ASSESSING THE IMPACT OF INTEGRATING POGIL IN ELEMENTARY ORGANIC CHEMISTRY

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ASSESSING THE IMPACT OF INTEGRATING POGIL IN ELEMENTARY ORGANIC CHEMISTRY

by

Ahmad Shatila

A Dissertation
Submitted to the Graduate Studies Office of The University of Southern Mississippi in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy

August 2007
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ABSTRACT

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by Ahmad Shatila

August 2007

Organic chemistry is a difficult subject to teach especially to non-chemistry majors. CHE 251, Elementary Organic Chemistry, is an introductory course in organic chemistry given to non-chemistry majors. It is usually taught the traditional way using lectures as the main method of presentation. In the fall of 2006, POGIL (Process Oriented Guided Inquiry Learning) activities were introduced in this course. POGIL is a program that integrates guided inquiry and cooperative learning in chemistry education. The purpose of this research study was to determine the effect of using POGIL activities in elementary organic chemistry. CHE 251, Elementary Organic Chemistry, was taught using a mixture of traditional teaching, lecturing, and POGIL activities. This was assessed by looking at the effect of using POGIL activities on student achievement. Furthermore, the study investigated possible effects of POGIL activities on students’ attitudes toward chemistry. Archival data on 28 students enrolled in the fall 2004 semester were used in this study. In addition, 27 students enrolled in the 2006 semester participated in the study by completing an attitudinal survey that was developed by the researcher. Finally, 9 students enrolled in the 2006 semester were interviewed to give additional insight to the study. The quantitative data concerning achievement revealed no significant difference between
groups, students who used POGIL did not differ from students who did not.

Further, the quantitative data concerning confidence levels of students in understanding and applying organic chemistry before and after going through the POGIL activities revealed no significant difference. This study showed that students in general (88.8% of surveyed students) liked POGIL activities and preferred them over lecturing. Students thought that POGIL activities helped them better understand and learn chemistry. Furthermore, students acknowledged the benefits of guided inquiry and cooperative learning, the two major ingredients of a POGIL workshop.
DEDICATION

To my parents, Mr. AbdulRazzak Shatila and Mrs. Majida Shatila who always believed in me and who encouraged me every step of the way. I dedicate this study to the two persons who taught me the real importance of education.

To my patient wife, Nisrine and my two lovely children AbdulRahman and Majida who sacrificed a lot and who gave me all the love and support I needed to complete this study.
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CHAPTER I
INTRODUCTION

Process Oriented Guided Inquiry (POGIL) is a program that integrates guided inquiry and cooperative learning in chemistry education. This program started in the 1990s as a way to improve chemistry education techniques by stressing content as well as process. It is based on research linked to constructivism, guided inquiry and cooperative learning (POGIL, 2006a). During these activities students work in groups of four to five, on materials that help them build knowledge. Four interchangeable main roles are assigned to students in each group: manager, reporter, spokesperson, and reflector. Teachers also have four roles: they lead the learning process, monitor the progress, facilitate the learning and the understanding, and evaluate the learning process (Hanson, 2006). Activities include a set of questions that lead students to learn a new idea or build a new concept from their prior knowledge. Students are graded as groups in POGIL activities and as individuals on exams.

The POGIL program offers educational material for different chemistry topics: general, organic, inorganic, biochemistry, physical, and analytical. It has been implemented in forty-two colleges and universities and it is now implemented at USM. Many studies have compared the effects of POGIL activities to traditional teaching and have reported increased effectiveness from implementation. POGIL participants made higher grades than traditionally taught students and had higher levels of mastery (POGIL, 2006b).

Technology is frequently a part of POGIL programs. Different computer programs (CAPA, LUCID, and OWL) have been used to compliment POGIL activities.
Some of these programs have provided students with simulations and interactive models to work with. Other programs have provided students with individualized online homework assignments. All of the programs proved to be helpful for POGIL implementation (POGIL, 2006b).

Education in general is a very diverse field. A method that works in math education might not work in chemistry education and vice versa. There is no "perfect" teaching method for education. Users of POGIL reported some limitations of the program. The time allotted for chemistry courses in universities is not sufficient for POGIL activities to cover all of the material. Some activities need more than fifty minutes and many students are not willing to continue them outside of class. Moreover, absence is a major problem in POGIL activities; groups cannot function adequately with missing members. Activities in general do not always give the "big picture". Guided inquiry is more difficult to use in advanced chemistry courses. Finally, textbooks do not always serve as proper references for POGIL activities (Hinde & Kovac, 2001).

Statement of the Problem

The Department of Chemistry and Biochemistry at the University of Southern Mississippi has tried a new method of teaching elementary organic chemistry. This new method integrates both lecturing and POGIL activities. The problem to be investigated in this study was to assess the effect of using POGIL activities on the attitudes and achievements of Elementary Organic Chemistry (CHE 251) students.

The Purpose of the Study

The purpose of this study was to determine the effect of using POGIL activities in elementary organic chemistry. CHE 251 Elementary Organic Chemistry was taught using
a mixture of traditional teaching, lecturing, and POGIL activities. This was assessed by looking at the effect of using POGIL activities on student achievement. Furthermore, the study investigated possible effects of POGIL activities on students’ attitudes toward chemistry. Student attitudes toward the activities themselves and the effect of these activities were investigated. Student attitudes toward the effects of these activities included confidence in their understanding of key concepts in organic chemistry, their understanding of laboratory experiments, and their understanding of other areas of science. Additional attitudes toward these effects included: student confidence in their ability to visualize key concepts, to be successful in future chemistry courses, and to apply organic chemistry to the real world. This study provided an assessment of the use of POGIL activities in elementary organic chemistry at USM.

The specific purposes of the study are to determine:

1. Is there a difference in achievement between students taught traditionally and those taught using POGIL activities?
2. Is there a difference in student attitudes toward their confidence levels in understanding and applying organic chemistry before and after the implementation of POGIL activities?
3. What are the attitudes of students towards POGIL activities as opposed to traditional learning when examined by the use of surveys and interviews?

Theoretical Framework

Researchers have developed many learning theories to guide educators in their teaching. One of these theories, constructivism, was developed in the 20th century. Credit for formalization of this theory is usually given to Jean Piaget who articulated ways to
internalize knowledge. Piaget suggested that a person constructs new knowledge from prior experience through the processes of accommodation and assimilation (Wadsworth, 1996).

Guided inquiry is a technique derived from the theory of constructivism. In this technique, teachers act as facilitators guiding students toward constructing their own knowledge. Students actively engage in activities that lead them to the ultimate goal, learning. Teachers are not the sole providers of knowledge; they provide students with the necessary means to construct knowledge. Educators cannot assume that students will be successful as passive learners. Chemistry teachers must provide students with activities and experiments that help them build knowledge and become productive members of the society (Grove & Bretz, 2005).

Researchers in the field of education have also stressed the importance of cooperative learning. In cooperative learning, classes are divided into small groups and are given activities for group work. Many surveys compared the effectiveness of individualized learning to cooperative learning and have revealed that cooperative learning is more effective in several facets (Hanson & Apple, 2004). In cooperative learning, students learn more, understand more, and remember more. They also feel better about themselves, the class, and their classmates. Furthermore, cooperative learning helps students build workplace skills such as: teamwork, communication, management, and assessment. Other studies have shown that students who engage in cooperative learning have higher grades (Cooper, 1995). Participating in cooperative learning prepares students for the “outside world” in which people work together for achieving goals. This process improves student-student and student-teacher interaction.
Cooperative learning helps students develop higher order skills, have increased retention, have more satisfaction with their learning experience, and take responsibility of their own learning.

Hypotheses

The following null hypotheses were investigated in this study with an alpha of 0.05 for all statistical tests:

$H_{01}$: There is no statistically significant difference in achievement scores on the final grades of elementary organic chemistry between students taught traditionally and those taught by POGIL.

$H_{02}$: There is no statistically significant difference in achievement scores on the final-test grades of elementary organic chemistry between students taught traditionally and those taught by POGIL.

$H_{03}$: There is no statistically significant difference in achievement scores on the first quiz grades of CHE 420 biochemistry course between students taught traditionally and those taught by POGIL.

$H_{04}$: There is no statistically significant difference in student attitudes toward their confidence levels in understanding and applying organic chemistry before and after going through the POGIL activities.

Delimitations

The subjects of the study were limited to students enrolled in Elementary Organic Chemistry in the fall semesters of 2004, 2006 and to students enrolled in Elementary Biochemistry in the summer of 2005 and the spring of 2007. Measurement of student attitudes towards POGIL activities and towards understanding and applying
organic chemistry were limited to the surveys and interviews that were conducted during the fall of 2006.

Assumptions

During the study the following assumptions were made:

1. Students responded to surveys and interviews in a way that accurately reflected their attitude towards POGIL activities.

2. Testing conditions in each of the elementary organic chemistry classes were appropriate and uniform.

3. Classroom conditions in the fall of 2004 and fall of 2006 were the same.

Definition of Terms

1. **CAPA**: Computer Assisted Personalized Assignments a computer software that provides students with individualized online homework assignments

2. **CHE 251**: Elementary Organic Chemistry a course given at the University of Southern Mississippi

3. **CHE 420**: Principles of Biochemistry a course given at the University of Southern Mississippi

4. **LUCID**: Learning and Understanding through Computer-Based Discovery computer software used in POGIL activities and is short for: learning and understanding through computer-based interactive discovery

5. **NSES**: National Science Education Standards

6. **NSF**: National Science Foundation

7. **OWL**: Online Web-Based Learning computer software that provides students with online homework assignments and is short for Online Web-based Homework
8. **PLGI**- Peer led guided inquiry

9. **POGIL**- Process oriented guided inquiry learning

10. **SFAL**- Student Focused Active Learning

11. **USM**- University of Southern Mississippi

**Justification**

The NSES, National Science Education Standards, call for increased use of guided inquiry and cooperative learning in science education. These techniques have been used to a limited extent at the high school level. At the college level, the use of guided inquiry and cooperative learning has been even more limited. The POGIL program integrates both guided inquiry and cooperative learning at the college level and has been successful at several institutions. The University of Southern Mississippi, USM, is trying to improve the way elementary organic chemistry (CHE 251) is taught by using POGIL activities. CHE 251 is a difficult course to teach because the students are Allied Health majors, are not highly motivated to learn chemistry, and are not equipped with a strong background in chemistry.

This study evaluates the effectiveness of using POGIL materials at USM and pilots new POGIL materials for Wiley Publishers. This first implementation of POGIL at USM was in a small controlled group, the perfect situation to investigate the program’s effectiveness before its implementation in larger populations. The manual used in this course was “General, Organic, and Biological Chemistry: A Guided Inquiry” by Michael P. Garoutte. The manual was In Press during fall of 2006 and we were part of the pilot program for Wiley Publishers (Garoutte, 2007).
CHAPTER II
LITERATURE REVIEW

Introduction

Chemistry and Lecturing

Lecturing has been the dominant method of teaching in all fields of education. In this method students used to gather around a famous scholar who supplies them with knowledge and wisdom as he lectures. Chemistry is one of the fields that have been taught through lecturing in both high school and college levels. Until recently, most educators thought that knowledge can be transferred intact from the mind of the teacher to the mind of the learner. Unfortunately, this is not the case. Teachers can teach well; they can be spectacular, but this does not always result in learning (Bodner, 1986). Furthermore, lecturing has been historically shown to be the least effective way of building conceptual knowledge (Bodner, 1992).

The general problem in science education is not the curriculum; it is rather the way the curriculum is delivered. Many students attend lectures solely to take notes; understanding is not one of their goals. "Reflecting on her experience in chemistry, Patricia Metz described one course as follows: "At times I felt the professor's notes became my notes without passing through either of our minds" (Bodner, 1992, 186). According to Bodner, what many lecturers do is simply read the book for the students; therefore, students do not really need to read books. Students simply memorize or try to understand the notes given by lecturers to pass the exam, not to understand chemistry.

Chemistry at the university level is almost always taught through lecturing. This is done to accommodate large numbers of students in a time-efficient and a cost-efficient
way, especially at the freshman level. However, many educators have been criticizing lecturing because it limits the interaction between teachers and students (Holme, 1993). Other techniques have been recommended based on two major models: guided inquiry, and cooperative learning.

**Guided Inquiry**

Guided inquiry is based on the theory of constructivism, which states that knowledge is constructed in the mind of the learner (Bodner, 1986). This theory, which opposes the old notion that students are empty jars waiting to be filled, is widely accepted today among educators. Students using guided inquiry techniques actively engage in exercises that help them build their own knowledge. With guided inquiry students draw their own conclusions and interpretations by analyzing data and discussing ideas.

The instructor is no longer the sole provider of knowledge; he or she is the facilitator who assists students in building their own knowledge (Farrell, Moog, & Spencer, 1999). The person standing in front of the class (usually called teacher or instructor) should shift from teaching by imposition to teaching by negotiation (Bodner, 1986). This dialogue between student and teacher usually starts from a concept that is familiar to the learner and then builds upon it. Education is a two-way flow between the educator and the learner. We should not teach from our points of view and based on what we know; teaching should be based on what students know. Ausubel suggested a rule that can be summarized as follows, “The best way to organize information after it is understood is not always the best way to organize it so that it will be understood in the first place” (Bodner, 1992, 189).
Almost all educators accept the generalization that active students learn better than passive students (Bodner, 1992). Learning is like a sport if you only watch, it is hard for you to become a good player; but if you practice, you can become a good player.

**Cooperative learning**

Cooperative learning is one of the ways educators prepare students for real life. Educators understand that when they are teaching they are not providing students with knowledge; they are trying to provide them with the means to survive in the “outside world”. Thus, more and more attention has been given to group learning or cooperative learning. Universities must become communities of learners where students learn from teachers and from one another. Over 600 research reports compared the effectiveness of individualized learning to cooperative learning and they all revealed that cooperative learning is more effective in more than one facet. This is not shocking if we consider that students who study via individualized methods are not facing the same intellectual challenge they might face in cooperative learning environments (Hanson & Apple, 2004).

When students work in groups they are training for actual fieldwork. Students who graduate from chemistry programs do not have enough training for teamwork, although desirable employees are those who are prepared to work in a group environment (Hanson & Wolfskill, 2000). Cooperative learning helps students build workplace skills such as: teamwork, communication, management, and assessment (Hanson & Apple, 2004).

One of the best ways to improve classroom communication is cooperative learning. It also serves as a way of intervention that improves students’ abilities to grasp the content of a course, especially a chemistry course (Pence, 1999). When students are
divided into groups they discuss course materials at the student level. It is hard for the instructor to bend to the students' level of understanding and build on it. Students understand each other more than they understand instructors. Students who study in a group learn more, understand more, remember more and feel better than students who study alone (Hanson & Apple, 2004). When students feel better about a course they tend to do better and to understand more than they do in courses with less positive feelings. Studying in isolation or alone can be exasperating, especially if the student faces something that he or she cannot understand. With time, this frustration becomes an overwhelming psychological problem that students cannot overcome (Hurley, 1993). Minorities and women usually have a feeling of isolation in science courses; cooperative learning helps those students feel better about chemistry courses (Hanson & Apple, 2004).

Large lecture classes are a very big problem to students in universities, because in them students are passive learners. Cooperative learning is one of the solutions because in it students:

1- Take responsibility of their learning and become actively involved. Some studies have shown that students usually have higher grades when they participate in cooperative learning.

2- Develop higher order thinking skills; and skills that would help prepare them for the business world.

3- Have increased retention.

4- Have more satisfaction with their learning experience than students who are taught exclusively by lecturing method (Cooper, 1995).
Lecturers do not usually embrace group work or cooperative-learning techniques because they feel that with it is very hard to finish all the material. Finishing “all the material” in chemistry is something almost impossible even with lecturing. The important thing is to equip students with the ability to learn on their own, which is to equip them with the higher order thinking skills to process any kind of information they may encounter. Further, lecturers are troubled with the lack of control that might happen when they do group work, but even with lecturing they have no control over what students are thinking. The third problem is that high achieving students may resent that low achieving students are benefitting from their skills while the reverse is not true. This can be overcome by explaining the advantages of group work (Cooper, 1995).

POGIL

What Is It?

POGIL, the acronym for process oriented guided inquiry learning, started in the 1990s after growing concerns about college chemistry education. It concentrates both on the process of learning chemistry and the content being taught. POGIL is a technique used in both classrooms and laboratories. It stresses process skills like analytical thinking and teamwork. It is mainly concerned with process education, which is an educational philosophy that focuses on enhancing skills required for success in college and life, lifelong learning, and continued growth (Hanson & Wolfskill, 1998). It is a process workshop which is “a classroom environment where students are actively engaged in learning a discipline and in developing essential skills by working in self-managed teams on activities that involve guided discovery, critical thinking, and problem solving and include reflection on learning and assessment of performance” (Hanson & Wolfskill,
In POGIL, large lecture groups are divided into small groups of four to six students to work on guided inquiry activities. It follows a constructivist method in which students construct their own knowledge. Students are supplied at the beginning of the activity with chemistry information and then guided by a set of questions to build their new knowledge. The instructor is not the provider of knowledge; he/she is the facilitator who helps students through the process of learning. The instructor’s main job is to observe and organize; he or she does not have to do any actual lecturing.

This program is based on research related to constructivism and cooperative learning. Research demonstrates that lecturing or teaching by telling is not effective for most students. Moreover, students who participate in interactive learning and who are part of an interactive community are better candidates for success. Also students who construct their own knowledge enjoy learning more and have greater levels of retention (POGIL, 2006a). In POGIL, learning is not treated as a process of memorization; it is an interactive process in which learners develop better understanding and develop new skills (Hanson, 2006).

The POGIL Project

The POGIL project is a science project funded by the NSF (National Science Foundation) and that concentrates on propagating methods and materials of POGIL. Interested educators can attend workshops, use POGIL material in their classrooms, and add or develop new material. Help is offered through the POGIL Official website. This program has been officially implemented in 42 universities and colleges so far (POGIL, 2006a). The program offers educational material for different chemistry topics: general, organic, inorganic, biochemistry, physical, and analytical.
Does It Work?

Many studies have tested the effectiveness of POGIL in chemistry courses and all of them reported positive feedback. Students, in general, preferred POGIL and had lower levels of attrition. Further, students in POGIL programs mastered the content more than they normally do in lecture courses (POGIL, 2006b).

One of the first published studies was done by Farrell, Moog, and Spencer in 1999. It was done on students taking general chemistry courses. POGIL was implemented on 438 students in general chemistry courses (Fall of 1994-Fall of 1997). POGIL activities replaced all lectures usually given in a general chemistry course. The scores of those students were compared to the scores of 420 students (Fall of 1990-Spring of 1994) who did not undergo the POGIL experience. W, D, F rates decreased from 21.9% to 9.6%. The rate of A grades increased from 19.3% to 24.2%, B grades increased from 33.1% to 40.6%, and C grades were almost the same (Farrell, Moog, & Spencer, 1999).

In 1994, Hanson and Wolfskill introduced POGIL in one of the three lectures in general chemistry courses given at Stony Brook University. They replaced this lecture with a peer-led team learning session. They reported an increased attendance from 10-20% to 80-90% in POGIL sessions. Student surveys showed that most students (75-90%) found the workshops helpful, 37% reported that it increased their interest in chemistry, and 54% reported that it increased their confidence levels in chemistry. Instructors received excellent evaluations that reflected positive student attitudes. Students in general had better grades, almost 20% shifted from lower to higher grades, and enrollment in second-year chemistry courses increased by 15% (Hanson & Wolfskill, 2000).
One study, done at a small liberal arts college, compared two small groups of organic chemistry students. The first group was taught the “old fashioned way” while the second one was taught using POGIL. The first group had the following grade distribution: 20% A, 20% B, 27% C, and 33% D, F & W. The second group showed better results and had the following distribution: 29% A, 35% B, 24% C, and 12% D, F & W (Hanson, 2006).

Another study, also at a small liberal arts college, compared student performance in a general chemistry test. Results from 1994 to 2003 had an average of 55.5% with the highest year being at 65.2%. When POGIL was implemented at this college the average on the same test was 68.5%, which is 3.3% higher than any other year and 13% higher than the average (Hanson, 2006).

In a study done at a large public university, POGIL was implemented on a group of 75 students in one of two sections of an organic chemistry course. The other section had 109 students and was taught solely by lecturing. The lecturer or the instructor of the second non-POGIL section wrote the final exam. The grade distribution for the POGIL section was 9% A, 32% B, 31% C, and 15% D, 1% F, and 12% W. The grade distribution for the second section was 12% A, 19% B, 16% C, and 1% D, 5% F, and 47% W (Hanson, 2006). Although the Percentage of A grades was lower in the POGIL class, B and C percentages were considerably higher. The biggest difference was in withdrawal percentages; POGIL students had more confidence in their ability to pass the course.

Lewis and Lewis (2005) conducted another research study and published their results in January 2005. The research was done at the University of South Florida. Two
groups of general chemistry students were chosen, one served as the control group and the other as the experimental group. The control group was taught using the traditional methods (lecturing), while the experimental group was taught differently. The experimental group was given two lectures and one POGIL activity per week. The activities were called PLGI, which stands for: peer-led guided inquiry. Statistics showed that students in the experimental section made better grades than students in the control group although the experimental group had one less lecture which was substituted for a PLGI workshop (the students compared had similar SAT scores). Students in the experimental group always outscored students in the control group in all exams. Student surveys indicated that 74% of students thought that the PLGI sessions were beneficial. Further, when asked if substituting one lecture for a PLGI activity was beneficial, 76% of students had a positive response. Furthermore, 85% of the experimental group students indicated that they would register for another PLGI supplemented course, and 58% indicated that they would attend PLGI activities even if they were not mandatory.

In another study done at the University of Tennessee, a physical chemistry course was supplemented with a computer based POGIL activity once every other week. The course was given in the spring of 1999 and the grades were compared to that of fall 1997 and spring 1997. There was no difference in student achievement (Hinde & Kovac, 2001).

POGIL Implementation

Technique

POGIL is a mixture of two main ingredients, guided inquiry and cooperative learning. Chemistry classes in a POGIL program or activity are divided into small groups
of three to five students. Members of each group discuss different questions (guided inquiry questions) that lead them to construct their own knowledge. Different tasks are assigned to every member of the group. Tasks are usually interchanged among group members when they move from one activity to the other. POGIL activities usually take one session (50 minutes), which could be extended depending on the material. Frequently students have quizzes before activities; this helps the instructor check individual progress. Answers to POGIL activities are submitted per group and not individually (Farrell, Moog, & Spencer, 1999). Individuals can keep copies of the group answers for later use.

Simply giving activities does not work; five more things are required: interdependence (one for all and all for one), individual accountability when it comes to understanding, promotive interaction, collaborative skills, and self-assessment (Hanson & Wolfskill, 2000). Group members have to know that they all have to work and they all have to understand. If one group member does not understand a specific concept the whole group is to blame. Furthermore, students are individually accountable; the final exam is not given as a group activity. Students should also have promotive interaction, which means that team members should support each other, and help each other learn. In addition, collaborative skills should be identified and enhanced. Finally, self-assessment is vital; students should acknowledge their strong points, their weak ones, and what they have learned.

Activities include a set of questions that range from direct to critical thinking. Questions are derived from students' common experiences and chemistry so that students can build on them. Key questions help students formulate the required concepts and guide them to the appropriate conclusions. Questions are discussed verbally and then written
down on paper. Many questions include tables that students have to complete; this helps
the students develop organization skills. Questions start at a simple level in order for
students to build confidence, and then more challenging problems are introduced. Harder
questions require higher order thinking and integration of concepts and information. By
the end of each activity students assess their work and their progress (Hanson &
Wolfskill, 2000).

Groups

Groups in POGIL are small and heterogeneous. Each group ideally contains four
members but it could range from three to ten members. High achieving students are
mixed with average and low achieving students. High achievers benefit a great deal from
explaining new material (it always helps when students explain concepts and ideas in
their own words) and low achievers benefit from the group discussion. The groups are
heterogeneous with respect to levels and gender (Hanson, 2006).

Students Roles

POGIL activities are usually designed without giving specific assignments to
different students. They are a set of guided inquiry questions that members of each group
have to tackle. The instructor or teacher should assign different tasks to different group
members depending on the number of students in each group.

In his POGIL instructor’s guide Hanson (2006) suggested four main roles to be
assigned to students. This is assuming that groups are constituted of four members. The
roles were as follows:
1) The manager: the head of the group, works with other members on the activities, keeps all members focused, delegates responsibilities, makes final decisions, and makes sure that everyone understands the concepts.

2) The spokesperson or the presenter works with other members on the activities and presents answers to other group.

3) The recorder works with other members on the activities, records all answers and discussions, and prepares the final report for the activity.

4) The strategy analyst or the reflector works with other members on the activities, identifies problem-solving methods, identifies the strong and weak points of the team, and prepares a report.

In the study done in Marshall and Franklin College, the same roles were used but with the addition of a fifth role. The groups had a technician who did all the technical work including use of calculators, computers, and/or any other equipment (Farrell, Moog, & Spencer, 1999).

The research done in Stony Brook University followed a PLGI technique. In the PLGI technique students were led or managed by a student who already finished the course and who is not actually taking it. The role of the leader was to act as a guide and not as a tutor; he or she guided students through activities and did not solve problems for them. The peer leaders were trained in group dynamics and were familiar with the learning theories that govern the activities. The groups at Stony Brook University were formed of six to eight students. Research was also done at the University of South Florida where it also followed a PLGI technique. The groups were formed of ten students and no specific roles were discussed (Lewis & Lewis, 2005).
POGIL is a student-centered technique; the most important ingredient in it is the student. All members of the group should actively participate in the learning process. When the groups are composed of more than four or five students, it becomes harder for the instructor to assign roles. Teachers can invent as many roles as they want, but after five it just becomes more difficult. In larger groups, different roles were not assigned and students just had to finish the activity together.

The Teacher Role

The teacher used to be the most important ingredient in a learning recipe. A “good” teacher would “force” students to listen, learn and be good students, and a “bad” teacher would not be able to “force” students to listen and learn. Recently, attention started to shift to different student-centered models. POGIL is one of these student-centered models in which students are responsible for their own learning. Students who actively participate in the learning process will be “good” students while students who refuse to actively participate will be “bad” students. It is no longer the teacher’s fault if students fail; it is the students’ fault. The teacher in the POGIL program is the facilitator of knowledge and not the provider of knowledge. This makes the teacher less responsible for student learning and makes students function more independently (Kovacs, 1994). POGIL activities and the teacher both serve as scaffolds of student learning and not as elevators. Teachers and POGIL activities are the means that students have to use to build their own learning. Students have to climb the scaffolds of knowledge; they are not in an easy elevator ride anymore.

The teacher in POGIL is still a very important ingredient of the learning process, but not the most important ingredient anymore. Teachers or instructors in POGIL play
four different crucial roles. The teacher is the leader of the learning process, the monitor of team performance and progress, the facilitator of learning and understanding, and finally the evaluator of the overall learning process (Hanson, 2006). Lecturing is not one of the major tasks the teacher has to do although very small lectures are sometimes given as a summary or as a warming up activity.

The teacher is always, and will always be, the leader of the learning process in the classroom. The instructor, being the leader, creates the learning environment. It is his or her job to specify learning and process objectives, describe the different elements of success, and organize the class. He or she should divide students into different groups, define the different roles students have to take, and set the time structure for the different activities (Hanson, 2006).

Instructors or teachers also serve as monitors of progress. They go around the classroom monitoring group performance. They also use the information to identify difficulties and misconceptions. This helps teachers in their third role as facilitators (Hanson, 2006).

The third and most important teacher role is the facilitator. The teacher moves around the class asking critical-thinking questions, and answering students’ questions. The answers provided should never be the direct answers to POGIL activity questions; the answers are usually open-ended and general. The teacher should help students reach the activity answers and not simply provide students with the answers. During group work, it is better if the teacher does not interfere unless it is really necessary. If everything is going well, and the students are progressing at an adequate pace, then no teacher intervention is required. The teacher simply joins a group for a brief interval of
time, listens to the discussion, and then moves on to another group. Questions can be posed to one or more group members to ensure that they are actively participating in the discussion. Sometimes students tend to sit aside and copy answers. This attitude contradicts the purpose of the activity. A small record of individual student progress may be kept for later use. When the teacher joins a group, he or she should check the group’s answers to critical thinking questions. If something is wrong, the teacher should consider intervening; however, it is not necessary. Frequently, students discover their mistakes as they continue working on an activity. This is usually a result of some kind of contradiction they encounter while working through the activity. Students learn better if they discover their mistake alone. Giving them the answer or correcting their answers might ruin their chance in building their own knowledge (Farrell, Moog, & Spencer, 1999).

The main purpose of teacher intervention is process-related issues. Teachers should make sure that students are following procedure and are actively discussing the questions in the activity. Teachers intervene by asking questions such as the following: Where are you stuck? What do you find confusing? Is this question related to previous questions? How is it related? Content related intervention should be minimized, and should not be done unless absolutely necessary. When content intervention is done it should not be by providing answers. It should be by leading students through discovering their mistakes and eventually understanding the concepts (Hanson, 2006).

The fourth teacher role is that of evaluation, and evaluation here does not mean grade assignment. The teacher should sum up the activity by asking team members (usually the reporters) to summarize the activity and to give details about their different
strategies and results. Consequently, the instructor evaluates each group as well as each individual and shares general comments with the whole class (Hanson, 2006).

The teacher in POGIL has an administrative role like any other classroom teacher. He or she prepares the syllabus, administers exams, reports grades, prepares course material, and deals with different student issues. The main difference is that, in POGIL teachers do less work in class. This is the case simply because this is a student centered model and not a teacher centered one.

In the PLGI technique, the teacher had to lecture two times a week. The third lecture was substituted by a PLGI activity during which a peer (another student) who has already finished the course led the groups. Group leaders were trained to handle these activities and were not always chemistry majors. The teacher never intervened in the PLGI activities. The PLGI activities were not meant to introduce new ideas, they were meant to reinforce student comprehension of covered material. Therefore, it was not the peer leader’s job to introduce new material; his or her job was to check for understanding of the new material (Lewis & Lewis, 2005).

Comparison between POGIL and Traditional Methods

Students

Students are at the center of POGIL activities, as they are in any guided inquiry/cooperative learning activity. In POGIL and similar models the student does not behave like he or she normally does in the traditional classroom. In the traditional classroom, students want to know the right answer, and that is it. They have limited interaction with each other, and they are supposed to keep silent and listen to the teacher. Further, they accept facts and explanations given by the teacher or the book, and at the
end of the course, they are expected to reproduce it. In a cooperative learning model, students explore and explain various solutions of one problem and then try to determine the “right” answer. As a result, students develop extra questions related to the topic. This encourages them to investigate further. Moreover, students interact with each other while discussing the material. They do not accept and idea just because they heard it from the teacher. They accept it because they are able to justify it and explain it to one another. Finally, students are not expected to mimic the book nor the teacher’s notes; they are expected to test hypotheses, suggest solutions, make decisions, and design experiments (Spencer, 1999).

**Teachers**

Traditionally, teachers were lecturers who explained concepts and provided students with valuable notes. They always had a definitive answer; they told students what is right and what is wrong; and they summarized and explained algorithms. POGIL follows the SFAL (student focused active learning) paradigm, and in it the teacher acts as a consultant for students. He or she provides students with critical thinking questions to derive new concepts. They do not give direct answers but respond to questions in a way that leads students to think about a concept. Thus, he or she would be able to identify misconceptions and would have a better chance at addressing them. Furthermore, the teacher gives students enough time to go through problems and allows them to assess their own learning. Finally, the teacher encourages students to explain new concepts to their classmates using their own words (Spencer, 1999).
POGIL and Technology

Preview

Technology has been a great factor in science education since the early 1900s. Year after year the increased use of technology is seen in all educational fields. Chemistry has been one of the fields that benefited considerably from technology. Chemistry education has also benefited considerably from technology especially in the use of computers. Currently, computers play a very important role in education. Teachers use computers to prepare exams, write syllabi, enter grades, and much more. Chemistry teachers in various universities are introducing new chemistry software that helps students in many different ways. Incorporation of computer software in guided inquiry activities has proven to be beneficial. More than one computer software program could be used or have been used to aide in POGIL and POGIL like programs. Some of these software are LUCID, OWL, and CAPA.

LUCID

LUCID (learning and Understanding through Computer-Based Interactive Discovery) is a software developed in 1998 to help in POGIL workshops. POGIL activities in general are paper-based activities that could be solved without the use of computers. They require students to actively engage in the learning process, but they are static. LUCID overcomes this static feature by being interactive. It also presents students with immediate feedback to promote confidence. In POGIL activities students usually shared their answers by writing them on the board or by presenting them in class. LUCID offers students the opportunity to share solutions and answers of problems by the use of
network reporting. Moreover, LUCID helps students assess their progress and the other teams' progress (Hanson & Wolfskill, 2001).

LUCID was implemented in three out of twenty seven sections of general chemistry in the spring of 1998 at Stony Brook University. All of the sections were taught via process workshops with a comparison between LUCID sections and the other sections (sections that had text-based activities). Student interviews showed that most of the students in the LUCID sections preferred it to the text-based activities. Analysis of student grades showed that LUCID students had an overall average that was 4% higher than the other sections. The greatest improvement (11%) was noticed in weekly quizzes (Hanson & Wolfskill, 2001). These results suggest that using LUCID is in general better than using text-based activities.

**OWL**

OWL (Online Web-Based Learning) is a software that can be used in POGIL activities or in any other chemistry education program. OWL has three stages: Basic OWL, Discovery OWL, and OWL Tutor. The first one provides students with an online homework system; the second one provides students with simulations of chemical phenomena; and the third one serves as an interactive tutor. OWL was described as one of the possible software to be used with PLGI activities (Hanson & Wolfskill, 1998).

**CAPA**

CAPA (Computer Assisted Personalized Assignments) is another system that is used with many POGIL activities. CAPA provides students with individualized homework assignments that are to be solved after a POGIL workshop. The homework assignment is printed at the end of the workshop and is unique for every student. Students
can work together on their homework assignments, but individual answers should be submitted. Answers are submitted electronically from any computer on campus (the computer should be connected to the university’s network). Feedback is supplied by the CAPA system itself; it tells the student whether he or she is right or wrong, and it offers hints and advices. Students can attempt to solve the assignment more than once and they are not penalized for increased number of attempts. Although CAPA provides teachers with a record of student attempts, its primary use is in learning and teaching (Hanson & Apple, 2004).

CAPA is helpful to the students and to the teacher in many aspects. It gives students immediate feedback and motivates the hard working ones. When facing a problem, weak students seek help from peers or from the instructor; this increases the amount of student-student and student-teacher interaction. CAPA saves the teacher a lot of time in preparing and grading homework assignments. It also motivates students to do more cooperative learning outside the classroom (Hanson & Apple, 2004).

CAPA has been also used in traditional chemistry classes and has proven to be a good tool. The majority of students who used it gave high approval rates and indicated that it motivated them to work more diligently (Kashy, Morrissey, & Tsai, 1995).

Reservations and Restraints

Time

Time factors are the most problematic features in the POGIL program. Teaching with the help of POGIL activities has proven to require more time than usually needed in traditional teaching. POGIL activities need more discussion time and more in-class practice time. POGIL or guided inquiry promoters defend this by saying that it is more
important to cover part of the material thoroughly while concentrating on high mastery
level than to go over “all of the material” and cover it in a shallow manner. POGIL
emphasizes process more than it does content following the famous saying “less is more”.
Evidence suggests that covering less material in class, but covering it well, may be more
advantageous (Bodner, 1992). Group work is another feature of POGIL that needs time;
lecturers do not like group work because they feel that with it is very hard to finish all the
material. They have to know that they can never finish all the material even with
lecturing. It is more important to equip students with the ability to learn on their own and
to equip them with the higher order thinking skills to process any kind of information
they may encounter (Cooper, 1995).

The actual time needed for one POGIL activity is another problem. Most
chemistry courses are 3-hour courses that meet 3 times a week for 50-minute sessions.
Many POGIL activities need more than 50 minutes and students need to meet outside
class to complete the work (Hinde & Kovac, 2001). It is hard to keep students after class
or divide the activity over 2 or more sessions. For students to master a new concept they
need time to construct it, and unfortunately there is not enough time allocated for these
types of activities.

In POGIL, students are the number one factor in setting the pace. If students set
the pace, it will be slow enough to accommodate their other classes (Hindi & Kovac,
2001). The instructor has to intervene if he/she discovers that the students are moving at
a very slow pace.
Students

Students enjoy the feeling of belonging to a team and not being competitors (Ditzler & Ricci, 1994), but in the real world competition is always a factor. High achievers in POGIL could feel that they are being slowed down by other members of their group (Hanson & Wolfskill, 2000). Some weak students do not participate in group discussions and just write down what other students are writing. Frequently, if the problems are focused for the level of the high achievers, lower achievers do not actively participate (Hinde & Kovac, 2001).

Student absence is a major problem; groups cannot function properly if one or two members are missing (Hinde & Kovac, 2001). It is hard for absent students to catch up, because it is hard to reproduce the group’s discussion. In traditional methods, a student who was absent could go to the teacher and ask for help. The teacher would explain and give the students some notes. In POGIL, if a student is absent, the teacher cannot serve as the student’s group.

Textbooks

POGIL activities require the use of references and textbooks. It is hard to find textbooks that could support all the POGIL activities given in a certain chemistry class. Some studies showed that students complained because the textbook was not a good resource for the guided inquiry activities (Hinde & Kovac, 2001).

Activities

The POGIL activities themselves could prove to be a little problematic. In various occasions, guided inquiry activities did not provide the big picture. Further, it became
harder to use guided inquiry as the material became more difficult (Hinde & Kovac, 2001).
CHAPTER III

METHODOLOGY

Subjects

The study was conducted at the Hattiesburg campus of the University of Southern Mississippi (USM). The University of Southern Mississippi was founded in 1910 and was originally known as Mississippi Normal College. Its primary purpose was to prepare teachers for Mississippi public schools. Later it evolved into a comprehensive research extensive university in 1962. Students can attend classes on two main campuses Hattiesburg and the Gulf Coast in addition to a few online courses. USM offers its services to more than 15,000 students coming from 82 Mississippi counties, 47 states, and 64 countries (USM, 2006).

The Department of Chemistry and Biochemistry at the University of Southern Mississippi was established in 1959. It prepares students for different careers in chemistry and biochemistry. The undergraduate program offers emphases areas in chemistry, biochemistry, ACS-certified chemistry, ACS-certified biochemistry, and an ACS certified chemistry teaching licensure option. The graduate program offers Masters and PhD degrees in chemistry and biochemistry.

The subjects of this study were undergraduate students enrolled in elementary organic chemistry (CHE 251) during the fall semesters of 2004 and 2006. The students who usually enroll in CHE 251 are Allied Health majors. Their chemistry background consists of only one or two college courses; General Chemistry I is a prerequisite, but some students also have General Chemistry II. The usual number of students enrolled in
this course is between 25 to 35 students. POGIL was administered in the fall 2006 class containing 27 students.

CHE 251 fall of 2006 students were asked at the beginning of the semester about their chemistry background (whether they General Chemistry I only or General Chemistry I and II). There were 8 students with General Chemistry I and II as their background and 19 students with only General Chemistry I as their background. Students were divided into groups of four with each group containing at least one of the 8 students who had completed General Chemistry I and II. Specific roles were not assigned to group members but they were told that they need to choose a person to present at the end of each activity. At the beginning of the semester, students were given a 50-minute lecture on a certain subject and then worked as groups on POGIL activities on the following class session. Later, students were directly introduced to subjects using POGIL activities, and there were no lectures. Activities usually took one or two 50-minute sessions. At the end of the activity’s last session, students were asked to present their answers. Following, the class would engage in discussion to evaluate presented answers. An example of a POGIL activity is provided in Appendix A.

Data Collection

The following steps were used in the collection of data:

1. An application for approval was sent to the University of Southern Mississippi Human Subjects Protection Review Committee to use that data and to administer interviews and surveys on the fall of 2006 CHE 251 class (Appendix B).

2. Achievement scores of CHE 251 students enrolled in the fall semesters of 2004 and 2006 were retrieved.
3. Achievement scores of CHE 420 students enrolled in the summer semester of 2005 and spring semester of 2007 were retrieved.

4. Results were collected on POGIL attitudinal surveys that were conducted in the fall of 2006.

5. Results were collected on the attitudinal confidence levels surveys that were conducted in the fall of 2006, before and after administering POGIL activities.

6. Interviews with CHE 251 students from the fall semester of 2006 were conducted.

The data collected for quantitative and qualitative analysis are summarized in Table 1 and Table 2.

Table 1.

Quantitative Data

<table>
<thead>
<tr>
<th>Variable</th>
<th>Control Group</th>
<th>Experimental Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Final Grades (Percentage Scores)</td>
<td>CHE 251 Fall2004</td>
<td>CHE 251 Fall2006</td>
</tr>
<tr>
<td>Percentage Scores on Final Exam</td>
<td>CHE 251 Fall2004</td>
<td>CHE 251 Fall2006</td>
</tr>
<tr>
<td>CHE 420 (Biochemistry) First Quiz Scores</td>
<td>POGIL Students with</td>
<td>Non-POGIL Students with</td>
</tr>
<tr>
<td>Attitudinal Confidence Levels Surveys</td>
<td>CHE 251 Background</td>
<td>CHE 251 Background</td>
</tr>
<tr>
<td>Fall 2006 Before POGIL 1st part of semester</td>
<td>Fall 2006 After POGIL</td>
<td>end of semester</td>
</tr>
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</table>
Table 2

Qualitative Data

<table>
<thead>
<tr>
<th>Tool</th>
<th>Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interviews</td>
<td>3 weak, 3 average, 3 strong</td>
</tr>
<tr>
<td>Surveys</td>
<td>All 27 students</td>
</tr>
</tbody>
</table>

Instrumentation

Confidence level Surveys

Students enrolled in CHE 251 were asked to complete two different surveys, one at the beginning of the course and one at the end. The first survey, “Beginning of Semester Confidence in Learning Survey” (Appendix C), concentrated on student attitudes toward confidence about learning in chemistry. This survey contained 17 Likert-type questions about attitudes, and three multiple-choice questions. Student attitudes about the effects of POGIL activities included confidence in their understanding of key concepts in organic chemistry, their understanding of laboratory experiments, and their understanding of other areas of science. Additional attitudes about these effects included student confidence in their ability to visualize key concepts and to be successful in future chemistry courses. The multiple-choice questions provided demographic data and information about the participants’ chemistry background. The survey used was originally developed by the LEAD (The Learning through Evaluation, Adaptation and Dissemination) Center at the University of Wisconsin-Madison for the education reform project, "New Traditions Systemic Reform Project." It was posted on the Internet with the permission to be used (National Institute for Science Education, 2006). The survey
was then revised to meet the needs of this particular study. The revised version was piloted at the beginning of the semester on the CHE 251 group and was found to be reliable with a Cronbach's alpha = 0.916. The second survey, “End of Semester Confidence in Learning Survey” (Appendix D), was the same as the first one with the exception of tense change.

**POGIL Activities Surveys**

Students enrolled in CHE 251 were asked to complete a questionnaire, The POGIL Attitudinal Survey (Appendix E), at the end of the CHE 251 course. This instrument concentrated on the attitudes of students towards POGIL activities. The questionnaire contained eleven open-ended questions that cover the same topics but provide greater details. These attitudes included understanding of key concepts in organic chemistry, their understanding of laboratory experiments, and their understanding of other areas of science. Additional attitudes included student attitudes about their ability to visualize key concepts, and to be successful in future chemistry courses.

This questionnaire contained open-ended questions about the implementation of POGIL activities. These questions addressed strengths, ways to improve, insights about learning, and would they like to use POGIL activities again. The survey replaced “POGIL activities” with “in-class group activities” because CHE 251 students did not know what the acronym POGIL stands for.

**POGIL Activities Interviews**

Nine students of the fall semester of 2006 enrolled in CHE 251 were interviewed about their attitudes towards POGIL activities. Students were chosen for the interviews based on achievement: three strong students, three average students, and three weak
students were chosen. Two Professors were consulted before the final version of interview questions was finished (Appendix F). The interviews were tape-recorded and analyzed. They contained specific attitudinal questions about POGIL activities and cooperative learning. The questions related the value of these methods to student learning. Content coding and major theme analysis were used to analyze the interview data. Interviews covered the same attitudinal topics as the previous surveys, but in a one-on-one informal environment. These interviews provided the students with an opportunity to give great detail about their experiences and attitudes. The interviewer used "in-class group activities" instead of "POGIL activities" because CHE 251 students did not know what the acronym POGIL stands for.

The Final Exam

The final exam that was used at the end of the fall semester for CHE 251 contained five questions that were identical to questions on the one administered by the same professor the fall of 2004. The assigned time for the test was 90 minutes. The scores were recalculated based on the identical questions and were then compared.

The First CHE 420 Quiz

Many Students enrolled in the biochemistry course CHE 420 are students who have already taken Elementary Organic Chemistry CHE 251. The first quiz in CHE 420 deals with similar material to the ones taught in the elementary organic chemistry. Grades of CHE 420 quiz 1 were collected and analyzed. The grades of students who were registered in the Elementary Organic Chemistry course in the fall of 2006 were isolated and served as the experimental group because they were taught using POGIL activities. The grades of other students in the class who have the same organic chemistry
background but have not used POGIL were isolated and were part of the control group. Further, first quiz grades of CHE 420 students, for the summer of 2005, were collected. Collected grades were only grades of students with CHE 251 background. Those grades were added to the control group. The first CHE 420 quiz given in the summer of 2005 was very similar to one given in the spring of 2007. The CHE 420 first quiz grades for POGIL students (the experimental group) were compared to CHE 420 first quiz grades for non-POGIL students (the control group).

Data Analysis

First, null hypothesis 1 (H_{01}) was:

There is no statistically significant difference in achievement scores on the final grades of elementary organic chemistry between students taught traditionally and those taught by the new curriculum.

The final percentage scores of CHE 251 classes from the fall semesters of 2004 and 2006 were tabulated and compared using an independent t-test. Students enrolled in the fall semester of 2004 were the control group because they did not use POGIL activities. Students enrolled in the fall semester 2006 were the experimental group (used POGIL). Students of fall 2004 and fall 2006 studied under almost identical conditions including the professor, enrollment semester, and final exam. All sections of CHE 251 studied similar topics and had the same chemistry background. The main difference between the control group and the experimental one was the use of POGIL activities in the classroom.
The second, null hypothesis 2 ($H_{02}$) was:

There is no statistically significant difference in achievement scores on the final-test grades of elementary organic chemistry between students taught traditionally and those taught by POGIL.

The final-test scores of CHE 251 classes from the fall semesters of 2004, and 2006 were tabulated and compared using an independent t-test. Students enrolled in the fall semester of 2004 were the control group because they did not use POGIL activities. Students enrolled in the fall semester 2006 were the experimental group (used POGIL).

The final exam that was used at the end of the fall semester for CHE 251 contained five questions that were identical to questions on the one administered by the same professor the fall of 2004. The assigned time for the test was 90 minutes. The percentage scores were recalculated based on the identical questions and were then compared for the two groups.

The third, null hypothesis 3 ($H_{03}$) was:

There is no statistically significant difference in achievement scores on the first quiz grades of CHE 420 biochemistry course between students taught traditionally and those taught by POGIL.

The first quiz scores of CHE 420 from the summer semester of 2005 and the spring semester of 2007 were tabulated and compared using an independent t-test. Students were effect coded according to whether or not they were enrolled in the CHE 251 course during fall 2006.
The fourth, null hypothesis 4 ($H_{04}$) was:

There is no statistically significant difference in the confidence levels of students in chemistry before and after going through the POGIL activities.

The data from the “Before” and “After” POGIL attitudinal surveys was one point for answering (a, strongly disagree), two points for answering (b, disagree), three points for answering (c, neutral), four points for answering (d, agree), and five points for answering (e, strongly agree). The scores on the Before POGIL attitudinal survey and the After POGIL attitudinal survey were compared using a dependent t-test.

All the calculations were done using SPSS version 13. The significance level for testing all hypotheses was set at 0.05.

Finally, answering question 3 which is “What are the attitudes of students towards POGIL activities as opposed to traditional learning when examined by the use of surveys and interviews?” was answered by qualitative research methods. Interviews conducted with CHE 251 students and answers to the POGIL activities surveys were tabulated and studied. Interviews and the attitudinal survey were analyzed using content coding and major theme analysis. This was done to answer Research Question 3 and to add more insight to the study. The Questions from both the attitudinal survey and the interviews were divided into nine categories or nine major themes:

1. Confidence in understanding key concepts in organic chemistry.
2. Confidence in the ability to visualize key concepts in organic chemistry.
3. Confidence in understanding lab experiments.
4. Confidence of their ability to succeed in future chemistry courses.
5. Strengths of POGIL activities.
6. Ways to improve POGIL activities.

7. Students’ developed insights about learning.

8. Whether or not students would like to use POGIL activities in other courses.

9. General attitudes of students towards POGIL activities.

Answers to these questions were then analyzed and reported categorically.

Analysis of data is presented in Chapters 4 and 5. Results and conclusions are presented in Chapter 6.
CHAPTER IV

ANALYSIS OF QUANTITATIVE DATA

Introduction

The purpose of the study was to assess the effect of using POGIL activities in Elementary Organic Chemistry. The first part of the study was to test the effect of those activities on achievement and on confidence levels of students. Three hypotheses on achievement were examined and one hypothesis on student attitudes toward their confidence levels in understanding and applying organic chemistry was also examined. The first three hypotheses on achievement were analyzed by independent sample t-tests and the fourth hypothesis was analyzed by a dependent sample t-test. The second part of the study was done qualitatively and results will be discussed in Chapter five.

Subjects

Archival data on 28 students enrolled in the fall 2004 semester were used in this study. In addition, 27 students enrolled in the fall 2006 semester were directly involved in the study. All of the students in both semesters were non chemistry majors; most of them were either nutrition or medical technology majors. Both groups were taught by the same teacher but with different techniques. The fall 2004 students were taught in a traditional learning environment and served as the control group while the fall 2006 students used POGIL activities and served as the experimental group. The final grades of 26 students from the experimental group were compared to the final grades of 28 students from the control group; one student from the experimental group dropped the course. Only 26 out of 28 final exams were retrieved from the fall 2004 semester; therefore, only 26 grades from the control group were compared to the 26 grades from the experimental group. In
addition, first quiz grades of 24 students who were enrolled in the CHE 420 biochemistry course in the spring of 2007 and 24 students who were enrolled in the CHE 420 biochemistry course in the summer of 2005, were compared. From those 48 students 18 were part of the experimental group of the fall 2006 semester and 30 were not. All 48 students had only Elementary Organic Chemistry (CHE 251) as their organic chemistry background. Only the grades on the first CHE 420 quiz were examined for those 48 students.

In the 2006 fall semester, students were surveyed, in class, about their confidence level in understanding organic chemistry. This survey was administered twice, at the beginning of the course and again at the end. At the beginning of the course, 23 students out of the registered 27 students took the survey, and at the end 24 students out of 27 took the survey. Questions 4 through 12 measured confidence levels and results of both surveys were compared using a paired samples t-test. There were only 20 students who completed both the “before” and “after” surveys, and the scores for these students were the ones analyzed.

Descriptive Data

The evaluation of the effect of POGIL activities on student achievement was based on three different grades. First, the researcher examined the final grades of fall 2004 (control group) students and those for the fall 2006 (experimental group). Both classes had a final average of 87%. The letter grade distribution for the fall 2006 group was: 46% A, 42% B, and 12% C. The letter grade distribution for the fall 2004 group was: 53% A, 36% B, 7% D, and 7% F. In both cases, the same grading scale was used, and there was no curving of grades.
The second step was to examine student scores on the final exam. The questions on the fall 2004 final exam were not all identical to the questions on the fall 2006 final exam, so the researcher recalculated the grades based on only identical questions. Five questions were identical and were used to check for differences. The fall 2004 students had an average of 88.4% while the fall 2006 group had an average of 85.5%. The letter grade distribution for the fall 2006 group was: 42% A, 31% B, 19% C, 4% D, and 4% F. The letter grade distribution for the fall 2004 group was: 54% A, 23% B, 19% C, and 4% D.

The third test compared the first quiz grades of students registered in the spring 2007 and summer 2005 CHE 420 biochemistry course having the same organic chemistry background, CHE 251. There were 48 students having the preceding criteria, 18 of whom were in the fall 2006 CHE 251 class. Those 18 students served as the experimental group while the other 30 served as the control group. The experimental group had an average of 66% while the control group had an average of 70.0%. The letter grade distribution was 5.5% A, 5.5% B, 27.8% C, 33.3% D, and 27.8% F for the experimental group and 20% A, 13.3% B, 23.3% C, 13.3% D, and 30.0% F for the control group. All the results for achievement comparisons are shown in Table 3.
Table 3

*Comparison of achievement scores*

<table>
<thead>
<tr>
<th>Variables</th>
<th>Control</th>
<th></th>
<th></th>
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<td>Mean</td>
<td>SD</td>
<td>n</td>
<td>Mean</td>
<td>SD</td>
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<td>Final Grades</td>
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<td>6.90</td>
<td>26</td>
<td>87.0</td>
<td>10.17</td>
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<td>Grades on Final Exam</td>
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<td>10.64</td>
<td>26</td>
<td>85.5</td>
<td>10.82</td>
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<tr>
<td>Grades on 1st CHE 420 Quiz</td>
<td>30</td>
<td>70.0</td>
<td>17.91</td>
<td>18</td>
<td>66.0</td>
<td>15.77</td>
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</tbody>
</table>

The confidence level of students in learning and understanding organic chemistry was tested two times, before and after implementing POGIL activities. Nine questions evaluating confidence levels were given to students in a survey that was conducted before and after implementing POGIL activities in the CHE 251 fall 2006 class. Questions were assigned points ranging from 1 to 5, 1 being the least confident and 5 being the most confident. Students scored an average of 3.6 on the first survey (the “before” survey) and 3.7 on the second survey (the “after” survey). The results are shown in Table 4.

Table 4

*Comparison of confidence levels*

<table>
<thead>
<tr>
<th>Before</th>
<th>After</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before</td>
</tr>
<tr>
<td></td>
<td>n</td>
</tr>
<tr>
<td>Confidence Level (1 to 5)</td>
<td>20</td>
</tr>
</tbody>
</table>
Tests of Hypotheses

The results from testing the hypotheses of the study are presented in this section. Each one of the four hypotheses is restated and then the analysis of the data is provided for each hypothesis.

Hypothesis 1:

$H_0$: There is no statistically significant difference in achievement scores on the final grades of elementary organic chemistry between students taught traditionally and those taught by POGIL.

The students who were taught using POGIL activities did not have different final averages than the students who were taught traditionally. The mean score for the 2004 fall was 87%, and so was the mean of the 2006 fall class. There was no statistically significant difference among the two groups $t(52) = 0.38, p = 0.970$. The means and standard deviations are presented in Table 3.

Hypothesis 2:

$H_0$: There is no statistically significant difference in achievement scores on the final-test grades of elementary organic chemistry between students taught traditionally and those taught by POGIL.

The students who were taught using POGIL activities did not score differently on the final exam than the students who were taught traditionally. The mean score for the 2004 fall class final exam was 85.5%, and the mean score for the 2006 fall class final exam was 88.4%. There was no statistically significant difference among the two groups $t(50) = 0.98, p = 0.334$. The means and standard deviations are presented in Table 3.
Hypothesis 3: 

$H_{03}$: There is no statistically significant difference in achievement scores on the first quiz grades of CHE 420 biochemistry course between students taught traditionally and those taught by POGIL.

The students who were taught using POGIL activities did not score differently on the CHE 420 first exam than the students who were taught traditionally. The mean score for the POGIL group was 66% and the mean score for the non POGIL group was 70.0%. There was no statistically significant difference among the two groups, $t(46) = 0.79, p = 0.434$. The means and standard deviations are presented in Table 3.

Hypothesis 4:

$H_{04}$: There is no statistically significant difference in student attitudes toward their confidence levels in understanding and applying organic chemistry before and after going through the POGIL activities.

Students did not score differently on the confidence level survey before and after they went through POGIL activities. The mean of the “before” survey was 3.6 (the scale was 1 to 5) and the mean of the “after” survey was 3.7. There was no statistically significant difference in student attitudes toward their confidence levels in understanding and applying organic chemistry before and after going through the POGIL activities, $t(19) = 0.54, p = 0.596$. The means and standard deviations are presented in Table 4.
CHAPTER V
ANALYSIS OF QUALITATIVE DATA

Introduction

Qualitative analysis was conducted to give further insight to the study. The tools used for the qualitative analysis were open ended surveys and personal interviews. All 27 students registered in the fall 2006 CHE 251 class answered the open ended surveys and 9 of those students were interviewed. The interviewed students were chosen on the basis of achievement levels: three academically strong students, three average students, and three weaker students were interviewed. The interviews contained 22 questions, but not all of them were used in this research. Questions 9, 11, 12, 13, and 18 were not directly related to the research question. Only the questions related to the research questions were analyzed. The surveys contained 11 open ended questions all of which were analyzed. Students were asked to explain their answers for all the questions. In both the surveys and the interviews, POGIL was substituted for in-class group activities because students were not introduced to the word POGIL.

The questions analyzed were used to answer Research Question 3 which was: What are the attitudes of students towards POGIL activities as opposed to traditional learning when examined by the use of surveys and interviews? Questions from both the surveys and the interviews were divided into nine categories or nine major themes:

1- Confidence in understanding key concepts in organic chemistry.
2- Confidence in the ability to visualize key concepts in organic chemistry.
3- Confidence in understanding lab experiments.
4- Confidence of their ability to succeed in future chemistry courses.
5- Strengths of POGIL activities.

6- Ways to improve POGIL activities.

7- Students’ developed insights about learning.

8- Whether or not students would like to use POGIL activities in other courses.

9- General attitudes of students towards POGIL activities.

Each question, from both the surveys and the interviews, and the results are discussed below in their respective categories.

Descriptive Data

The open ended survey instrument used in this research was composed of 11 questions. Out of the 11 questions 7 were yes-no questions. These questions were numbered 1, 2, 3, 4, 5, 6, and 11. Questions 7 through 10 could not be answered by ‘Yes” or “No”. Students were asked to explain their answers. Some students chose to give a neutral answer. Answers that were not a definite “Yes” or a definite “No” were designated as “Other”. Table 5 summarizes the answers for those 7 questions. The questions are distributed among their respective category. The number of people who took the survey was 27.
Table 5

Answers for the Open Ended Survey Questions

<table>
<thead>
<tr>
<th>Category</th>
<th>Survey Question</th>
<th>Yes</th>
<th>No</th>
<th>Other</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Understand key concepts (1)</td>
<td>help you understand key concepts</td>
<td>19 (70%)</td>
<td>8 (30%)</td>
<td>0</td>
<td>27</td>
</tr>
<tr>
<td>Visualize key concepts (2)</td>
<td>help you in visualizing molecular structures</td>
<td>14 (52%)</td>
<td>8 (30%)</td>
<td>5 (18%)</td>
<td>27</td>
</tr>
<tr>
<td>Understand lab experiments (3)</td>
<td>help you in understand lab experiments</td>
<td>7 (26%)</td>
<td>20 (74%)</td>
<td>0</td>
<td>27</td>
</tr>
<tr>
<td>Ability to succeed in future chemistry courses (4)</td>
<td>helped you or will help you in other science courses</td>
<td>20 (74%)</td>
<td>7 (26%)</td>
<td>0</td>
<td>27</td>
</tr>
<tr>
<td>Ability to succeed in biochemistry courses (5)</td>
<td>help you succeed in biochemistry</td>
<td>12 (44%)</td>
<td>4 (15%)</td>
<td>11 (41%)</td>
<td>27</td>
</tr>
<tr>
<td>Like to use POGIL activities in other courses like this one (11)</td>
<td>would you take another course taught</td>
<td>18 (67%)</td>
<td>5 (18%)</td>
<td>4 (15%)</td>
<td>27</td>
</tr>
<tr>
<td>General attitudes like these in-class group activities (6)</td>
<td></td>
<td>22 (81%)</td>
<td>3 (11%)</td>
<td>2 (8%)</td>
<td>27</td>
</tr>
</tbody>
</table>
The interviews used in this research were composed of 22 questions. Only 17 questions were used to conduct this research. Out of the 17 questions 16 were yes-no questions. These questions were numbers 1, 2, 3, 4, 5, 6, 7, 8, 10, 14, 15, 16, 17, 19, 20, 21. Question 22 could not be answered by ‘Yes” or “No” and Questions 9, 11, 12, 13, 18 were not used for this research. Students were asked to explain their answers. Some students chose to give a neutral answer. Answers that were not a definite “Yes” or a definite “No” were designated as “Other”. Table 6 summarizes the answers for those 16 questions. The questions are distributed among their respective category. The number of people who were interviewed was 9. Questions 4 and 16 were asked in a negative way and therefore a “Yes” on these questions means that they actually liked POGIL activities and a “No” means that they did not.
Table 6

**Answers for the Interview Questions**

<table>
<thead>
<tr>
<th>Category</th>
<th>Interview Question</th>
<th>Yes</th>
<th>No</th>
<th>Other</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Understand key concepts (1)</td>
<td>helped you understand and learn (2)</td>
<td>5 (56%)</td>
<td>4 (44%)</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>help you prepare for tests (14)</td>
<td>8 (89%)</td>
<td>1 (11%)</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>would help you score higher on chemistry tests (15)</td>
<td>8 (89%)</td>
<td>1 (11%)</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>help you better understand major concepts (19)</td>
<td>6 (67%)</td>
<td>3 (33%)</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>absence for the activities negatively affects achievement scores (21)</td>
<td>7 (78%)</td>
<td>2 (22%)</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td>Insights about learning (7)</td>
<td>learn how to solve problems (3)</td>
<td>6 (67%)</td>
<td>1 (11%)</td>
<td>2</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>learned and understood more by working in a team (7)</td>
<td>7 (78%)</td>
<td>2 (22%)</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>working in a team has increased your confidence (8)</td>
<td>5 (56%)</td>
<td>4 (56%)</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>feel encouraged to study for the chemistry course (10)</td>
<td>6 (67%)</td>
<td>3 (33%)</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td>Like to use POGIL in other courses (8)</td>
<td>like activities to be implemented in other chemistry courses (20)</td>
<td>7 (78%)</td>
<td>2 (22%)</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td>General attitudes (9)</td>
<td>activities were challenging and worthwhile (1)</td>
<td>5 (56%)</td>
<td>1 (11%)</td>
<td>3 (33%)</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>activities were stressful and frustrating (4*)</td>
<td>2 (22%)</td>
<td>4 (56%)</td>
<td>3 (33%)</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>activities were more beneficial than lectures (5)</td>
<td>7 (78%)</td>
<td>2 (22%)</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>activities helped you feel good about your progress in the course (6)</td>
<td>6 (67%)</td>
<td>3 (33%)</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>activities were way too time-consuming (16*)</td>
<td>2 (22%)</td>
<td>5 (56%)</td>
<td>2 (22%)</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>time invested on activities was worthwhile (17)</td>
<td>7 (78%)</td>
<td>1 (11%)</td>
<td>1 (11%)</td>
<td>9</td>
</tr>
</tbody>
</table>

* Questions asked negatively
Analysis of Data

*Questions about Confidence in Understanding Key Concepts in Organic Chemistry*

Category one included questions about confidence in understanding key concepts in organic chemistry. This topic was addressed in Survey Question 1 and Interview Questions 2, 14, 15, 19, and 21.

**Survey Question 1.** Did the in-class group activities help you understand key concepts in chemistry?

Out of the 27 students surveyed 19 gave a positive answer to this question and believed that the in-class group activities helped them understand key concepts in chemistry. Comments included: “It did because it forced us to learn”, “It was an opportunity to work together and help each other out”, “Yes it helped to practice the material rather than hear about it”, “I feel that it helped because it gave us hands on experience, and more time to learn”, and “I am a visual learner, so having the group discussions really helped”. Students indicated that group work and the activities themselves helped them better understand chemistry. Students who gave a negative response to this question mostly wanted more explaining to be done by the teacher. Some comments from those students were: “lecture first then activities would have worked fine”, “I learn better when I am presented with material in an ordered way and be able to go over it myself”, “I didn’t feel it was a good way of understanding concepts because you almost had to teach yourself”, and “I am used to lecture type environment”.

**Interview Question 2.** Do you think that the in-class group activities helped you understand and learn the course material?
Six out of nine students answered “Yes” to this question indicating that the activities helped them more than simple lecturing. Some comments were: “I learned it and I think that I learned it even better than just by taking notes”, “with that you actually have to think about it and learn and not just memorize”, and “I learned it much better than just somebody writing notes on a board and me reading them”. Students liked the idea of working in the class instead of only listening to the lecturer. The three students who answered “No” to this question (two average students, and one strong student) did not elaborate a lot on the reasons with one student stating: “It was kind of hard to do them not having anything taught before” referring to doing the activities without being lectured to first.

**Interview Question 14.** Do you think that the in-class group activities helped you prepare for tests?

Eight students out of the nine interviewed students answered “Yes” to this question indicating that the activities helped them prepare for tests. One student commented, “When you’re in groups something that I didn’t understand other people did understand and it was an easy way to study while you were in class”. The others liked the fact that the activities gave them a guideline of what to study. The student who said “No” was a strong student and did not elaborate or give further information.

**Interview Question 15.** Do you think that the in-class group activities helped you score higher on chemistry tests?

The same eight students who answered Yes to the previous question answered “Yes” to this question. They all thought that POGIL activities helped them score higher on chemistry tests. One student commented, “I think that it helps allow the students to
understand and really insure that they understand the knowledge rather than just lecture to them and hope that they would understand it”. The student who said “No” was a strong student and did not elaborate or give further information.

Interview Question 19. Do you think that the in-class group activities critical questions helped you better understand major concepts?

Six students out of the nine interviewed students gave a positive “Yes”. They thought that the critical questions that were on the POGIL activities helped them better understand major concepts. Student comments included: “I think so because you had to really think through what the question said to get the answer” and “They were a lot tougher than the questions that we had so I actually knew how to do the harder stuff so when you go to the easier they are easier”. The other three students were one weak, one average, and one strong student. The weak student said, “On some worksheets yes but on others no”, the average student said, “When someone explained what the activities were trying to say”, and the strong student said, “No”.

Interview Question 21. Do you think that absence for the in-class group activities negatively affects achievement scores?

Seven students indicated that being absent for the POGIL activities negatively affected their understanding and their grades. Those students said, “I was not absent for that very reason because I definitely relied on my group to help discuss and work together”, “I missed a day and I got kind of confused”, “You can do them at home but people do need to be present so that they can get other people’s ideas”, and “There is a guy in our group who missed a lot and he’s really a smart guy but when it comes to test grades it really showed because he wasn’t there for the activities in class versus the other
girl’s grade that made it to class and done the activities”. Those students thought that doing the POGIL activities in class helped them to better understand lessons and to score higher on the exams. One weak student thought that if a person had a good chemistry background he or she can do without attendance, but since that student did not have a strong chemistry background she needed to attend class. The other two students, one average and one strong, thought that if they had the worksheets, they would be able to do them at home alone. Further, they thought that if students were presented with the answers without going through the trouble of going through the problems themselves, they would understand the concepts and do well on tests.

Questions about Confidence in the Ability to Visualize Key Concepts in Organic Chemistry

Category two included questions about confidence in the ability to visualize key concepts in organic chemistry. This topic was addressed in Survey Question 4.

Survey Question 4. Did the in-class group activities help you in visualizing molecular structures?

Out of the 27 students surveyed 14 students answered “Yes” to this question, 4 students answered “Sometimes” and 8 students answered “No”. Students, who answered by a “Yes” or by “Sometimes”, thought that models helped them more in visualizing molecular structures. The activities themselves were not mentioned a lot in answering the questions. Some student comments were, “Along with the activities the teacher would show us the ball and stick model to help us see it in a 3-D way”, “Having the molecular modules in class helped a lot”, and “I have a clearer understanding of molecular structures and how molecules are arranged”. The students who answered “No” gave
similar comments like “I learn better from actual models”. In general, most of the answers indicated that the activities themselves did not help a lot in visualizing molecular structures. Most students thought that models would help more than the activities themselves. The students who answered “Yes” were assuming that the models were part of the POGIL activity.

Questions about Confidence in Understanding Laboratory Experiments

Category three included questions about confidence in understanding Laboratory Experiments. This topic was addressed in Survey Question 2.

Survey Question 2. Did the in-class group activities help you in understand lab experiments?

Only 7 out of 27 students thought that POGIL activities helped them understand lab experiments. The other 20 students thought that the activities and the lab experiments were not correlated. Some student comments were: “Labs did not always follow exactly with the class”, “It would have been more helpful in the lab and class activities coincided”, and “The lab covered concepts we had not done in class or things that we will not get to cover”. Most of the students did not see any real connection between POGIL activities and the lab experiments they were doing.

Questions about Confidence in Ability to Succeed in Future Chemistry Courses

Category four included questions about confidence in ability to succeed in future chemistry courses. This topic was addressed in Survey Questions 3 and 5.

Survey Question 3. Do you think that the in-class group activities helped you or will help you in other science courses?
Most of the students gave a positive answer to this question (20 out of 27).

Students thought that since they actually learned the material in this class it would help them in other science courses. They felt that the activities helped them prepare for other science courses since they really understood the concepts in the class. Almost all of the students thought of other science courses as chemistry courses so they gave answers based on that notion. Student comments included: “Yes, since I did learn while doing the activities”, “I feel well prepared for anything dealing with chemistry”, “Although they were very challenging it prepared me for organic chemistry”, “Because now I understand the general concepts of organic chemistry”, and “I learned more in this course than in previous chemistry courses”. The other 7 students who thought it did not or it would not help them in other science courses did not like the whole idea of working in a group. Some of their comments were: “I never learn well in a group. Either I do not like the people I’m working with and too distracted by being aggravated, or I like them and chitchat with them. Either way I’m not learning” and “I am not a good group learner, I learn better from lecture style learning”.

Survey Question 5. Do you think that the in-class group activities will help you succeed in biochemistry?

The students answered this question in various methods 12 students said “Yes”, 4 students said “No”, and 11 students did not know, but hoped it would. The students who said “Yes” thought that since they really understood the concepts in this course they should be able to do well in the biochemistry course. Some comments were: “They gave me more confidence in getting ready for biochemistry”, “The studies helped me understand it better”, “I have a good understanding on the stuff we covered”, “I did learn
a lot working together”, and “Because they provided a more interactive experience and that is easier to remember/learn”. The students who said “No” thought that they would have learned better in a lecture format class, one of them said, “Because the concepts were not grasped as fully as they could have been if taught by a teacher” and another person said, “I didn’t learn much just from being in a group”. The other students were unsure of whether or not it would help them and gave comments like: “Hopefully, honestly I do not know what to expect so I do not know if it will help or not”, “I hope so; I did learn a lot working together”, “I don’t know, but I hope so. I have a better understanding of all the topics we talked about”, and “I hope so, I did learn a lot working together”, and “I hope so but I don’t know if I am fully prepared on the key concepts”.

Questions about the Strengths of POGIL Activities

Category five included questions about the strengths of POGIL activities that student acknowledged. This topic was addressed in Survey Question 9.

Survey Question 9. Describe at least one strength of this course.

The answers to this question seemed to concentrate on two aspects group work and the teaching staff. Many students liked the idea of working in a group and felt that it was one of the strengths of the course. They gave comments like: “The group activities help me understand certain problems cause of my partners”, “We make discussions about activities we do”, “Working in groups has helped me a lot more than working on my own”, “The course was more interactive than most classes; thus it was easier to understand and remember”, “Working together helped us learn together and build relationships”, and “It helped me learn and retain what I learned because we had to work through the problems together as a group and you develop friendships which makes the
setting laid back which is a good learning environment”. Some students liked the fact of having more than one teacher moving around the class. They also liked the fact that teachers were giving explanation time to each group alone. Their comments included: “I liked that the teachers worked together so we would have an understanding of the class”, “The teaching staff was always available and willing to help”, “Being able to be given the paper and have one on one help if needed”, and “The greatest strength of any course is the knowledge and teaching ability of the professors”. Five students thought that the activity and the activity sheets themselves were one of the course’s strength. They thought that the activities gave structure to the course and helped them prepare for tests and quizzes.

Questions about Ways to Improve POGIL Activities

Category six included questions about ways of improving POGIL activities. This topic was addressed in Survey Questions 7 and 8.

Survey Question 7. Suggest ways to improve the content and format of theses in-class group activities (ex: order of questions, number of tables, pictures...).

More than half of the students surveyed (14 out of 27) wanted more lecturing to be done prior to the activities. They thought that a brief explanation of the activities or of the concepts would have helped them better understand the activities. The students did not want all the class to be done lecture-style, but they wanted the activities to come after a concise lecture. Some of their comments were: “Lecture before the activities”, “More discussion about the activities before handing them out”, “An introduction of the chemistry concepts before giving the activities”, and “Lecture by the teacher of the concepts and then the group activities”. Five students thought that the activities were fine
and needed no modification. Three students wanted the activities to correlate more with the book or they wanted to be given more supplemental readings. Two students wanted the activities to contain more examples and problems. The last three students had three different answers. One thought that some of the problems were too advanced for elementary organic chemistry, another one wanted more presentations to be done by students, and the last one found it hard to picture molecules in 3-D.

Survey Question 8. Suggest ways to improve the implementation of these in-class group activities (ex: number of people in a group, time...).

Ten students indicated that the implementation of POGIL activities needed no alteration with comments like “No change needed”. Six students thought that a small lecture before the activities would have helped a lot and one student wanted a lecture to be done at the end of each session explaining the answers. Three students commented on the time aspect of the activities; they thought that the activities took a lot of time, and that it would have been better if there was a time limit. Three students thought that the groups should be composed of only two students to make sure everyone is working. One student went as far as asking for the activities to be done individually. The rest of the students felt that there should be more interaction in the class by allowing groups to discuss things with other groups or by increasing the number of instructors.

Questions about Students' Developed Insights about Learning

Category seven included questions about insights that student developed about learning after going through POGIL activities. This topic was addressed in Survey Question 10 and Interview Questions 3, 7, 8, and 10.
Survey Question 10. What insights about how you learn did these in-class group activities provide you with?

The answers to this question were diverse but seemed to cluster around three main ideas: guided inquiry, cooperative learning, and lecturing. Ten students deduced that they learn better by doing and by solving problems (a guided inquiry model). Their comments included: “I learn better by working out problems”, “You retain more knowledge by working through it yourself and actually working problems than just memorizing lectures”, “You’re teaching yourself as well as learning”, and “I am more of a hands-on person so I learn best by doing things”. Six students acknowledged that they learn better in groups and in doing cooperative learning. Their comments included: “I learn better in groups” and “I learn best with interaction with others”. Four students preferred lecturing to POGIL activities and did like neither the guided inquiry problems nor the cooperative learning. Their comments included: “I learn better when someone explains things to me first” and “As much as I do not enjoy lecture, I think I learn better with more lecture”. Three students did not like being in a group with comments like “I work better by myself versus working in a group” and “Working in a group is sometimes frustrating”. The rest of the students did not give an answer to this question.

Interview Question 3. Do you think that the in-class group activities helped you learn how to solve problems?

Out of the nine interviewed students six thought that POGIL activities helped them learn how to solve problems. They thought that talking through problems and discussing them with their peers helped them understand how to solve problems. They gave comments like “It just helped you talk through stuff and I’m a talker” and “Very,
very, very much, now I am a problem solver". Two students, one average student and one strong student, thought that it only helped them prepare for similar problems. They did not know if they could solve different problems on the same subject, and one student commented, "I don’t know that I would understand how to do other ones like if new or different problems had been on the test different from what was on the sheets I don’t know if I would have felt as comfortable". There was only one strong student who answered by “No” but did not elaborate further.

Interview Question 7. Do you think that you learned and understood more by working in a team than if you had worked individually?

Seven students answered this question by a “Yes” stating that they learn better by working in groups than by working individually. Students thought that group discussions helped increase their confidence in understanding major concepts. They stated that listening to other people’s answers and views helped get a better grasp of the material. Some of their comments were: “I always like to study with some one with a group of people because I find that discussing any amount of material all the way through helps me understand and make sure that I’m on the same page with the way it should be done”, “What you didn’t know maybe somebody else knew”, and “We all put our heads together and it helped pull through and you understood by the time you came to the test”. One of the two other students was an average student and said, “I was lucky to have some good people to work with this semester but I’ve been in groups where people were just terrible and so it just depends on the group”. The last student who was a strong one answered by a simple “No”.

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Interview Question 8. Do you think that working in a team has increased your confidence in studying and learning chemistry?

Interview Questions 7 and 8 were answered differently. Students who thought that they learned better in groups did not necessarily think that working in a group increased their confidence in studying and learning chemistry. Five students thought that working in a team had increased their confidence in studying and learning chemistry and four thought it did not. The five students who gave a positive answer gave comments like “Working in groups here in organic you know I came to actually like organic I feel more comfortable with it and I feel that I can do it pretty well” and “I wasn’t on my own with my answers so I would say it definitely helps increase my confidence in answering”. The other four (two average students, one strong student, and one weak student) gave comments like “Not so much confidence level I mean they only helped the ability to learn but I don’t think confidence level” and “No, because when I didn’t know something then they didn’t know it either so we didn’t really help each other out so much”.

Interview Question 10. With the in-class group activities did you feel encouraged to study for the chemistry course?

Six students felt that POGIL activities encouraged them to study for the course. They thought that doing the activities made them actually learn in class instead of just write notes. Some of their comments were: “When you did the activities you actually learned things while you’re doing them where when you take notes you’re just working on getting everything written down”, “Because being that I actually understood what I was doing I felt more confident to study so I wouldn’t be as confused”, and “I would definitely consider it more than I would, knowing that they were all retro based”. The
other three students (one weak student, one strong student, and one average student) answered by “No” and did not elaborate more except for one who said “I don’t like to study for anything”.

Questions about Whether or Not Students Would Like to Use POGIL Activities in other Courses

Category eight included questions about whether or not students would like to use POGIL activities in other courses. This topic was addressed in Survey Question 11 and Interview Question 20.

Survey Question 11. If you had the option would you take another course taught like this one with in-class group activities rather than traditional lecturing?

Most students seemed to like POGIL activities to be implemented in other chemistry courses. They pointed out that they would take another course taught like this one with in-class group activities rather than traditional lecturing if they had the option. Out of the 27 students surveyed 18 students answered “Yes” to this question. The “Yes” was followed many times by “definitely” or “anytime”. Some students said “In a heartbeat, it gave many more insights from different people and it helped a lot”, “It made class more enjoyable”, and “This was a great way to learn”. Five students preferred traditional learning and gave comments like “I enjoy traditional lecturing classes”. Two students thought that mixing the two techniques would be better than either one alone. The last two students did not answer this question.

Interview Question 20. Would you like these in-class group activities to be implemented in other chemistry courses?
Seven interviewed students out of nine stated that they would like POGIL activities to be implemented in other chemistry courses. Those students thought that these activities made them learn chemistry better and enjoy it more. Some comments were: “I think that overall these types of activities helped me enjoy chemistry in the class more and helped me like really want to learn”, “It helped me understand better because I’m a visual person and being able to do it myself instead of someone saying this is how you do it so I actually got practice while I was in class”, and “It helped me to understand the concepts so much better and to learn so much easier”. The two students (a strong one, and an average one) who gave “No” for an answer did not elaborate more.

Questions about the General Attitudes of Students towards POGIL Activities

Category nine included questions about general attitudes of students towards POGIL activities. This topic was addressed in Survey Question 6 and Interview Questions 1, 4, 5, 6, 16, 17, and 22.

Survey Question 6. Did you like these in-class group activities?

Out of the 27 surveyed students 22 students (81.5%) liked POGIL activities. Three students did not like them and said that they preferred lectures. One of the other two students did not answer this question, while the other person indicated that he only liked some of them. Students who liked the activities gave various reasons like “It made us learn the concepts”, “Related with my fellow classmates”, “It always helps having 3 people’s knowledge vs. one”, and “It made class more interesting since to me chemistry is so boring”. Three of the students who answered “Yes” to this question mentioned that they would prefer the activities to be done after brief lectures; they did not like the idea of working on something without being introduced to it first. One of their comments was “I
would have wanted to be taught a little before hand because sometimes we didn’t have a clue when we received the activities”.

Interview Question 1. Do you think that the in-class group activities were challenging and worthwhile?

The answers to this question were of three types: “Yes”, “Yes, but…”, and “No”. Five students answered by “Yes” indicating that they thought POGIL activities were challenging and worthwhile. Those students explained that although the problems were challenging, doing them made them learn. Some of their comments were: “They were very challenging definitely made me test my own knowledge” and “Because they were challenging but you could talk through them so you could understand them so they were worthwhile”. Three students answered by a conditional “Yes”, one of them was an average student and liked the activities but not the group work. The other two (an average student and a strong student) thought that the activity would have worked better if it was preceded by a lecture. One of there comments was: “If lectures came first and then the activities I think they would have been a lot better”. The last student interviewed who was a strong student did not like the activities and did not elaborate further.

Interview Question 4. Do you think that the in-class group activities were stressful and frustrating?

Four people thought that the activities were not stressful and frustrating with the exception of some parts. Two students (a weak student and an average student) thought that the activities were stressful and frustrating, because they were not preceded by lectures and because students did not know what to do. Their comments were, “Especially when you didn’t know what you were doing and other people in the group
didn’t either” and “Only because we didn’t have the lecture before hand”. The other three students thought that the activities started out as stressful and frustrating, because they were new but later on they were not. Some of their comments were: “As we started to get used to the activity papers they were better not easier but better to know the format” and “When I first got one I fainted because I had no clue what it meant no clue and then starting with nothing and then finding it makes you learn it better”.

Interview Question 5. Do you think that the in-class group activities were more beneficial than lectures?

Most of the interviewed students (7 out of 9) thought that POGIL activities were more beneficial than lectures. They thought that since these activities made them learn by doing, and not by listening, they were better than lectures. Students also liked the idea of getting one-on-one help from the teacher. They gave comments like “I’m a more hands on person and I rather do it than hear about it”, “I like to learn by you know just working”, and “I actually found it more one on one than somebody writing notes on the board”. The other two students (an average student and a strong student), who thought that lecturing would be more beneficial, thought that the POGIL activities could help a lecture but not substitute it; one of them said, “I think that they could really help a lecture but not by themselves”.

Interview Question 6. Do you think that the in-class group activities helped you feel good about your progress in the course?

Six students confirmed that POGIL activities helped them feel good about their progress in the course. They thought that since they actually learned and understood what they were doing they were confident they were doing a good job. Comments included “I
feel that I have learned an adequate amount of knowledge”, “Since I actually understood what I was doing learning how to do it I felt a 100% confident”, and “You used to could just memorize and now I feel like I've actually learned things”. Three students (two average students and a strong student) thought that POGIL activities did not help them feel good about their progress in the course. One of them (an average student) pointed out that, “they would be benefiting if you had a lecture first then the activities, but I think that without the lectures they really don’t substitute it at all”.

Interview Question 16. Do you think that the in-class group activities were way too time-consuming?

Out of the nine interviewed students five thought that the activities were not too time-consuming; two (an average student and a strong student) thought they were; and two (an average student and a weak student) thought that they would have consumed less time if preceded by a lecture. Students who stated that the activities were not too time-consuming thought that in order to really learn something you need to take your time; one comment was, “Because you’re learning it so you need to take your time to get it let it sink in rather than just rushing through it”. Students who stated that the activities were too time-consuming thought that “We spent more time on them than we should”. Students who stated that they would have consumed less time if preceded by a lecture gave comments like “A little bit of lecturing could have been done you know to kind of explain certain things”.

Interview Question 17. Do you think that time invested on the in-class group activities was worthwhile?
Most of the students interviewed (7 out of 9) indicated that the time, invested on POGIL activities, was worthwhile. They pointed out that the time spent helped them develop a real understanding of the material. Their comments included: “It helped me gain that basic understanding of what organic chemistry is”, “I have a better understanding of the material and I feel more confident in it now”, and “Working in groups is a lot better than just sitting there listening to a lecture”. One of the students who indicated that the time, invested on POGIL activities, was worthwhile thought that with lectures it would have helped more. The two students (an average student and a strong student) who gave a negative answer mainly thought that, “In the group thing we could spend like two three class periods doing something that I could have done at home in half an hour or less”.

Interview question 22. Do you have any other comments on the activities in general?

Most of the students did not have any comments except for a few. One student thought that the activities should be prepared in such a way that they would only take one class hour. She said, “When you get started on them its like you get the hang of it and then you have to stop... I’m one of those kinds of persons that I like to get done within a time frame because if I don’t and I have to wait to the next period there will be a lot of information that I forgot I just like to do everything in one session”. Another student commented, “You actually ask questions and you get more in depth in learning”.

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CHAPTER VI
SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Introduction

This chapter presents a summary of the findings and conclusions that are related to both the statistical analysis of the collected data as well as the qualitative part of the study. Conclusions are then followed by recommendations made as a result of the findings of this study. The general purpose of this study was to determine the effect of using POGIL activities in Elementary Organic Chemistry. The specific questions of the study were:

1. Is there a difference in achievement between students taught traditionally and those taught using POGIL activities?

2. Is there a difference in student attitudes toward their confidence levels in understanding and applying organic chemistry when surveyed before and after the implementation of POGIL activities?

3. What are the attitudes of students towards POGIL activities as opposed to traditional learning when examined by the use of surveys and interviews?

Summary of Procedures

The study was conducted in the fall semester of the academic year 2006. Archival data constituting final scores and final exam scores for students enrolled in the fall 2004 semester were retrieved for this study. In addition, 27 students enrolled in the fall 2006 semester were directly involved. Moreover, grades for 24 students enrolled in CHE 420 spring 2007 semester and 24 students enrolled in CHE 420 summer 2005 semester were collected. In the first part of the study, an independent t-test was used to compare
achievement scores (final scores and scores on final exam) of students who used POGIL (2006) and students who did not (2004). Further the data from the “Before” and “After” POGIL attitudinal surveys conducted for the fall 2006 section was analyzed using a dependent t-test. Finally, the first quiz scores of CHE 420 from the spring 2007 and summer 2005 semesters were tabulated and compared using an independent t-test. In the second phase of the study, interviews and the attitudinal survey questions were analyzed using content coding and major theme analysis. The interviews and the attitudinal survey were conducted for the fall 2006 section. The Questions from both the attitudinal survey and the interviews were divided into nine categories or nine major themes:

1. Confidence in understanding key concepts in organic chemistry.
2. Confidence in the ability to visualize key concepts in organic chemistry.
3. Confidence in understanding lab experiments.
4. Confidence of their ability to succeed in future chemistry courses.
5. Strengths of POGIL activities.
6. Ways to improve POGIL activities.
7. Students’ developed insights about learning.
8. Whether or not students would like to use POGIL activities in other courses.
9. General attitudes of students towards POGIL activities.

Summary of Quantitative Results

Analyses of the data resulting from testing of the hypotheses were provided in Chapter 4. A summary of those tests are listed below:
1. There was no statistically significant difference in achievement scores on the final grades of elementary organic chemistry between students taught traditionally and those taught by POGIL.

2. There was no statistically significant difference in achievement scores on the final-test grades of elementary organic chemistry between students taught traditionally and those taught by POGIL.

3. There was no statistically significant difference in achievement scores on the first quiz grades of CHE 420 biochemistry course between students taught traditionally and those taught by POGIL.

4. There was no statistically significant difference in student attitudes toward their confidence levels in understanding and applying organic chemistry before and after going through the POGIL activities.

Conclusions

Using the data presented in Chapters 4 and 5, the following conclusions were drawn:

1. Achievement

The quantitative data concerning achievement revealed no significant difference between groups. Students who used POGIL did not differ from students who did not. The data from these measurements are displayed in Table 3.

2. Confidence Levels

The quantitative data concerning confidence levels of students in understanding and applying organic chemistry before and after going through the POGIL activities revealed no significant difference. Only 20 students completed both before and after surveys and
their scores were used for the analysis. The data from this measurement are displayed in Table 4.

3. Attitudes toward Confidence in Understanding Key Concepts in Organic Chemistry

In the open-ended attitudinal survey, 19 out of 27 students believed that POGIL activities helped them understand key concepts in chemistry. Students indicated that group work and the activities themselves helped them better understand chemistry. Other students thought that it would have been much better if more explanation were done by the teacher.

Interviewed students answered five questions related to this theme. Six out of nine students thought that the activities helped them more than simple lecturing. The other three students were two average students and one strong student; they wanted more lecturing to be done. They thought that it was hard to begin working on activities without being introduced to major concepts first. In the second question, eight out of the nine interviewed students indicated that the activities helped them prepare for tests. The only interviewed student, who thought otherwise, was a strong student. The third question was not very different from the second question, and the same eight students thought that POGIL activities helped them score higher on chemistry tests, while the same strong student thought otherwise. Six students thought that the critical questions that were on the POGIL activities helped them better understand major concepts and three did not. Those three students were one weak, one average, and one strong student. In answering the last question for this category, seven students indicated that being absent for the POGIL activities negatively affected their understanding and their grades. Students thought that the process of going through the activities was important. The other two
students, one strong student and one average student, thought that as long as they were provided with the answers they could study without going through the POGIL process learning.

In conclusion, both the interviews and the survey showed that POGIL activities gave most students a positive attitude toward their confidence in understanding major concepts in organic chemistry.

4. Attitudes toward Confidence in the Ability to Visualize Key Concepts in Organic Chemistry

Students surveyed thought that models helped them visualize molecular structures and did not say a lot about POGIL activities. Most of the answers indicated that the activities themselves did not help a lot in visualizing molecular structures. Students thought that models would help more than the activities themselves. The students who answered "Yes, the activities helped us in visualizing molecular structures" were assuming that the models were part of the POGIL activity.

5. Attitudes toward Confidence in Understanding Lab Experiments

The majority of students surveyed thought that the activities and the lab experiments were not correlated. Students did not see any real connection between POGIL activities and the lab experiments they were doing.

6. Attitudes toward Confidence in Ability to Succeed in Future Chemistry Courses

In general, students had a positive attitude toward their ability to succeed in future chemistry courses after going through POGIL. Students thought that since they actually learned the material in this class it would help them in other chemistry courses. The few
students who had a negative attitude either did not like the idea of group work or preferred lectures to POGIL activities.

7. Strengths of POGIL Activities

The two major strengths of POGIL activities that students concentrated on were that students worked in groups, and that they had more than one teacher to help. Many students liked the idea of working in a group and felt that it was one of the strengths of the course. Some students liked the fact of having more than one teacher moving around the class. They also liked the fact that teachers were giving explanation time to each group alone.

8. Ways to Improve POGIL Activities

Students wanted a little explanation to be done before going through the activities. They did not like the idea of getting the activities and trying to go through them with no previous background. In general, students preferred that a small lecture be given before each activity set. Some students thought that the activities should be given a time limit so that students would be pressured to finish them and decrease the possibility of wasting time.

9. Students’ Developed Insights about Learning

Out of the 27 surveyed students 10 students deduced that they learn better using a guided inquiry model; 6 acknowledged that they learn better through cooperative learning; 4 students preferred lecturing and liked neither the guided inquiry problems nor the cooperative learning; and 3 did not like cooperative learning. So, more than half the class thought that they learn better using guided inquiry and cooperative learning models.
Interviewed students (9 students) answered four questions related to this theme. In the first question, six thought that POGIL activities helped them learn how to solve problems. They thought that talking through problems and discussing them with their peers helped them understand how to solve problems. Two other students, one average student and one strong student, thought that it only helped them prepare for similar problems and one strong student thought it did not help understand how to solve problems. In the second question, 7 students stated that they learn better by working in groups than by working individually. Students thought that group discussions helped increase their confidence in understanding major concepts. An average student thought that group work is good only if you have good group members, and a strong student did not like group work. Answers for the third question revealed that 5 students thought that working in a team had increased their confidence in studying and learning chemistry and 4 thought it did not (two average students, one strong student, and one weak student). For the last question, 6 students felt that POGIL activities encouraged them to study for the course. They thought that doing the activities made them actually learn in class instead of just write notes. The other three who did not feel that POGIL activities encouraged them to study for the course were one weak student, one average student, and one strong student.

In conclusion, most students acknowledged that students learn better with guided inquiry and cooperative learning, the two major components of POGIL.

10. Whether or Not Students Would Like to Use POGIL Activities in Other Courses

Most surveyed students pointed out that they would take another course taught with POGIL activities rather than traditional lecturing if they had the option. Five
students preferred traditional learning to POGIL, and two students thought that mixing the two techniques would be better than either one alone. Seven out of nine interviewed students stated that they would like POGIL activities to be implemented in other chemistry courses. Those students thought that these activities made them learn chemistry better and enjoy it more. The two other students, a strong and an average student, stated that they would not like POGIL activities to be implemented in other chemistry courses. In general, students liked POGIL activities and wished that they would be implemented in other chemistry courses.

11. General Attitudes of Students toward POGIL Activities

Students in general liked POGIL activities and preferred them over lecturing. Only three surveyed students said that they did not like POGIL activities. Some students indicated that they would have liked POGIL even more if they were given a small lecture before each activity.

The nine interviewed students answered 6 questions related to this theme. In the first question, eight students thought POGIL activities were challenging and worthwhile. Those students said that although the problems were challenging, doing them made them learn. One average student liked the activities but not the group work and one strong student did not think POGIL activities were challenging and worthwhile. Answers for the second question showed that most students thought that the activities were not stressful and frustrating. Two students, a weak student and an average student, indicated that the activities were stressful and frustrating, because they were not preceded by a lecture.

In answering the third question, seven interviewed students thought that POGIL activities were more beneficial than lectures. They thought that since these activities
made them learn by doing, and not by listening, they were better than lectures. Students also liked the idea of getting one-on-one help from the teacher. The other two students (an average student and a strong student) thought that the POGIL activities could help a lecture but not substitute it. Answers for the fourth question confirmed that POGIL activities helped students feel good about their progress in the course. Students thought that since they actually learned and understood what they were doing they were confident they were doing a good job. Three students (two average students and a strong student) thought that POGIL activities did not help them feel good about their progress in the course.

The fifth and sixth questions dealt with the time aspect of POGIL activities. Answers showed that five students thought that the activities were not too time-consuming, two (an average student and a strong student) thought they were, and two (an average student and a weak student) thought that they would have consumed less time if preceded by a lecture. Further, most of the students interviewed (7 out of 9) indicated that the time, invested on POGIL activities, was worthwhile. They pointed out that the time spent helped them develop a real understanding of the material. The two other students, an average student and a strong student, thought that more work could have been done individually.

In conclusion, most students liked POGIL activities and thought that they were a good learning tool. Some average and some strong students thought that the activities were frustrating and time consuming.
Discussion

Achievement

The results of this study did not support the literature findings when it comes to achievement. Most of the studies done in implementing POGIL showed that students using POGIL scored higher than students who did not (POGIL, 2006). In this study, there was no significant difference in achievement scores between students who used POGIL and students who did not. This study was different than most of the other studies since most of the other studies were done on general chemistry courses. Previous studies done on organic chemistry students only showed a difference in letter grade distribution (Hanson, 2006). There was one study that was done on a physical chemistry class and POGIL had no effect on achievement scores. It seems that as the chemistry topic being taught becomes harder, POGIL has a lower effect on achievement scores. When harder chemistry topics are taught, students need strong backgrounds in chemistry and in math to understand. POGIL cannot supply students with this background; therefore, POGIL becomes less active at higher levels, because of the stronger effect of student backgrounds.

Confidence Levels

There was no significant difference in student confidence levels in understanding and learning chemistry before and after going through POGIL. In a previous study done by Hanson & Wolfskill (2000) 54% of students reported an increase in confidence levels. In the qualitative part most of the students reported an increase in confidence levels. Quantitative analysis of the “Before” and “After” attitudinal POGIL surveys did not
reveal any difference. Students, in general, find chemistry a hard subject and it seems more than one POGIL experience is needed to improve their confidence levels.

*Attitudes toward Confidence in Understanding Key Concepts in Organic Chemistry*

In this study interviews and the survey showed that POGIL activities gave most students a positive attitude toward their confidence in understanding major concepts in organic chemistry. In the study done by Hanson and Wolfskill (2000) 75-90% found POGIL activities helpful in learning chemistry. Lewis and Lewis (2005) reported that 74% of students thought that the PLGI sessions (POGIL like activities) were beneficial. The POGIL site reports that in general students in POGIL programs mastered the content more than they normally did in lecture courses. Further, Gosser and Roth (1998) reported that participants and professors had endorsed workshop models that follow guided inquiry. The interviews in this study showed that students who do not think that POGIL activities were helpful were rare and tend to be average or good students. This is supported in the literature since strong students may feel that they are wasting their time explaining to weak students (Hanson, 2006). In this study, 70% of surveyed students and 67% of interviewed students thought that POGIL activities were helpful, and 89% of interviewed students thought that it helped them prepare for and score better on tests. It is clear that the majority of the students found that POGIL activities were helpful.

*Attitudes toward Confidence in the Ability to Visualize Key Concepts in Organic Chemistry*

Most students thought models would help more in visualizing molecular structures than POGIL activities. POGIL activities being mostly paper and pen activities did not help a lot in the ability to visualize molecules. The question related to this theme
only dealt with visualizing molecular structures. There was no mention in the literature about the effect of POGIL on the ability to visualize molecular structures.

*Attitudes toward Confidence in Understanding Lab Experiments*

Inquiry based lab experiments contain many positive aspects for students if they take advantage of it (Deters, 2005). Chemistry educators usually rely on “cookbook” experiments since it is easier to follow and saves time (Ault, 2002). Other educators prefer inquiry based labs in which students identify and explain the pattern in collected data (Monteyne & Cracolice, 2004). POGIL programs encourage the use of inquiry labs. In this study students did “cookbook” labs. The lab experiments were not correlated with the POGIL activities according to 74% of students surveyed. As a result, students thought that the POGIL activities did not help them understand lab experiments.

*Attitudes toward Confidence in Ability to Succeed in Future Chemistry Courses*

In general, students thought that POGIL activities helped them better understand chemistry and, therefore, would help them succeed in future chemistry courses. A high percentage of surveyed students (74%) indicated that POGIL activities would help them in other chemistry courses. They felt that the activities helped them prepare for other science courses since they really understood the concepts in the class. This correlates with the literature that reported increase in enrolment in advanced chemistry courses after going through POGIL. A previous study showed that students had an increased interest in chemistry as a major after exposure to POGIL-like activities (Gosser, Weiner, & Woodward, 1993). Hanson and Wolfskill (1998) reported a 15% increase in second year organic chemistry enrollment after applying POGIL in general chemistry sections. Higher enrollment in advanced chemistry courses after going through POGIL indicates that
POGIL boosted students’ confidence in their ability to succeed in chemistry courses. Although the surveys showed no statistical improvement in confidence levels, the qualitative part did.

*Strengths of POGIL Activities*

Students surveyed concentrated on two aspects of POGIL implementation when they were asked to name at least one of the course’s strong points. Group work and the availability of more than one instructor were those two aspects. This definitely correlates with the literature. In the study conducted by Farrell, Moog, and Spencer (1999) half of the students surveyed mentioned group work as being one of the course’s strength. Students in this study also liked the idea of getting more one-on-one interaction with the teacher. This was enhanced by the presence of more than one instructor in the class. Clearly students appreciated it when they got the chance to participate in in-class discussion. This helped them digest the major concepts being discussed.

*Ways to Improve POGIL Activities*

Lecture is usually not part of POGIL activities. POGIL workshops are substitutes for lecturing. Birk and Foster (1993) suggested that no real learning occurs as a result of lectures. Further Zoller (1993) stated that traditional lecturing and learning are compatible for some LOCS (Lower Order Cognitive Skills) but incompatible with most HOCS (Higher Order Cognitive Skills). In previous studies, POGIL workshops only substituted some of the lectures, but not all of them. There was no mention in these studies of students’ suggestions to improve POGIL. Hanson and Wolfskill (1998) introduced POGIL in one of the three lectures in general chemistry courses given at Stony Brook University. In another study done at the University of Tennessee by Hinde...
and Kovac (2001) a physical chemistry course was supplemented with a computer-based POGIL activity once every other week. In the study done by Lewis and Lewis (2005) the experimental group was given two lectures and one POGIL activity per week. Farrell, Moog, and Spencer (1999) used POGIL activities exclusively in their teaching. The current study had two stages, at the first stage students were given a 50-minute lecture, and in the next class they were given POGIL activities. In the second stage POGIL activities were used exclusively. Students, in general, favored the way class was conducted in the first stage. It seems that a mixture of lectures and POGIL activities would work better than each one alone. Students should be introduced to the major concepts before tackling POGIL activities.

Students' Developed Insights about Learning

The results of this study showed that 37% of students acknowledged that guided inquiry helped them learn chemistry better and 22% acknowledged the benefits of cooperative learning. This correlates with the literature that emphasized the importance of guided inquiry and cooperative learning in learning chemistry (Hanson, 2006).

In the interviews 67% indicated that POGIL workshops, that integrate guided inquiry and cooperative learning in learning chemistry, helped them learn how to solve problems. The rest (33%, two strong students and one weak student) did not think that POGIL activities helped them become better problem solvers. Moreover, 78% acknowledged the benefits of cooperative learning while 22% (one average student and one strong student) did not. Finally, 67% of interviewed students felt that POGIL activities encouraged them to study for the course while only 22% (one strong and one average) thought it did not. It is clear that as mentioned in the literature (Hanson, 2006)
some strong students tend to feel less comfortable with cooperative learning, they feel that they are wasting their time explaining to weaker students.

*Whether or not Students Would Like to Use POGIL Activities in Other Courses*

Most surveyed students (72%) seemed to like POGIL activities to be implemented in other chemistry courses. Further, 78% of interviewed students stated that they would like POGIL activities to be implemented in other chemistry courses. Students, in general, thought that POGIL activities made them learn chemistry better and enjoy it more. Only one strong and one average interviewed student did not like the idea of POGIL being implemented in other chemistry courses. Results of this study support the results from previous studies. Lewis and Lewis (2005) reported that 85% of surveyed students indicated that they would register for another PLGI (POGIL-like activities) supplemented course and 58% indicated that they would attend PLGI activities even if they were not mandatory.

*General Attitudes of Students toward POGIL Activities*

This study showed that students in general (89% of surveyed students) liked POGIL activities and preferred them over lectures. Further, 89% of interviewed students thought POGIL activities were challenging and worthwhile; 78% thought that the activities were not stressful and frustrating; 78% thought that the activities were more beneficial than lectures; 67% confirmed that the activities helped students feel good about their progress in the course; and 78% thought that the time invested in the activities was worthwhile. The few students who had negative attitudes toward POGIL activities were mostly strong and average students. In general most students liked POGIL activities and thought that they were good learning tools. This correlates with previous studies that
tested the effectiveness of POGIL in chemistry courses and reported positive feedback (POGIL, 2006). Students, in general, preferred POGIL, and had lower levels of attrition. Further, students in POGIL programs mastered the content more than they normally did in lecture courses.

Limitations

The main limitation in this study was the confidence level survey conducted before and after POGIL. The survey was not sensitive enough to measure differences in confidence levels. This led to the quantitative result reported in Chapter 4: There is no statistically significant difference in student attitudes toward their confidence levels in understanding and applying organic chemistry before and after going through the POGIL activities. The qualitative part of the study showed that students had increased confidence in understanding and applying organic chemistry after going through POGIL. If the survey used in the quantitative part was sensitive enough to measure differences in confidence levels, it would have showed the differences that were reported in the qualitative part.

Recommendations for Practice

This research shows that students, in general, liked the idea of POGIL activities being implemented in chemistry classes. It also shows that the way it was implemented in this research could be improved. The current study had two stages, at the first stage students were given a 50-minute lecture, and in the next two classes they worked on POGIL activities. In the second stage, POGIL activities were used exclusively. In general, students favored the way class was conducted in the first stage. Students preferred a mixture of POGIL activities and lectures to sole lecturing or sole POGIL.
Teachers who wish to use POGIL activities should take this into consideration. It is better to use POGIL as a major part of the course than to make the whole course about POGIL. Further, POGIL should be implemented at the early stages of chemistry education before it is implemented in higher courses. This would probably improve students’ chemistry background and make POGIL more effective in higher courses.

This research showed that POGIL had no effect on student achievement but it had a big effect on students’ attitudes. Students liked POGIL and liked the course better because of POGIL. It is very important to notice that POGIL made students enjoy chemistry more. The fact that students enjoyed themselves while learning chemistry is a success by itself. It is recommended that teachers use POGIL in college chemistry courses, especially the introductory courses. Teachers who choose to use POGIL should consider using a mixture of lectures and POGIL activities. Further, they should notice that implementation of POGIL needs more than one instructor. Graduate students or trained undergraduate students could help in the process. The need for more instructors makes the course more expensive to teach. Universities who wish to implement POGIL should consider the cost effect of the process before making the final decision.

Recommendations for Future Research

After the researcher analyzed the results of this study, the following recommendations were made:

1. It is recommended that the study be repeated in other academic institutions. This would give more insight on the effect of POGIL activities.
2. It is recommended that the study be repeated in other chemistry disciplines. This would give a better picture of the difference in effect of POGIL between introductory and advanced levels of chemistry.

3. It is recommended that the study be repeated in the same discipline but using a bigger number of students. A comparison between this study and the future one would be of high importance on the educational level and the marketing level of the POGIL program.
ChemActivity 30

Constitutional and Geometric Isomers

(Are they identical, or are they isomers?)

Model 1: Representations of some organic molecules

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<th>Ball-and-stick structure</th>
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</table>

Critical Thinking Questions

1. Consider the Lewis structures in Model 1. How many covalent bonds does each carbon have?

2. In skeletal representations, the hydrogens are not shown. Explain how it is still possible to tell how many hydrogens there are on each carbon.

3. Draw a Lewis structure representation of the molecule for which a skeletal representation is shown below.
Model 2: Constitutional Isomers

<table>
<thead>
<tr>
<th>Column 1</th>
<th>Column 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>structure</td>
<td>molecular formula</td>
</tr>
<tr>
<td>[ \text{C}<em>5\text{H}</em>{12} ]</td>
<td>[ \text{C}<em>5\text{H}</em>{12} ]</td>
</tr>
<tr>
<td>[ \text{C}<em>5\text{H}</em>{12} ]</td>
<td>[ \text{C}<em>5\text{H}</em>{12} ]</td>
</tr>
<tr>
<td>[ \text{C}<em>5\text{H}</em>{12} ]</td>
<td>[ \text{C}<em>5\text{H}</em>{12} ]</td>
</tr>
</tbody>
</table>

Critical Thinking Questions

4. Complete Model 2 by writing in the missing molecular formulas in both columns.

5. What do the molecules in a given column (1 or 2 in Model 2) have in common with the other molecules in that column?

6. What do the molecules in a given column \textbf{not} have in common with the other molecules in that column?

7. All the structures in a given column are constitutional isomers of one another, but the structures in Column 1 are not constitutional isomers of structures in Column 2. Based on this information, write a definition for the term constitutional isomers.

8. If the molecule shown below were placed into Model 2, would it belong in \textbf{Column 1} or \textbf{Column 2} (circle one)? Explain your choice.
Model 3: Representations of methylcyclobutane

- **Skeletal ("stick")**
- **Wedge and dash**
- **Wedge and dash with explicit hydrogens**
- **Perspective**
- **Ball-and-stick**

Model 4: 1,2-dimethylcyclobutane, shown with ring carbons numbered 1–4

- **(a)**
- **(b)**

**Critical Thinking Questions**

9. Are the molecules in boxes (a) and (b) of Model 4 constitutional isomers of each other? Explain.

10. **Other than bonds to carbons within the ring,** what two groups are bonded to the following carbons?
- a. carbon 1 in box (a)?
- b. carbon 1 in box (b)?
- c. carbon 2 in box (a)?
- d. carbon 2 in box (b)?

11. If you have access to a model kit, make models of the two molecules in Model 4 (C = black; H = white; use the short bonds for single bonds). Is it possible to rotate single bonds in the models such that the molecule in box (a) is the same as the one box (b)?

**Information**

Since each carbon in the molecule in box (a) in Model 4 is bonded to the same four groups as the corresponding carbon in the molecule in box (b), the molecules are said to have the same **connectivity**.

You confirmed in CTQ 11 that the two structures of 1,2-dimethylcyclobutane shown above are not simply **conformers** of each other.

Imagine that the four carbons of the cyclobutane ring define a plane. In one structure, the two methyl groups are on the **same side** of this plane, and in the other they are on **opposite sides** of the plane. The single bonds in the ring cannot rotate without breaking the ring. Two groups on the **same side** of the plane are considered to be **cis** to one another. Groups on **opposite sides** are called **trans**.

**Geometric isomers** (cis-trans isomers) are molecules that have the same **connectivity** and differ only in the **geometric arrangement** of groups.
Critical Thinking Questions

12. Label one box in Model 4 with the name "cis-1,2-dimethylcyclobutane" and the other with the name "trans-1,2-dimethylcyclobutane." Then add perspective representations into each box.

13. Draw wedge-and-dash and perspective representations of cis- and trans-1,3-dimethylcyclobutane. (Note: that is "1,3-dimethyl," not "1,2-dimethyl.")

Exercises

1. Indicate if the following pairs of structures are identical, conformers, geometric isomers, constitutional isomers, or not isomers.

   a. 1,2-dimethylcyclobutane and 1,3-dimethylcyclobutane

   b. 

   c. 

   d. 

   e. 

   f. 

   g. 

   h. 

   i. 

   j. 

   k. 

2. Draw a structure for a molecule not shown in this activity that would belong in Column 2 of Model 2.

3. Read the assigned pages in your textbook and work the assigned problems.
TO: Deborah Booth & Ahmad Shatila  
118 College Drive #5043  
Hattiesburg, MS 39406-0001

FROM: Lawrence A. Hosman, Ph.D.  
HSPRC Chair

PROTOCOL NUMBER: 26081401  
PROJECT TITLE: Curricular Restructure for Principles of Organic Chemistry, CHE 251

Enclosed is The University of Southern Mississippi Human Subjects Protection Review Committee Notice of Committee Action taken on the above referenced project proposal. If I can be of further assistance, contact me at (601) 266-4279, FAX at (601) 266-4275, or you can e-mail me at Lawrence.Hosman@usm.edu. Good luck with your research.
The project has been reviewed by The University of Southern Mississippi Human Subjects Protection Review Committee in accordance with Federal Drug Administration regulations (21 CFR 26, 111), Department of Health and Human Services (45 CFR Part 46), and university guidelines to ensure adherence to the following criteria:

- The risks to subjects are minimized.
- The risks to subjects are reasonable in relation to the anticipated benefits.
- The selection of subjects is equitable.
- Informed consent is adequate and appropriately documented.
- Where appropriate, the research plan makes adequate provisions for monitoring the data collected to ensure the safety of the subjects.
- Where appropriate, there are adequate provisions to protect the privacy of subjects and to maintain the confidentiality of all data.
- Appropriate additional safeguards have been included to protect vulnerable subjects.
- Any unanticipated, serious, or continuing problems encountered regarding risks to subjects must be reported immediately, but not later than 10 days following the event. This should be reported to the IRB Office via the "Adverse Effect Report Form".
- If approved, the maximum period of approval is limited to twelve months.

Projects that exceed this period must submit an application for renewal or continuation.

PROTOCOL NUMBER: 26081401
PROJECT TITLE: Curricular Restructure for Principles of Organic Chemistry, CHE 251
PROPOSED PROJECT DATES: 08/23/06 to 05/31/07
PROJECT TYPE: Dissertation or Thesis
PRINCIPAL INVESTIGATORS: Deborah Booth & Ahmad Shatila
COLLEGE/DIVISION: College of Science & Technology
DEPARTMENT: Chemistry and Biochemistry
FUNDING AGENCY: N/A
HSPRC COMMITTEE ACTION: Exempt Approval
PERIOD OF APPROVAL: 08/14/06 to 08/13/07

Lawrence A. Hosman, Ph.D.
HSPRC Chair
APPENDIX C

BEGINNING OF SEMESTER CONFIDENCE IN LEARNING SURVEY

Please answer the following questions:

1. Year in College:   A. Freshman   B. Sophomore   C. Junior   D. Senior   F. Graduate
2. Which Chemistry courses have you taken (all that apply)?   A. 1 year High School   B. 2 years high school   C. General Chemistry I   D. General Chemistry II
3. What grade do you expect to make in this course.

   For the following questions use this scale:

   A = strongly disagree;   B = disagree;   C = neutral;   D = agree;   E = strongly agree

4. I am very confident that I will understand the key concepts of this course.
5. I am very confident that I will be able to solve the required problems in this course.
6. I am very confident that I will understand the chemistry in the laboratory experiments.
7. I am very confident that I will be able to perform the laboratory experiments satisfactory.
8. I am very confident in my understanding in other areas of science.
9. I am very confident in I will be able to visualize the key concepts of this course.
10. I am very confident that I will be able to apply my knowledge of organic chemistry to the real world.
11. I am very confident that I will succeed in this chemistry course.
12. I am very confident that I will succeed in a chemistry-related discipline (my major).

Rate the relative importance of each factor in terms of how you learn. Use the following scale:

A. Absolutely Not important;   B. Somewhat not important;   C. Neutral
D. Somewhat Important   E. Very Important

14. Reading sample problems in the textbook

15. Reading Explanations in the textbook

16. Working with friends or informal groups (out of class)

17. Working on organized course activities (in class)

18. Completing Laboratory experiments.

19. Asking the Instructor questions.

20. Participating in Group Work during class.
APPENDIX D
END OF SEMESTER CONFIDENCE IN LEARNING SURVEY

Please answer the following questions

1. Year in College:  A. Freshman  B. Sophomore  C. Junior  D. Senior  F. Graduate

2. Which Chemistry courses have you taken (all that apply)?  A. 1 year High School
B. 2 years high school C. General Chemistry I D. General Chemistry II

3. What grade do you expect to make in this course.

   For the following questions use this scale:

   A = strongly disagree;  B = disagree;  C = neutral;  D = agree;  E = strongly agree

4. I am very confident that I understood the key concepts of this course.

5. I am very confident that I am able to solve the required problems in this course.

6. I am very confident that I understood the chemistry in the laboratory experiments.

7. I am very confident that I was able to perform the laboratory experiments satisfactory.

8. I am very confident in my understanding in other areas of science.

9. I am very confident in I was able to visualize the key concepts of this course.

10. I am very confident that I will be able to apply my knowledge of organic chemistry to the real world.

11. I am very confident that I will succeed in this chemistry course.

12. I am very confident that I will succeed in a chemistry-related discipline (my major).

Rate the relative importance of each factor in terms of how you learn. Use the following scale:  A. Absolutely Not important;  B. Somewhat not important;  C. Neutral
D. Somewhat Important  E. Very Important

14. Reading sample problems in the textbook

15. Reading Explanations in the textbook

16. Working with friends or informal groups (out of class)

17. Working on organized course activities (in class)

18. Completing Laboratory experiments.

19. Asking the Instructor questions.

20. Participating in Group Work during class.
APPENDIX E
THE POGIL ATTITUDINAL SURVEY

Please answer the following questions and explain your answer.

1. Did the in-class group activities help you understand key concepts in chemistry?

2. Did the in-class group activities help you in understand lab experiments?

3. Do you think that the in-class group activities helped you or will help you in other science courses?

4. Did the in-class group activities help you in visualizing molecular structures?

5. Do you think that the in-class group activities will help you succeed in biochemistry?
6. Did you like these in-class group activities?

7. Suggest ways to improve the content and format of theses in-class group activities
   (ex: order of questions, number of tables, pictures…).

8. Suggest ways to improve the implementation of these in-class group activities
   (ex: number of people in a group, time…).

9. Describe at least one strength of this course.

10. What insights about how you learn did these in-class group activities provide you with?
11. If you had the option would you take another course taught like this one with in-class group activities rather than traditional lecturing?
APPENDIX F

INTERVIEW QUESTIONS

1. Do you think that the in-class group activities are challenging and worthwhile?

2. Do you think that the in-class group activities helped you understand and learn the course material?

3. Do you think that the in-class group activities helped you learn how to solve problems?

4. Do you think that the in-class group activities are stressful and frustrating?

5. Do you think that the in-class group activities are more beneficial than lectures?

6. Do you think that the in-class group activities helped you feel good about my progress in the course?

7. Do you think that you learned and understood more by working in a team than if you had worked individually?

8. Do you think that working in a team has increased your confidence in studying and learning chemistry?

9. Do you think that working in a team has increased your interest in chemistry?

10. Do you think that the with in-class group activities you felt encouraged to study for the chemistry course?

11. Do you think that the quiz questions were challenging and worthwhile?

12. Do you think that the homework assignments helped you understand and learn the course material?

13. Do you think that the in-class quizzes were valuable in preparing for the hour examinations?
14. Do you think that the in-class group activities helped you prepare for tests?

15. Do you think that the in-class group activities helped you score higher on chemistry tests?

16. Do you think that the in-class group activities were way too time-consuming?

17. Do you think that the time invested on the in-class group activities was worthwhile?

18. Do you think that the in-class group activities questions did not correlate with the material in the textbook?

19. Do you think that the in-class group activities critical questions helped you better understand major concepts.

20. Would you like for the in-class group activities to be implemented in other chemistry courses?

21. Do you think that absence for the in-class group activities negatively affects achievement scores?

22. Do have any other comments about the in-class group activities?
REFERENCES


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