty workshops on POGIL usually use teams of 4 sitting around a table; however, many faculty implement POGIL in classrooms or lecture halls with fixed seating. Thus, POGIL workshops should address how POGIL can be adapted to different classroom environments, and perhaps even model POGIL in other settings.

Faculty worry about teamwork and roles (section 4.3). This is an ongoing challenge, even for many experienced POGIL faculty, but it might also highlight how faculty are thinking more about what and how students learn, and less about "coverage".

Faculty worry about institutional challenges (section 4.4). This suggests that POGIL workshops and mentoring should do more to explore how often to use POGIL, how to present POGIL to students and colleagues, and how to present the effort and impact of POGIL in yearly evaluations and promotion packages.

6 CONCLUSIONS

Teaching with POGIL can be a significant paradigm shift for faculty, especially when adopting POGIL for the first time. But overall, the results are consistent with faculty perceptions of other active learning approaches (see e.g., [13]). Faculty are concerned about the amount of time needed to do POGIL well—both preparation time and classroom time. And they worry about "covering" less content during class time in order to facilitate the activities.

The concerns raised in the interviews illustrate the need for ongoing professional development and mentoring. Issues like the alignment of POGIL to a specific curriculum can be addressed through the creation of new materials. Others, such as class room space challenges and institutional barriers, require additional research and support.

In spite of their concerns, faculty continued to be motivated to use POGIL for reasons that ranged from:

- POGIL will help with retention
- POGIL will help weaker students and reduce isolation
- POGIL will improve student attendance and engagement
- POGIL will improve student performance

During the next phase of our research, we will examine the impact of POGIL adoption on student learning and outcomes. We are working with a wide range of faculty, from new assistant professors to full professors with decades of experience. We are particularly interested in how faculty perceptions change over time and how their teaching practices impact their students.

ACKNOWLEDGMENTS

The authors thank the National Science Foundation for support under award DUE-1626765. All opinions reflected in this paper are those of the authors and not necessarily those of the National Science Foundation.

REFERENCES

- [1] Michelene T. H. Chi and Ruth Wylie. 2014. The ICAP framework: Linking cognitive engagement to active learning outcomes. *Educ. Psych.* 49 (2014), 219–243. Issue 4. <https://doi.org/10.1080/00461520.2014.965823>
- [2] Thomas Eberlein, Jack Kampmeier, Vicki Minderhout, Richard S. Moog, Terry Platt, Pratibha Varma-Nelson, and Harry B. White. 2008. Pedagogies of engagement in science. *Biochemistry and Molecular Biology Education* 36 (2008), 262–273. Issue 4.
- [3] John J. Farrell, Richard S. Moog, and James N. Spencer. 1999. A Guided-Inquiry General Chemistry course. *Journal of Chemical Education* 76, 4 (1999), 570–574.
- [4] Indiana University Center for Postsecondary Research. 2015. The Carnegie classification of institutions of higher education.
- [5] Charles Henderson, Andrea Beach, and Noah Finkelstein. 2011. Facilitating change in undergraduate STEM instructional practices: An analytic review of the literature. *Journal of Research in Science Teaching* 48, 8 (2011), 952–984. <https://doi.org/10.1002/tea.20439>
- [6] H. H. Hu and P. B. Campbell. 2017. A Framework for Levels of Student Participation and Stages of Relevant Curriculum. *Computing in Science Engineering* 19, 3 (May 2017), 20–29. <https://doi.org/10.1109/MCSE.2017.44>
- [7] Helen H. Hu, Clifton Kussmaul, Brian Knaeble, Chris Mayfield, and Aman Yadav. 2016. Results from a survey on faculty adoption of Process Oriented Guided Inquiry Learning (POGIL) in Computer Science. In *Proceedings of the Annual Conference on Innovation and Technology in Computer Science Education (ITiCSE)*.
- [8] Helen H. Hu and Tricia D. Shepherd. 2013. Using POGIL to help students learn to program. *Transactions on Computing Education* 13, 3 (2013), 13:1–13:23. <https://doi.org/10.1145/2499947.2499950>
- [9] Helen H. Hu and Tricia D. Shepherd. 2014. Teaching CS 1 with POGIL activities and roles. In *Proceedings of the 45th ACM Tech. Sym. on CS Education*.
- [10] Adrianna J. Kezar. 2011. What is the best way to achieve broader reach of improved practices in higher education? *Innovative Higher Education* 36, 3 (2011), 235–247. <https://doi.org/10.1007/s10755-011-9174-z>
- [11] Shreya Kumar and Charles Wallace. 2014. Instruction in software project communication through guided inquiry and reflection. In *IEEE Frontiers in Edu. Conf. Madrid, Spain*.
- [12] Clif Kussmaul. 2012. Process Oriented Guided Inquiry Learning (POGIL) for computer science. In *Proceedings of the SIGCSE Technical Symposium on Computer Science Education*. Raleigh, NC, USA.
- [13] Cynthia Bailey Lee, Saturnino Garcia, and Leo Porter. 2013. Can Peer Instruction be effective in upper-division Computer Science courses? *ACM Transactions on Computing Education* 13, 3 (2013), 12:1–12:22.
- [14] Richard S Moog, Frank J Creegan, David M Hanson, James N Spencer, Andrei Straumanis, Diane M Bunce, and Troy Wolfskill. 2008. POGIL: Process Oriented Guided Inquiry Learning. In *Chemist's Guide to Effective Teaching: Vol II*, Norbert J. Pienta, Melanie M. Cooper, and Thomas J. Greenbowe (Eds.). Prentice Hall, 90–107.
- [15] Michael Prince and Richard Felder. 2007. The many faces of inductive teaching and learning. *Journal of College Science Teaching* 5 (2007).
- [16] Andrei Straumanis and Emily A Simons. 2008. A multi-institutional assessment of the use of POGIL in Organic Chemistry. In *Process Oriented Guided Inquiry Learning (POGIL)*, Vol. 994. American Chemical Society, 226–239.