

Implementing POGIL in Allied Health Chemistry Courses: Insights from Process Education

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Abstract

This paper traces the development of POGIL (Process Oriented Guided Inquiry Learning) as an innovative teaching philosophy and strategy which increases student success in college level chemistry courses. POGIL philosophy and practice draws heavily from Process Education™ in its emphasis on conceptual understanding and the development of process skills. This paper examines the benefits and drawbacks of POGIL implementation in allied health courses (General, Organic, & Biochemistry or GOB) at Gaston College. With POGIL instruction in CHM 131, the first semester of a two-semester GOB sequence, final exam performance and retention results were encouraging. In CHM 130, a one-semester GOB course, POGIL was less successful, due to lack of student readiness for a more challenging learning environment. Models predict that students must have sufficient cognitive, affective, and team skills to succeed in team based learning at a higher cognitive level. The majority of CHM 130 students function at Piaget's concrete operational stage, as measured by the Group Assessment of Logical Thinking (GALT) survey, and have difficulty thinking abstractly, a key skill for chemistry (Bunce & Hutchinson, 1993). Gradually increasing cognitive challenge and the amount of student self-direction is more likely to lead to student growth and effective learning in allied health chemistry at Gaston College.

Introduction

In the last twenty years, the need for reform of introductory college chemistry courses has been well established. Student success in introductory college chemistry courses can be increased by replacing content laden lectures with team based learning that promotes concept understanding and skill development.

Process Oriented Guided Inquiry Learning (POGIL) is one of the techniques for improving chemistry instruction. POGIL provides a teaching strategy and a philosophy of learning that enables chemistry faculty members to transition from a model of transmitting knowledge from teacher to student to a developmental model of student-centered instruction. This paper reviews POGIL instruction in college level chemistry. It describes the POGIL instructional strategy and considers its underlying educational theory, as well as its relationship to Process Education. Evidence is presented that POGIL is effective and that the overall philosophy is flexible and easily modified for a variety of academic settings.

Most of the published POGIL literature focuses on general and organic chemistry at colleges or universities with baccalaureate degree programs. Less data is available about the effectiveness of the POGIL approach in allied health chemistry courses offered at community colleges. This paper describes the effects of POGIL instruction at Gaston College in CHM 131, the first semester of a two-semester, general, organic, and biochemistry (GOB) sequence and the implementation of POGIL in CHM 130, a one-semester GOB course.

The observed benefits of POGIL instruction in CHM 131 and the effects on student retention and final exam performance are presented.

Established POGIL practices implemented in CHM 130 were less effective compared to published studies of POGIL success. This discussion offers an opportunity to examine the causes. The Accelerator Model (Morgan & Apple, 2007) and Grow's Staged Self-Directed Learning Model (SSDL) (Grow, 1991/1996) identify the critical factors for raising the level of cognitive outcomes and transitioning from teacher directed learning to more self-directed independent learning. Student readiness for this shift in instruction is considered based on student cognitive, affective, and team skills. Students' cognitive development in terms of Piaget's stages is measured by the GALT (Group Assessment of Logical Thinking) (Bunce & Hutchinson, 1993). The adaptation of POGIL for high school instruction is discussed as a potential model for allied health chemistry instruction at a community college. An SII (Strengths, Improvements, Insights) analysis (Wasserman & Beyerlein, 2007) provides direction for planning, implementation, and assessment for the effective introduction of teaching practices which promote student growth in allied health chemistry courses.

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

The Slowly Changing Framework of Chemical Education

Experiences in general chemistry and organic chemistry courses often discourage college students from careers

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in science, engineering, and the health professions. These chemistry courses commonly cover too much content and disregard the interests of the students who are predominantly not chemistry majors (Cooper, 2010). Additionally, traditional lecture instruction fails to promote understanding of basic content. In many institutions for both general chemistry and organic chemistry, the percentage of failures, withdrawals, and barely passing grades (D) are unacceptably high, ranging from 30 to 50% (Lamba, 2008; Straumanis & Simons, 2008).

Teaching practices in these critical chemistry courses change slowly because few chemistry faculty members have formal training in education. They teach as they were taught, using lectures and modeling problem solving by example. This mode of chemistry instruction is strongly “teacher-centered” with a primary relationship between teacher and content (Pratt & Associates, 1998). Educational objectives in introductory courses often remain at Level 1 of Bloom’s taxonomy, the knowledge level achieved by memorization with limited comprehension (Bobrowski, 2007). As a result, introductory chemistry students successfully solve problems algorithmically, but cannot correctly explain chemical concepts (Pickering, 1990). Students develop conceptual misunderstandings which persist even among beginning chemistry graduate students (Bodner, 1991).

In, 1994 and 1995, the National Science Foundation (NSF) awarded large Systematic Change Initiative grants for reform of chemistry education. These grants recognized a potential for greater student success in college chemistry courses resulting from teaching practices based on understanding how people learn. 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 innovation in chemical education with available ongoing faculty 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). 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 structured guided inquiry activities lead students to higher levels

of knowledge by emphasizing concept development (Level 2 of Bloom’s taxonomy) and by applying 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).

Key components of POGIL activities include a descriptive title, models for student exploration, key (or critical thinking) questions to promote concept development, exercises for practice, and problems to apply the concepts (Hanson 2007a). Sources and examples of POGIL activities can be found on the POGIL website (POGIL c).

Philosophy of POGIL and Connections to Process Education

POGIL is both an educational philosophy and a classroom technique. POGIL and other recent initiatives in chemical education are based on constructivist learning theories which connect educational practice with insights about how learning occurs. According to Merriam and 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.” 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 & Cafarella, 1999).

Compared to problem-based learning and peer-led team learning, 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 (Eberlein, Kampmeier, Minderhout, Moog, Platt, Varma-Nelson, & White, 2008). POGIL activities are based on a three-stage learning cycle of exploration, concept invention, and application. The

three-stage learning cycle was developed by Karplus in the 1960s as a teaching method for elementary school science (Karplus, 1977); it forms the basis of the best current practices in K-12 science education (Chiappetta, Koballa, & Collete, 1998).

The goal of POGIL is to develop process skills in addition to content mastery. This 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 model specifically addresses how to develop expert problem-solving skills by providing various levels of problem-solving challenges.

The connection to Process Education is 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 from a strong process orientation to greater focus on concept development through guided inquiry. The author's experience has been that using guided inquiry to teach chemistry is a natural fit because the approach parallels the general methodology of chemical research. Incorporating process skills in instruction has proven to be more challenging. An awareness and practice of Process Education has helped address how to develop student process skills and has provided additional resources for POGIL implementation. Minderhout and Loertscher (2007) outline a POGIL biochemistry course which relies heavily on Process Education practices to establish a framework for effective cooperative learning and to provide students with tools for active learning.

Instructors who initially implement POGIL in their teaching practice are generally not familiar with Process Education. The POGIL technique presents a manageable transition from traditional lecture to more active student engagement and a methodology to move from sole focus on content to consideration of learner self-development. POGIL offers a narrower framework of educational theories, processes, and tools in comparison with the entire array offered by Process Education. The POGIL workshops and published materials provide a foundation to enable instructors to more confidently shift their teaching practices.

Measuring the Effectiveness of POGIL

Since POGIL is a relatively new approach to chemistry education, it is important that there exists a body of

scholarly literature about its effectiveness, and that it continues to be published. Individual instructors who implement POGIL must also develop ways to measure the effectiveness of the approach, and to examine how implementation can be improved. Bauer, Cole, and Walter (2005) suggest a variety of questions and tools to investigate the effect of POGIL on attitudes, teamwork, personal learning goals, and metacognition.

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, student retention is improved, mastery of content increases, and students generally 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 many 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). The percentage of successful students (A, B, or C grades) in the POGIL sections was significantly higher than in the lecture sections. 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).

Many studies employ some type of student opinion survey focusing on student rating of POGIL instruction. Straumanis and Simons (2008), relying on the Student Assessment of Learning Gains (SALG, n. d.) survey, determined that students in POGIL sections perceived greater value in the way the course was taught and reported greater growth in process skills than students in lecture sections. Studies report favorable student response to POGIL instruction (Farrell, Moog, & Spencer, 1999), but considerable variation in student response has been demonstrated (Trout, Padwa, & Hanson, 2008; Ruder & Hunnicutt, 2008; Mewhinney &

Zückerman, 2008; Lees, 2008; Rajan & Marcus, 2009). This varied student response will be considered later in the discussion of POGIL implementation at Gaston College.

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, Improvements, and Insights) analysis. Other assessment methods include surveys, classroom observations, and student interviews, as well as student and instructor journals. For instructors, peer assessments of the classroom, of activities, and of the course 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. The POGIL methodology was originally developed for general chemistry, followed by rapid adaptation 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 to 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. The POGIL-IC (Process Oriented Guided Inquiry Learning in Context) project specifically addresses the development of chemistry problem-solving skills by working “real life” examples (Goodwin, Slusher, Gilbert, & Hanson, 2008).

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 funded a grant to expand the implementation of POGIL in high school biology and chemistry education (POGIL e).

The flexibility of the POGIL approach accounts for its adoption and success in 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 (Yeziarski, Bauer, Hunnicutt, Hanson, Amaral, & Schneider, 2008; Jin, Bierma, & Loftus, n.d.). POGIL laboratory activities shift the focus from technique introduction and concept verification to concept development and scientific processes (Creegan, 2003; Kerner & Lamba, 2008).

POGIL can be combined effectively with other student-centered methodologies such as peer-led learning (Lewis & Lewis, 2005) and problem-based learning (Lees, 2008). Communication and individual accountability in the POGIL classroom can be increased by the use of technology, such as tablet P-Cs (Mewhinney & Zückerman, 2008), classroom personal response clickers (Ruder, & Hunnicutt, 2008), and computer based assignments (Hanson & Apple, 2004).

Implementing POGIL at Gaston College in Allied Health Chemistry Courses

The impetus to change teaching styles came from the author’s initial experiences teaching introductory allied health chemistry courses at Gaston College. In these courses, students often lack basic math skills, demonstrate little interest in chemistry, struggle with the heavy content load, complain about lack of clear explanations, and, at best, successfully memorize facts without significant comprehension. A traditional lecture approach fails to help these students learn chemistry. This is highlighted by results of a final exam question from the one-semester CHM 130 GOB course, a simple metric system equality or conversion problem, given as a multiple choice question (Figure 1). In spring 2009, 32% of the students chose an incorrect answer to this question. And these are students who will be administering medications!

Figure 1: Metric equality question from CHM 130 GOB final exam

What is the metric relationship between grams and micrograms?

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

In 2003, the author attended a workshop on the teaching innovations resulting from the NSF Systematic Change Initiative for improving chemistry education described

earlier in the paper (Burke, Greenbowe, Lewis, & Peace, 2002). POGIL appeared to be the most compatible with the community college environment because it works with small class sizes and does not require recitation sections or upperclassmen to act as peer leaders.

POGIL Benefits

The author attended several POGIL workshops and then introduced varying amounts of POGIL instruction primarily in CHM 131, the first semester of a two-semester GOB sequence. With repeated experience, the benefits of POGIL instruction became obvious, including increased student engagement, transparency of student thought processes, and community building within the context of the course.

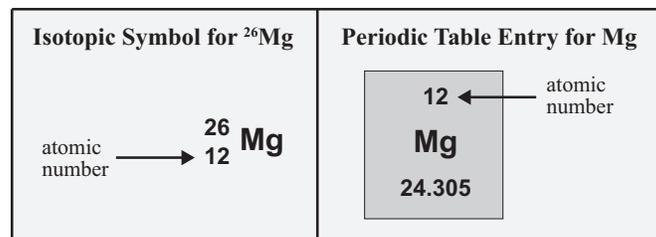
Students are more actively engaged during POGIL activities compared with their involvement during lecture instruction. It is extremely difficult for students to fall asleep, text message, or work on assignments for other classes. Students who might become bored because they quickly understand the concepts reinforce their learning by assisting other students. Students who are having difficulty ask questions and listen to other students' explanations. Energy builds in the classroom and it is exciting for the instructor to hear students talking about chemistry, arguing about the concepts, and correctly using terminology.

While observing students working on the guided inquiry activities, the instructor often discovers why students don't understand. For example, students working on an activity on isotopes often display confusion about identifying the atomic number because it is located in different positions for isotopic symbols compared to the element entry on the periodic table (Figure 2). During the POGIL activities, students do go off track in their reasoning processes, but issues can be resolved promptly by the instructor, either by giving 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. Assessment of student understanding and misunderstanding also guides future instruction by allowing the instructor to better anticipate why students have difficulty with certain concepts.

Community building does not always occur within a predominantly POGIL classroom, but the author has had two classes in which some level of community formed and had positive effects. The students encouraged each other to attend class, they contacted classmates when they missed class, and interacted outside of class to work on chemistry. In informal feedback surveys given in these

classes, students expressed a sense of 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 in which students tend to 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.

Figure 2: *Students experienced confusion about identifying the atomic number because of its different positions in the two types of symbols.*



Results of POGIL Instruction in CHM 131

The combined sections of CHM 131 have the largest chemistry enrollment at Gaston College because it fulfills a general education science requirement for the Associate of Arts degree. The course transfers as an equivalent to the first semester of allied health chemistry in the University of North Carolina system. The content is similar to a high school level chemistry course, but it is learned at a much faster pace. The lecture and laboratory are separate co-requisite courses.

Retention data and final exam results have been tracked for the semesters when the author taught the evening section of CHM 131. These results are then compared with daytime sections of the same course which were taught by the other full time chemistry instructor using interactive lectures. The data is encouraging and indicates the need to further investigate whether the POGIL method is a significant factor in increased retention and improved final exam performance.

Quantifying the effect of POGIL instruction on retention and final exam averages is complicated by additional variables impacting the day and evening sections. These variables include:

- Class size: The day class has been a double section since the fall 2006 semester with an enrollment of 48 compared with 24 students in the evening section
- Class delivery method: The day section is fully seated. With the exception of a fully seated evening section in fall 2008, the evening section has been offered as a hybrid course with half of the hours completed online. POGIL instruction has been used in the seated portion of the evening course.

- Student demographics: The evening sections have a larger population of non-traditional students (over age 25) compared to the day sections

Retention data comparing the two sections is shown in Figure 3. Retention is defined as students completing the course with a passing grade (A-D). There are relatively few “F” grades because students with low grades have ample time to withdraw, with the deadline just prior to the eleventh week of the semester. The retention for the evening section is generally lower than for the day section, which has been the case since evening chemistry sections were reinstated in fall 2004. The increased retention of the fall 2008 evening seated POGIL section is encouraging and may be connected to the observation that the students in this class developed a sense of community. The increased retention also corresponds with a high point in day section retention, and may be due to factors unrelated to the course structure and instructional methods.

Final exam averages are compared for day and evening sections in Figure 4. The trend for the POGIL sections is encouraging, but cannot be clearly linked to POGIL instruction. Common final exams are given in all sections of a course from semester to semester, with some variation using replacement questions from a common test bank. In the more recent semesters, evening students

performed as well as and possibly better than the day students.

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 those from sections using 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. Based on end-of-course instructor administered surveys, 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

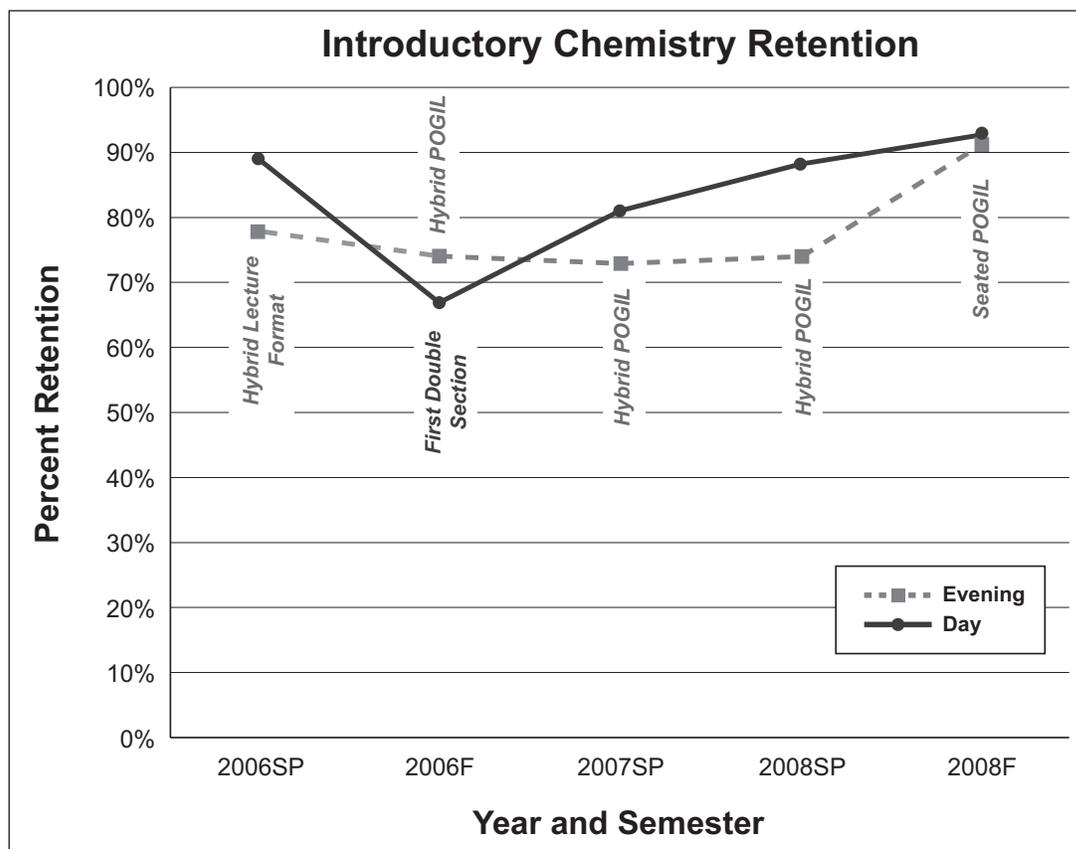
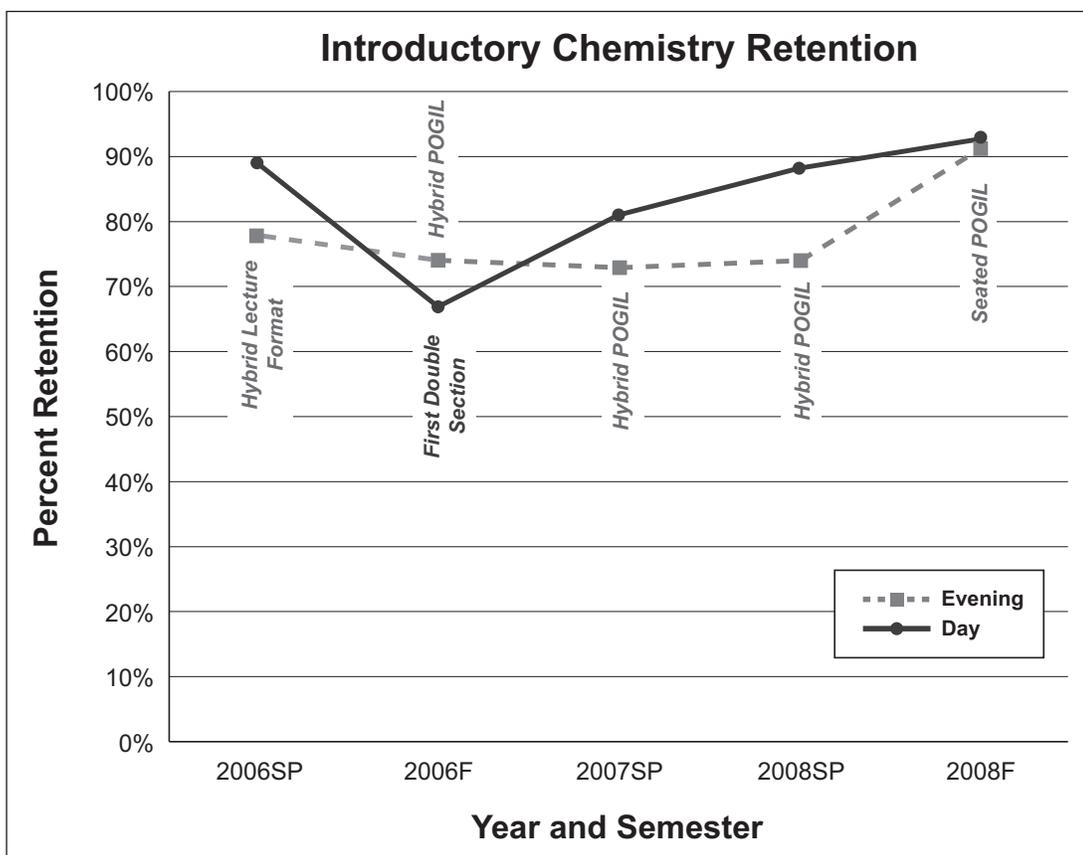


Figure 3: Student Retention in CHM 131 Introductory Chemistry

Figure 4: Comparison of Final Exam Averages for CHM 131 Introductory Chemistry

- Coming up with ways to help remember the information
- Learning the material more quickly than with the lecture approach
- Gaining confidence in the ability to lead a group

Despite these positive remarks, there were significant 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 the extent of 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 published studies of POGIL indicate that student opinion is generally favorable, discussions at national and regional meetings reveal that many instructors receive more negative student evaluations with POGIL than with traditional lecture instruction, especially when POGIL is first implemented. In examining the POGIL literature, introductory chemistry students tend to respond less favorably to the POGIL approach. Rajan and Marcus (2009) found that POGIL instruction in an introductory chemistry course for non-science majors

resulted in improved student performance and more positive attitudes about communication and team work, but negative student opinion about the POGIL method. In large chemistry lecture sections, POGIL instruction resulted in improved exam scores and student attitudes, but students in general chemistry wanted more traditional lecture, while organic chemistry students preferred POGIL instruction (Ruder & Hunnicutt, 2008). Mewhinney and Zückerman (2008) report a similar difference. Organic and physical chemistry (second- and third-year chemistry) students attribute their success to POGIL instruction, while introductory physical science students are more negative about the POGIL method.

Background: The One-Semester CHM 130 GOB Course

Until fall 2008, POGIL instruction in the one-semester CHM 130 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).

Several factors influenced the decision to implement POGIL as the major instructional method in CHM 130. 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 instruction. 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 have recently been published in a one-semester GOB textbook (Frost, Deal, & Timberlake, 2011).

CHM 130 has 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 is a co-requisite of the lecture. The mandated course descriptions include a list of topics, but some leeway exists for instructors to select content.

CHM 130 is required for the AAS Veterinary Technician and AAS Dietary Technician programs. The population in the course consists of a majority of students in the veterinary technician program with a few students enrolled in the dietary 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. Based on an informal survey, prior to enrollment at Gaston College, few of the students had anticipated that a chemistry course would be required for their college program.

A variety of active learning strategies (Felder, 2009), including ConcepTest questions (Landis, Ellis, Lisensky, Lorenz, Meeker, & Wamser, 2001; Mazur Group, 1999), had previously been used in CHM 130 to promote student engagement. 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 CHM 130 GOB Course

The POGIL approach was implemented in the fall 2008 CHM 130 GOB course. The discussion of the CHM 130 POGIL implementation is based on the author's

observations during and immediately after the end of the course. The original data is no longer available.

Compared to prior POGIL classes, more effort was made the first day of the semester 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 desired for hiring an administrative assistant for a health clinic. They identified items such as teamwork and communication. This served to lead into an explanation of how the POGIL approach teaches these skills as the students learn chemistry.

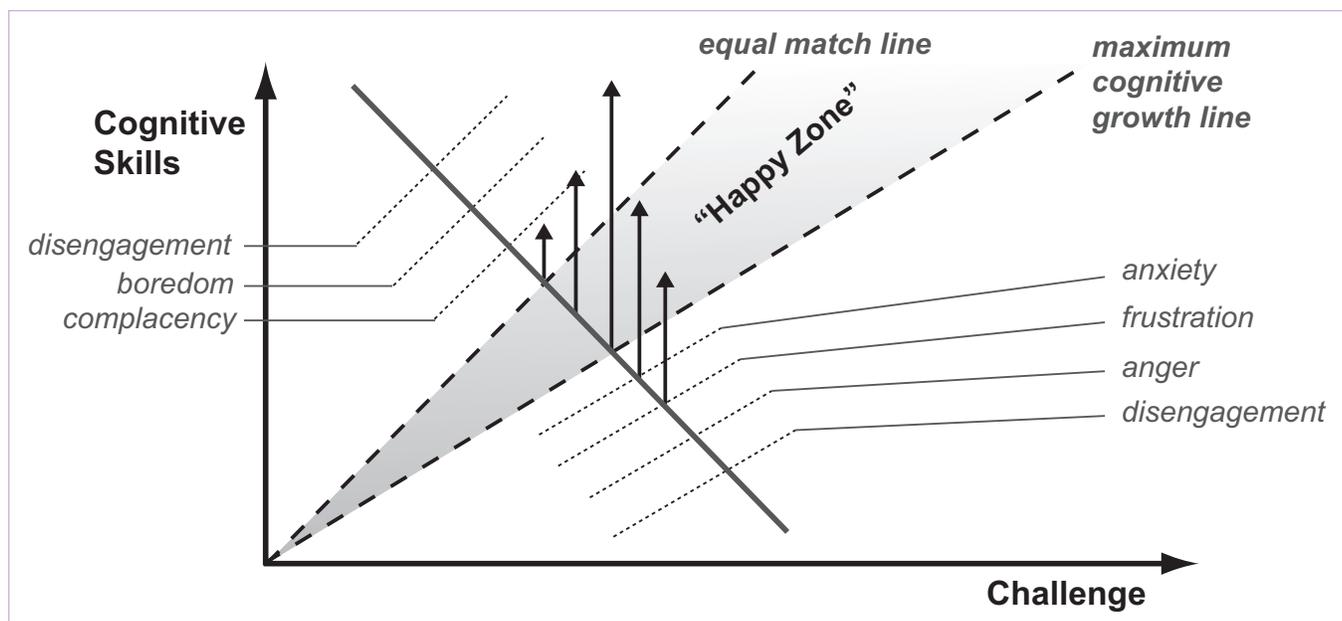
In the initial weeks of POGIL instruction, student participation was high. The average score on the first exam was similar to that for previous semesters. By the second exam, student performance had significantly decreased. The initial class enrollment was 21 students. Between the first and second exams, regular class attendance dropped to the range of 13-17 students present with 4 students no longer regularly attending class. This made 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, lecture with some active learning activities was used for instruction. A concept mapping process was used to identify topics that needed to be reviewed before new material could be attempted. 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: Underprepared Students Given Overwhelming Challenge

The effects of POGIL implementation in CHM 130 were opposite to the positive outcomes reported in the literature. In almost all published studies, POGIL instruction results in greater student success. The lack of success and acceptance of POGIL in CHM 130 can best be explained by the lack of student readiness for the increased challenge of POGIL instruction.

Two other factors which may have influenced the results are the use of POGIL as the sole method of instruction, and tests which emphasized more conceptual under-

Figure 5: Accelerator Model

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

standing (Level 2 knowledge) and less memorization (Level 1 knowledge). While POGIL has been successfully used as the primary method of instruction, it is more often used in combination with other instructional techniques. Novice POGIL practitioners find that using POGIL as a primary method of instruction is very challenging and requires strong facilitation skills.

Hinde and Kovac (2001) identified the tendency of instructors in POGIL environments to increase the level of cognitive challenge on tests. Most studies comparing POGIL with lecture instruction use the same examinations. Students in the POGIL CHM 130 section were less successful in part due to the increased exam difficulty.

If students are highly dependent learners who lack cognitive, teamwork, and affective skills, failure and dissatisfaction can result from shifting instruction toward increased self-direction and greater cognitive challenge. CHM 130 students were not ready to face the challenge of a POGIL classroom. This explanation is supported by models of how characteristics of students influence the success of moving from instructor dependence toward self-direction in learning, by evidence that students operating at lower levels of cognitive development are at risk in college level chemistry courses, and by the necessary modification of POGIL practices for successful high school chemistry instruction.

Models

The Accelerator Model (Morgan & Apple, 2007) and Grow's Staged Self-Directed Learning Model (SSDL)

(Grow, 1991/1996) both predict that an unproductive learning environment occurs when the level of self-directed learning and cognitive challenge is increased before students are ready. The Accelerator Model examines the effects of students' cognitive and affective skills in accepting greater levels of instructional challenge. Grow's SSDL Model analyzes the stage of learner self-direction in relationship to the stage of instruction. Both models conclude that the rate of increase of self-directed learning and cognitive challenge must be adjusted to the level of student readiness.

According to the Accelerator Model (Figure 5), the cognitive skill set of students and the degree of challenge set by the instructor regulate the growth and development of students' learning skills (Morgan & Apple, 2007). The "equal match line" represents a situation in which a student can comfortably meet the level of challenge based on current skills. Optimal growth occurs when students are slightly uneasy, being challenged beyond their current skill set, but within the "happy zone." As the challenge increases beyond maximum cognitive growth, students experience anxiety, frustration, anger, and disengagement, and effective learning ceases. When students have strong affective skills or are given support to manage affect, the area of the "happy zone" widens, allowing greater challenge and faster cognitive growth.

By the second exam in CHM 130, a significant number of students were in the "unhappy" zone and the learning process was disrupted. Compared to lecture sections of CHM 130, the level of challenge increased with POGIL's emphasis on higher learning outcomes in

addition to the expectation that students would work in cooperative learning groups. Low levels of cognitive and affective skills narrowed the “happy zone.” Ongoing assessment techniques for monitoring student affect and performance outcomes were insufficient to provide an “early warning” system to indicate that the “line of maximum growth” had been exceeded. The level of challenge could not be supported by the students’ skill levels.

The Staged Self-Directed Learning Model (SSDL) developed by Grow (1991/1996) affirms the view that a more challenging learning environment 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 ranging from authoritarian to consultant. The highly dependent CHM 130 learners tend to want a teacher who is an authority figure and a subject matter expert. Grow (1991/1996) 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 that requires the students to assume more responsibility for their learning. Students are content with an exact match of teaching style to stage of learner development, but 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.

Student Skill Levels

Another factor which must be considered in analyzing the CHM 130 POGIL implementation is the Piaget stage of student cognitive development (Merriam & Caffarella, 1999). Students who are not operating at Piaget’s formal operational stage and are unable to think abstractly are at significant risk for failing general chemistry (Lewis & Lewis, 2007). A recent study of the effect of cognitive development on performance in general chemistry demonstrated that students who are not at the formal operational stage performed significantly worse on the ACS final exam and often used an algorithmic rather than a conceptual approach to problem solving (Bird, 2010). The GALT (Group Assessment of Logical Thinking) survey used in these studies has been shown to be a reliable tool to measure the Piaget stage of cognitive development (Bunce & Hutchinson, 1993).

The inability to think abstractly is likely to be a greater factor among students in a community college

introductory chemistry course than it is for general chemistry students in bachelor’s degree programs. Observations of Gaston college students performing basic lab operations suggest that many are operating at Piaget’s concrete operational stage of cognitive development. For example, when determining the mass of water in a beaker, students often report the combined mass of water and beaker, instead of subtracting out the beaker’s mass. A more quantitative assessment of the level of cognitive development was obtained by administering the abbreviated version of the GALT survey in two fall 2009 introductory chemistry courses at Gaston College. The survey was completed by sixty students, with results indicating that 60% of the students are at a concrete learning stage, and thus may experience difficulty in learning chemistry. These students can think logically, understand concepts and the relationships between ideas, but have not reached Piaget’s formal operation stage of cognitive development characterized by the ability to deal with multi-variable problems, formulate hypotheses, operate with abstract symbols, as well as understand abstract and complex ideas (Chiappetta, Koballa, & Collete, 1998).

Determining the level of students’ affective skills is a subjective exercise, but behavior provides clues. Many of CHM 130 lack self confidence. A common student response on mid-term assessments to the question about their own 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 manifests as an increase in absenteeism whenever there are exams in their required discipline courses. When they are bored, disinterested, or overwhelmed, a few students tend to act-out, disrupting the class.

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 & Loertscher, 2007). In CHM 130, 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, it becomes difficult to determine when to best intervene. Some percentage of the students slip into the “unhappy” zone of the Accelerator Model and the negativity is contagious.

The proposal that student “readiness” is a key factor in successful POGIL implementation is reinforced by experience in high school chemistry. In this environment, the POGIL methodology has required significant modification to achieve improved student learning and student acceptance (Trout, Padwa, & Hanson, 2008). Activities have been rewritten to shorter “chunks,” with appropriate vocabulary and math levels, and less reliance on prior knowledge. POGIL instruction is used as one of several instructional techniques to avoid student boredom. Very explicit expectations about group work must be set and groups of three students randomly assigned allows for effective group interaction.

SII

Strengths

Although the results of POGIL instruction in the CHM 130 GOB course did not match initial expectations or intentions, it is important to recognize and build upon the strengths of this implementation. The strengths include the following:

- The POGIL approach was identified as a tested strategy with available resources for increasing student engagement, promoting deeper learning, developing learning skills, and assessing student performance in “real time.”
- Initially, as a result of POGIL instruction, students were more engaged and energetic; in learning teams, the students who really struggle with chemistry had a low-risk opportunity to ask questions and seek clarification.
- Planning and using mid-term student assessment of instruction provided valuable feedback about the level of confusion the students were experiencing and, along with test performance, motivated the author to modify the course teaching approach.

Areas for Improvement

The broader framework of Process Education provides resources to meet the challenge of creating a successful learning environment in the CHM 130 GOB course. Discussions with Dr. Dan Apple of Pacific Crest have highlighted opportunities for improvement in this course:

- Revise learning outcomes
 - o Explicitly identify the desired level of knowledge for cognitive outcomes
 - o Reduce content by focusing on areas relevant to allied health practice

- Design the 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
 - o Motivate students on an ongoing basis
 - o 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 in chemical education associates wide content coverage with greater student learning and higher academic standards. Despite this preference for instruction by inundation, 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 is a growing recognition that depth of student learning can be achieved by studying fewer topics. Frost, Deal, and Timberlake (2011) recently published a one-semester, integrated general, organic, and biochemistry text which focuses on chemistry content relevant to allied health students. The integrated approach uses organic and biochemical examples to introduce basic concepts usually presented in inorganic chemistry. The text has twelve chapters, 458 pages, compared to the current textbook used at Gaston College (Timberlake, 2009), which contains eighteen chapters, 676 pages. Garoutte (2008) has specifically 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.

Gradually increased challenge is more likely to result in student growth and success. According to the Accelerator Model (Morgan & Apple, 2007), students should initially be challenged enough so that they are slightly uncomfortable. As they gain skills, the level of challenge can be increased without reaching the “unhappy zone.” Grow’s model (1991/1996) proposes that a near match of teaching style and learner stage encourages student growth. For highly dependent students, the teacher should move from the role of an authority to that of a motivator.

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 the lecture can be used to increase student engagement. Activities with partners introduce a less demanding cooperative learning environment. Greater success with POGIL in allied health chemistry courses is likely to be achieved with strategies successful in high school chemistry.

Even a gradual progression of increased challenge will 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 & Apple, 2007). This includes motivating students on an ongoing basis, 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 (Nuhfer, 2005). For highly dependent learners, expectations must be made clear and any planned departure from lecture instruction must be justified. 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.

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
- An observation checklist for the instructor or an outside observer to monitor team interactions to identify 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.

Insights

Based on the experience with the CHM 130 one-semester GOB course, insights were gained:

- 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 students than whole scale immediate adoption of the POGIL strategy
- To be successful with a Process Education approach, the issue of student resistance to active learning and increased expectations must be explicitly addressed when working with students who have lower levels of cognitive and affective skills
- Ongoing contact with POGIL practitioners and process educators provides resources, encouragement, and insight about teaching practice and its effect on student learning
- The institutional environment has a significant impact on the implementation of POGIL and process oriented learning; what works at one institution may need significant modification to be successful someplace else
- A commitment to improving student learning and to developing learning skills that will last beyond the immediate course sustains an instructor who finds that innovative teaching approaches do not achieve the desired results

Conclusions

POGIL offers tremendous potential to transform chemistry education by promoting deeper student learning, encouraging increased student responsibility for learning, developing process skills needed for employment, and increasing student satisfaction. POGIL has been demonstrated to be effective in improving student retention and performance. The POGIL approach provides a manageable transition for chemistry faculty members to move from teacher and content-oriented instruction to more student-centered instruction.

Benefits of POGIL instruction at Gaston College have been observed in CHM 131, the first semester of a two-semester allied health GOB chemistry sequence. These benefits include increased student engagement, transparency of student thought processes, and community building. Possible improvements occurred in student retention and final exam performance. Students recognized the benefits of the POGIL approach, but continued to prefer lecture instruction.

POGIL implementation in CHM 130, a one-semester GOB course, was less successful. Initial student response

was favorable, but by mid-term, student performance had decreased and students had little confidence that they had learned or understood the material. These assessments occurred too late to reverse the high level of student dissatisfaction about the course and teaching approach.

The demonstrated effectiveness of the POGIL approach was not achieved in CHM 130 due to the lack of student “readiness” to learn in a completely realized POGIL environment. CHM 130 students tend to be highly dependent learners who are comfortable with very structured, directed teaching. The majority of students function at Piaget’s concrete operational stage of cognitive development such that they have difficulty understanding the abstract concepts and symbolic language of chemistry. POGIL instruction raises the level of cognitive outcomes and expects students to work in teams. Analysis using the Accelerator Model (Morgan & Apple, 2007) suggests that the level of challenge increased to the extent that students were in

the “unhappy zone,” where their cognitive and affective skills were insufficient to maintain effective learning. Grow’s SSDL model (1991/1996) further reinforces that student dissatisfaction tends to increase and learning decreases when the level of teaching differs significantly from the level of the learners. According to this model, highly dependent learners can be moved toward more self-directed learning by a gradual change in teaching level.

The wide variation in POGIL implementation affirms that “one size does not fit all,” and that it is important to adapt the approach to the instructor, the students, and the institution. CHM 130 POGIL instruction was based on practices that have been successful in general chemistry courses at 4-year colleges. A more appropriate model for POGIL implementation in introductory chemistry courses at a community college may be based on POGIL practice in high school chemistry, an approach which varies instructional strategies and provides more guidance to students.

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