Process-Oriented Guided Inquiry Learning: POGIL and the POGIL Project

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Abstract
Recent research indicates that students learn best when they are actively engaged and they construct their own understanding. Process-Oriented Guided Inquiry Learning (POGIL) is a student-centered instructional philosophy based on these concepts in which students work in teams on specially prepared activities that follow a learning cycle paradigm. The POGIL Project is a professional development effort providing various types of support for undergraduate instructors interested in implementing a more student-centered approach in their classrooms.

Introduction

> Some few years ago I was looking about the school supply stores in the city...We had a great deal of difficulty finding what we needed, and finally one dealer, more intelligent than the rest, made this remark, "I am afraid we have not what you want. You want something at which the children may work; these are all for listening." That tells the story of the traditional education... It is all made 'for listening' (John Dewey 1920, 31).

Since Dewey made this observation early in the last century little has changed in the delivery of science instruction. The traditional model of teaching has been and continues to be based on textbook readings and lectures. In many of today's classrooms, there is little student-teacher interchange and almost no student-student interaction. One study has shown that about 80 percent of most classroom time is teacher talk (Christensen, Garvin, and Sweet 1991).

Lecturing is based on a series of assumptions about not only the cognitive capabilities of students but also about how students learn. This methodology assumes that all students need the same information, presented orally and at the same pace, without dialogue with the presenter, and in an impersonal way. The instructor often assumes, many times without being consciously aware of it, that students learn the same way the instructor did and that they all have similar prior knowledge. Many science faculty believe, based on their own experiences, that they are teaching effectively and students will learn if:

- The instructor covers the material using clear explanations.
- The instructor organizes the course logically, and motivates and excites the students.
- The instructor provides good resource materials.
- The students work hard, take good notes, read the text in preparation for lecture, and practice by doing a lot of problems on their own.

Given these assumptions, it is not surprising that the traditional methodology for teaching is centered on the instructor, who lectures, explains, and models problem-solving techniques. Textbook assignments provide further explanations, examples of problem solutions, and emphasize drill and practice. In this environment many students succeed by memorizing information and algorithms, but neither understand the relevant concepts nor develop essential thinking and problem-solving skills.

This paradigm for instruction is based on misconceptions that effective teaching must be instructor-centered and that content and understanding can be passed directly from the expert (professor) to the novice (student) (Johnstone 1997). Although lecturing is an efficient way to present information, it does not necessarily result in efficient learning (D. W. Johnson, R. T. Johnson, and Smith 1991; Mazur 1995; Zoller 1993). Horowitz (1988) has shown that after about ten minutes of a typical lecture, 50 percent of the class is lost. George Bodner of Purdue University, in numerous presentations, has suggested that there are three situations in which the lecture is the most effective approach for the introduction of new material: (1) when only factual information, no conceptual understanding, is involved; (2) when there is no textbook available; and (3) preaching. In general, none of these apply in the context of undergraduate science education.

Recent developments in cognitive learning theory and classroom research results suggest that students generally experience improved learning when they are actively engaged and when they are given the opportunity to construct their own knowledge (Lawson 1995, 1999). In contrast to the typical faculty assumptions mentioned above, much research indicates that most people learn best by:

- constructing their own understanding based on their prior knowledge, experiences, skills, attitudes, and beliefs;
- following a learning cycle of exploration, concept invention, and application;
- discussing and interacting with others; and
- reflecting on progress and assessing performance.

Based on research of how people learn, the "views of how effective learning proceeds have shifted from the benefits of diligent drill and practice to focus on students' understanding and application of knowledge" (Bransford, Brown, and Cocking 1999). All of these ideas form the basis for a student-centered instructional approach in which students are guided to construct their own understanding through the use of small groups while also focusing on the development of important learning skills.

What is POGIL?

Process-Oriented Guided Inquiry Learning, or POGIL, is a student-centered instructional strategy and philosophy. In a POGIL classroom or laboratory, students work in small groups on specially designed activities that follow a learning cycle paradigm. There are three key characteristics of the materials used in a POGIL learning environment:

1. They are designed for use with self-managed teams that employ the instructor as a facilitator of learning rather than as a source of information.
2. They guide students through an exploration to construct understanding.
3. They use discipline content to facilitate the development of important process skills including higher-level thinking and the ability to learn and apply knowledge in new contexts.

The goal of the POGIL approach is not only to develop content mastery through student construction of their own understanding, but also to enhance important learning skills such as information processing, oral and written communication, critical thinking, problem-solving, and metacognition and assessment. The key components of POGIL—active engagement of all students through group learning, guided inquiry materials based on the learning cycle paradigm, and a focus on process skill development—are described below.

Active Engagement and Group Learning

Being actively engaged and interacting with others is now recognized as essential for most students to gain real understanding and retention of knowledge. As described in *How People Learn* (Bransford, Brown, and Cocking 1999), a large amount of evidence now exists from all areas of science that unless individuals take an active role in what they are studying (including asking questions, engaging in dialogue and discussion, recreating ideas in their own minds, and manipulating and transforming them as needed in new contexts), the learning is not lasting and, generally, the ideas just disappear. Complementing this recognition are the results from current research on learning showing that the acquisition of knowledge and its application are fundamentally social acts (Christensen, Garvin, and Sweet 1991). Thus, the use of small groups of students, interacting with each other as they try to understand new ideas, has a basis in research on cognition and learning. This is consistent with the large and growing literature on cooperative learning and its effectiveness. Research documents that students working in learning teams learn more; understand more; remember more; feel better about themselves and others; have more positive attitudes regarding the subject area, course, and instructors; and acquire critical thinking skills, cognitive learning strategies, and other process skills that are essential to their development as independent learners. Because students work together to construct understanding, reconcile differences, and share ideas and strategies, their performance as individuals, e.g. on examinations, improves. Learning teams are particularly effective for women and other non-traditional students in science because this approach addresses the inhibiting feelings of isolation and competitiveness that many report. Recently, Cooper (2005) provided an excellent introduction to the use of small groups in the classroom and their effectiveness in science classrooms.

The Learning Cycle

The learning cycle is an inquiry strategy for teaching and learning that is based on constructivist principles. This approach and its effectiveness have been discussed in some depth recently (Abraham 2005); a brief summary is given here. As described by Lawson (1995), a learning cycle has three phases. The first phase is an "Exploration" phase in which a learner seeks a pattern of regularity in the environment or data. A model, some data, a laboratory experiment, a demonstration, or a reading designed to raise questions or complexities that students cannot readily resolve on their own may be used in the "Exploration" phase. Students generate and test hypotheses in an attempt to explain or understand the information that has been presented to them. In the second phase, "Concept Invention" or "Term Introduction", a concept is developed from the pattern and a new term can be introduced to refer to the previously identified trends or patterns. By placing the "Term Introduction" phase after the "Exploration" phase, new terms are introduced at a point when the student already has a mental construct in place to which a term may be attached. This contrasts with the typical presentation in a textbook (or lecture) in which terms are often introduced and defined first, followed by some examples of their use. In the final "Application" phase, the concept is applied in new situations (Abraham and Renner 1986; Lawson 1999). This phase generalizes the concept's meaning to other situations, generally requiring deductive reasoning skills. Thus, a learning cycle experience guides students to develop a concept for themselves, imparting a sense of ownership and participation and providing epistemological insight into the nature of scientific inquiry.

A brief example of a portion of a POGIL activity based on the learning cycle and how it differs from a more traditional presentation can help clarify these ideas. Consider the introduction of some basic ideas concerning the components of an atom in an introductory chemistry class. In a typical lecture, the instructor tells the students that atoms are composed of protons, neutrons, and electrons and that the number of protons in the atom is known as the "atomic number" and determines the atom's identity. The POGIL approach to this content is very different. The students work in small groups (of three or four) on a specially designed activity, with the instructor serving as a facilitator who listens to the discussion and intervenes only when necessary. This activity might begin with a series of diagrams providing examples of a number of atoms, identifying the corresponding element and the number and location of the protons, neutrons, and electrons in each. Through a series of guiding questions, the students would be led to recognize that all of the atoms with the same number of protons are identified as the same element (for example, six protons in the case of carbon). They would also note the correspondence of this number (6) with the number on the periodic table that identifies carbon. Only at this point, after the concept has been developed, would the term "atomic number" be used to describe the number of protons in one atom of a given element. In this way, an "exploration" of the information presented in the diagrams allows each student to develop the concept that the number of protons determines the identity of an element; the term "atomic number" is then introduced following this construction. The "application" of this concept would be to use the periodic table to identify the number of protons characterizing other elements.

There are two key aspects to the design of the POGIL activity. First, the appropriate information must be included in the initial "Exploration" so that it is possible for the students to develop the desired concepts. Secondly, the sequence of guided questions must be carefully constructed to allow the students to reach the appropriate conclusion while at the same time encouraging the development of various process skills. Typically, the first few questions build on students' prior knowledge and direct attention to the information provided in the model. The next few questions help promote thought to develop relationships and find patterns in the data toward development of a concept. The final questions may require divergent thought to find relevance or to look for the boundaries in generalizing students' new knowledge and understanding. Thus, the questions build on each other in complexity and sophistication, leading student groups toward discovery of a chemical concept while also requiring (and developing) an array of skills.

A Focus on Process

One of the most important aspects of implementing POGIL as an instructional strategy is to recognize that there are important learning outcomes that are independent of the specific course content. Many, if not the vast majority, of post-secondary institutions indicate their mission, at least in terms of undergraduate education, is to produce independent life-long learners, who will lead meaningful lives and be contributors to the society in which they live.Yet, for most faculty members, particularly those in the sciences, working toward this mission is not generally an intentional part of the instructional planning process—and certainly not at the individual class meeting level. A POGIL approach, however, places an emphasis on the development of process skills that will help achieve these goals—or whatever other goals the instructor has in mind for that day or course, Thus, the POGIL philosophy is that the development of process skills (information processing, critical thinking, communication, assessment, etc.) is a focus of the classroom implementation; improving these skills will not only complement and enhance the mastery of course content for the student, but will also help achieve the overall goals of the institution.

How is POGIL Implemented?

There are a wide variety of ways that the POGIL approach can be implemented, depending on such factors as the institutional culture, class size, the nature of facilities, and instructor preferences. A few successful models include replacing essentially all lectures with POGIL sessions (Farrell, Moog, and Spencer 1999), replacing one lecture session each week with a POGIL session (J. E. Lewis and S. E. Lewis 2005), converting standard recitation sessions at a large university to POGIL sessions (Hanson and Wolfskill 2000), and using a POGIL activity as part of each class meeting. In fact, every implementation of POGIL is different, adapted to the unique institutional, departmental, and individual circumstances and goals inherently present for each instructor and course. However, as mentioned previously, there are several common threads in all of these implementations:

- during the POGIL activity, the instructor does not lecture, but rather serves as a facilitator of learning;
- students work in small groups (usually of three or four) and they generally have assigned roles;
- the activities have been specifically and carefully designed—usually based on the learning cycle paradigm—to be used in this context; they are not simply "hard problems from the end of the chapter" that the students work on together.

When this situation is described to groups of faculty and administrators, questions that often arise include "What does the instructor actually do?" or "It seems as though the instructor doesn't do any teaching using this method. Don't they just give the students a worksheet and have them figure everything out on their own?" In reality, the instructor has a vital role to play—making decisions about when to intervene, what to say, when to leave a group alone, when (if at all) to deliver a mini-lecture, when (and how) to have groups interact, etc., all based on instructor observations of the progress and dynamics of the class and keeping in mind both the content and process goals for the course and for that day's activity. Thus, even if the instructor has not written the activity that the students are using, the manner in which the instructor implements the activity requires thoughtfulness and intentionality, knowledge and creativity.

Effectiveness of POGIL

The effectiveness of POGIL in various courses has been assessed at a wide range of institutions (Farrell, Moog, and Spencer 1999; Hanson and Wolfskill 2000; Lewis and Lewis 2005). In addition to these formal, published studies, a number of informal and unpublished evaluations of student learning outcomes have also been undertaken. In general, similar outcomes are observed independent of the type of institution, size of course, and course being studied. Implementation in the classroom generally results in lower student attrition from the courses using POGIL than courses using traditional methods (with attrition being considered earning a grade of "D" or "F" or withdrawing from the course), along with student content mastery that is at least as high or higher than that for students in comparable traditional sections.

For example, one study of a full POGIL implementation in general chemistry at Franklin and Marshall College compares the performance of over four hundred students taught using the POGIL approach over a four-year period to a similar number taught in previous years using a traditional approach by the same instructors (Farrell, Moog, and Spencer 1999). The attrition rate decreased from 22 percent (traditional) to 10 percent (POGIL). The percentage of students earning an "A" or "B" rose from 52 percent to 64 percent.

Similar results have been obtained when POGIL is used as a component of large lecture classes. In general chemistry classes at Stony Brook University, using a POGIL approach facilitated by graduate teaching assistants in the recitation sessions for general chemistry resulted in students performing better on examinations, with the gains exhibited uniformly for low through high achieving students (Hanson and Wolfskill 2000). Lewis and Lewis (2005) studied the effect of replacing one of three general chemistry lectures each week with a peer-led team learning session using POGIL materials at another large, urban university. They found that the students who had attended the group learning sessions generally performed better on common examinations. At a large, urban university in the southwest United States with a large minority population, a moderately-sized (seventy-seven students) first semester organic chemistry course was taught using a POGIL group learning approach as the predominant form of instruction during the "lecture" meeting in a tiered lecture hall. The number of students withdrawing from this course prior to the final exam was reduced to 12 percent from a historical departmental average of 38 percent. In fact, in the particular semester of implementation, the traditionally taught section had a withdrawal rate of 47 percent. A common final exam was given to both sections, written exclusively by the "traditional" instructor, and all but one of the POGIL students earned a passing score on the exam, as opposed to a failure rate of about 5 percent of the traditional section students—even though almost half of the traditional section students had already withdrawn and did not take the exam.

When first hearing about POGIL, many instructors are intrigued by the approach and can see its advantages, but are concerned that the pace of movement through the material would necessarily be significantly slower than for a lecture-based course. Our experience is that this is not a problem. One measure of this is the performance of students on a standardized exam, comparing the average outcomes against those of students from the same institution who experienced a traditional approach. The 1993 ACS General Chemistry Exam was used as a basis for comparison for general chemistry students at a small liberal arts college in the southeastern United States. From 1994-2003, in traditionally taught classes of about forty, the exam average was 56 percent, with the highest average in a single year being about 65 percent. In the first year of POGIL instruction, the average was 68 percent correct (McKnight, pers. comm). This result is consistent with those obtained for an organic chemistry course at a mid-sized private, urban university in the same region. In this instance, the ACS Organic Chemistry Exam, a comprehensive exam covering the content of a standard full-year organic chemistry course, was used to compare the performance of students in a POGIL organic chemistry course in the Spring 2005 semester to the performance of students in two traditionally taught sections that same term and the performance of traditionally taught students from several recent years. In this case, the POGIL course used the POGIL methodology as the predominant form of instruction for all of the class time. The POGIL students averaged in the 81st percentile nationally, significantly higher than lecture students from that year (59th percentile) and lecture students from five previous years (64th percentile). These results support the notion that a POGIL approach does not hinder students from mastering as much course content as would occur in a traditional instructional setting.

In general, students respond positively to POGIL and find it effective in helping them learn and succeed. We hear this anecdotally from students and instructors from scores of institutions across the country, and we also have conducted a student survey to provide further support for this contention. A survey was given to several hundred organic chemistry students at six different institutions of various types and sizes, both public and private. Almost all of the students in the courses volunteered to participate, with nearly four hundred responses from students enrolled in POGIL sections at all six institutions and over three hundred responses from students enrolled in traditional lecture sections at two of them. A series of questions were asked concerning how well various aspects of the course enhanced their learning, or helped them develop important learning skills; in almost all cases, the POGIL students indicated that they thought they had been helped more. Of particular interest were the responses to the statement "I would recommend the method of teaching used in his course to a student taking this course next year." For the POGIL sections, 80% of the students either strongly agreed (57%) or agreed (23%) with the statement (as opposed to being neutral, or disagreeing or strongly disagreeing) whereas for the traditional sections only 26% strongly agreed and 23% agreed – for a total of 49% positive response. This difference is statistically significant to a very high level ($p<0.0005$). Further details about the effectiveness of the POGIL approach can be found at the POGIL Web site (http://www.pogil.org).

The POGIL Project and the Dissemination of POGIL

Many who have attempted to implement new ideas in the classroom have found that bringing about change in the college science teaching community is not easy and requires more than desire and research-supported pedagogical ideas. There are compelling reasons for faculty to adopt a traditional lecture style rather than a more student-centered approach. Lecture is the comfortable and conservative choice. New teachers are familiar with it from their own student days, and, more likely than not, it is the style used by most members of the department. Without some support to help overcome the practical and psychological barriers of change, it is easy for faculty to maintain the status quo, justifying that decision with the logic that lecture must be an intelligent choice since it is the method used by so many intelligent faculty.

Factors that lead to adopting a new teaching paradigm include dissatisfaction with the current state of affairs, access to new information, experience with a new approach, an opportunity to meld the new approach with the needs of the learning community, and interaction with other innovators. Faculty often attend workshops and learn about one particular aspect of student-centered learning, but have a difficult time solving the problems of adapting the approach to their own institutional setting. The POGIL Project aims to introduce and support the adoption and adaptation of the learning approaches described here to new and diverse teaching situations by taking the natural progression of change into account. We have created a multi-dimensional dissemination plan providing opportunities for engagement of faculty who are at various stages of familiarity and experience with student-centered teaching approaches. In addition to a workshop-style introduction to POGIL, we have built a framework of support for faculty at all stages of the adoption process.

Dissemination of the POGIL approach to teaching chemistry (and other disciplines) takes place through the POGIL Project, with financial support provided by the National Science Foundation (DUE 0231120). The focus of the project is on faculty development, helping instructors at the undergraduate level (and increasingly in high school also) find ways to better achieve the goals that they have for their students. We provide a variety of opportunities for faculty to learn about POGIL and provide support for their continued growth as professional educators.

One example demonstrates how the combination of activities and support mechanisms provided by the POGIL Project can produce substantial and effective changes at an institution. In June 2003, Sally Hunnicutt of the chemistry department of Virginia Commonwealth University attended the first POGIL three-day workshop held at Duke University. Following this experience, Hunnicutt described what she had learned to her colleague, Suzanne Ruder, who teaches organic chemistry. During the 2003-2004 academic year, Hunnicutt and Ruder implemented POGIL approaches in their classrooms: Hunnicutt used commercially available materials in a medium-sized physical chemistry course and Ruder wrote her own materials and implemented them during a course with about 150 students in a tiered lecture hall. Early in the second semester, at their request, a pair of POGIL consultants made a two-day visit to observe them in their classes and make suggestions for improvements. Over the next two years, they continued to interact with the project through telephone and e-mail consultations and presented their experiences at national meetings. Ruder attended an advanced POGIL workshop dealing with activity writing and classroom facilitation in May 2005 and served as a co-facilitator at an introductory three-day workshop in June 2005. Finally, during the 2005 fall semester, individuals from Old Dominion University and from the University of South Florida traveled to VCU for an on-site visit, to observe the classes taught by these two instructors as exemplars of POGIL implementations. Thus, in a little over two and a half years, these two colleagues transformed themselves from novices to POGIL experts. Similar transformations have taken place at institutions across the country.

More information about the POGIL project, and any of the project activities, is available from the POGIL Web site at http://www.pogil.org or by contacting the POGIL Office at pogil@pogil.org.

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