Classroom Implementation of

Process Oriented Guided Inquiry Learning

A practical guide for instructors

including comments on the use of

Organic Chemistry
A Guided Inquiry, *Second Edition*

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A film will be dull and boring, no better than Hallmark™, if I simply tell people what I know. It will only be interesting if, in viewing it, they get to discover what I discovered while making it.

– Ken Burns

How to Use This Guide

This guide describes how POGIL materials have been used in a wide range of classroom settings. There are three sections. Section 1 contains an overview of the underlying principles of POGIL, and a discussion of key aspects of POGIL implementation. Section 2 contains tools that you can use or adapt, including descriptions of how POGIL has been used in specific circumstances, a sample syllabus, and other sample instructions for students. As you get deeper into your POGIL journey you will have many questions. Section 3 contains answers to frequently asked questions from dozens of workshops I have facilitated. If your question is not listed there, or an answer is not sufficient please take advantage of the live resources available through the POGIL website at www.pogil.org, the companion site at www.guidedinquiry.org and the Guided Inquiry discussion group found at http://groups.yahoo.com/giorganic.

A Brief Overview of POGIL and the POGIL Project

POGIL was adapted from methods used in chemistry classrooms at Franklin and Marshall College by Rick Moog, Jim Spencer, and John Farrell in the mid-1990's. The method they developed was basedadapted from the hard work of others. From the start, assessment has been a key part of the POGIL Project, allowing continued improvement and the propagation of best practices. The result is a set principles and teaching methods that can serve as the backbone of learning in many different classroom environments.

The research that inspired POGIL is not new, and POGIL is not the first reform effort that has put this research into practice. Our success is likely due to a number of factors, not the least of which is a warming of attitudes toward research based teaching, and the willingness of teachers to question old assumptions about the value of lecture. If you have been working to make your classroom more active, it is likely you will find many POGIL techniques familiar. We hope you will also take away something new from this guide. For further reading, you may want to consult the following excellent resources on learning.[1,2,3]

A common and effective strategy for using POGIL materials involves devoting most of each class meeting to student groups (of three or four) working on a specially designed activity worksheet. Such worksheets follow the learning cycle model, which contains three parts: Exploration, Concept Invention, and Application. This recapitulation of the scientific method allows students to discover course content and simultaneously develop skills that are critical for both scientists and citizens: information processing, critical thinking, problem solving, communication, teamwork, management, and self-assessment. The instructor serves as facilitator: observing student group work, answering questions, and intervening when necessary. Common interventions include answering a question, having students present their answer to the class, leading a whole-class discussion, or delivering a three-minute summary or mini-lecture. We have found this basic format can be adapted to many environments and any class size.

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[1] Bruffee, Kenneth A. *Collaborative Learning: Higher Education, Interdependence, and the Authority of Knowledge.* Baltimore: Johns Hopkins Press, 1993.
[2] Johnson, D. W.; Johnson, R. T; Smith, K. A. *Active Learning: Cooperation in the College Classroom*; Interaction: Edina, MN, 1991.
[3] Bransford, J.D.; Brown, A.L.; Cocking, R.R., *How People Learn*; National Academy Press: Washington DC, 1999.

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SECTION 1: Introduction to POGIL

How People Learn

If you had to summarize what we know about learning in three bullets they might be…

- Teaching by telling (on its own) does not work.[3]
- Students learn best when they are given an opportunity to construct their own understanding.[4,5]
- Learning is a fundamentally social act. (Discussion is a critical part of the learning process.)[1,2]

Imagine a typical large lecture hall with hundreds of science students sitting quietly, watching a professor chalk structures or equations on the board. Now imagine this same lecture hall bustling with discussion and the excitement of discovery ("Aha!"... "Oh, I get it!"… "I see how it fits!"). A small team of facilitators, led by the instructor, move through the crowd, answering questions, providing encouragement… facilitating learning.

The latter image is the product of more than a decade developing and testing a learning method called Process Oriented Guided Inquiry Learning (**POGIL**), a method based on research on how students learn best.[1-5]

Many past attempts to reform science education have failed. The relative success of POGIL seems to coincide with a surge of dissatisfaction with the traditional lecture model. The new buzz words among students, teachers, administrators, and funders are:

- Discovery learning (constructivism)
- Active learning
- Cooperative learning
- Learning by teaching (peer instruction)
- Skill oriented learning (learning to learn)

What is POGIL?

POGIL is a structured, adaptable and portable classroom system that is grounded in educational research, and exhibits Rogers' five characteristics of a readily diffusible innovation: 1) relative advantage, 2) compatibility, 3) lack of complexity, 4) trialability, and 5) observability.[6] These characteristics mean that, with just the training provided in a site visit or one-day workshop, an instructor can use POGIL to modularly replace one topic, one section, or the entire lecture portion of a course, and expect to see an increase in student engagement and achievement, without changing the content.

A POGIL classroom differs dramatically from a traditional classroom in that there is little formal lecture. The instructor serves as the facilitator of learning rather than the primary source

[4] Abraham, M. R., Inquiry and the learning cycle approach. In Chemists' guide to effective teaching (Vol. 1), ed.; Pienta, N.J.; Cooper, M.M.; Greenbowe, T.J., eds. Prentice Hall: Upple Saddle River, NJ, 2005.
[5] Lawson, A. E., "What Should Students Learn About the Nature of Science and How Should We Teach It?" Journal of College Science Teaching 1999, 401-411.
[6] Rogers, E.M., *Diffusion of Innovations*. ed.; Free Press: New York, 1995.

of information and students work in self-managed teams to analyze data and draw conclusions, modeling the way a team of scientists function in the research laboratory.

POGIL's central claim is that it helps students simultaneously develop content knowledge and key process skills. The hypothesized mechanism is two-fold, stemming from marriage of the PO (Process Oriented) and GI (Guided Inquiry) methodologies implied in the name. The "GI" part is achieved via use of carefully designed learning cycle[7,8] activities that guide students toward construction of their own understanding. Such discovery experiences have been shown to improve confidence while helping students to understand and remember more.[4,5] The "PO" part comes from the frequent or exclusive use of small groups. There is a large body of evidence suggesting that cooperative learning fosters positive attitudes toward the subject matter, as well as growth in process skills such as critical thinking, teamwork, and metacognition.[1] Perhaps most importantly, the positive interdependence generated in a small group setting has been shown to attenuate the feelings of isolation, disorientation and competition that often correlate with underachievement or failure in a traditional classroom environment, especially for women and minorities.[9,10,11]

Content and Process Goals

Most instructors have clearly defined content goals for their course. Their syllabi might list topics like "Nucleophilc Substitution" or "Acid-Base Reactions." Often teachers must be mindful of courses for which their course is a prerequisite.

Less often, a course is designed with specific process skill goals in mind. The philosophy of POGIL is that certain key process skills are at least as valuable as content students might learn in the course.[12] This is for two reasons: 1) the process skills listed below help students learn the content and 2) these process skills help students create new knowledge, and are applicable beyond chemistry.

POGIL's Targeted Process Skills

Information Processing
Critical Thinking
Problem Solving
Communication
Teamwork
Management
Self-assessment

Perhaps the most important but lease self-explanatory skill on this list is self-assessment. Self-assessment is not needed to memorize facts and algorithms and churn out answers to familiar exercises, so many students are not familiar with it. A simple way to explain self-assessment is: the ability to tell if you are right or wrong. Even students who believe there will always be an answer key respond to the idea that during an exam it can be useful to know if you are right or wrong.

Experienced students sometimes describe self-assessment as the feeling you get when you finally figure something out…the "Ah ha! moment." Or, perhaps more important is the ability to recognize the absence of that feeling: the confusion and frustration associated with not understanding.

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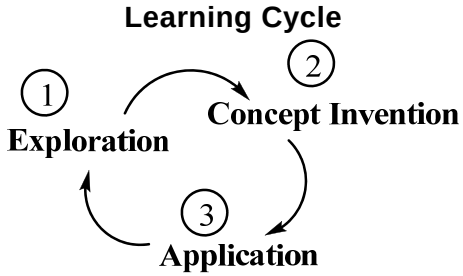
[7] Karplus and Thier. *A New Look at Elementary School Science*. Chicago, Rand McNally (1967).
[8] Piaget, J.; *J. Res. Sci. Teach.* 1964, 2, 176.
[9] Hewitt, N.A.; E. Seymour, *Factors Contributing to High Attrition Rates Among Science, Mathematics, and Engineering Undergraduate Majors: A Report to the Sloan Foundation.* 1991, Denver: U. of Colorado Press.
[10] Tobias, S., "Women in Science - Women and Science" *J. of Col. Science Teach*. 1992, 21, 276.
[11] Treisman, P.U. Innovations in Educating Minority Students in Math and Science; Dana Foundation: 1988.
[12] Moog, R. S.; Creegan, F. J.; Hanson, D. M.; Spencer, J. N.; Straumanis, A., Process Oriented Guided Inquiry Learning. In *Chemists' guide to effective teaching (volume 2)*; Pienta, N.J.; Cooper, M.M.; Greenbowe, T.J., eds. Prentice Hall: Upper Saddle River, NJ, 2009.

The Structure of a POGIL Activity: The Learning Cycle

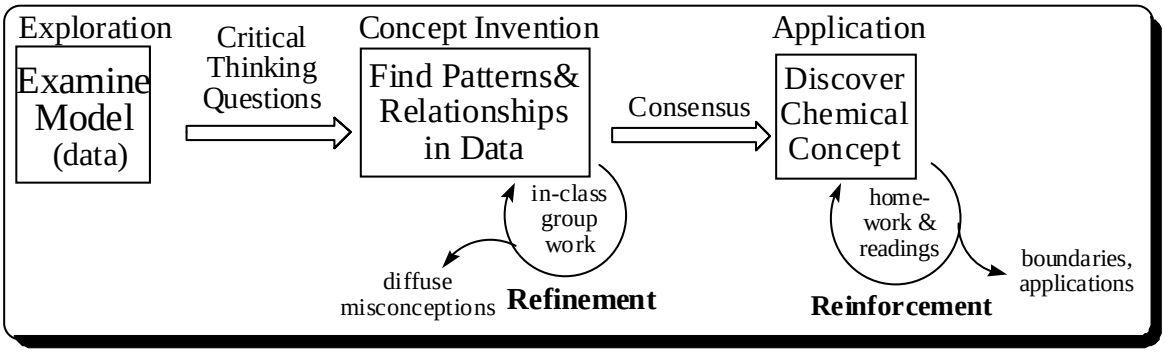
The learning cycle, developed by Karplus and Piaget,[7,8] is similar to the scientific method.

We have found that activities that follow a learning cycle are very effective at generating Ah ha! moments, and encouraging development of targeted process skills such as critical thinking and self-assessment.



Exploring the Model: Directed Questions

A POGIL learning cycle activity begins with a Model. This model often contains enough information such that a group of students could extract from it the target concept. However, to help students, Critical Thinking Questions are provided to guide students toward this concept. The questions usually begin with the very simple. Such questions help with the Exploration phase, and may simply direct students to look at the appropriate part of the model (for this reason they are called directed questions). For example, a directed question for the figure below might be: "What aspect of POGIL implementation helps diffuse student misconceptions?"



Coming to Consensus: Convergent Questions

After a few directed questions, the activity usually contains a question that requires students to process the data and find patterns. This is not a clean, linear process, but with work students usually come to a consensus that resembles the targeted concept. These types of questions are termed convergent questions since most students will converge on the same answer.

Though many student groups will converge on the same answer to a convergent question, they still may lack confidence in their answer. Confirmation by the instructor is often not the most valuable next step. As described below, it can be much more useful for the instructor to lead a whole-class discussion that centers of students presenting their various correct or partially correct answers.

Confirming Your Understanding: Teacher Talk, Homework, and Readings

The final stage of the learning cycle is Application. The purpose of the Application phase in a successful POGIL activity is to help students assimilate their student-level understanding with expert explanations, including familiarizing themselves with expert terminology. This is best done with a combination of teacher talk (summary mini-lecture), homework, and reading from a complementary textbook. Textbooks provide a concise explanation of key concepts in expert terminology, but most students are not ready to read this explanation until after they have had a

chance to discover the concepts for themselves. For this reason, most POGIL courses ask students to read the assigned sections of the text *after* they have completed the activity on that topic.

In general, forcing students to figure out if they have the concepts is far superior to simply publishing the answers to the in-class critical thinking questions. Any time students work toward an understanding they will learn more and retain it longer. When students are given an answer key, there is a great temptation to look at the expert answers without first assessing the validity of their own answers, and this circumvents a critical part of the learning process.

Use of a Traditional Textbook as a Supplement

Most POGIL materials are intended to be used in conjunction with a traditional textbook. I find most organic textbooks are written at a level such that reading in the text serves as an excellent review for students who have already been introduced to the basic concepts via an activity. For this reason, I assign reading after the relevant activity, and tell my students that a good goal, and a test of their mastery of a given unit, is whether they can read and understand the assigned sections in the text.

I strongly discourage use of the text as a reference during class since this causes students to hunt for answers to questions, rather than coming to their own conclusions. The former would be similar to filling in a crossword puzzle using the answers as reference. I encourage students to read in the text *after* class. Some of the most successful students read in the text after each class to try and confirm their answers to the in-class Critical Thinking Questions. If you have ever waited for tomorrow's paper to check your crossword answers, you know that "expert" answers are extremely interesting only if you have spent hours struggling to come up with your own incomplete version.

Formal Roles

One of the great challenges of using groups is trying to generate equal participation among group members. Equal participation is important both in terms of content goals (students who do not participate may not learn as much), and process goals. That is, students who do not participate will not have an opportunity to develop the key process skills listed in the previous section.

Many POGIL classrooms employ formal roles (described below). Often roles are rotated every class meeting so that every student experiences each role and its responsibilities. Some instructors have had success rotating roles less frequently.

Even without formal roles, an instructor can informally encourage equal participation. For example, a question may be posed directly to a less active student. Similarly, the instructor can call on certain individuals to present information at the board, or to serve as spokesperson for the group. In large classrooms (more than 50 students) the management of roles may not be possible. In my large classes I have resorted to describing the role of manager and suggesting that students use this role and rotate who is the manager. The following are the most commonly used roles.[13]

Manager Manages the group. Ensures that members are working together, no one is left behind, and that assigned tasks are being accomplished on time, including that all members of the group participate in activities and understand the concepts. The instructor responds only to questions from the manager who must raise his or her hand to be recognized. This encourages groups to do some internal processing of a question instead of immediately asking the instructor.

[13] Farrell, J.J.; R.S. Moog, and J.N. Spencer. "A Guided Inquiry General Chemistry Course." *J. Chem. Ed.* Vol. 76, No. 4, April 1999. p 570-574.

Presenter Presents oral reports to the class. These reports should be as concise as possible; the instructor will normally set a time limit.

Recorder Recorder keeps a record of the group's official answers in his or her workbook. This allows you to keep tabs on all the groups and encourages groups to come to consensus about each answer. If some report is required from the group, it is the recorder who prepares it. (Some instructors require each group to turn in a description of the one or two most important concepts from the activity, along with any unanswered questions. This would be placed in the group folder.) *Ask for a recorder's report only if you intend to give the group feedback in response to submitted work.*

Reflector Observes and comments on group dynamics and behavior with respect to the learning process. These observations should be made to the manager on a regular basis (no more than 15 minutes between reports) in an effort to constantly improve group performance. The reflector may be called upon to report to the group (or the entire class) about how well the group is operating (or what needs improvement) and why.

Other roles can be used, but are not described here (e.g., Technician, Encourager; Checker).

Assigning Group Membership

There are three basic strategies for assigning groups:

- Instructor assigns heterogeneous groups based on quiz or exam scores
- Students self-select into groups (usually resulting in homogeneity)
- Instructor assigns groups organically based on some criterion (e.g. functionality)

Assigning Groups in Small Classes

Instructor assignment of group membership is an opportunity to gain valuable insight into the personalities of your students. The more you know about your students, the better you will be able to place them in functional groups (and the better able you will be to push them toward their potentials). For even a class of twenty this can be a time consuming but rewarding process. For larger classes (>50) this will be impossible, and you will likely have to resort to an algorithmic strategy for assigning group membership, or simply let them choose.

When I have had the luxury of assigning group membership based on skills and personalities (in a small class), the main parameter I thought about was assertiveness. (I find this is more important than gender or other variables.) I never put one quiet person in a group with three loud people, and some of my most successful groups were the result of putting four quiet, thoughtful students together, or four loud, talky students together.

Assigning group membership gets easier if you collect information about your students. To speed this process, I periodically ask that each student send me a confidential email detailing who they like to work with, who they do not like to work with, and why. In doing this, they end up revealing what type of group member they are, but you can also ask them explicitly for a self-assessment.

Of course, at the beginning of a semester, you may have no information. I always start with alphabetical assignments. Then, for the first few weeks I mix things around weekly so that students get to know each other, and experience a variety of learning styles. By mid-semester I hope to have students into a set of static groups so they can begin building specific dynamics.

In a small class, I may tinker with the groups if I see a problem. This may mean moving a person from a productive group to help "save" a dysfunctional group. My goal is to find an overall arrangement that works best for everyone. Usually, the greatest challenge is finding a place for problem individuals. At times I have been lucky and found a configuration that works well for everyone, but usually I must make some compromises. If you know your students, you will be able to assess which students will best tolerate being placed in a group with a lazy, argumentative, nit-picking, or disgruntled student. As a last resort I put three or four non-cooperative students together in a group to protect the other students.

Try different arrangements. Often logic can be applied to the process, but just as often you will be surprised by the results.

Assigning Groups in Large Classes

This is what I do in my 400 student sections with 10 week quarters:

- Alphabetical seating the first week (often by recitation section). The seating chart is posted on line and on the door outside of class the first day. For large lecture halls with fixed seating, groups of three work best.
- At the start of the second week, students are placed in new groups so that they get to meet two new people.
- By the start of the third week they are expected to form groups of their own choosing and register a group of three or four. Coincident with this, I assign a group take home exam (worth 2% of their grade). The rules of this exam specify that students can only discuss the exam with their week-three, self-selected group mates. If they have not registered a group yet, they have to do the exam entirely on their own. When they register their group they also choose a block of seats in the classroom. This is done the same way you select seats for a ball game or theater performance on-line (except that I break the seats in the class into pre-set groups of 3 and 4). This is another incentive to register as part of a group, since the sooner they form a group the more choice they get in terms of seating. Your IT department can help you set up a registration site, or you can simply use your discussion group to let students register for seats. (The instructions I give to students can be found in Section 2.)

Instructor's Role as Facilitator

A key guiding principle in facilitation is that students gain far more from correcting their own answers than from being corrected by the instructor. Do not interpret this as meaning that instructors should refuse to answer questions. A skilled facilitator will give students in a group the minimum amount of information required for them to correct their own mistake, while making them feel supported and encouraged. If the instructor commonly answers questions such as "Is this correct?" students will quickly get the message that they cannot trust their own self-assessment skills, and must always get expert confirmation of their conclusions. This is poor training for success on quizzes, exams, and especially for the real world, where there are no answer keys.

As a facilitator moves around the room observing student group work, it can be the best course of action not to intervene, even when he or she sees a problem. The facilitator should observe and determine if the problem is likely to be solved without intervention.

The following table shows some common interventions that can help students self-correct, without developing dependency on instructor confirmation.

Small Class (< 40) Facilitation	**Large Class (> 50) Facilitation**
Observe <u>each</u> group so you know which groups are having problems, and where each group is in the activity.	Observe a <u>sampling</u> of groups to get a sense of common problems and student progress in the activity.
Intervene with <u>individual</u> groups when necessary. For common problems a whole-class intervention may be preferable.	You may intervene with individual groups, but usually a <u>whole-class</u> intervention is also needed (timed so that most groups have had time to grapple with the topic first).
(Examples) Ask a group to… • Read the question out loud • Assess confidence in own answer • Check if all group answers match • Read the next question or model • Consult with a neighboring group • Report answer to whole class • (Whole class) Vote on competing answers	Whole-class interventions: • train groups to use the first five bullets at left to self-assess • Ask group(s) to share their answer to a key question (on the board or pass out an overhead) • Call on a group to critique or explain an answer • Pose a clicker question • Instructor mini-lecture

As you interact with groups, keep in mind the tendency of students to not question or even critically evaluate about instructor comments. The more you use student-offered explanations, the more students will critically evaluate these explanations. A correct answer offered by a student may be identical to the answer you would have offered, yet the former will win more scrutiny from students without your endorsement.

At the end of a discussion, especially involving a complex topic, it may be helpful to have some kind of closure. This can mean instructor endorsement of one answer over others (but only after time for discussion), but a simple vote or clicker question may be endorsement enough.

Another pitfall of facilitation is for the instructor to fall into a dialogue with just one member of a group. It is especially damanging to carry on such a dialogue with a student is way behind and needs extra help. Experience has taught me that involving the rest of the group is worth the time and energy, even if it means slowing down the other group members. Building interdependence is critical for the success of all group members, but this may not be clear at first to stronger students. They will eventually come to see that a weaker student who asks lots of questions is an asset to a group because of the power of learning by teaching. You may need to jump start group interdependence by, for example, asking a stronger member to explain a concept to a weaker member.

Just as the way you address a group can send powerful messages about how you want a group to interact, you can also encourage inter-group interactions with your facilitation. When a group has the same problem as another group, I often have a representative of each group switch chairs. Or if they are close enough I simple point to the other group and say something like: "Those guys are stuck on the same question that you are discussing. I think you will find their answer very interesting." In the future they may consult a nearby group without you suggesting it.

Summary Lectures and Other Teacher Talk

Even a small POGIL class usually includes several short periods of teacher talk. I always start class with a brief (three-minute) overview of the previous class, and a one-minute preview of the upcoming class. A general rule is that the larger the class, the more time I spend at the front of the room, speaking to the class as a whole.

Teacher talk can be a useful tool for speeding student work on an activity. If the progress of a group or the whole class is too slow, interrupting group work and giving away an answer shuts down further discussion since the "expert" has ruled in with the "correct" answer. Be aware that your input may have this effect, and that each attempt to speed the class along has a cost. You have to decide which is more beneficial at that moment: to move them toward the main concept waiting at the end of an activity, or to foster discussion and maintain the integrity of their discovery experience.

Before doing this, I spend time eavesdropping, and try to time my comments such that most groups have had an opportunity to struggle with a question long enough that hearing the answer has some benefit.

Whole class discussions can take many forms. I have found this part of the method draws most heavily on my creativity and instincts. Examples include: calling for a student to present the ideas of the group, summarizing answers from each group on the board, leading a discussion of interesting wrong answers, trading student emissaries between groups with conflicting answers, or using a mini-lecture to try and explain away a misconception held by a large number of students.

Intervening too frequently reinforces the commonly held student belief that no answer is correct until confirmed by the instructor. With that said, however, revealing too little can cost you the students' trust. Especially when beginning a new instructional method, frustration thresholds are very low. The number one complaint from POGIL students continues to be "the instructor refuses to answer my questions." I have found that explaining the pedagogy (essentially telling students "it is for your own good when I force you to figure out answers for yourselves") only intensifies anxiety and frustration. At the first sign of trouble, I have found it best to at least acknowledge the tricky spot, and perhaps give a hint. This lets the students know you want to help. Ideally, you get to know each student's tolerance threshold so you can give only the minimum information required for a group or individual to figure the concept out for themselves.

According to Piaget, frustration is an important part of learning.[8] The trick is to push students, but not make them snap. Some students have high tolerance for the cognitive discomfort inherent in learning; others do not. It is deeply gratifying to know your students at this level, and very exciting when this knowledge helps you push their limits.

Setting Clear Expectations about Timing

At the start of class, or in your syllabus announce the target stopping point for each day. Without a clear (and ambitious) goal, some groups will spend the entire class pondering the first challenging question. You want to avoid a situation where students sense that they can slow the pace of the course, and reduce the overall amount of material covered, by working inefficiently in class. To avoid this, I rarely let work on an activity roll over into the next class period.

I make it clear that students are responsible for finishing each activity before the start of the next class. Challenging them to complete the activity during or after class will do two things: 1) keep them on task during class and 2) encourage out-of-class group work. At the end of the first few classes, I suggest that students exchange cellular numbers or arrange a good time to meet outside of class.

In 50 minute sections it is nearly impossible to finish one part of an activity. I tell my students to do their best to work through as much of the activities before class (at least the first two pages), or they will be finishing it on their own after each class. If you have a 75 minute option, I would take it and shift some auxiliary topics to lab (spectroscopy), or homework (nomenclature). 50 minutes is very rushed.

Encouraging Students to Develop Self-Assessment Skills

Students clamor for answers. This can become a delicate tug-o-war with a student who is frustrated and insistent. A POGIL organic chemistry course leaves some students feeling very insecure at times. They will say things like "How am I supposed to know if I am learning the 'right' things if you don't tell me what is right and what is wrong?!" One purpose of this type of instruction is to give students the opportunity to develop confidence in their reasoning abilities, and telling them your (or my) answer whenever they ask will interfere with this process. Some POGIL instructors believe that it is pedagogically damaging to even give students access to the answers to the homework Exercises. (If you agree, you must ask your bookstore to restrict access to the *Student Solutions Manual*.) Most every instructor agrees that you should restrict student access to the *Annotated Instructors Edition*, which contains answers to the in-class Critical Thinking Questions. (Note that the IAE contains full solutions, written in a voice appropriate for students. In the past, I have given students supervised access to the IAE as part of a review for the final exam.)

Evaluation: Exams and Quizzes

Exams and quizzes are taken individually in my course. I find that group grading sends the wrong message, especially to stronger students who may have bad memories of weaker students riding their coattails for group assignments in high school.

You may choose to include a 5% group participation grade. Some instructors keep a notebook and record a "+" or "–" next to a student's name each day they demonstrate above or below average participation. Alternatively, you could use confidential peer evaluations to assign a group participation grade. A system for doing this is described in the FAQ, but in general students resist evaluation each other for a grade.

Importance of the Daily Quiz

In my course, every period (except the first class period and the period after each hour exam) *begins* with a three-minute quiz. The quiz covers an important concept developed during the previous class meeting. The purposes of the quiz are: to give the instructor some immediate feedback about how well the concept was learned; to reinforce the concept in the student's mind; to encourage the student to do the homework Exercises *before* the quiz is given; to partition the course material into small, manageable sections; to encourage students not to cram for exams; to develop good study habits; to encourage good attendance and on-time arrival. Five minutes, including going over the quiz, is sufficient to do this. (If you do not go over the quiz, students will spend the first five minutes of group work time discussing the answer to the quiz.)

POGIL Exams

For the most part, traditional questions are used for quizzes and exams in POGIL courses. You may find that your question writing changes as a result of spending most of each class observing what your students know and do not know. My exams questions have become increasingly focused on concepts, and sometimes mimic the structure of an activity, with some information (a Model) followed by questions asking the student to interpret data in the Model. Pre-medical students appreciate this type of exam question since a majority of the MCAT exam is so structured.

Curves Discourage Cooperation

I strongly recommend not using a traditional curving strategy for exams since it may discourage cooperation between students. I recommend an absolute scale (>90% = A, etc.), or weighting system that is below student radar. The more explicit the curve, the more likely students will calculate that helping their group mates is against their self-interest.

Group Take-Home Exams

A great too for fostering group interdependence is a group take-home exam. For such an exercise, I let the students form their own groups of either three or four, and require that each group turn in only one copy of the exam. I specify that they can consult any published work, but they can only talk to their group-mates or me about the exam. After such an exercise, I observe an increase in the number of out-of-class study groups. For this reason, I always do this type of bonus-exercise after the first exam.

Assessment: Improving Your and Their Performances

Particularly in your first year of doing POGIL, it can be useful to conduct student assessment at least one time per semester. One strategy is to give students ten minutes of class time to describe "at least one strength" of the course, to suggest "at least one area for improvement," and to make other comments. For small classes, to ensure anonymity, a student can be assigned to collect the forms and give them to the department secretary, who types them and destroys the originals.

Another way to collect this information is to use an anonymous web-based form that emails student responses to the department secretary, who cuts off the headers and gives you the now-anonymous responses. To ensure full participation you can ask the secretary to keep a list of all those who respond, and award bonus points for completing the form. Alternatively, your computer support people can write a script that will deliver you the comments, and generate an alphabetical list of all responders. If you do not offer bonus points compliance is likely to be low and you may only receive feedback from self selected extremes on the positive and negative ends.

Several times, particularly at the start of a semester it can improve group dynamics to have each group do a group self-assessment. This is the same as above, except that students write down one strength of their group, and one area for improvement. Reporting can be strictly within groups, or (better) you can ask for volunteers to report their insights to the whole class.

Encouraging Students to Answer the Central Meta-Question

On the surface, the students' job is to construct and refine answers to the Critical Thinking Questions, but the real learning takes place when they access the next level and answer the meta-question that underlies most every question in every activity:

> ***"What is the purpose of this question; what point, distinction or concept is the author trying to convey by asking us this question; what am I supposed to learn about the Model from this question?"***

Answering the meta-question is often a challenge. It requires a student to see the forest from within the trees, and to get inside the author's mind. I have tried to be very clear, but sometimes even an instructor will not see where I am going with an activity. To help with this, I have provided an *Instructors Annotated Edition*, with comprehensive answers to the CTQs. Use such resources to help answer the meta-question for yourself, and then encourage your students to use the meta-question to achieve a deeper understanding of the material.

Final Words of Advice

Most students and faculty need at least a few class periods to find their rhythm with POGIL, but by mid-semester it should start to come together. If it does not feel right, seek help early. Contact your workshop leader or the POGIL office. Things always improve the second year, but there is no reason to suffer through a whole first year before making changes. The hardest part appears to be figuring out when to interrupt and what to say when you do. Use your good instincts, but at the beginning err on the side of interrupting more often and saying more. It is easier to step students back from overdependence on you than to repair frustration with you.

If you think of this as an experiment, do not let on. For your students, this course is a huge deal and you do not want to give the impression that you are "playing around" with their lives. Let the materials guide you, but be proactive. Do not sit back and "let the materials do their thing." Each activity is a guide for getting students to think more and interact more. Beyond that, it is up to you to make it work with your specific students, in your unique institutional environment.

Section 2: Implementation Tools

Ten Tools for the New Adopter

Each implementation of POGIL is unique. Your success depends on your ability to make POGIL your own. With that said, below are ten tools to consider when starting a new adoption:

1. Daily one-question quiz to encourage students to prepare for and attend every class (some alternatively use graded homework, though the latter lacks individual accountability).
2. Read through sample syllabi from POGIL courses and adapt sections to your needs. My syllabus is published in this guide. Rick Moog's is found at www.pogil.org in Resources.
3. Use an absolute grading scale, or be circumspect about how you curve your class. The goal is to encourage cooperation. Ideally, students should get the message that teaching others does not hurt their own grade, and that your grading scheme allows for the possibility that everyone will pass the course.
4. Generate group bonding and save class time for activities by assigning take home group exams in place of one or two hour exams.
5. Show your investment in group work by assigning groups and shuffling frequently at first.
6. Use group roles to the extent you are able to manage these roles. A good start is to identify the manager by having him or her hold the group folder or a colored card during class.
7. Only respond to questions from the manager, or use other facilitation strategies that encourage interactions between group members, and internal processing of questions.
8. Do not sit on your hands and "let the activities do their thing." Be very conscious of student frustration. Err on the side of responding to frustration. It is easier to back off later, than to repair your reputation as someone who "refuses to answer questions."
9. Do not give a really hard first exam (this can break their confidence at a critical point in the course). Once they gain momentum you will be surprised at how hard you can push them.
10. Students resist change. Prepare yourself (and your colleagues) for some negative feedback the first time through, especially in the first weeks. Reassure students that most students come to like POGIL better than lecture. Nearly all of your best students will come around. If there is a culture of POGIL at your institution you may get to skip this induction period.

Here are some additional considerations specific to adoption of Organic Chemistry: A Guided Inquiry (OC:AGI) that may apply in other circumstances.

11. Make a calendar of which activities you are doing and when. It is best to plan to do one activity per day regardless of whether you have 50 or 75 minute classes. For OC:AGI you can assign spectroscopy and nomenclature in lab or for homework. This means you can almost fit the 57 remaining activities into two 14 week semesters.
12. Join the giOrganic yahoo group (go to http://groups.yahoo.com). This is not just for organic chemists. As you go along you will have many specific questions. The yahoo group is very eager to share solutions, as they were all in your position once. Also, do not hesitate to email me directly if you have comments, suggestions, questions, or find errors in OC:AGI (straumanis@gmail.com).
13. Go to www.pogil.org/straumanis and check out the offerings there including PowerPoint presentations that dovetail with each ChemActivity in OC:AGI. Some of the material is

instructor only and you must register to get the password. (This content is updated periodically.)

14. Do not expect students to be able to finish activities in 50 minutes. I tell my students to do their best to work through as much of the activities before class (at least the first two pages), or they will be finishing it on their own after each class. If you have a 75 minute option, I would take it and shift some auxiliary topics to lab (spectroscopy), or homework (nomenclature). 50 minute classes work, but it can feel very rushed.

A Typical Day in a Small POGIL Class

- Seating chart with names (and roles) is posted on-line and on the door.
- Each group has a folder (numbered or color coded). The first person in a group to arrive picks up the group folder before the start of class. The folder contains graded work including quizzes from the previous class, which are distributed to members of the group as they arrive. Students may use the time before class to examine the recorder's report and instructor responses to any questions in this report.
- The group folder also contains blank copies of the upcoming quiz (face down in the folder). When the bell rings for class to begin, the Manager distributes these copies of this one question quiz.
- After three minutes, instructor calls time and the completed quizzes are placed in the group folder. (The group folder can be collected at this time if no other work will be submitted.)
- Instructor briefly goes over the quiz. (Alternatively, you can give students 2-3 minutes to decide on an answer to the quiz, but as coming to consensus may take more than 3 minutes, this discussion may distract students from work on the new activity during group time.)
- Instructor briefly (< 3 minutes) reviews the key concepts from the previous class, and very briefly (< 1 minute) previews the upcoming activity.
- The instruction to begin work on the new activity is given. It is best to write on the board how many minutes groups have to work on a given set of questions. (For example: "You have 5 minutes to work on Questions 1-3." This tells students that Questions 1-3 are fairly easy or review, and helps them manage their time effectively.
- The instructor circulates and examines the answers to the CTQs, intervening when necessary.
- It is best to stop the class at the end of the time allotted for the first group of questions and report out at least one answer from a group.
- After a brief whole-class discussion, the directive on the board can be replaced with a new directive (e.g. "You have 20 minutes to work on Questions 4-10.") Even in small classes, these directives can be compiled into a PowerPoint presentation that might also include pre-prepared examples or auxiliary questions.
- One or more times during class and as the final event at the end of class, the instructor may choose to interrupt group work for some variety of whole-class discussion. This often consists of a Presenter reporting an answer followed by instructor-led discussion of that answer, or any other productive presentation or discussion. This type of interruption is especially necessary when students are having difficulty with a topic.
- If you have time, class can end with preparation of a recorders report. This report may be focused on content (e.g. ask "What were the most important concepts you learned today, and what questions remain unanswered?") or process ("What is one strength and one area

for improvement for your group's performance today?"). Answers should be placed in the folder along with any other Recorder notes.

- The class ends on time. If the room is unoccupied after your class, you may want to invite student groups to stick around and complete the activity. When this is an option, I schedule an office hour after class and hold it in the classroom or in the hall outside class.

A Typical Day in a Large POGIL Class

- A 400 seat lecture hall is filled to capacity. Students have been previously assigned to groups of three, but communication between groups is easy since there are few empty seats.
- Class begins with a one-question, three-minute clicker quiz over the previous day's material. No talking or other communication is allowed during this quiz.
- When time expires, the instructor spends no more than 3 mintues going over the quiz.
- This leads into a 3-minute overview of concepts from previous class, followed by a 1-minute preview of the upcomming class.
- The instruction for students to begin work on a new activity appear on the screen (a "timing side"). This contains an explicit directive (such as, "There will be clicker questions in 15 minutes covering Questions 1-8.") that lets students know exactly how much time they can devote to this section.
- The instructor, aided by 2-5 volunteer undergraduate co-facilitators (*see* note on "**Volunteer Undergrad Assistants**" below) walk around observing group work and answering questions during this 15 minutes of group work time.
- After 15 minutes of group work, most students have at least partially discovered the key concept(s). Group work is paused, and a "clicker question" is put on the screen which is designed to assess their progress toward the targeted concept. (*See* note on "**Clickers**" *below*) The clicker question gives students feedback, and helps the instructor decide if clarfication of the concept is required.
- Often an instructor mini-lecture follows a clicker question, either to clarify the concept, or extend it. This type of just-in-time lecturing is very different from traditional lecturing in two ways: 1) it is short, and 2) its purpose is not to introduce a new topic, but rather to clarify a topic that students have already partially discovered for themsleves. For both these reasons students find such lectures satisfying and easy to follow, and instructor impact is maximized by being able to cut direclty to the heart of the topic of the lecture.
- In many instances students are invited to put their own work on the screen for discussion. This can be accomplished by handing a group a blank piece of overhead projetor film and a overhead marker. This works best when the student answer is voted on using clickers. The response choices I use for such questions are as follows: A) No Errors, B) One small error, C) Two small errors, D) At least one major error, or several small errors, E) Not Sure, F) Need more time. (See note on "grading clicker questions" for an explnation of the Not Sure and Need More Time options.)
- Typically, this cycle (group work…clicker question…mini-lecture) can repeat twice in a 50 minute classperiod, but longer periods with longer group work or more cycles work even better.

- If there is time, I ask students groups to assess their group's performance. Though it can be hard to collect recorders reports in a large class, a clicker question can be used to collect and tabulate some information.
- The class ends on time. If the room is unoccupied after your class, invite student groups to stick around and complete the activity. When this is an option, I schedule an office hour for after class and hold it in the classroom or in the hall outside class (if the classroom is not available).

Note on Volunteer Undergrad Assitants

The group work in a POGIL classroom gets many students excited about teaching. Each year, I select several students from the top of the class to serve in the following year as co-facilitators. Even though I offer no pay nor credit, each year there are 20 applications for each spot, and I am able to choose from among the very best. In terms of content knowledge and interpersonal skills, these students far exceed the abilities of typical graduate student teaching assistants. An added benefit of this program is the development of the undergrad assistants themselves. I have observed that each assistant makes a quantum leap forward in terms of content knowledge, confidence, and interpersonal communication skills. All aspects of this program, but espeically its zero-cost, are appealing to large institutions.

Note on Clickers

Electronic response devices, or "clickers" (like those used to "poll the audience" on Who Wants to Be a Millionaire), are becoming more and more eubiquitous in large lecture courses. However, their use in these contexts is essentially to wake up students. Since students in a tradtional lecture courses do very little actual synthesis of ideas during class, it is impossible to expect lecture students to, during class, answer a concpetual question over the previous ten minutes of lecture. In contrast, POGIL students are developing conceptual understanding in real time, and so I can ask them to answer deeper conceptual questions using their clickers. New advances in clicker technology have allowed development of a new class of non-multiple choice, but computer scored clicker questions.

Note on Scoring Clicker Questions

Each clicker question has, as the last two options, "Not Sure" and "Need More Time." I tell students that they get full credit for the correct answer, 80% credit for any incorrect answer, and 90% credit for choosing "Not Sure" and "Need More Time." The purpose of this is to discourage guessing and get useful feedback. I beg them not to guess, and tell them I am actually paying them an extra 10% not to guess. Unfortunately, some students still simply submit the same answer as the person in the group who they perceive as being strongest.

Sample Syllabus (for Organic Chemistry)

Instructor:

Professor Andrei Straumanis
e-mail: Andrei2@u.washington.edu
Mailbox: Bagley
Office Location: CHB 404J
Office Hours: Wednesday and Friday, 3:20-4:30, ARC 147

Course Website: http://faculty.washington.edu/andrei2
Links to the syllabus, seating charts, discussion board (Go Post), quiz and exam keys, and clicker presentations (posted after the class in which they were used).

Emailing the Professor: Please use CHEM 238 as the subject line in any correspondence. Only email the professor directly if you have a question that is personal in nature. All other questions should be sent via the Go Post. (Otherwise I end up answering the same question multiple times.) If you email me and I don't respond, try the Go Post since this usually gets a much faster response.

Required Text: Organic Chemistry: A Guided Inquiry, *2nd Edition*, Straumanis, Houghton Mifflin. (The Solutions Manual for the homework Exercises found in Organic Chemistry: A Guided Inquiry, *2e* is not required, but is available in the bookstore. Only the first three activities are posted on the course website.)

Required Equipment: Turning Technologies Rf response card. (This is the UW sanctioned clicker that is used in GenChem, Biology and other UW courses). **Bring your clicker to class every day!!** You are responsible for keeping your clicker working. I will drop the lowest clicker quiz and the lowest participation grade so you will not be penalized the first time you forget your clicker, miss class, or your clicker does not work.

Recommended Texts: **Organic Chemistry, 7th *Edition*,** by McMurry. Brooks Cole-Cengage. *(Though the Second Edition of Organic Chemistry: A Guided Inquiry follows McMurry most closely, any standard textbook can be used as a supplement to the activities.)*

Recommended Equipment: You should have access to a molecular model set.

Grading:		
	Quiz Section Quizzes (drop lowest of 7 QSQs)	90 pts, 9%
	Clicker Quizzes (CQ) **one at the start of each lecture**	110 pts, 11%
	Clicker Participation (CP) during each lecture	25 pts, 2.5%
	Take Home Exam 1 (TH1)	25 pts, 2.5%
	Take Home Exam 2 (TH2)	50 pts, 5%
	Midterm 1 (MT1)	200 pts, 20%
	Midterm 2 (MT2)	200 pts, 20%
	Final Exam	300 pts, 30%

Notes on Quizzes and Exams: All quizzes and in-class exams will be taken individually. For exams, and on the first day of class, students will have assigned seats. The seating chart will be posted on the course website. Please know the location of your seat before coming to class. On exam days, please be able to provide the name of your TA and your quiz section.

Quiz Section Quizzes (QSQ): Seven Quiz Section Quizzes worth 15 points each. We will drop your lowest quiz score. This means you can earn a maximum of 90 points in quiz section.

Clicker Quizzes (CQ): At the start of each lecture there will be a 5 point CQ (clicker quiz) over the material covered in the previous class period. Clicker quizzes will be taken individually. Please remain quiet until time is called. Your lowest clicker quiz score will be dropped. This means you will not be penalized the first time you miss class, forget your clicker, or your clicker malfunctions. It is the students responsibility to keep their clicker in working order.

Clicker Participation (CP): After the clicker quiz and during each lecture there will be several clicker questions. Unlike the clicker quizzes, you are encouraged to work with your group to answer these clicker questions. When you have arrived at an answer you must each individually key in your response. 2.5% of your grade is determined by your answers to these clicker questions according the following scheme: full credit for a correct response, 90% credit for a response of "Not Sure" or "Need more time" and 80% credit for an incorrect response, 0% for no response.

Group Take Home Exams (TH1 & TH2): Take home exams are to be completed collectively by your group. Here are the rules.

- Take Home Exam Groups are the same as your in-class groups
- You may consult with the instructor, TAs assigned to this section, or any student in your group
- You may use any published resource (e.g. your textbook or workbook but not the notes of a person outside your group)
- You may NOT consult with or receive aid from any other person (especially TAs not assigned to our course or students outside your group).

Midterm Exams (MT1 & MT2): Each midterm will be worth 200 points and be cumulative, but focus on the most recent material.

Final Exam (FE): The cumulative final will be worth 300 points

Makeup Exams: There will be no makeup exams or rescheduled exams for any reason. In the event of an unavoidable absence, the reason for the absence must be approved preferably in advance. The proper procedure that you should adopt in such cases is as follows:
1) Personally report your absence from an hourly exam within 72 hours
2) Bring proof of your unavoidable cause such as a doctor's note, an accident report, a memorial folder, or similar documentation. The documentation must include a contact name, a telephone number, and an e-mail address.
3) If the absence is determined to be excusable, then the weight of your final exam will be increased proportionately towards calculating the course grade. If your absence does not meet the above criteria and is determined inexcusable, you will be given a zero for that exam.

Re-grades: Requests for re-grades must be submitted no later than one week from the first day exams are available for pickup. Submissions after the deadline will not be considered regardless of their merit. Your request must be made through your TA and it should include your name, the page number in which an error was made, and an explanation of the grading error. The entire exam will then be re-graded (you may lose points if your final score is lower than your original score). To minimize meaningless re-grades, only re-grades that result in a change of at least 5 points will be accepted. **A percentage of all exams will be photocopied prior to being returned to you and any exams submitted for re-grade that have been altered in any way will be given a zero.**

Academic Honesty: Please do not cheat! Cheating of any sort, including communicating during the clicker quizzes, will not be tolerated. The policy of the college on academic misconduct will be strictly enforced. This is a collaborative course, but the guidelines on when you can and cannot collaborate are clearly defined in this document.

Homework: After each class period you must do the following (though homework is not collected or graded)

- **Complete the ChemActivity if your group did not finish in class (including Exercises)**
- **Do any assigned homework problems in the text**
- **Make a list of sticking points or questions for your group, TA, or instructor**
- **Read any assigned sections in the text** (this should be your final preparation for the clicker quiz)

Preparing for the quiz will be most effective if you do it in the context of a regular and productive study group, or with a study partner. Just as you would for a successful exercise routine, it is best to set up standing weekly dates with your study partner(s). **This is the single most important thing you can do to make yourself successful in this course!!**

Group Work in Class

- The bulk of class time will be spent actively thinking, drawing structures, working with models etc. as part of a self-managed team of three or four students.
- Group work will not be graded. The purpose of group work is to learn the material, dispel misconceptions, and ask questions.

Group Membership and Team Management

- Each team may appoint a manager, or may choose to collectively ensure there is agreement on each question before moving on, that no one is going ahead or falling behind, no one dominates the discussion, and everyone feels comfortable speaking up, especially if they are frustrated, confused or behind.
- The instructor will assign the group membership for week 1 & then reshuffle group membership for week 2. (Please check the website for your assigned seat before coming to class).
- By the end of week 2 you will be asked to form your own groups, and choose a block of 3-4 seats in the classroom using the Go Post (course discussion board). These seats/groups will remain for the rest of the quarter. (If you have a conflict in your group, I am happy to help you resolve it. If this does not work, a change can be made.) The more active you are in the process of choosing a group that fit your needs, the more likely you are to be satisfied with your group and have a positive experience in this course.

Special Needs

The University of Washington is committed to providing access, equal opportunity, and reasonable accommodation in its services, programs, activities, education, and employment for individuals with disabilities. To request disability accommodations contact the Disability Services Office at least ten day in advance at: (206) 543-6450/V, (206) 543-6452/TTY, (206) 685-7264 (FAX), or dso@u.washington.edu.

Sample Schedule

Monday	Wednesday	Friday
Sept 22 *In class: do* **ChemActivity 1** ***Homework*** *(to complete before the next class*): in **Straumanis**: Exercises for CA 1 on pp. 13-14; **McMurry**: Read section 1.9; Do problems 1.42a,b **Register you clicker by going to the course website (http://faculty.washington.edu/andrei2) and clicking on the clicker registration link.**	**Sept 24** **Starting today each class will begin with a clicker quiz over the previous ChemActivity (e.g. CA 1).** *During class your group will do…* **ChemActivity 2** *Homework (to complete before Fri):* **Straumanis**: Exercises for ChemActivity 2; **McMurry:** Read sections; Do prob's	**Sept 26** *In class…* **CA 3** *Homework*: **Straumanis**: Exercises for ChemActivity 4A; **McMurry:** Read sections; Do prob's
Sept 29 *In class…* **CA 4A** *Homework*: **Straumanis**: Exercises for ChemActivity 4A; **McMurry:** Read sections; Do prob's	**Oct 1** *In class…* **CA 4B** **Straumanis**: Exercises for CA 4B; **McMurry:** Read sections 1.11-1.12; Do prob's 1.22-1.26 Seat/Group Registration Begins: When you have a group for Take Home Exam 1 click on the "group registration" link on course website	**Oct 3** *In class…***CA 4C** **Straumanis:** Exercises for CA 4C; **McMurry:** Read; Prob's Be sure to memorize the seven pK_a values listed in Table 4.6, and know that all strong acids have a very low pK_a **(assume it is close to zero)**

My view of organic chemistry:
Many students view organic chemistry as a cruel hurdle placed in their path to test their tolerance for pain. Consistent with this view, many students' main goal is to survive the course with a decent grade. I encourage you to expect more from this course for two reasons:

1. I have found that students are more successful at organic chemistry when they enjoy it, so I have worked hard to create a course that students can enjoy if they work hard.
2. Organic chemistry is an opportunity to hone skills like data analysis, problem solving, and working effectively as part of a group. If you invest the time and energy you will learn skills in this course that will make you more effective in your other courses and in whatever career you choose.

Organic chemistry is not a hurdle; it is a staircase to a new and powerful way of dealing with the world. That is why, more than any other course, admissions committees and future employers care about your grade in organic chemistry.

Advice from Past Students

I know you also care about your grade. Who better to give advice about how to be successful in this course than students who have been through it? The following are student answers to the question: What advice do you wish someone had given you at the start?

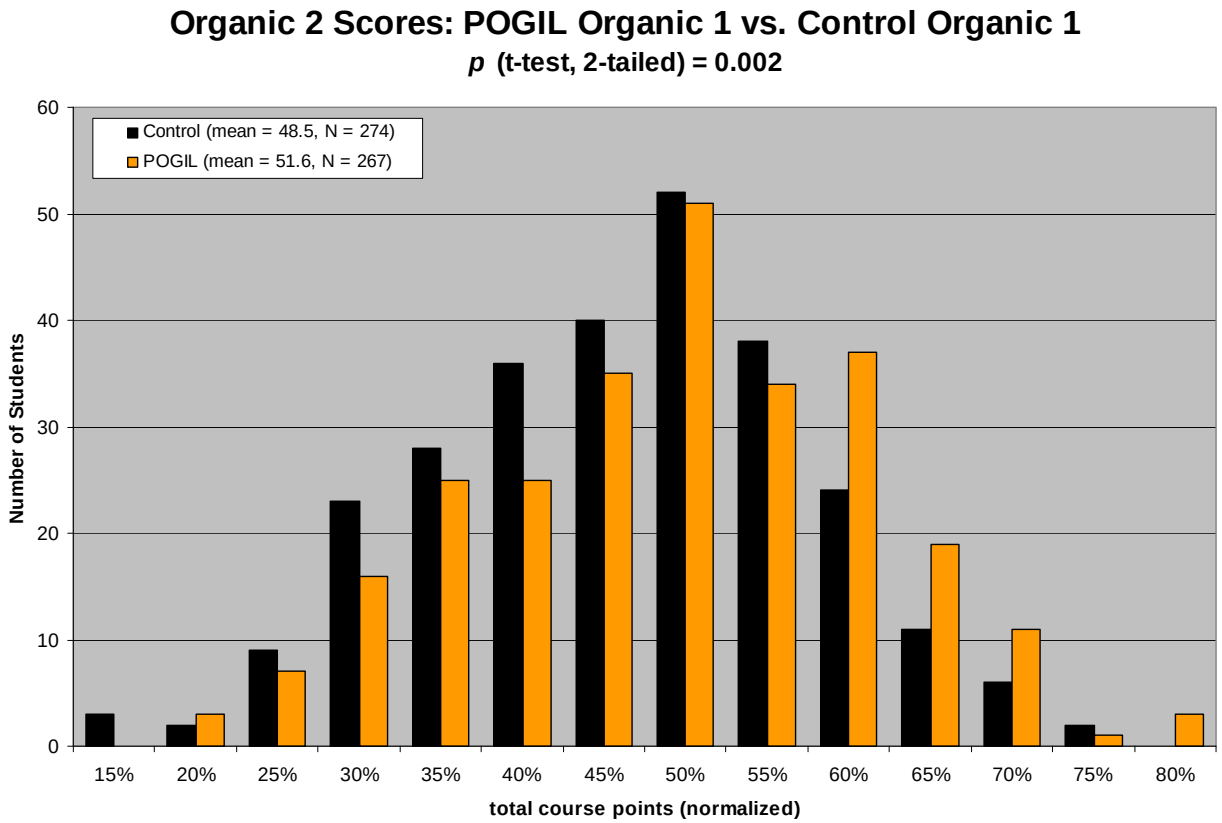
- You may think (like I did) that group work in organic chemistry is a bad idea. (I thought it would be the blind leading the blind.) But it really does work. I experienced both. I had lecture for Organic 1, and I have really enjoyed the group work in Organic 2.
- If I was starting out I would want someone to tell me that 1) there are no stupid questions and you should always ask your group because their thoughts will help, 2) get in a group with people you work well with because if you don't interact well learning is harder, and 3) use your in class study groups for studying outside of class. Good luck!

- Don't fall behind. Playing catch up is not fun. Don't be afraid to ask questions and argue in your group. That is the way learning is done in this class.
- Give yourself some time to settle into group learning. Lots of us did not think we would like it or that it would work. It does.
- I really didn't want to do group work at first because I have been successful taking notes and studying by myself. But it works. Do not hesitate to talk and meet other students in and out of class. They understand things you don't, and vice versa.
- Learn the reactions and read the textbook (McMurry).
- Working together is the most important asset you have. Teaching others is an awesome way to reinforce what you have learned.
- Don't be afraid to share your opinions with your group.
- Do the (homework) Exercises before the quiz.
- Keep up. Do the homework and go to quiz section.
- If you sit passively in your group, you don't help anyone (especially yourself).
- Find people you work well with in and out of class. It helped me to find a study partner who I could meet with twice a week outside of class.
- Do not be afraid to get involved with your group. Everyone is interested in doing well and will be very willing to help you out.
- I wish I had asked more questions and been more engaged in group discussions from the start.
- Do not let yourself feel discouraged. The teacher and your classmates can and will help you.
- Feel free to ask a question in group even if you think it is a stupid question.
- I was intimidated at first. Don't be afraid to ask questions.
- This format is much more fun and less intimidating than a lecture.
- You actually learn in class. In my lecture classes it was always about going home and trying to figure it out later.
- This method helped me learn more and remember more than I thought possible.
- Don't be afraid to express your misconceptions from gen chem. We all have them.
- Make note cards.
- Get to know your group.
- It seems strange at first, but get to know your classmates. The faster you meet people and become comfortable the better the class will be.
- Finish each activity before the quiz. Meet with your group outside of class.
- Don't sit quietly in your group. The more you talk about organic chemistry the more you will understand.
- Find a study group ASAP and meet regularly every week. I wish I had done this sooner.
- At the start, I didn't think I would like it. I usually like to work and study individually. But I really liked the group work.
- If you think you are right, speak up to your group. You might be, but in any case your whole group will learn from it.
- I wish I had started with a more positive attitude, and that I had got to know more people at the start who I could study with outside of class.
- Get comfortable with your group as soon as possible and do not be afraid or embarrassed to ask questions of them.
- Finish the exercises each time.
- I loved the way this class was taught. It really helped me learn the material in a way that would make it stay with me. If I had been in a lecture section I wouldn't have done so well.
- Come to class expecting to learn a new concept, not just scribbling notes for an hour and a quarter.
- Set aside a little time to study organic every day. If you do this you will not be so overwhelmed come exam time.
- Don't be afraid to ask questions. Everyone is in the same position as you.
- I liked the idea of group work, but was afraid it would not prepare me for the final exam. My advice to future students: Don't worry. Fall into the format and it will carry you through.
- Don't let yourself take the course lightly just because class is fun and relaxed. Do the homework and reading.

Does POGIL Work?

Student achievement data regarding POGIL versus lecture has been collected from a wide range of settings, but the conclusions of each study are nearly identical.[14] In each, achievement was at least as high in the POGIL section as in the lecture section. In a representative study, students in both a lecture course and a POGIL course were given the same standardized final exam (ACS first semester organic exam, or two-semester organic exam), to which neither professor had access. POGIL students did significantly better ($p < 0.005$) in both cases. In a just completed study[15] of 750 students enrolled in Organic 1 at a large research university (half in a POGIL section, half in a lecture section), students in both cohorts were given the same final exam questions prepared by the lecture section instructor. POGIL students did as well on the exam, and significantly better in Organic 2. (The Organic 2 sections were taught by professors not involved in either the lecture or POGIL Organic 1 courses, and the POGIL and lecture cohorts were equivalent based on all available independent variables.)

A graph showing Organic 2 course points by Organic 1 teaching method is shown below. It can be useful to show these data to students or concerned colleagues. The primary message is not "POGIL works better" but rather, there is no evidence that POGIL harms student learning. Beyond this, it is best to allow others to draw their own conclusions, hopefully based on first hand experience in a workshop or observing a POGIL class.



[14] Straumanis, A.; Simons, E.A.; "A Multi-Institutional Assessment of the Use of POGIL in Organic Chemistry" in Process-Oriented Guided Inquiry Learning; Moog, R.S.; Spencer, J.N., eds., American Chemical Society Symposium Series, American Chemical Society, Washington, DC, 2008.
[15] Straumanis, A. *unpublished results.*

Do Students Like POGIL?

In all of these comparison studies, students were asked which they like better: POGIL or lecture. In every setting, less than 10% of POGIL students say they prefer lecture over POGIL; with the vast majority being highly positive about POGIL.[9]

Motivating Students to Work Smarter (and Harder)

Some traditional instructors think their job is to simply be a content expert, and that students should motivate and direct themselves. This kind of thinking has led to enormous self-selection for success, and homogeneity in our field. I actually think that the opposite is the case. The most important job of a teacher is to motivate and direct students—to teach them HOW to learn. The content is just a medium for building learning and thinking skills.

There are a number of things I tell students to motivate them and help them get off to good start. I find that such speeches are ignored until students receive some negative quiz or exam scores. The following are two emails I send out, the first one after the first week, the second after the first exam.

Encouragement email sent after first week

Subject: Crunch time is NOW

Many students think of the END of the quarter as crunch time, the time when you make up for missed opportunities, missed classes, and other shortcomings by studying all night.

ORGANIC CHEMISTRY DOESN'T WORK LIKE THAT.

No amount of catch up work makes up for not building a good foundation of understanding in the first weeks of the course. Now is crunch time.

This is the week when it is determined who will do well in this course and who will not. YOU DECIDE, NOT ME. If you fall behind now, or do not catch up quick...it will be much more difficult later. The concepts we have explored so far and will be exploring in the coming weeks are woven through every activity, quiz and exam question in this course. Setting up a good approach this week will pay out rewards for the whole year-long course. And don't do it alone. Do the networking required to find a good study partner. Research on learning consistently shows that students who are isolated are much more likely to fail.

With that said, do not give up hope if you got low quiz scores this week. Do not conclude: "I got low scores because I'm no good at organic chemistry." Instead, TAKE ACTION.

This is what a low quiz score should say to you..."MY PREPARATION FOR THE QUIZ WAS INADEQUATE. I HAVE SOME CATCH UP WORK TO DO IN ADDITION TO PREPARING FOR THE NEXT QUIZ."

Right now your focus should be on finding a study partner or group mates with whom you enjoy working.

Encouragement email sent after first exam

Subject: Top 10

Top 10 Ways to Improve Your Performance in This Class (Much of this advice also applies to other classes):

10) Research on learning consistently shows that students who are isolated are much more likely to fail. Find a study partner who you like and set up regular (2-3 times a week) meetings outside of class. If the folks in your group don't want to do this, set something up with someone outside your group.

9) Put the Synthetic Transformations on note cards. Keep these note cards in your pocket and study them when you are standing at the corner waiting for a red light, or any other time you have a moment. Learn your note cards, then exchange note cards with your study partner to make sure you didn't miss any.

8) Go over the activity and PowerPoints after class, summarize key points in your own words in a notebook and write down anything to be memorized on note cards.

7) Arrange to meet your group before class, or stay after and work with your group after class.

6) Do your homework in a location where there are other organic students. If you have a Organic Study Skills Center do it there and pepper the TA with questions...even better...work with your study partner at the Organic Study Skills Center and ask the TA questions that the two of you can't figure out.

5) Do the homework without looking at the answer key until the end.

4) For each CTQ ask yourself "what is the purpose of this question...what am I supposed to get from this question?" If you can't answer this with confidence, ask someone what they think the purpose of the question is. Perhaps you are missing something important.

3) Read the assigned reading in the textbook (it can be hard going...1 page = 15 minutes) with a pencil in your hand (not a highlighter). Draw structures and curved arrows, do the example problems. Make sense of each sentence one word at a time as if it were a puzzle. Your goal should be to understand the activity, then check your understanding by reading the textbook. If the text reading doesn't make sense you probably missed something important.

2) Make a list of things you don't understand, and ask your study partner, TA or me about them each week.

1) Do as much of the activity as you can before class. Write your pre-answers in pencil or jot them down in the margins. When you get to class you can correct your work, discuss your answers, fill in gaps in your understanding, and answer the "meta" question..."What is the purpose of each question?"

Group Registration Instructions

Your IT department may be able to set up a better system for reserving seats in a large class, but the instructions below work surprisingly well using just a class discussion group.

FORM A GROUP

If you have already decided exactly who you are working with, go ahead and choose your seats.

One member of the group will reserve seats on behalf of all 3 (or 4) of you, so make sure you coordinate with ALL members of your group before you sign up for seats.

Warning: If you reserve a block of seats without having a complete group, these seats will be returned to the available seats pool. If a name appears in two different blocks of seats, BOTH sets of seats will be returned to the available seats pool.

INSTRUCTIONS FOR RESERVING YOUR GROUP'S SEATS

1) Go to the course website

2) Look at the seat map. Decide with your group mates where you want to sit, and find a suitable block of seats that you would like to try and reserve. Blocks of 3 are reserved exclusively for groups of 3, and blocks of 4 are reserved exclusively for groups of 4. Blocks are defined by the bold boxes on the seat map.

3) Write down the Row and Seat Number of the first seat in the block you want. (e.g. if you want the block of 4 seats on the far left of Row B, jot down "B1"). This is your group's official name--know it in case I ask for this information in future.

4) Log into the discussion group

5) Click on the "Seat Registration" discussion area

6) Use the search function to check and make sure the seat block you want is still available. (Sometimes two groups try to reserve the same seat block before I can update the seat map. This is usually only a problem in the first hour that seat registration is open.) If your block has been taken, go back to the seat map and choose another block.

7) When you have found an available block that works for your group, click on the "New Conversation" button.

8) In the Subject box, put ONLY the GROUP NAME (e.g. "B1"). Recall that your GROUP NAME is the Row and Seat# of the first seat in your block of seats.

9) In the Message box, write the names of all 3 (or 4) members of your group in the following format: lastname1 firstname1, lastname2 firstname2, lastname3 firstname3

10) Click on the Post button

11) Go back in and check to make sure another group did not post seconds before you. If they did you must go back and find an available seat block.

If you change your minds and want to change seats, DO NOT EDIT YOUR ORIGINAL POST. Instead, reply to your original post and write "Returned to available seat pool" in the body of your reply (Message Box).

Section 3a: Index of Frequently Asked Questions

(answers follow in the next section)

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Section 3b: Frequently Asked Questions (and answers)

Planning for POGIL

What is the best way to get started? Should I just jump in with two feet?

You set the culture of your classroom on the first day. You will face less student resistance if you let them know exactly when and how much group work will take place. If you don't do this, after the first lecture, expectations may be set. With that said, it is common to hear of people who switch to POGIL after coming home from a mid-semester workshop, and do fine. Others feel that the best way to get their feet wet with POGIL is to replace all or part of one lecture with a POGIL activity with a group of students you already know. The bottom line is that you will likely get less resistance if you make it clear that students do not get to choose how you teach. (You can ask them for "Strengths" and "Areas for improvement" in a mid-semester evaluation, but do not let on that you are questioning or that the structure of your course is an issue up for debate.)

What is the total time commitment of POGIL vs. lecture?

Total time commitment of doing POGIL is smaller if you consider that you do not have to write lecture notes. The first time through using a particular set of materials you should spend the time to do each activity before class. After the first year, it is similar to lecture in that you can pretty much show up to class cold.

Writing and grading a daily quiz is time consuming, but a daily quiz has great value no matter how you teach.

Of course, there is a huge time commitment associated with writing your own activities. This is why the POGIL project is devoting more and more resources to the production of high quality materials in different disciplines.

How can I possibly cover the same amount of material using POGIL as lecture?

There is strong evidence that POGIL provides at least as good coverage, and preparation as compared to traditional lecture. Understandably, most people new to POGIL say: "How can students DISCOVER material at the same rate I tell them about it." The flaw in this thinking may be obvious: telling students something does not mean they will learn it. Certainly it takes students longer to discover a concept than it takes for you to tell them about it, but when they discover it they are more likely to be able to use it going forward. This can actually make learning much more efficient later in the course. In summary, all of the following likely contribute to the fact that using POGIL, instructors *can* cover at least as much as lecture students.

- Lecture is not as effective as most teachers assume.
- Less repetition is necessary in POGIL because students get more the first time.

- Process skills developed during he course help students study and learn more effectively so students are more productive (i.e. time invested learning process skills pays off).
- POGIL students are better equipped to discover concepts outside of class, for example, you can assign activities for out of class and expect they will learn the material on their own.
- Depth is more important than breadth in an interrelated and cumulative field such as chemistry (i.e. time invested in learning concepts sows the seeds of better understanding later in the course).

What role does a traditional text play in a POGIL course?

Most people who use POGIL assign readings and homework problems from a mainstream textbook. The key difference from most lecture courses is that students are told to read the text and do the problems AFTER completing the relevant activity. Most texts are written for instructors, not novice students. (After all, who makes textbook adoption decisions?) Students with a beginning understanding of the concepts will get much more from reading the text. I tell my students that their goal should be to read the text and understand it. The activities are essentially designed to help them get there.

What textbook goes best with POGIL materials, and where can I find assignment lists?

Most POGIL materials can be used in conjunction with any textbook. Organic Chemistry: A Guided Inquiry has been used with almost every book, but the sequence follows McMurry most closely. Many instructors have posted their reading assignments to the GIorganic yahoo group (http://groups.yahoo.com). The Moog General Chemistry materials are tied to general chemistry text by Spencer, Bodner, Rickart (Wiley).

How do you deal with room and seating issues such as fixed seating?

An ideal POGIL environment has 20 students in five groups of four, each sitting at a square table with four chairs. Few people have the luxury of such a classroom. (For example, I have 400 students in a fixed-seating lecture hall with no empty seats.) Most everyone has to make some kind of accommodation to their specific environment. Here are a few examples:

- In a fixed seat lecture hall groups of three work best. Groups of four often become two groups of two.
- If your lecture hall is large enough, leave every third or forth row open so you can walk down the empty rows and field questions from above and below without squeezing past students knees and tripping on their backpacks.
- In general, encourage students to work in a way that is comfortable. In my lecture hall some students kneel on their seats to interact with group mates in the row behind. Others have preferred to come down to the front and sit on the floor.

- If you have chairs with attached side-arm desks, tell students to "circle the wagons" after the quiz. The main problem with this is that some groups are reluctant to make a circle tight enough for effective group work. They may require some encouragement to scoot close enough to hear each other and see each others papers.

Will POGIL hurt my chances of making tenure?

I would not recommend switching to POGIL in a year you are up for tenure. While many teachers do very well with POGIL in the first year, most say that things get much better in each of the first three years. It can help to tell your chair or colleagues that it might take a year or two to get back to your current levels on student evaluations etc.. This will lower expectations and give you some breathing room.

Generating Buy-in

What should I do in my first class?

Some teachers like to establish the culture of the POGIL classroom by doing a team building exercise of some sort. This could be a POGIL activity on a non-science topic, but one that is relevant to the course such as "a POGIL exploration of the syllabus" or "how to use this book". Others do an activity on a review topic from a prerequisite course. Usually, the prevailing view of students who are new to POGIL after they realize what is going to happen is the following "This is fine for review material or non-science material, but when we get to the hard stuff IT WON'T WORK—it will be the blind leading the blind!" At this point it can be useful to show data on other science classrooms or bring in students who have been through the course. Some instructors leave a former student in the room, and allow the new students to ask him or her questions without the professor in the room.

I give a five-minute mini-lecture on the effectiveness of POGIL, and launch immediately into the first activity. I find that organic chemistry students resent being asked to do anything that will not be explicitly tested for on the exam.

It gets easier and easier to generate student buy-in as a culture of POGIL is established on your campus. The reason to care about buy-in is that students who are focused on "This can't possibly work." will find that it does not. The sooner you can get students to settle into the method and get to work, the more they will learn.

How do you deal with skeptical colleagues or deans?

There is plenty of data indicating that POGIL is a responsible way to teach (i.e. POGIL students do at least as well as lecture students based on traditional assessments). It is best NOT to claim that POGIL is better than lecture for two reasons: 1) the content gains of POGIL over lecture are, in many cases, modest, and 2) "I want to use POGIL because it is better." Implies that your

colleagues SHOULD use POGIL too. This is not a palatable message for most faculty. Go easy on your colleagues. You need only convince them that there is little chance of you doing harm. Don't try to sell them on POGIL. If you collect data, don't share it unless you are really sure they can handle the comparison. Try not to project the impression that you think lecturing is ineffective, or that what you are doing is better, even if you think so.

Deans are usually more supportive than faculty who are still using traditional teaching methods. If your dean reads about teaching and learning or attends deans' conferences she is likely in touch with the recent push for active learning, discovery learning, and cooperative learning, and may even have heard about POGIL. This may make your dean your strongest supporter, though you don't want this to alienate your colleagues. Your dean may naively believe that you can "convert" your colleagues, and may put pressure on them to adopt your interactive teaching methods. This is a recipe for trouble. I recommend coaching an enthusiastic dean to give faculty the space to come around to POGIL in their own time. The most she should do is pay for a POGIL workshop and suggest faculty attend.

Do most students have past experience with non-POGIL group work?

Unfortunately, most students have had some bad experiences with forced group work in the past and so they may come into POGIL with negative expectations. Interviewing students I have found that the primary concern among stronger students is that weaker students will ride their coat-tails and get a better grade than they deserve. It helps enormously to emphasize that group work does not mean group grading (*see* topic "Group Grading"). The other key point (and this is hard for them to see at first), is that learning by teaching is a powerful force working in their favor. In fact, just as lectures are of questionable benefit to the listeners, so does the explainer gain far more than the listener in a student-student interaction. Many students come to really appreciate having a person who asks lots of questions in their group.

Why are the best students skeptical about POGIL at the start?

Fear (and past bad experiences) regarding other students riding their coattails is a factor. Most strong students had a bad experience in high school in which they did all the work for a group project, and they still resent the fact that the other group members got the same good grade.

Another common sentiment among strong students goes as follows: "I know I can be successful in the traditional format, so I don't want to risk using a different format." These fears do not really go away until after the first exam, when most strong students decide that POGIL works. The most common comment I get from strong students at the end of the course is that "POGIL saved me lots of time." When I probe deeper into this, students say that in a POGIL class they get to start doing the understanding during class, while in a traditional lecture class they have to wait to go home and start understanding the material.

I don't advertise this because it is fairly rare and sends the wrong message to the majority of students (who must do lots of work outside class), but some very confident and sophisticated

learners do not need to do much outside of class in a POGIL format since they "get it" during class, and even get to test their understanding by explaining it to their group-mates.

The bottom line is that the best students start by being most skeptical, and end up being the greatest advocates of the method. The few (3-5%) of students who hate if from start to finish and say they would prefer lecture are the weakest students who would have likely failed in any format. By doing something different from lecture I give them an opportunity to export the blame for their failure. This phenomenon decreases dramatically once the idea that "POGIL works" is established in your student population.

How do you deal with resistant students?

Surprisingly, it rarely happens that a student is resistant for more than a few days. If you sense resistance, it can be helpful to speak with the student outside of class. Listen, then ask them to temporarily suspend their doubts. Especially if you sense they are an opinion leader, open resistance can make your job harder, and can hurt student learning. Most students come around after a few class meetings. One underhanded technique is to call on such a student in class when you have looked at their worksheet and know they know the answer. Get them involved and their resistance will melt away. If someone is a really disruptive and an unproductive group member see the next question.

How deal with an unmotivated student?

Try to find a group of people who the student enjoys working with. If the student is not productive in any group, put him or her with the group that is least bothered by the distraction. If you have multiple students in this category (and you are done trying to bring them into the fold) put them together in a "crash and burn group." Amazingly, when I have done this in the past it always happens that one or two people in this group end up becoming the leader of the group. The learning opportunities afforded by this help this one student to actually succeed.

Assigning Groups

How do you form groups?

Most instructors assign groups alphabetically on the first day. Typically, instructors rotate these random assignments (weekly or biweekly) until the first exam. After the first exam some instructors generate heterogeneous groups by exam score (e.g. top student + bottom student + 2 in the middle). Others try to jigsaw personalities, or ask students who they want to work with. The sky is the limit in terms of how much you want to play around with group formation. One rule: Put quiet people together to help each of them come out of their shell. Do not mix dominant people with quiet people.

When I had small sections (less than 50) and 28 weeks with the same kids, this is the algorithm I would use to assign groups:

Random assignment on the first day. Random rotation every week for the first three weeks. In week three, I send out an email asking for confidential information on who you like to work with, who you don't like to work with, and why. I find this very helpful, but it can be hard to keep track of all their preferences. In the forth week I assign a take home, open book, group exam. To get a blank exam, they must give me an index card with 3 or 4 names on it. The rules of the exam are that they may only discuss the exam within their group. I have found such an exercise is very important for group bonding. The class after the cards are handed in, I put the students into their "chosen groups." Usually, these need some tweaking to deal with problem areas. Once I get them into a reasonably functional arrangement, I keep them there for the rest of my time with them.

Is it better to let students select their own groups, or assign them to groups?

There is some evidence that homogeneous groups lead to the most rapid adjustment to group work, and even leads to better content gains. On the other side of this ledger is the fact that "learning to work with a diverse range of people" is frequently cited as the most important process skill for success in today's world. It is up to you to balance these competing goals.

Do you consider race and gender in forming groups?

Your institution will have its own culture. Students can learn so much from mixed race and gender groups; however, if a student of any particular race or gender feels isolated, he or she is less likely to succeed. I have found that when I let students choose their own groups there is a large amount of self selection for homogeneity with respect to both race and gender.

How do you keep dominant student from dominating the group and lecturing?

Do not put a loud student with quiet students. Put quiet students together and loud students together. Make sure a loud and bright student understands that he is hurting his group mates' learning by lecturing to them or always blurting out the answers. One way to generate realization on this issue is to have students do the Exercise at the end of the IntroActivity, or to simply have groups do a self-assessment of their group dynamics.

What do you do if a group keeps talking during whole-class teacher talk?

Do not start your comments until they are quiet. Most students want to hear what you have to say. (Some even think they are going to get ANSWERS from you.) The other groups will very quickly shush the rude group.

How do language barriers or ESL issues effect a POGIL classroom?

I have found that if you let students form their own groups they will get together with students who are like themselves in every possible dimension. Students who speak the same non-English language definitely gravitate toward one another. This can help them from a content perspective; however, it may be more beneficial to an ESL student to practice speaking English. In a POGIL classroom they can do this while learning course content (e.g. chemistry).

How does POGIL affect students with learning differences: reading, ADHD, ADD, ESL?

Because POGIL is student centered, it allows students to adapt the classroom to their strengths. Students who are verbal learners can talk it out. Students who learn by listening can listen. Students who learn by reading can read…etc. We have had instances of hearing and visually impaired students and have found that the POGIL learning environment is very flexible and conducive to making accommodations.

Course Management

What is a group folder?

In most small classes, and in some large classes, each group has a folder. The group folder is used to return graded quizzes or other work at the start of class. Folders are placed on the head table, and a group representative comes and gets the folder before class begins. At the end of class, group managers may be asked to place work to be graded in the group folder before it is returned.

Do you post the answers to the in-class or homework questions?

Students will ask you to post the answers to the in-class CTQ's. Doing so can interfere with the learning of your students (as well as other people's students who find your site by searching). I tell students that most of the learning in a POGIL environment takes place while you are trying to figure out the answers to the in-class questions. This is done by talking with group mates, asking questions, listening to teacher talk, reading the textbook, and doing the homework and seeing if it makes sense. In essence, the heavy lifting in a POGIL class is FIGURING OUT IF YOUR ANSWES TO THE CTQ's ARE VALID. Just as a weightlifting coach would not lift the weights for the athletes, telling students the answers to in-class questions short-circuits learning.

Occasionally, for example before an exam, I post answers to an activity that I assigned for homework, or where significant misunderstandings continue to be a problem for students;

HOWEVER THESE ARE ALWAYS POSTED TO A SECURE SITE (e.g. Blackboard or WebCT) so that students in other classes at other institutions cannot search for and find these answers.

How do you answer the question: "How do I know if my answers are correct?"

Many students understandably ask, "How do I know if my answers to the in-class Critical Thinking Questions are correct?"

Some practical answers to this are given in the FAQ on page 2 of the workbook. Another good answer to that common question is to say…

"You do have access to the answers to the homework Exercises, so, if you don't get the homework Exercises right, there is a good chance you need to go back over the in-class CTQ's with a friend, TA, or an extra critical eye, and perhaps compile a list of specific questions for office hours."

A student may then ask "Wouldn't it be easier for us to learn the 'right' answers if you posted the right answers?"

"Of course it would be easier if my goal was simply to have you memorize the answers to the CTQs. However, the CTQs are far too easy to put on an exam. (They are designed to be your introduction to a topic). It turns out that memorizing answers to simple questions does not help you answer harder, more conceptual questions. HOWEVER, wrestling with simple questions and coming up with your own answers is a fantastic entry into a topic, and the best preparation for your further study via homework, the teacher's mini-lectures, and quiz and exam questions."

Another was of saying this is: "When a student reads a question and doesn't immediately know the answer, the tendency is to immediately look at the answer key if it's available. This hurts the learning process since most learning takes place as you try to figure out the answer to a question by talking to others, reading the textbook, revisiting the activity, etc. In summary, wrestling with the CTQs is an important part of the learning process in this class, and giving out the answers severely short circuits this process."

Why don't my students do the reading I assign in the traditional textbook?

Ironically, a big problem in a POGIL classroom is that students leave each class period understanding more than they would have after a lecture. I try to emphasize that no matter how much they feel they understood the activity during class—class is just the start. Many of them erroneously decide they are ready for the quiz because they successfully answered most of the CTQ's with their group.

I describe a progression and draw a wedge on the board. An in-class activity is the thin part of the wedge. It is designed to help them understand my summary mini-lecture at the end. The mini-lecture is to help them understand the workbook homework. The workbook homework is designed to help them do the textbook homework. The final step is to be able to read the assigned sections in the text and really understand it. Most importantly, they must be aware that IF AT ANY STAGE

THEY DON'T UNDERSTAND (e.g. my mini-lecture, homework, textbook reading) IT MEANS THEY DIDN'T FULLY UNDERSTAND THE ORIGINAL ACTIVITY--and they must go back and figure it out.

Many students who are used to cramming before the exam, or just memorizing copies amounts of algorithms and practice problems need help building more appropriate and useful process skills. In other words, they need help changing their approach to my course.

How do I help students build process skills that will help them in my course?

There are a number of techniques described elsewhere in this guide that can help build process skills. The most important of these are:

- The daily quiz helps combat cramming.
- Take home group exams help build group dynamics. At least one, early in the semester, ensures that they have each other's cell numbers and that they have met outside class.
- Self-assessments (*see* entry on SII) can be fun, illustrative, and lead to more functional groups.
- Putting more of your time into role management may lead to more balanced participation within groups.
- Incorporate student critique of student answers into whole-class discussions. Having students present their work (verbally or by writing it on the board or overhead), and critique it builds an array of skills.

Exams and Grading

How do you evaluate students? What are POGIL tests like?

The short answer is that many people switch to POGIL and continue using essentially the same exams. This may not make sense if your exams are more about memorization than concepts. Ask yourself "If I was a student, what would be the most efficient way to prepare for this exam?" If the answer is to memorize, then you students will memorize (despite efforts to get them to work toward conceptual understanding). POGIL encourages conceptual learning, but you will send a mixed message if you give them non-conceptual exams. Compared to, for example, the ACS exam I give harder questions, but fewer of them. I find my students spend time working out mechanisms and deriving answers, where students in lecture classes memorize more algorithms, mechanisms and sample problems.

It can be fun to give activity-like exams: questions that lead students toward understanding of a new but related concept. In Organic 1 I sometimes give them questions on Organic 2 material that

they have not seen yet, but is an extension of what they have learned. This encourages them to really think rather than remember.

Are there inquiry or conceptual tests available for organic chemistry?

There is a conceptual ACS test for general chemistry, but not currently for organic. There are concept inventories for various fields including physics. The difference between a conceptual exam and a concept inventory is that the former asks students questions that cannot be answered using simple algorithms or memorization alone. Whether a question is conceptual for a given student depends on what practice problems he or she has encountered, analyzed or memorized. The latter is purposely designed to root out common misconceptions, and is generally used as formative assessment (to help students correct their misconceptions), not summative assessments (to help determine a grade).

Is there evidence for longer term retention or better performance in subsequent courses?

Yes. A study that is currently underway in a large, top-ten R1 chemistry department found that students who had a POGIL Organic 1 course did significantly better in Organic 2 than students who had lecture for Organic 1. (The cohorts were otherwise comparable. The Organic 2 professors lectured exclusively and were not involved in any way in the Organic 1 courses.)

Do minority students do better in POGIL classes?

There is evidence that minority students do better in POGIL classrooms than in lecture classrooms, but no evidence for a differential advantage for minority students. That is, a rising tide lifts all boats. One hypothesis is that some of the barriers that minority students face in the sciences are attenuated in the structured group-work setting of a POGIL classroom. In short, when students who hold stereotypes of one another get a chance to work together in class there is a chance that they will eventually put their stereotypes aside and begin to see each other as two students working toward the same goal.

Why do my students seem to have so many misconceptions?

POGIL instructors get to see what their students know and don't know. After lecturing for years, and assuming that certain concepts are straightforward, some instructors are surprised at what their students think, especially about concepts that were covered in prerequisite classes. There are two factors that likely explain this: 1) Students no longer have the opportunity to parrot back what you have said during lecture, and 2) you get to watch them struggle with concepts and grow their understanding through some very sensitive (and even ugly) stages – their initial conclusions and the misconceptions carried from prior classes can be fascinating and unexpected. This combination can be discouraging for professors who are used to students getting the right answers on questions

that mirror lecture. With that said, there are certainly students who struggle. (*See* the entry "How do I help students build process skills that will help them in my course?")

What is your grading scheme?

My syllabus (available at www.pogil.org/straumanis) lays out my grading scheme in detail, but the basic breakdown is as follows:

- Two mid-term exams (40%)
- Final Exam (30%)
- Quizzes (25%)

(The above are all taken individually, with no chance for help from group mates)

- Two take-home exams (5%)

Do you use group grading?

At the start of the course I am careful to emphasize that "GROUP WORK DOES NOT MEAN GROUP GRADING." As the grading scheme above indicates, only 5% of the grade is at all linked to group work. For the stronger students this calms their fears that weaker students will pass the course by riding on their coattails. Interestingly, every year there is at least one weak student who fails the class and comes to me afterwards with the following logic: "I got a 90% on both take home exams. How could I have failed the course?!" My thought (though not my response) is that a student who does not understand weighted averages may also have difficulty with many course concepts.

What are the pitfalls of having students grade or evaluate each other?

Be very careful asking students to evaluate one another. In the past, I have sometimes had them trade papers and grade each others quizzes. This is a very valuable learning experience for them, both with respect to content, and insight into my job as their evaluator. With that said, there can be strong resentment among students on a number of levels from "We are doing your job for you." to issues of subjectivity in grading. When I have done this I am very careful to write questions that respond well to all or nothing grading for each part, or what I call "journal grading." Journal grading simply means that each answer is worth up to 3 points using a rubric similar to the one used to determine the publishablity of a journal article: 3 = no changes needed, 2 = acceptable with the correction of 1-2 minor errors, 1 = not acceptable (many small or some large errors), and 0 = nothing correct.

Another area where you may be tempted to have students evaluate each other is group participation. Here is one system I have used (though I found student resistance to outweigh the

benefits for my student population): after some period of group work, have each group member distribute 9 points among the other three group members (for a group of 4). The only rule is that each person cannot give any two students the same number of points, and each score must be a whole number. This means a student will usually assign 4, 3, and 2 points to the strongest, middle, and weakest group members; but could choose 5,3,1; 6,2,1; 8,1,0; etc. (but cannot give 3,3,3; or 4,4,1; etc.).

Though the score each person gives is anonymous, a student can still read much into receiving a low or high summed score. That is, if your total from your three group mates is below 4 you know you have not contributed enough in the view of all three group mates.

One nice feature of this system (that is not against the rules) is that student groups with real trust in one another can (and do) collude so that every person receives exactly nine points total. Though this appears to circumvent the rules encouraging differentiation, I think it is indicative of other good things going on in the group, so I allow it, but do not suggest it. (They have to come up with it on their own.)

Assessment and Improvement

What is an SII?

It is an assessment tool that many POGIL instructors use to improve their classroom environments, and help students build self-assessment skills. It is a simple tool that will grow in utility as students get better as using it. It consists of three questions (usually on a worksheet with plenty of white space to write).

1. Describe at least one STRENGTH of _____ (the topic), and explain WHY it is a strength?
2. Describe at least one area for IMPROVEMENT of _____, and if possible, suggest a WAY it could be improved.
3. Write down any INSIGHTS you have had recently about this topic.

One challenge of an SII is to get participants (e.g. students) focused on the same topic. For example, at the end of a class, you might ask them to do an SII on their group dynamics. Some may talk about how their group was fun, but got off task frequently. But others may asses the value of POGIL in general, or talk about how much they hate the subject (organic chemistry). The key is to focus them on a clearly defined subject and write this on the board, or on the worksheet.

Another area where SII's often can be improved is in the "explain why" for strengths, and in the "suggest a way" for improvements. The stronger the answers to these follow up questions, the more useful the SII. For example, if you are doing an SII on the POGIL teaching method, students should do more than just list things like: "Explaining things to others." They should follow that up with why this is a strength of POGIL (e.g. "because I learn better when I have to explain something to another").

Some common SII topics are:

- My contribution to my group
- Our group interactions
- Our group's learning
- The instructor
- This class (in general)
- The POGIL teaching method (or "group learning method")
- The activity worksheets
- The traditional textbook
- An exam, review session, TA recitation, clicker questions, take home exams, or any other feature of the course

Do be aware that students can easily reach assessment overload. They are stressed about their grade, and most of them do not realize that self-assessments are very relevant to improving their performance in the class. The more you can build awareness of this relevance, the more they will tolerate SII assessments.

How can I determine if POGIL is working in my classroom?

Most instructors assess their own teaching using student opinion surveys (end of course evaluations) and their own gut feelings about how things are going in their classroom. Certainly, this is the norm among faculty who use traditional teaching methods. If you want a more objective measure there are a number of options. Most people find common exam data to be most convincing. If your department has several sections of your course, give POGIL and lecture sections the same exam. The data is most valid if the exam was written by a third party. If this is impossible, a collaborative exam can make sense. On several occasions my only option was the give the lecture professor's exam. (In this case, there will be an obvious bias toward the lecture students that is difficult to account for; but for similar reasons, it is of little value for the POGIL professor to write a common exam.)

In terms of administration and grading of the exam, it is best if students take the exam on the same day, and all parties involved grade it collaboratively and blindly. Multiple choice exams such as the ACS exam remove possible grading bias. With an exam written by a third party (e.g. ACS exams) both instructors should agree in advance not to look at the exam questions to avoid teaching to the test.

If you want to collect other types of data there are a multitude of instruments that purport to measure everything from cognitive ability to attitudes toward science. Many of these are pre-post type tests, but any claims of POGIL's advantages over lecture would require collecting control data from a willing lecture professor's section.

What should I do with data that I collect in my classroom?

If you want to share your data in any official capacity it is very likely that your institution requires you get Human Subject Review Board (or Institutional Review Board – IRB) approval BEFORE you begin collecting data. This can be a very simple process at most institutions if you plan to analyze data that you might normally collect as part of your course (e.g. student opinion surveys and exam scores). Most IRBs will give you exempt status to analyze and share such data over a multi-year range for all your classes as long as your reporting protects privacy. Contact your IRB officer for more information and ask about the process for applying for exempt status.

The POGIL Project can give you specific advice on how and where to publish it. It is very helpful to others considering this approach to hear about your experience. Data that is not publishable as chemical education research often makes an excellent talk at a regional or national meeting. There is usually a POGIL symposium at every national ACS meeting. These types of talks are very popular even if you do not have advanced statistics, or a huge sample size. It is best to have a conversation with a education researcher before you begin to collect data. We may help you avoid some common pitfalls.

Can I visit a classroom where POGIL is being used?

The POGIL project has money to send you to a site where POGIL is happening. This can be the most valuable thing you can do prior to implementing or to solve problems you are having in your implementation.

Why spend so much energy improving students' process skills? *(Isn't my job to teach chemistry?)*

A POGIL class is as much about critical thinking, problem solving and group work as it is about the content (e.g. organic chemistry). In today's world, you cannot be a successful scientist or other professional without these skills. In fact, these skills are much more generally applicable than the course content you are learning. Alums from POGIL classes report that the process skills they learned helped them get into and succeed at jobs, grad/med school etc. As an aside, a common comment is that POGIL is a great thing to talk about in a job or grad school interview. It is new enough that many interviewers have never heard of it, and it fits well with the big push at many institutions for creative problem solvers who work well as part of a team.

How can I track development of process skills?

We have tracked students' perceptions of their development with respect to process skills. These data suggest that POGIL students have significantly greater gains than traditional students. This is not surprising with respect to group work, team management, etc. since lecture courses do not attempt to address these issues. But we also see greater gains in problem solving, critical thinking, information processing and metacognitive skills.

How do I improve on a bad first experience using POGIL?

When someone says they had a really bad first year using POGIL, it usually turns out that there are several vocal and negative students complained during and after class, and the instructor experienced a drop in end of year course evaluation scores (student opinion scores).

Note that complaints to the chair and student grumbling in the first week is totally normal for any POGIL class, and is expected the first time POGIL is used for a given course. No action is required for this; however, in a course in which at least half the class never comes around to embrace POGIL drastic changes may be warranted.

It is true that the temperament of individual sections can be swayed by a small core of vocal students. While this is a contributing factor in every "bad semester" you should not let yourself off the hook that easily. There is always room for improving your teaching, especially after the first year of using POGIL.

When I first began using POGIL I had several really good semesters, then, unexpectedly, I had a poor semester with more negative feedback than usual. In the end, I ended up attributing it to a larger than usual group of negative students who were able to poison the waters; but it also may be that I become overconfident. Subsequently, I have been careful to do a few things that help me improve my teaching, promote buy-in and help with end-of-course evaluations. Some of these things work regardless of your teaching method.

1) No sarcasm, jokes, etc., especially about sex, sexual orientation, religion, or politics. When you are sticking your neck out by doing something new, it does not help to make yourself a target in other ways.

2) Be nice. Some people think you have to scare students to motivate them. I try to figure out what they want to hear and give them as much of it as I can. For example, I say things like "My tests are designed to give you an opportunity to show me what you know." I don't really know what that means, but I remember that I liked hearing it when I was a student.

3) Do an anonymous midterm evaluation in which you ask them for at least one "strength" of the course and one "area for improvement." Then (this is important!) come in the next class having at least skimmed them all and make some obvious and visible changes based on their suggestions. Usually there are some good suggestions, and it is easy to wholeheartedly make a change or two. (More lecture, less lecture, harder quizzes, easier quizzes, a review session, posting something online, etc.) But even if there are no good suggestions, pick some popular suggestion and at least make a move in that direction. It is the sentiment that counts. It makes them feel like you are on their team and listening.

In this same vein, I do not hide the fact that POGIL is still not widely used, and is a work in progress that can benefit from suggestions and improvements. This gets them more interested and invested in the process.

4) At the start of each class, I say the words..."I am going to lecture now, so please take out your notebooks if you like, however, these slides will be posted online after class." Hearing this

repeatedly makes it harder for them to say on the end of course evaluations "lecture more" or "He doesn't lecture."

5) Most importantly, don't take it (too) personally if you get some negative reviews. This teaching method can be like a target on your chest. Students get frustrated in organic chemistry. That is a timeless fact. Some small percentage of students will always blame me and/or POGIL for their frustration and lack of success. Some students (or their parents) will go straight to your chair or dean. This is not fun and seems personal and vindictive, but, in their defense, it makes lots of sense: A disgruntled student in a lecture class has no reason to complain, and no expectation that anything would change if they did complain. A disgruntled student in a POGIL class has an easy explanation for their failure: "If you would have lectured I would have done so much better!"

Classroom Facilitation

Do you miss your role as Sage on the Stage?

No. Though I do not talk the whole time, the talking I do is much more satisfying. In my large classes I am at the lectern about 25% of the time, but not for more than 5 minutes at a time. And when I am not talking to the whole class, I am walking around the room telling stories, giving analogies, or otherwise participating in discussions with individual student groups. Many of us became professors because we like to explain, profess, and otherwise share our love and understanding of our chosen topic. You don't give that up by using POGIL. In fact, I find it far more satisfying to deliver a 5-minute mini-lecture and see heads nodding in agreement (instead of nodding to sleep), and see eyes blazing (instead of glazing).

How do you deal with fast vs. slow groups?

There are a number of facilitation techniques to deal with the diversity of group work rates.

- Slow groups are often slowed by one or two students who like to work slowly and think hard about every question. Ask the slow students to do the activity beforehand. After trying this once, they will find it self-evident that this strategy allows them to get so much more out of group discussion and teacher talk.
- Groups that go really fast often miss the point of some key questions. It can help to simply point this out.
- A group of very bright and confident students may work quickly through an activity and get everything they are supposed to get from it.
    - It can be fun to give this group an auxiliary question of a more challenging nature.
    - Alternatively, get the group to stand up and walk around as co-facilitators, checking the conclusions of other groups.

What do you do when you see a student write a wrong answer to an in-class question?

A student will learn more if they find their own error and correct it with the minimum instructor intervention. I have used several different techniques to coax students toward understanding.

- Simply having one student in the group read the question out loud can help the group see an error of interpretation.
- Often one student in a group will have a correct answer. Rather than pointing this out, simply point out that there is a difference of opinion within the group. (It is up to you if you tell them that one group member is more right.)
- If a whole group is wrong, a great technique is to have one member of the wrong group switch chairs (temporarily) with a member from a correct group, not telling them which group is wrong and which is right.
- If a large number of groups are off target on a question you should lead a whole class discussion. One good format is to have a representative from several (or all) groups put their answer on the board. (If you have limited board space you can pass out blank overhead sheets and overhead pens.) Voting usually reveals the strongest answer, and can lead into a useful discussion of why the wrong answers are wrong.

What do you do in the last 5-10 minutes of class?

Many teachers use this time in the first week to have the reflectors report out to the class. This helps them work through group dynamics that might hinder them going forward. There is an exercise on being a good group mate in the Exercises section of the IntroActivity in OC:AGI.

Others facilitate a whole-class content summation at the end of each class. This can be presented wholly by the instructor or (even better) by students. The more challenging the material, the more important it is to have a content summary at the end.

What is a Recorder's Notebook, and how is it used?

Especially if you don't have time for a content summary at the end of class, it can be useful to require students or groups keep a "recorders notebook." In this, students write down the two or three most important concepts from the activity. You can check these during the quiz in the next class. If you have too many students to check all groups, just spot-check and give them credit or no-credit for having them done. (Don't grade them, use them as formative assessments).

What if students don't finish the activity in class?

Most activities in Organic Chemistry: A Guided Inquiry are too long to finish in a 50 minute class period. You must make it clear to students that it is on them to finish outside of class, either on

their own, or as a group. It sometimes helps to cover some of the unfinished material in a mini-lecture at the end of class to get them started and give them confidence going forward.

If you choose to let them finish in the next class, you will cause students to work more slowly in future. There has to be some negative consequences of their not finishing the activity or they will attempt to slow you down and reduce their content responsibilities. Set clear expectations in terms of content and stick to them. This will cause students to put more effort into managing clas time effectively, or to attempt the activity before class (as described below).

How do you get students to pace themselves to finish the activity on time?

As stated in the previous entry, clear expectations will help students manage time and meet your expectations. One very helpful technique for making expectations even more explicit is to break the activity into chunks and give students a specific amount of time to complete that chunk. For example, after your introduction, you can begin class by writing on the board "You have 15 minutes to complete questions 1-6." This gives groups a smaller chunk of time to manage. Hopefully the manager of a group that is still on Question 1 after 10 minutes will say "We have to get moving." This technique is very useful for conveying to students that you expect a certain block of questions to be easy or review. For example, you could write "You have 5 minutes to answer questions 1-5." In OC:AGI, questions that do not require deep analysis and can be pulled directly from the model are marked with an "E" for Exploration. Nevertheless, students sometimes get stuck contemplating them as if they are being asked for some deeper meaning.

Using a clicker question to back up timing guidelines is particularly effective (see section on clickers).

Should I ask students to attempt the activity before class?

It depends on the length of your class. With 50 minute classes, I expect my students to do the first page or two of each activity BEFORE class. Perhaps a better questions is: "Will they do this if I ask them to?" The answer is yes even though I do not check, because it is self evident to them (once they try this) that it greatly enhances what they get out of both my comments and their group discussion. With my materials, it is the only way that most groups will finish an activity during a 50 minute class. It therefore allows them to avoid being stuck doing an activity after class, by themselves, or without my help. I also tell them that, because of the cumulative nature of the course, doing well on the quiz is often helped by doing the next activity.

What should I do when I (the instructor) make a mistake?

First, and most importantly, don't feel bad. It happens to all of us. The experience of thinking on your feet is very different from lecturing. Students will point out legitimate inconsistencies in the field that you have never noticed. They will also make reasonable sounding arguments leading to conclusions that happen not to be correct. Occasionally, I get confused by one of these and end up confirming an incorrect conclusion or making an incorrect statement that leads students astray.

The climate of your classroom, and the scope of the error should determine how you handle unwinding the error, but the general rules is that less is more when correcting an error. That is, keep the correction simple. The only exception to this is if your error directly effects an upcoming exam or quiz question. In such cases you need to stop and explain everything to everyone.

Usually errors involve advanced concepts, and it may be that only a handful of students would understand a complete explanation if you made one. This is why I often let such errors go, or address them after class with the few students who are interested and directly affected.

Particularly if you are new to POGIL or new to a group of students you do not want to erode trust by carefully detailing the logic of some esoteric error you made. There is a strong temptation to do this, but you should spare them because they may get the wrong message. The result will be to confuse them into thinking this concept is really important (since you are giving it extra special attention). At the same time you will be eroding some of their faith in you as a coach and leader. I'm not saying you should hide your error, but usually there is no need to make a full and public confession about it.

When in doubt, defer the issue to the next class so you have some time to discuss it with colleagues (or the GIorganic yahoo group), and decide if you need to say something to resolve the issue.

How do you answer a group's question in a POGIL classroom?

The most important part of answering a question is LISTENING to try and figure out where a group is really stuck.

TRY TO GET OTHER GROUP MEMBERS INVOLVED. Ask what other group members put for the question. Even ask folks in nearby groups what they put. The point of this is to show them strategies that can be used when there is no instructor available (e.g. outside of class).

It is dangerous to simply tell students the answer to a question, especially if they are not stuck and just looking for confirmation--they will quickly get "addicted" to your confirmations. One key goal for the course is for students to learn how to tell, for themselves, if they are right or wrong.

How do you answer the question "Is this right."

At the start of a POGIL course, especially, students will ask you the question "Is this right."

Don't be abrupt and say "I can't answer that." Instead, ask them to explain their answer, or why they think they are right or wrong. No matter what they ask you, encourage them to talk about what they know and don't know. This usually helps you hone in on some misconception or bad assumption. Once you figure out where they went wrong, try to give them the minimum amount of help required to get them unstuck. Learning is quite like weight lifting...the more "work" they do themselves, the more they learn. The most important part of teaching is listening.

If you think they misread the question tell them this and have one group member read the question out loud. Sometimes, I point out a particular word of phrase to help them hone in on their error.

If often helps to read the next question. Suggest this if you think it will help them. You can also give them hints and encouragement (like "you guys are really close to the answer, think about which carbocation is more likely to form"). When they are on the right track I try to let them know.

With that said, if you are short for time, or the group seems really frustrated, you always have the option of simply telling them the answer, or at least telling them where they went wrong. If a group becomes so frustrated that they disengage, this can have long term and systemic implications that far outweigh damage to their confidence that you might cause by giving them an answer now and then.

How do you get the whole group involved when a question clearly belongs to only one person?

If you are using formal roles, and enforcing that only the manager can ask a question, this only comes up when it is the manager's question. I do not use formal roles in my large classes, so when I approach a student with their hand up, I often ask who is in their group (because it's not obvious in a filled lecture hall), then point to another student in the group and say "Do you know what her question is?" Usually the answer is no. Then I say to the original questioner "Explain your question to your group, and I will stand here and listen." (Or you can tell them you will come back in a couple minutes.) Often this allows them to figure it out for themselves, and it gets them in the habit of internally processing their questions.

How do you moderate a discussion between two students when only one of them is right?

One thing that often happens: two members of a group will be arguing about something, and one is right and the other wrong. One technique is to eye contact with the person who is right or tap them on the shoulder and give them a nod and a smile of encouragement so they know they should not give up on their position in the argument.

What do you tell a frustrated student who is demanding an answer or ready to give up?

As you get to know individual students (this is where it can really be fun), you will have a sense of how hard you can push certain individuals. If a student seems really frustrated he or she might interpret indirect help or hints as further tormenting. In such a case, feel free to tell them the answer or otherwise directly address their issues (even if this means you are doing the "work" for them). The benefits of discovery have to be balanced with the harm that occurs if a student gets so frustrated that they shut down.

Large Classes

How do you form groups in a very large class?

Some teachers of very large POGIL classes just say "Sit with people you want to work with, and work together." The advantage of this is that it requires zero management. The disadvantage is that (based on anecdotal accounts), up to half the students ignore this directive and continue to work, essentially on their own.

When the instructor puts time and effort into forming groups two things happen: 1) Forcing students into groups helps break the ice and get group work going. Simple things like a PowerPoint slide that says: "Introduce yourself to your group mates and click in the birth month of the person in your group closest to you in age." 2) When they see you putting effort into groups they see that you think it is important, so many more of them will think it is important. Many of them secretly want to work in a group, and many more of them will eventually find that working in a group is a very effective strategy for getting ahead in this class…but it sometimes take awhile to realize this.

See "Assignment of Group Membership" in Section 2 for specific suggestions.

What is the maximum class size for small class implementation of POGIL?

Small class implementation is defined as "the instructor can reasonably get to all the groups at least 3 times during each class period." This number is around 50 students (about 13 groups).

What does large-class implementation look like?

If you have more than 50 students I strongly suggest you consider using clickers. If you have more than 100, clickers will dramatically improve you sense of control and satisfaction with your course. The structure of my large class implementation is set by a PowerPoint presentation (containing clicker questions) that I run in conjunction with group work. Beta versions of my presentations for each chapter in OC:AGI are available at www.pogil.org/straumanis. Each presentation has the following structure:

3-minute clicker quiz (over previous class). Start when the bell rings to get them into seats.	Go over clicker quiz (1 minute) followed by 3-minute review of previous class	1-minute preview of upcoming class	Timing Slide which says something like: "Work with your group on ChemActivity 17A. There will be clicker question(s) covering CTQs 1-6 in 10-15 minutes."	1-3 Clicker Questions	Follow-up to clicker question with an animation, explanation, interesting wrong answers, auxiliary data, etc. (often accompanied by mini-lecture or discussion.

First 8-10 minutes of class	Repeat once for 50-minute class periods, more for longer classes.

In a class with more than 40 students, how do you respond to all the requests for help?

The best answer is to use volunteer undergrad TAs (as described in the Teaching Assistants section). I find I get much better help from my volunteer undergrad TAs than my grad TAs, and it's free! Toward the end of spring I put out an application for co-facilitators for the next fall. Often half of my best students will apply, and I have to turn interested parties away. I try to have 3-5 helpers for my class of 400 students. For a class of 50, you might have one or two helpers. The following entry tells you more about what I expect from these volunteers.

How does large class implementation differ from small class implementation?

In a lecture hall with fixed seating, groups of three work best. (Groups of four often become two pairs.) If you have enough seats it can help to put one empty seat between groups. In terms of managing group roles (this is very hard to do effectively), one strategy is to have the person in the middle be manage, and tell them to rotate this position frequently. I do not check if they are doing this, and beyond giving them the description of the manager's role (found in my syallbus), I do not manage group roles in my very large classes.

One key difference between large and small class implementation is that, instead of checking in on each group, I sample the class by checking in with a few groups. This reminds me about common problems that occurred last year, and gives me a sense of student progress. When I identify a major point of confusion, I intervene with the whole class by delivering a mini-lecture or leading a whole-class discussion. My goal is to discuss 2-3 of the key questions in the activity. The timing of these discussions is such that they occur AFTER a majority of groups have had a chance to consider that question by themselves. (My interventions usually begin with a clicker question. This gets them focused on me. If I just try to interrupt them, many students will continue working.)

Group assignment may have to be left up to the students for the most part. You can start by assigning random groups the first few class periods. This will allow students with few prior connections to meet some people. After that you may want to let them make their own groups. You may have to intervene to resolve problems. The main problem you will see is a single student who always works alone.

Clickers

Should I give credit for clicker questions?

The first clicker question of the day is always a quiz over the previous class. In my class this is worth 5 (out of 1000) points. There is no discussion allowed during this clicker quiz (though I'm sure some student groups have worked out hand signals and such). There is more about how I score this clicker quiz in the next section.

For every subsequent clicker question that same day (after the quiz) discussion is allowed and encouraged. I find that the following scoring works well (though it sounds complex, be sure to read the disclaimer at the bottom).

Each clicker question has, as the last two options, "Not Sure" and "Need More Time." I tell students that they get full credit for the correct answer, 80% credit for any incorrect answer, and 90% credit for choosing "Not Sure" and "Need More Time." The purpose of this is to discourage guessing and get useful feedback. I beg them not to guess, and tell them I am actually paying them an extra 10% not to guess.

Underlying all of this is the fact that the clicker questions (minus the quiz) are worth a total of 20 (out of 1000) points for the whole quarter. This means I am giving them 16 point for just showing up, and the difference between a kid who answer all clicker questions right and one that answers them all wrong is only 4 points (or 0.4%). Of course, they do not think about it this way, and the psychology of it works to my (and their) advantage: they don't guess, but work hard to figure out the correct answer, or at the very least ask the strongest group member what the correct answer is (and hopefully also ask why). When I am rushing them way too fast, or they really have no idea they tell me so (which is very useful for deciding what to say, and how to pace the class).

When I interview students about attendance, they often say that the clicker questions get them to come to class, and that knowing there will be a set of clicker questions at the end of class keeps them from leaving early. On one occasion I (naively) made it clear that due to technical problems there would be no clicker questions in the following class. Attendance in this subsequent class was markedly lower (though it was also a rare sunny May day here in Seattle).

If you do not want to deal with scoring tenths and hundredths of points, you can simply give students credit each day (1 point out of 1000) for showing up and clicking in on at least one question. The math will almost always work out the same to four significant figures (I have checked!), though I strongly suggest you do not tell students this is what you are doing, or some will leave after the clicker quiz each day.

How do you score clicker quizzes (the first clicker question of the day, taken individually)?

Feedback from students indicates that the clicker quiz is a critical tool for motivating students to work between classes, come to class, and be there on time. They thank me for them, but hate them all the same. When I ask students what stresses them out about the course, after exams, clicker quizzes are the number one answer. My clicker questions are quite hard, and though they are multiple-choice in nature, there are usually nine options, making guessing or other narrowing strategies ineffective. When only the correct answer garners points (and typically only half the class gets it right), students feel demoralized, and after a string of zeros, some even conclude that it is not worth it to come to class. To combat this, I make the best answer worth 5 points, the second best answer(s) worth 2-3 points. Finally (and this really reduces stress and makes them glad they came to class), I give them 1 point for just answering the clicker quiz.

How do you manage clicker quiz and clicker question data?

This can be a significant barrier to using clickers. I have developed a complex spreadsheet, but now that it is done, I can basically plug data into the template and not think about it too much. To be confident with this approach I needed to become very handy with Excel. If you teach a large class, your department likely has a person who can help you set something up. If you would like a copy of my Excel template, please feel free to contact me (straumanis@gmail.com).

Teaching Assistants

How do you train graduate TAs?

If you want TAs (who has not been through the course using POGIL) to facilitate POGIL in recitation sections it is very helpful if a POGIL-trained facilitator meets with the TAs every week and facilitates them through a "master class" in which they go through the activity(ies) for that week. This allows you to model the facilitation you would like them to do. I have found that if I do not do this (sometimes I don't have time), the TAs do not do the activity. A frustrating consequence of this is that the TAs don't know the material as well as the students. If your TAs are not required to come to class, they will often NOT do the activity on their own.

How do you recruit volunteer undergraduate TAs?

I find that a majority of my best students (though they are skeptical about POGIL at first—and rightly so since they know they could get an A if I just ran a "normal" course), become strong advocates for POGIL. Recruiting volunteer undergrad TAs to co-facilitate with me the following year is almost as easy as simply asking for volunteers. I usually get ten times too many applicants. They appear to be motivated largely by the fact that it is fun to help students learn using POGIL. They discover this within a few weeks, and they are eager to continue it as your helpers. They are also motivated by other factors: 1) the opportunity to review for the MCAT, PCAT, etc., 2) the opportunity to get mentoring from me, 3) as a general resume builder. Of course, this is hard to do the first time you teach a course at a given institution.

What are the benefits of being an undergraduate TA?

This is what I tell students:

This opportunity is great for anyone interested in teaching, but you don't have to be a future teacher to apply. Practice thinking on your feet and guiding students toward answers will improve your confidence and skill in many areas.

Interestingly, studies of peer leader programs and undergrad TAs programs conclude that the most significant benefits of the program are for the TA him/herself. TAs gain confidence both in their content knowledge and their leadership skills, communication skills, etc.

This is a good opportunity to build connections to other excellent students (your fellow TAs and students you will be helping in the course), and to be mentored by a faculty member (me!). Since I can't pay you or give you credit, I will do my best to give you advice about choices you might face in the coming year(s).

What are the responsibilities of being an undergraduate TA?

- Walk around during class and respond to student questions. (NOTICE, I DON'T SAY "ANSWER STUDENT QUESTIONS"—see below for more on this.)
- There is no grading or out of class work (other than reviewing the activity on your own before class).
- It is fine to miss a few classes, but I like to know in advance so I can make sure there is coverage.

How do you train TAs to answer questions appropriately?

I have found that the best training an undergraduate TA can get is to go through the course with me. This is so important that I recommend going without a TA the first time you teach a particular course.

Beyond taking the course, there is certainly value in providing further training. My goal is to create a system that others can implement without additional work on the part of the instructor. For this reason I consciously do not provide the undergraduate TAs in my course with any training other than being a student in my course (and doing well), and the following short email. This is what I tell my undergrad TAs in this email:

First, and most importantly, don't feel bad if you forget something, or even tell a student something wrong. It is a very complex topic, and you should expect to make a mistake now and then. Feel free to ask me questions during class, or to help you out if you are not sure how to unwind an error you have made.

Since there will be up to 5 of us in class, we will really have time to answer questions properly. The most important part of answering a question is LISTENING to try and figure out where they are really stuck.

TRY TO GET OTHER GROUP MEMBERS INVOLVED. Ask what other group members put for the question. Even ask folks in nearby groups what they put. The point of this is to show them strategies that can be used when there is no TA available, outside of class, etc.

It is dangerous to simply tell students the answer to a question, especially if they are not stuck and just looking for confirmation--they will quickly get "addicted" to your confirmations. One key goal for the course is for students to learn how to tell, for themselves, if they are right or wrong.

At the start, especially, they may ask you the question "Is this right."

Don't be abrupt and say "I can't answer that." Instead, ask them to explain their answer, or why they think they are right or wrong. No matter what they ask you, encourage them to talk about what they know and don't know. This usually helps you hone in on some misconception or bad assumption. Once you figure out where they went wrong, try to give them the minimum amount of help required to get them unstuck. Learning is quite like weight lifting...the more "work" they do themselves, the more they learn. The most important part of teaching is listening.

Here are some techniques for getting students to do the work of un-sticking themselves (i.e. without simply telling them where they are wrong). Of course, if you are short for time, or the group seems really frustrated, always feel free to tell them the answer, or tell them where they went wrong.

When I approach a student with their hand up, I often ask who is in their group, then point to another student in the group and say "Do you know what her question is?" Usually the answer is no. Then I say to the original questioner "Explain your question to your group, and I will stand here and listen." (or you can tell them you will come back in a couple minutes.) Often this allows them to figure it out for themselves, and it gets them in the habit of internally processing their questions.

If you think they misread the question tell them this and have one group member read the question out loud. Sometimes, I point out a particular word of phrase to help them hone in on their error.

If often helps to read the next question. Suggest this if you think it will help them.

Give them hints and encouragement (like "you guys are really close to the answer, think about which carbocation is more likely to form"). When they are on the right track I try to let them know.

Other Contexts

Are there POGIL materials for other courses?

There are now published materials for general chemistry, organic chemistry, biochemistry, physical chemistry, chemistry for allied health majors (GOB), and preparatory chemistry. As of this writing, there are materials in the pipeline for analytical chemistry, high school chemistry, and several others. At the time of writing we are planning a major effort to generate materials in other fields such as math, biology and physics.

Can you use POGIL with a very small class?

POGIL has been used successfully in classrooms as small as 3-5 students. Essentially, there is one group and the instructor sits at the table with the group, listening and interacting when appropriate. It must be very difficult in such situations to NOT intervene immediately when you see students making mistakes, but there is clear evidence that students learn much more from their mistakes if they are given an opportunity to correct them without instructor involvement, or with the minimum instructor help.

Can POGIL be used for distance or on-line learning?

POGIL has been used in virtual classrooms. The best of these had several different groups, but for each group the members were physically in the same location. The different groups and the instructor were in different locations, and communicated via the internet. This required technology that allowed the facilitator to draw structures for the remote student groups.

Is POGIL useful for summer courses and other long classes? How long is too long?

I have found that students can sustain effective group work for two hours without a break. I have not tried three hours without a break, but certainly this must be more palatable than a three-hour lecture. (I'm not sure how students handle three hours of organic chemistry lecture a day.)

Does POGIL do K-12 teacher training?

POGIL has a high school initiative sponsored by Toyota USA Foundation that is currently running workshops for HS teachers. Contact the POGIL office for more information.

How is POGIL implemented in Lab?

The lab is a perfect place for the scientific method, and thus for POGIL. There are few published POGIL laboratories to date, but there are a number of open source labs that are available through POGIL.org. Essentially the only difference between a classroom POGIL experience and a laboratory POGIL experience is that in the classroom data is presented in a neat and controllable form. (You can even present real data, including anomalies, but since it is pre-collected and tabulated you can control the type and magnitude of the anomalies.) Of course, this can be a huge difference since a student trying to draw a conclusion from a set of data can be thrown way off by a bad data. One thing that happens in most successful POGIL labs to combat this is to have the classroom pool all data before final analysis.

What advice do you have about writing activities?

1) Read over several Activities on topics with which you are reasonably familiar. (The first few chapters of any set of POGIL materials are a good bet.) As you are reading, try to think about structure, specifically the learning cycle (Exploration → Concept Invention → Application.

2) Choose a topic in your field and clearly identify 1-3 related concepts you would like to convey to students in the activity. Fewer is better.

2b) List course-specific prior knowledge students are expected to know to be able to complete this activity you are writing...i.e. you do not need to list "basic math" but do list "ability to identify all the bones in the hand" if this is to be covered in a prior class and is necessary knowledge for the activity you are writing.

2c) In general, it is better to assume less and provide nearly everything students need in the "Model" section of the activity.

3) Compile examples, data, etc. might be used to help students "discover" this concept. A good place to find these examples are in your old lecture notes on this topic.

4) Sketch out some leading questions that might guide students toward discovery of this concept. The questions usually follow the three stages of the learning cycle: Exploration, Concept Invention, Application

4a) It is best to start with very simple questions that direct students to the appropriate parts of the model. I mark these "exploration questions" with an (E) to let students know these are supposed to be review or directly extractable from the model.

4b) Follow up with convergent questions that have an answer that most experts would agree on, but that require students to do some synthesis (i.e. the answers cannot be simply read from the model).

4c) At the end of a learning cycle there should be at least one application question. Ideally, this question would help you or students evaluate if they "got" the main idea. (These make good clicker questions.)

5) Read the POGIL screening rubric (available at www.pogil.org) and decide if what you have created is a POGIL activity according to these criteria. The POGIL Project has a handout called "Authoring guidelines" with similar advice to above.

Misc

How did you get involved in POGIL?

When I was a student at Oberlin College I had excellent teachers, but the format was straight lecture, so it was my experiences *after* each class that shaped my contributions to what eventually became POGIL.

Every day in my organic chemistry class I wrote down everything the professor put on the board so I could figure it out later. I was lucky to have two other students in the class who were on the soccer team. On the bus going to away games we would sit in the back and work together. Home game weeks we would meet in a study room in the library. (We tried meeting in a dorm room once, but he had a TV and we ended up watching Magnum PI.)

Outside of my study group meetings, I spent half an hour per day, seven days a week in quiet study of my lecture notes. (I actually set a timer and forced myself to work until it rang without getting up because I found this part so boring.)

This is what I did during those thirty minutes. (I don't remember why I started doing this but it was very effective.) I started each time at the very beginning of my notebook, and quickly flipped through my lecture notes until I got to the newer stuff that I didn't understand yet. This quick look every day really helped me understand the fundamental stuff at the beginning. When I reached the new stuff and slowed down and started going carefully through my notes I tried to figure out the purpose of each example, asking myself "What concept or distinction is the professor trying to convey with this example?" I wrote down any questions that I had. At the same time I wrote any new reactions on note cards, making 3-4 note cards for each reaction, as described in the Exercises for ChemActivity 8 in OC:AGI.

When I met with my group, we worked through our questions, and then did the homework problems together. If we came up with a question we couldn't answer, one of us would go to the professor's office.

It struck me that many of the other successful students in the class were doing the same thing as we were, but that there were also many students who were struggling, working on their own.

Later, in graduate school at Stanford, I started developing techniques to get my students to work in groups like I had in college. After reinventing the wheel for a few years I began to read research on learning. The work of Uri Treisman and others explained why my system was effective, and gave me lots of ideas about how to improve my system.

Another important influence was a guided inquiry group theory textbook assigned for one of my graduate classes. On the first page, it started with “this is an equilateral triangle” and built smoothly from there to complex symmetry elements and point groups.

About this same time I met Rick Moog while he was visiting his former graduate research advisor (also at Stanford). He invited me to attend his talk the next day at the ACS Meeting in San Francisco. It turned out that we had been developing very similar teaching methods, both of which combined elements of group learning and guided inquiry. I found Rick was way ahead of me in terms of classroom tested guided inquiry activities that utilized the learning cycle. I was so stimulated by his 15 minute talk that as soon as he finished, my hand shot up, and I asked: “Who is writing similar activities for organic chemistry?” He looked me in the eye and said “You are.”

My teaching has changed and improved during the past 15 years, but my primary goal remains the same: to create a classroom environment that encourages as many students as possible to form groups and ask lots of questions of each other in their discovery of organic chemistry.