PAPER DIALOGUE: IMPLEMENTING POGIL PRACTICES IN CHEMISTRY FOR ALLIED HEALTH: INSIGHTS FROM PROCESS EDUCATION

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Abstract

This paper traces the development of Process Oriented Guided Inquiry Learning (POGIL) in response to the need for reform of chemistry education, describes POGIL's instructional strategy and considers its underlying educational theory. Examination of the relationship of Process Education and POGIL reveals that Process Education practices improve POGIL effectiveness. The benefits and drawbacks of POGIL implementation in chemistry instruction at Gaston College are described. A case study of POGIL implementation in a one semester General, Organic, & Biochemistry (GOB) course is presented and analyzed with the Accelerator Model and Grow's Staged Self-Directed Learning Model (SSDL). Insights from a Process Education perspective identify improvements needed to create a more successful learning environment in the GOB course.

Introduction

Process Oriented Guided Inquiry Learning (POGIL) provides a strategy for teaching and a philosophy of learning that enables chemistry faculty members to transition from a content oriented transmission perspective of education to a developmental perspective. Instruction shifts from teacher-centered to learner-centered. Instead of a predominant focus on presenting established content, the goal becomes developing content understanding and building skills so that students become more successful learners. (Pratt & Associates, 1998).

This paper traces the development of POGIL in response to the need for chemistry education reform, describes the POGIL instructional strategy and considers its underlying educational theory. The influence of Process Education on the ongoing development of POGIL is described. Drawing from the broader framework of Process Education enhances the effectiveness of POGIL. The benefits and drawbacks of POGIL implementation by the author in chemistry instruction at Gaston College are described. A case study of POGIL implementation in a one semester allied health chemistry (GOB) course is examined and analyzed with the Accelerator Model (Morgan, 2007) and Grow's Staged Self-Directed Learning Model (SSDL) (Grow, 1991/1996). Insights from a Process Education perspective help identify improvements needed to create a more successful learning environment in this course.

POGIL: A Strategy and Philosophy for Early 21st Century Education

The Changing Framework of Chemical Education

In the last 25 years, chemistry departments expanded introductory chemistry offerings from General Chemistry to add allied health chemistry and chemistry courses for non-science majors. This trend recognizes the need to prepare K-12 teachers and allied health professionals with a solid foundation in chemistry, as well as citizens equipped to work and live in an increasingly complex, rapidly changing technological society (Narum, 2008). Although a wider range of students are taking chemistry courses, teaching practices and philosophy often remain entrenched in the paradigm of training an elite core of future research chemists. In many institutions for both General Chemistry and Organic Chemistry, the percentage of failures, withdrawals, and barely passing grades (D) are unacceptably high (Lamba, 2008; Straumanis and Simons, 2008). A similar situation exists for nursing and other allied health programs which require either a one semester course or two semester sequence in General, Organic, and Biochemistry (GOB). Less prepared in math and science than the General Chemistry population, students in GOB courses commonly find the chemistry requirement a stumbling block for program completion.

The prevailing lecture mode of chemistry instruction represents a transmission perspective of teaching, strongly "teacher-centered" with a primary relationship between teacher and content (Pratt & Associates, 1998). Educational objectives often remain at Level 1 of Bloom's taxonomy, the knowledge level achieved by memorization with limited comprehension (Bobrowski, 2007). As a result of this type of instruction, introductory chemistry students successfully solve problems algorithmically, but cannot correctly explain chemical concepts (Pickering, 1990). In this environment, students develop conceptual misunderstandings, which persist even among entering chemistry graduate students (Bodner, 1991).

Relying heavily on lecture instruction and delivery of factual knowledge in teaching ignores advances in cognitive science. The information processing model, based on research in cognitive and developmental science, reveals the role of working memory and information processing in learning. Working memory has definite limits of handling 3-4 items, although this can be increased with memory aids and training (Rouder, Morey, Cowan, Zwilling, Morey, & Pratte, 2008). Information in working memory is chunked (organized into group or patterns); familiar information is handled without recall thinking (automization). Information in long term memory is organized by associating related pieces of information, a process referred to as deep processing versus the shallow processing of working memory (Merriam & Cafarella, 1999).

The consequence of the information processing model for teaching is that students can no longer be treated as passive receptacles of transmitted knowledge, but must be actively engaged in creating their own knowledge. The model predicts that lectures which appear to efficiently deliver content actually overwhelm the limitations of working memory (Lamba, 2008). More effective teaching strategies acknowledge the limited capacity of working memory and allow its optimal use. Such strategies are more likely to result in deep processing (Hanson, 2008).

In, 1994 and 1995, the NSF awarded large Systematic Change Initiative grants for reform of chemistry education. These grants recognized that improved teaching practices based on understanding how people learn offered potential for greater student success in college chemistry courses. The funded projects promoted development of conceptual understanding and greater student involvement in the learning process. The student-centered approaches generated by these grants continue to influence innovations in chemical education with available ongoing training and support networks. The initiatives are Peer Led Team Learning (PLTL, 2007), Molecular Science, which includes Calibrated Peer Review (CPR, 2001), ChemConnections (W. W. Norton, 2004), and Process Oriented Guided Inquiry Learning (POGIL a). Although not separately addressed in these initiatives, problem based learning (PBL) is used in chemical education to connect chemical concepts with real world problems (National Center for Case Study in Science, 2008).

POGIL: A Strategy for Chemistry Instruction

The POGIL technique emphasizes both content mastery and development of process skills essential for success in the rapidly changing work environment. The guided inquiry activities lead students to higher levels of knowledge by emphasizing concept development (Level 2 of Bloom's taxonomy) and by application of learned knowledge to new contexts (Level 3). The targeted process skills are: information processing, critical thinking, problem solving, communicating, teamwork, and assessment (Hanson, 2006a; Moog et al., n.d.).

In a POGIL classroom, students work in self managed learning teams with the instructor acting as leader, facilitator, assessor, and evaluator. The groups report their findings to the larger class, reflect on their learning, and self assess both content mastery and teamwork (Hanson, 2006a; Hanson, 2006b). Compared to traditional instruction, POGIL classrooms are characterized by a high level of activity, student discussions about the content, partnerships among students, and immediate feedback to the instructor about what students know and how they are thinking (POGIL-IC Authoring Workshop, Litchfield, SC, January 2007, unpublished notes). A video of a POGIL classroom can be viewed at the POGIL website (POGIL b).

Elements of a POGIL activity as outlined by Hanson (2007a) include:

- A descriptive title
- An explanation of why the content is important
- Learning objectives
- Success criteria
- Needed prior knowledge and skills
- Resources and information, generally linked to the course textbook
- Glossary
- Models which lead the students to learn the material
- Key questions which promote student exploration of the model
- Skill exercises which apply the material to simple or familiar contexts
- Problems requiring application of the knowledge in similar contexts and in some cases, progressing to real-world applications (Goodwin, Slusher, Gilbert, & Hanson, 2008).

Not all available POGIL activities contain every element. The common elements are the models, key questions (also referred to as critical thinking questions), exercises, and problems. Examples of POGIL activities can be downloaded from the POGIL website (POGIL c).

Philosophy of POGIL and Connections to Process Education

POGIL is an educational philosophy, as well as a classroom technique. POGIL and other recent initiatives in chemical education are based on constructivist learning theories which connect insights about how learning occurs with educational practice. According to Merriam & Cafarella (1999, p. 261), "A constructivist stance maintains that learning is a process of constructing meaning; it is how people make sense of their experience." Constructivist theory applied to science education postulates that engaging students in scientific processes produces meaningful learning. For community college instructors teaching adults, the validity of the constructivist approach for teaching science is further reinforced by its parallels to adult learning theory with its emphasis on prior experience, self-direction and reflective practice (Merriam & Cafarrella, 1999).

A comparison of Problem Based Learning, Peer-Led Team Learning, and POGIL clarifies the similarities and differences in the theoretical foundations of these techniques currently employed in chemical education (Eberlein, Kampmeier, Minderhout, Moog, Platt, Varma-Nelson, & White, 2008). All three approaches are grounded in constructivist learning theory and engage and guide students in experiences to build their own meaning and understanding. The three approaches rely on cooperative learning in teams. The unique characteristics of POGIL are its use of the learning cycle to promote inquiry and its focus on developing process skills through the use of defined team roles.

A three stage learning cycle of exploration, concept invention, and application forms the basis of POGIL activities with guided inquiry leading to concept development. The learning cycle parallels the process of scientific research. This similarity lends credibility to the concept that educational theory can inform teaching practice for faculty trained as Ph.D. research chemists. In the 1960's, Karplus developed the three stage learning cycle as a practical teaching method for elementary science. Variations of the learning cycle are used in science education to promote inquiry and intellectual development (Chiappetta, Koballa, & Collette, 1998).

The goal of POGIL to develop process skills in addition to content mastery establishes a direct connection to Process Education. Process education principles have guided the development of POGIL as a result of collaboration between Dr. Dan Apple of Pacific Crest and the POGIL pioneers (Spencer & Moog, 2004). Hanson and Apple (2004) established a more direct link by developing a Process Education model for POGIL General Chemistry recitation sections. The components in this model which promote the development of process skills are: cooperative learning, discovery learning, critical thinking, problem solving, reporting, personalized assessments and assessment. The model specifically addresses how to develop expert problem-solving skills by providing various levels of problem solving challenges.

The key elements of Process Education are present within the POGIL approach. The definition of Process Education (Pacific Crest, 2007) describes these key elements:

Process EducationTM is a performance-based philosophy of education which integrates many different educational theories, processes, and tools in emphasizing the continuous development of learning skills through the use of assessment principles in order to produce learner self-development.

The connection is generally not made explicit in POGIL training workshops and the degree of alignment with Process Education depends on the POGIL practitioner. While both concept development and process orientation are key elements of POGIL, the emphasis varies within the POGIL leadership, with Dr. David Hanson (SUNY Stony Brook) advocating a strong process orientation, while Dr. Rick Moog (Franklin and Marshall College) focuses more on concept development through guided inquiry. A case can be made that for new practitioners, POGIL implementation is more effective with an awareness and practice of Process Education. Minderhout and Loertscher (2007) provide an example of a POGIL biochemistry course which relies heavily on Process Education practices. The course goals go beyond the usual cognitive goals set for biochemistry courses and include affective, social, and lifelong learning goals. The course set up established a framework for effective cooperative learning and provided tools to prepare students for active learning.

Instructors who initially implement POGIL in their teaching practice are not generally familiar with Process Education. POGIL offers a narrower framework of educational theories, processes, and tools than the entire array of Process Education. For instructors who want to change their teaching approach, the POGIL technique presents a manageable transition from traditional lecture to more active student engagement and a methodology to shift from sole focus on content to consideration of learner self-development.

Measuring the Effectiveness of POGIL

Since POGIL is a relatively new approach to chemistry education, it is important that a body of scholarly literature about its effectiveness exists and continues to be published. It is also important that individual instructors who implement POGIL in their classrooms develop ways to measure how effective the approach is, as well as examine how implementation can be improved.

Most of the literature about POGIL addresses two questions about its effectiveness.

- Is student success increased by the use of POGIL?
- Do students perceive POGIL to be an effective approach to instruction?

POGIL effectiveness has been measured at different types of institutions in a variety of chemistry courses (Moog et al., n. d.; POGIL d). The results of these studies consistently show that for courses taught using POGIL compared to lecture instruction, retention is improved, mastery of content increases, and students prefer the POGIL methodology.

The retention data is based on the comparison of successful students with course grades of A, B, or C to unsuccessful students with grades of D, F, or W (course withdrawal). In all cases, the percentage of successful students significantly increased. Content mastery is measured by common final exams given to POGIL and lecture sections. An extensive study of POGIL implementation in organic chemistry at seven institutions compared final exam results within each institution for POGIL and lecture sections (Straumanis & Simons, 2008). In all cases, the percentage of successful students (A, B, or C grades) in the POGIL sections was significantly higher than in the lecture section. American Chemical Society standardized final exams (American Chemical Society, n. d.) offer a convenient measurement of content mastery and provide a basis for more rigorous statistical studies comparing POGIL with lecture instruction (Lewis & Lewis, 2005; Perry & Wight, 2008).

Almost all studies employ some type of student opinion survey focusing on student rating of POGIL instruction. Straumanis & Simons (2008), relying on the Student Assessment of Learning Gains (SALG, n. d.) survey, determined that students in POGIL sections reported greater growth in process skills than students in lecture sections.

Considerable data about content mastery and student perception has been published, but it is highly desirable to measure one of POGIL's unique outcomes, the development of process skills. Bauer, Cole & Walker (2005) suggest a variety of questions and tools to investigate the effect of POGIL on attitudes, teamwork, personal learning goals, and metacognition.

A variety of assessment tools have been developed which can be applied in chemical education research and the implementation of POGIL. These include:

- Attitude toward the Subject of Chemistry Inventory (Bauer, 2008)
- Chemistry version of the Colorado Learning Attitudes from Science Survey (Barbera, Adams, Wieman, & Perkins, 2008)
- Chemistry Self Concept Inventory (assess student self perception as a chemistry learner) (Bauer, 2005)
- CHEMX: Cognitive Expectations for Learning Chemistry Inventory (Bretz Research Group, 2008)
- Chemical Concepts Inventory (Division of Chemical Education, ACS, n. d.)
- A general tool for all disciplines, the MSLQ: Motivated Strategies for Learning Questionnaire (Pintrich, Smith, Garcia, & Mckeachie, 1993)

For an instructor implementing POGIL, less rigorous analytical methods than those required for publication suffice to determine whether the desired outcomes are being met. Tools used for POGIL assessment are familiar to process education practitioners (Cole & Bauer, 2008). One of the common tools is the SII (Strengths, area for Improvement, and Insights) analysis. Other assessment methods include surveys, classroom observations, student interviews, as well as student and instructor journals. For instructors, peer assessment of the classroom, of activities, and of the course can provide useful feedback.

Expansion and Flexibility of POGIL

The POGIL approach has been demonstrated at all levels of the college chemistry curriculum. The POGIL website (POGIL a) summarizes many of these activities and lists available POGIL materials. The POGIL methodology was originally developed for General Chemistry, then rapidly adapted for Organic Chemistry. The POGIL technique is well established for physical chemistry, analytical chemistry, and biochemistry; it has been applied to introductory biology courses, as well as one-semester and two-semester GOB courses. More recently, the approach has been tested in preparatory chemistry courses, inorganic chemistry, and in graduate level instruction. The POGIL methodology has been successfully implemented at universities with large chemistry enrollments, at small liberal arts colleges, and at community colleges.

Trout, Padwa, and Hanson (2008) advocate POGIL as a good fit for high school chemistry instruction to address the need for scientific-inquiry lessons as outlined by the National Science Education Standards. Recognizing the potential of POGIL to improve high school science instruction and raise student performance levels, the Toyota USA Foundation recently awarded a grant to Franklin and Marshal College to expand the implementation of POGIL in high school biology and chemistry education (POGIL e).

The POGIL methodology has proved remarkably robust and adaptable to a variety of situations. At some institutions, POGIL is used primarily in recitation problem solving sessions. At other schools, it is the exclusive or primary method of instruction in chemistry courses. There is no one way to implement POGIL and it can be tailored to suit the instructor's personality and style. POGIL was developed for small classroom instruction, but has been successfully modified for large lecture use (Yezierski, Bauer, Hunnicutt, Hanson, Amaral, & Schneider, 2008; Amaral, Bauer, Hanson, Hunnicutt, Schneider, & Yezierski, 2005). POGIL laboratory activities shift the focus from technique introduction and concept verification to concept development and scientific processes. Tested POGIL laboratory activities have been published and guidelines for POGIL laboratory materials are available (POGIL f; Kerner & Lamba, 2008).

POGIL can be combined with other student-centered methodologies such as peer led learning (Lewis & Lewis, 2005) and problem based learning (Lees, 2008). Technology in the POGIL classroom is used to improve communication and increase individual accountability. Tablet P-C's promote more effective classroom communication and increase student involvement in the learning process (Mewhinney & Zückerman, 2008). Providing assignments with a Computer Assisted Personalized Assignment system ensures individual student accountability in a cooperative learning environment (Hanson & Apple, 2004). Classroom personal response clickers enable the implementation of POGIL in larger classes (Ruder, & Hunnicutt, 2008). Assigning reading and practice problems through online course management systems or electronic homework systems generates increased in-class time for guided inquiry and problem solving activities.

Implementing POGIL at Gaston College and the One semester GOB Case Study

Implementing POGIL at Gaston College

The impetus to change teaching styles came from initial experiences with the one semester GOB course. Students in this course lacked basic math skills, demonstrated little interest in chemistry, struggled with the heavy content load, complained about lack of clear explanations, and at best, successfully memorized facts without significant comprehension. The final exam always includes at least one simple metric system equality or conversion problem, given as a multiple choice question (Figure 1). Consistently, a significant number of students choose an incorrect answer. And these are students who will be administering medications!

What is the metric relationship between grams and micrograms?

A) 1 g = 1 000 000 mg
B) 1 g = 1000 mg
C) 1 g = 0. 001 mg
D) 1 g = 100 mg
E) 1 g = 0. 000 001 mg

Figure 1. Metric equality question from GOB final exam

After attending a workshop which presented the results of the NSF Project initiatives for improving chemistry education (listed earlier in the paper), POGIL appeared to be most compatible with the community college environment. POGIL can be done in small classes while maintaining rigid scheduling of separate lecture and lab classes and does not require upper classmen to act as peer leaders. The lack of appropriate materials for the one semester GOB course was a significant barrier to full scale adoption.

The author initially implemented POGIL instruction in Organic Chemistry and in the two semester GOB sequence, discovering that the POGIL process is not easily adapted for very small classes. Good class dynamics can be obtained if there are at least sixteen students divided among four teams. After four years of varying amounts of POGIL instruction, the benefits have been sufficient to commit to more consistent use. The main benefits are increased student engagement, transparency of student thought processes, and community building within the context of the course.

While engaged in POGIL activities, it is extremely difficult for students to fall asleep, text message, or work on assignments for other classes. Students who might become bored because they quickly understand the concepts have the opportunity to assist other students. Students who would disengage because they don't follow a lecture can ask questions and listen to other students explain. Energy builds in the classroom and it's exciting for the instructor to hear students talking about chemistry, arguing about the concepts, and correctly using terminology. Issues can arise with groups getting off task, but this is easier to address than pulling individual students back into the class process.

In listening to students working on the guided inquiry activities, it is possible for the instructor to identify what is causing difficulty with the content. Misunderstood vocabulary and very fundamental misconceptions are quickly identified. Even with well designed guided inquiry questions, students get off track in their reasoning processes. These issues can be resolved promptly either by a mini-lecture or by asking further probing questions. In contrast, with the lecture format, misunderstandings are rarely uncovered and they become entrenched misconceptions which persist throughout and beyond the course. The feedback from observing students working with content also guides future instruction, since the instructor better anticipates the difficulty students will have with specific concepts.

Building community does not always occur within a predominantly POGIL classroom, but the author has had two classes where community formed and had positive effects. In these classes, students expressed reassurance that they were not alone in facing the challenges of learning chemistry. One class was a four week summer session, the other was an evening course. Both are situations where students withdraw because they find it difficult to meet the course expectations within the time constraints; yet only one student withdrew from each of these classes. In the evening class, the students regularly maintained contact with each other outside of class by phone and texting.

At Gaston College, no improvement in content mastery as a result of POGIL instruction has been observed, but students perform at least as well as those in lecture sections. Common final exams are given in all sections of a course from semester to semester, with some variation as a few questions are replaced from a common test bank. Although a valid statistical treatment of the data would be difficult, the exam averages for the POGIL sections of the same course are similar to lecture sections, taught by the same or a different instructor (Geiger, unpublished results).

The most persistent drawback of POGIL instruction has been student resistance. At the end of each semester, students complete a survey evaluating the course and the instructor (Gaston College Instructional Assessment System). For POGIL sections, scores on two items are consistently lower than with traditional lecture instruction. These are:

- The instructor used practical and meaningful teaching methods.
- The instructor explained the material clearly.

The preference for lecture instruction appears to persist even when students recognize the benefits of the POGIL approach (Geiger, unpublished data). In the Organic and Biochemistry course, students identified positive aspects of cooperative learning, such as

- Increased assurance that they understood the material
- Explaining concepts to teammates solidifies understanding
- Getting help from teammates
- Talking about the concepts and working problems with teammates
- Coming up with ways to help remember the information
- Learning the material more quickly than with the lecture approach
- Gaining confidence in ability to lead a group

Despite these positive comments, there were a significant number of requests for “more lecture” and comments about how a lecture organizes and clarifies the material. With the POGIL approach, students may not consistently make important connections or recognize their own learning.

These observations are consistent with those of other POGIL practitioners who can demonstrate improved student performance, but experience student resistance to a different style of teaching and learning. Although most of the published studies of POGIL indicate that student opinion is favorable, discussions at national and regional meetings reveal that many instructors receive more negative student evaluations with POGIL than with traditional lecture instruction. Rajan and Marcus (2009) describe similar results from a study of POGIL implementation in an introductory chemistry course for non-science majors. They report positive gains in student content mastery and student attitude toward group work, but students remained critical of the instructional method.

Background: The GOB Course

The one semester General, Organic, and Biochemistry (GOB) course has one the highest enrollments of chemistry courses offered at Gaston College, with approximately 70 students per year. The course has prerequisites of developmental introductory algebra and developmental reading. No prior chemistry is required. The laboratory course is separate and a co-requisite of the lecture. The mandated course descriptions include a list of topics, but some leeway exists for instructor selection of content. Several textbooks are available for a one semester GOB course. The current textbook used at Gaston College, authored by Timberlake (2009) contains eighteen chapters starting with measurement, energy and matter, through basic organic chemistry and concludes with several chapters on introductory biochemistry (Pearson Education, 2009).

The course is required for the AAS Veterinary Technician and AAS Dietary Technician programs. The population in the course consists of a few students who are enrolled in the dietary technician program with the majority of students in the veterinary technician program. The remaining students take the course to enhance their transfer standing for a variety of selective two year allied health programs. The students are predominately female, recent graduates from local high schools. Relatively few males, older non-traditional students, or minority students enroll in the course. In spring 2009, of forty-nine students, thirty-three had taken a high school chemistry course and nine had completed math courses beyond the prerequisite. Prior to enrollment at Gaston College, few of the students anticipated that a chemistry course would be required for their college program (Geiger, unpublished data). Fall semester classes generally have around twenty students, while spring semester classes are larger, with up to fifty students.

Until Fall semester 2008, POGIL instruction in the one semester GOB course was limited to a few activities to develop key concepts, without investing sufficient time to build effective teamwork skills for cooperative learning. The activities were modified from those developed for general chemistry (Moog & Farrell, 2008; Hanson, 2007b), since activities at the appropriate level were not available until recently.

Attempting to engage students and develop higher levels of knowledge, ConcepTest questions (Landis, Ellis, Lisensky, Lorenz, Meeker, & Wamser, 2001; Mazur Group, 1999) and a variety of active learning strategies (Felder, 2009) have been introduced in the GOB course. The students generally resist new teaching strategies, preferring instructor directed instruction of lecture presentations and test reviews that explicitly address what they need to know to achieve a specific letter grade. Grow (1991/1996, p. 129) characterizes such students as highly dependent learners who want "explicit directions on what to do, how to do it, and when."

POGIL Implementation in the GOB Course

Several factors influenced the decision to implement POGIL as the major instructional method in the GOB course. Student response to regular use of POGIL activities in other chemistry courses became more positive as the instructor gained facilitation skills. A Process Education Teaching Institute offered at Gaston College in May 2008, signaled a potentially more favorable environment for expanding POGIL implementation to the GOB course. Additionally, POGIL activities developed for a one semester GOB course at Georgia Southern University were made available to Gaston College (L. Frost, private communication). These activities accompanied a recently redesigned course with learning outcomes targeted to help allied health students succeed in the GOB course and to more explicitly link chemistry content to allied health applications.

The POGIL approach was implemented in the fall 2008 GOB course. Table 1 compares this course with prior POGIL classes at Gaston College. Several factors were significantly different and potentially influenced the outcome of the POGIL implementation.

- Fixed seating in the lecture room made group work more awkward.
- The GOB students are likely to be more dependent learners because they are mostly recent high school graduates and their focus is employability rather than further education.
- It was the first time the GOB POGIL activities were used at Gaston College.

POGIL instruction starts the first day in any course where POGIL will be the primary method of instruction. POGIL instruction is supplemented by “mini-lectures” to address concepts when the level of student frustration rises. Compared to prior POGIL classes, more effort was made at the start of the GOB course to obtain student “buy-in” for a different approach to learning. Using an exercise based on Dr. David Hanson’s initial activity at POGIL workshops, the students (working in groups with defined roles) were asked to brainstorm a list of qualifications and characteristics for hiring an administrative assistant for a health clinic. Of course, they identified items such as teamwork and communication. This serves to lead into an explanation of how the POGIL approach teaches these skills as the students learn chemistry.

Table 1. Comparison of Fall 2008 GOB with Prior POGIL Classes

	Fall 2008 GOB	**Prior POGIL Classes**
Class size	21 students (17 completed)	5 – 24 students
Course setting	Tiered lecture room (seats 60) with fixed seating	Classrooms (seat 30-40) with moveable desks
Time	2 lectures (75 minutes) at noon on Monday and Wednesday	Various
Students	Predominantly recent high school graduates, mostly female	More diverse with significant percentage of students out of high school for more than 5 years
Degree Program	AAS programs	AA program
Plans after Gaston College	Entering work force	Transfer to 4 year institutions
POGIL activities	Developed and tested for one semester GOB course at Georgia Southern University	Published activities or modified from published activities

In the initial weeks of POGIL instruction, student participation and performance was high. The average on the first exam was higher than expected, although direct comparison with prior semesters could not be made because of different topic inclusion. By the second exam, student performance had significantly decreased and regular class attendance had dropped, making it difficult for the teams to sustain cooperative learning. After the second exam, the students completed a mid-term assessment of the course. The most revealing feedback was in response to the question, "What three topics would you like to review?" The students listed almost every topic introduced since the first exam. Both evaluation and assessment results led to the conclusion that not much effective learning had occurred since the first exam.

For the remainder of the semester, predominately lecture with some active learning activities was used for instruction. A concept mapping process was used to identify topics that needed review before attempting new material. After the review, there was insufficient time to present the topics initially planned for the course. Students were involved in the process of selecting the remaining topics for study.

Diagnosis: Too Heavy on the Accelerator Pedal

The Accelerator Model (Morgan, 2007) provides insight about why this POGIL implementation was less than successful. According to the model (Figure 2), the cognitive skill set of students, the affective skill set of students, and the degree of challenge set by the instructor regulate the growth and development of students' learning skills. Optimal growth occurs when the students are slightly uneasy, being challenged beyond their current skill set, but not at a level where they experience anxiety, frustration, anger, and disengagement. In retrospect, by the second exam in the GOB course, the students were clearly in this "unhappy" zone where the learning process is disrupted.

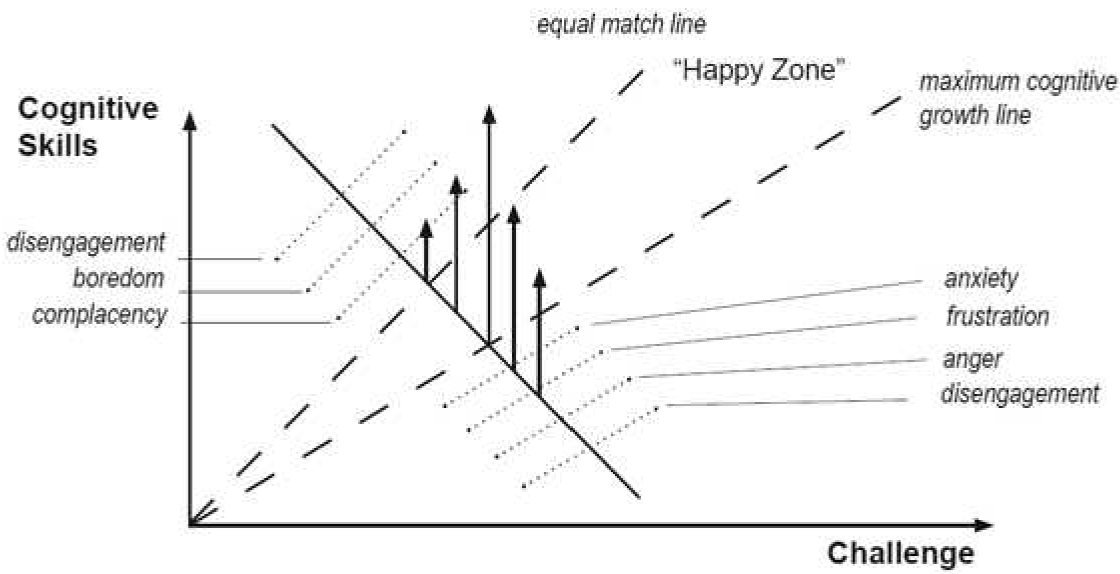

Figure 2. Accelerator Model (used with permission from The Accelerator Model, Faculty Guidebook 4th ed., Published by Pacific Crest)

The level of cognitive skills for GOB students is generally low. Considering Piaget's signs of cognitive development (Merriam & Caferella, 1999) many of the students are concrete learners who understand concepts and the relationships between ideas, but have not developed an ability to think abstractly (Piaget's formal operational stage). This insight is based on observations of a laboratory measurement activity. Students are directed to weigh a beaker, add water and weigh the beaker plus water. When asked to determine the mass of the water, a significant number of students report the combined mass of the beaker and water, even after being told to subtract out the mass of the beaker. The issue of cognitive development is recognized as a risk factor for student success in chemistry courses. Evidence exists that significant percentages of students entering General Chemistry have not developed the ability to think abstractly (Lewis & Lewis, 2007), and the percentage is likely to be higher with GOB students who have less math and science experience.

Although the activities had been developed for and tested with a one-semester GOB course at Georgia Southern University, there are two significant differences between the students at Gaston College and those at GSU. Gaston College is open to any high school graduate while GSU has admission standards based on SAT scores and high school performance. This difference suggests that some of the Gaston College students perhaps have lower cognitive skill abilities than those at GSU. The second difference is that at Gaston, GOB students are in 2 year AAS programs with the goal of entering the work force after graduation. At GSU, the GOB students are enrolled in 4 year degree programs. It is likely that the Gaston students need to see a direct relationship between their course work and their chosen career path and that connection is not always obvious in the GOB course.

Determining the level of students' affective skills is a subjective exercise, but behavior often provides clues. Many of the GOB students lack self confidence. A common response on mid-term assessments to the question about strengths in the course is that they have no strengths. When the course work requires problem solving, loud complaints arise, such as "I can't do math," or I can't do word problems." A lack of coping skills also appears as absenteeism increases whenever there are exams in their required discipline courses. When bored, disinterested, or overwhelmed, a few students tend to act-out, disrupting the class.

It is unlikely that the level of cognitive or affective skills was significantly different for the POGIL group compared to prior classes. What changed was the level of challenge, with increased cognitive challenge and the expectation that students would work in cooperative learning groups. Much of the prior lecture based instruction emphasized Level 1 factual knowledge. While some Level 2 knowledge was introduced, the testing focused on recall and solving familiar problems. By using the POGIL approach, the content level shifted to Level 2, developing conceptual understanding and making connections among course topics. In planning the course, the list of topics allowed one to two 75 minute classes for each major content area. This did not give students sufficient time to achieve the deeper understanding of content that the POGIL approach fostered.

Expecting students to work in cooperative learning teams added to the challenge. Experienced POGIL practitioners advise that students may not work well together in groups because they lack the process skills necessary for cooperative learning (Hanson & Apple, 2004; Minderhout & Lewis, 2007). In the GOB class, the higher achieving students who work well by themselves are sometimes reluctant to share their expertise with classmates. Resentment flares when students perceive that teammates have come to class unprepared or are not contributing to the team processes. When the instructor is facilitating a class with uneven team performance and low tolerance of frustration, determining when to best intervene becomes unclear. Some portion of the students slip into the "unhappy" zone of the accelerator model and the negativity is contagious.

The Staged Self-Directed Learning Model (SSDL) developed by Grow (1991/1996) affirms this view that a more challenging learning environment quickly leads to stress for highly dependent learners. The SSDL Model proposes four stages of learner development moving from dependent to self-directed, matched with four teaching styles from authoritarian to consultant. The highly dependent GOB learners want a teacher who is an authority figure and a subject matter expert. Grow observes that highly dependent learners lack the skills, "such as goal-setting, self-evaluation, project management, critical thinking, group participation, learning strategies, information resources, and self-esteem" to perform effectively in an environment which requires the students to assume more responsibility for their learning. Although students are content with an exact match of teaching style to stage of learner development, this match fails to help students develop the skills needed for self-direction and future success. A significant mismatch of learner development and teaching style leads to student dissatisfaction and an environment which hinders learning.

In the GOB class, the assessment tools for monitoring student affect and learning were insufficient to provide an "early warning" system for implementing the POGIL approach. Although team interactions were observed, the tendency is to focus on what is happening instead of what is not happening. It is possible that the discussions were dominated by the more confident and skilled students while one or two of the group members were more passive, unwilling to speak up when they did not understand. Although the mid-term assessment provided valuable feedback, students tend not to be entirely honest about dissatisfaction about the course, as evidenced by discrepancies between the mid-term feedback and the college administered student evaluation. In the case of the GOB course, the level of student dissatisfaction was not obvious in answers to questions about course strengths or desired course changes, but was detected by the high level of confusion about many course topics.

Areas for Improvement

The broader framework of Process Education provides resources to meet the challenge of creating a successful learning environment in the GOB course. Discussions with Dr. Dan Apple of Pacific Crest have highlighted opportunities for improvement in this course.

- Revise learning outcomes
    - Explicitly identify the desired Level of knowledge for cognitive outcomes.
    - Reduce content by focusing on areas relevant to allied health practic
- Design course structure to support team interdependence and personal responsibility
- Ease into cooperative learning, using a variety of teaching strategies appropriate for individual, partner, and group work
- Address student affect
    - Include affective domain outcomes in the course design and syllabus
    - Motive students on an ongoing basis
    - Monitor student affect

Course structures to promote effective cooperative learning are adequately addressed in the Faculty Guidebook (Beyerlein, Holmes, & Apple, 2007). The issue of reduced content coverage must be addressed because it is extremely controversial among chemistry educators. The prevailing mindset associates wide content coverage with greater student learning and higher academic standards. Despite this prejudice for inundation as the preferred method of chemistry instruction, the recent American Chemical Society General Chemistry textbook has significantly reduced content coverage in favor of a student-centered, active learning approach (American Chemistry Society, 2009).

There are two variables that must be considered in deciding content coverage, the number of topics and the desired Bloom's Level of knowledge. The higher the Bloom's Level of knowledge, the more time is needed for students to achieve success. The author is consulting with the program chairs for the veterinary technician and dietary technician programs to prioritize topics for inclusion and to determine the desired level of learning.

Garoutte (2008) has addressed the issue of reduced content coverage in GOB courses. He stresses that adequate time be allowed to establish student skills in basic measurement and mathematical unit conversion and recognizes that math skills need to be reviewed for specific topics. The result is that some topics must be cut. Many instructors have limited the organic chemistry segment to topics directly related to biochemistry. Additionally, basic chemistry concepts can be introduced using organic and biochemistry examples rather than less relevant inorganic chemistry examples. This represents a significant departure from the way chemistry has been and is taught (Reingold, n. d.). At least one GOB textbook based on this strategy has been published (Raymond, 2005).

Grow (1991/1996) characterizes the second stage of learner as "interested" and the matching teacher as "motivator and guide." He further proposes that a near match of teaching style and learner stage encourages student growth. This growth can be fostered by a progression within a course, or even within a class session moving from more directed teaching strategies (lecture or worksheet) to a less directed approach. POGIL activities provide a framework consistent with this concept of gradually decreasing student dependency. Lecture and shorter POGIL activities could form the basis of instruction. More active learning opportunities within lecture such as ConcepTests can be used to increase student engagement. Activities with partners such as "Think, Pair, and Share" introduce a less demanding cooperative learning environment.

Even a gradual progression of increased challenge is likely to meet resistance from the GOB students. The Accelerator Model suggests that addressing the affective domain of learning allows students to better accept increased challenge (Morgan, 2007). This includes motivating students on an ongoing basis, including affective learning outcomes in the course design, and monitoring student affect.

The first day of class is extremely important for setting the tone for the course. The importance of first impressions is well known, but educators may not be aware that student satisfaction measured by end-of course surveys is highly correlated with the "gut instinct" reaction generated on the first day of class (Nufer, 2005). For highly dependent learners, expectations must be made clear and any planned departure from lecture instruction must be justified. Generating excitement about chemistry with a "whiz bang" demonstration can counter some of the initial negative attitude about taking a chemistry course. Ongoing motivation involves constantly relating course content to allied health applications and using relevant examples to promote student interest and engagement. Providing opportunities for student success builds self confidence. Mixing types and levels of learning activities selected on the basis of student learning styles also encourages broader student engagement (Morgan, 2007).

Including affective learning outcomes in the course design and syllabus informs students the instructor's intent to build skills which will make them more successful in the course and in the workplace. Suggesting that learning chemistry involves emotional skills will seem very odd to students and this concept needs to be introduced carefully to avoid negative judgments. Reflective writing exercises can be used to assess growth in affective skills.

Assessment tools are needed to provide an effective "early warning system" to alert the instructor to increased levels of student frustration. Such tools might include:

- A "mid-term" assessment conducted around the time of the first exam (three or four weeks into the course)
- Occasional end of class reflection questions about what is helping or hindering student learning
- Observation checklist for the instructor or an outside observer to monitor team interactions for

student withdrawal or elevated levels of frustration
- A small advisory group of students who meets regularly with the instructor to provide feedback. Given an opportunity to vent so that individual comments cannot be traced, students may be more open about their concerns.

In the GOB course, a gradual transition from the directed instruction expected by students to a more student-centered approach is more likely to achieve the desired growth of student than whole scale immediate adoption of the POGIL strategy. With a Process Education perspective, this type of gradual growth is achievable. To travel such a journey requires that outcomes be clearly defined, instruction varied, and student affect must be supported and monitored.

Conclusions

POGIL is a classroom technique and philosophy of education developed in response to needed reform of chemistry instruction to foster the development of 21st century students. The POGIL approach provides a manageable transition for chemistry faculty members from a transmission perspective of education to a more developmental perspective. POGIL bases instruction on the Learning Cycle, an approach grounded in constructivist learning theory which applies insights about how people learn to educational practice. POGIL has been heavily influenced by Process Education. Access to the broader framework of Process Education improves POGIL implementation. Studies of POGIL effectiveness have consistently shown improved student retention and increased content mastery based on student performance on common final exams. The flexibility of the POGIL methodology has been demonstrated across the chemistry curriculum, in lecture and laboratory instruction, and in both small classrooms and large lecture sections. POGIL is easily combined with other innovative approaches to student-centered instruction. Technology has been used to enhance the effectiveness of POGIL instruction.

The benefits of POGIL implementation in chemistry instruction at Gaston College have been increased student engagement, transparency of student thought processes, and community building within the context of the course. These benefits outweigh the drawback of student resistance. The case study of POGIL implementation in the one semester GOB course presents the development of a learning environment which discouraged student learning. Analysis of this case with the Accelerator Model and Grow's SSDL model led to the conclusion that the level of challenge presented by POGIL implementation with a group of highly dependent learners pushed the students into the "unhappy" zone of the Accelerator Model. Both models suggest learner growth can be achieved by intentionally and gradually increasing the challenge level while addressing student affect. POGIL remains an important component, but designing and delivering the course to successfully increase student content mastery and build student learning skills will require a broader array of Process Education practices.

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