IMPLEMENTATION OF A GENERAL CHEMISTRY DISCOVERY LABORATORY COURSE IN A LARGE UNIVERSITY SETTING: A QUALITATIVE CASE STUDY

by

KIMBERLY JO SMITH, B.S.

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ABSTRACT

Traditional verification experiments are the overwhelming choice for teaching the general chemistry laboratory courses at large universities. Discontent with these cookbook laboratories has caused some chemistry educators to look for alternatives. Discovery laboratories have existed for decades and yet have not gained popularity in large university settings. This qualitative case study examines the project laboratory course, a discovery lab, taught in the first semester general chemistry program at a large university. The project lab utilizes cooperative learning strategies to teach social skills, problem-solving ability, higher cognitive thinking, and chemistry content. Three long, multi-faceted experiments, named projects, are conducted over a thirteen week period by the students in cooperative groups. The course is described in detail and is evaluated through examination of the projects, the instructors, the students, and their reactions to the course. Recommendations for successful full scale implementation are given.

CHAPTER I

INTRODUCTION

Recent concern has arisen as to whether the general chemistry laboratories currently taught in large universities are effective, valuable, and appropriate for today's science, engineering, and premedical students. The laboratories taught in most major universities basically have not changed since their development in the 1960's, while the student body has evolved greatly in the past three decades. Growing discontent with the laboratory courses has compelled a group of laboratory coordinators from large universities to call for the reform and the rethinking of the general chemistry laboratory course.

The desire for reform is caused by many reasons. The current laboratory course in most large universities can be called "cookbook" due to its prestructured nature, step-by-step detailed instructions, and fill-in-the-blank data and results sheets. Cookbook labs were originally implemented because they are easy to teach, easy to follow, easy to grade, and insure reasonable uniformity for multi-sections with different instructors. However, cookbook labs do not develop cognitive skills, do not teach problem solving, do not arouse excitement or curiosity, and do not foment interest in chemistry.

In order to maintain or increase science enrollment, it is very important for general chemistry courses to keep student interest and promote an appreciation for science. Boring cookbook labs, which seem to have no connection to daily life, are not appealing to today's student.

A steering committee of eight large university general chemistry directors met in August of 1992 to discuss appropriate goals for the current laboratory course. These goals are to

1. Increase student independence;
2. Demonstrate what a chemist does in lab;
3. Show scientific processes;
4. Teach how to judge the validity of data;
5. Relate chemistry to real life;
6. Teach experimental design; and
7. Encourage students to be responsible for their learning.

In January 1993, twenty-one general chemistry laboratory program directors held a conference and developed a plan to create forty laboratories, test them at universities, and then develop a strategy for implementing the tested and approved labs full-scale at other large universities. The laboratories would be "projects" which would last several weeks, allow students to work at their own pace, and require students to develop their own experimental design. Such a lab would successfully meet the predetermined goals.

The directors also decided that the project labs would incorporate three elements of effective lab instruction which are active learning, social interaction, and development of manipulative and cognitive skills. The very nature of a laboratory includes active learning as students participate in hands-on activities. Social interaction is accomplished by having the students work in cooperative learning groups. Manipulative skills include lab techniques such as sampling, weighing, measuring, and should develop to the level where reproducibility is obtained. Cognitive skills include planning, identifying a problem, generating solutions, interpreting data for validity, and communicating results through presentations.

In October 1993, the general chemistry coordinators were ready to test some of the new project laboratories at other universities. Texas Tech

University was chosen as a test site and in the spring semester of 1994, the project lab was taught in six out of nineteen sections of CHEM-1107, the first semester general chemistry lab. The results of the project lab and recommendations for implementation full-scale will be presented in the remaining chapters.

CHAPTER II

REVIEW OF THE LITERATURE

The Purpose of the Laboratory

What is the purpose of the laboratory? Chemistry educators have been trying to answer this question for years. In fact, at no time has an agreement ever been reached on the goals of the general chemistry laboratory. In some periods of history, the very existence of the laboratory was questioned. Many educators felt it had no purpose and should be omitted from college chemistry entirely. What teaching approaches have been tried in the laboratory? How has the lab course evolved? What research has been conducted on the general chemistry laboratory? Perhaps by looking at the lab's history and examining past mistakes, chemistry educators can come closer to an answer.

In the 1920's, the general chemistry course resembled a descriptive inorganic course. Correspondingly, the accompanying lab was primarily simple preparations and simple reactions of elements and compounds. This decade and the next witnessed a serious battle over whether or not laboratory instruction should be included in the college general chemistry course. Most universities were having severe financial problems and the operation of a laboratory was very expensive. Administrators wanted to replace the individual laboratory experience with instructor demonstrations and many chemistry teachers agreed. Proponents of the laboratory had to fight to save the lab course.

Supporters of the lab course agreed that both demonstrations and laboratories had the ability to cultivate curiosity, a major goal of chemistry at the time. But many educators such as Bowers (1924) argued that only in hands-on training can the student pass from simple observation to a deeper scientific thinking. They believed that just as doctors need hands-on training, so do chemists. Bowers believed that "information learned by contact is retained" (p.205), and his research showed that laboratory information remained in the memory longer than textbook information. Victor Noll (1929), another proponent, tested five hundred and eighty students and concluded that chemistry sections taught with a lab consistently achieved significantly higher on exams than sections taught with demonstrations.

Opponents, such as Lucasse (1928), said demonstrations should replace individual laboratory instruction because the lab course cost too much, the students were not all chemists so they did not need it, it was too time consuming, and the graduate students made poor teachers because they were too concerned with their own studies. Payne (1932), a leading opponent, said the aims of general chemistry were to teach knowledge, thinking skills, inspiration, and appreciation for chemistry. For his aims, he believed demonstrations were just as effective as the laboratory course, so he saw no absolute necessity for lab work which took so much time and money. Barger (1935) agreed that demonstrations were superior if they were conducted as a large group experiment. He advocated using many students to perform the demonstration under teacher direction so that the entire class was involved.

After years of debating the superiority of demonstrations versus laboratory instruction with no end in sight, a new cry arose for reform of the laboratory. These new voices said that the laboratory should be part of chemistry education, but not in its current form. The problem was not whether to have a lab course, but rather how to teach it. In the early 1930's, the general chemistry course changed from descriptive inorganic to focus on chemical principles, so now the lab course also needed to change.

Herbert Smith (1926) was one of the first to call for reform. He believed the current lab to be a waste of time and money, and if it did not change soon, the lab course would be dropped due to expense. He proposed reducing the cost by eliminating expensive equipment which he felt was unnecessary to achieve an effective course. Many educators (Bradt & Smoker, 1929) began the push toward more quantitative labs which would use unknowns. The emphasis would be placed on data and these labs would be easy to grade.

Soon it was generally agreed that the laboratory must be changed, not eliminated. An impatient Adams (1942) demanded the end of the old argument by saying that the demonstration is dead and the laboratory is superior. He reported how society was becoming increasingly technical so technique must be taught. He advocated grading manipulative skills and technique, not just knowledge by pen-and-paper tests. Deming (1948) agreed and said "the first assignment in lab is to hammer on technique" (p. 446).

From the mid 1930's through the 1950's, the laboratory course became increasingly quantitative in nature. As with any change, criticism soon followed. Conflict arouse as to whether lab time should be spent training students in technique, instrumentation, and analysis, or if lab time should be spent teaching students how to ask scientific questions and then how to solve them.

Carmody (1935) also called for reform early. He also agreed that the lab could be superior to demonstrations if taught properly. Like Payne, he aimed to develop interest, appreciation, knowledge, and scientific thought in students. However, he did not believe a quantitative laboratory course could meet his aims. He countered that arriving at a correct final answer had no permanent value and should not be the focus of lab. He believed, "the entire procedure is what has value, method development and thinking should be the focus" (p. 235). He advocated the use of three types of experiments with minimal direction. First, method training to develop interest by using unknowns. Second, technique training to develop a pride in accomplishing difficult manipulations. Third, informative labs which focus on real life problems. Although he did advocate unknowns and technique, his purpose differed from most other chemists as seen by his statement, "Nothing is more deadening to interest than the fully detailed experiment with spaces to be filled in with 'results.' I would rather turn them [the students] loose" (p.237).

Schlesinger (1935), like Carmody, criticized the structured quantitative labs. He supported independent students planning tests, collecting data, judging results, and drawing conclusions. He believed trying to conduct too many experiments would not allow students time to think about what they observed. Thomas (1934) also opposed detailed directions and said students should be allowed to make errors so that they would have to discover and correct them.

Despite the criticism, quantitative labs had become the overwhelming choice of chemistry educators in the 1950's. The American Chemical Society general chemistry workshop of 1954 recommended quantitative labs which determined densities, molecular formulas, and concentrations through the use of unknowns. Gabriel (1956) still complained that too few labs used unknowns and called for the inclusion of significant figures in laboratories.

Criticism still continued as some educators believed curiosity needed to be rekindled by allowing students to create their own problems and design experiments to solve them (Xan, 1954). These chemistry teachers explained that developing schemes would be fun and interesting to the students as well as get them to think critically and independently (Stubbs, 1959). The term "cookbook" was more and more often derogatorily applied to the quantitative lab. Critics claimed the cookbook lab failed to give meaning and significance to chemical concepts (Nechamkin, 1952).

However, the majority seemed to follow opinions like Walter's (1968) when he stated that beginning college students were simply not equipped to undertake independent investigation. He claimed, "They have neither knowledge nor manipulative skill so experimental procedure should be detailed and lead to quantitative data" (p. 672).

By the late 1960's, the general chemistry lecture had changed to resemble an elementary physical chemistry course. The cookbook labs became even more structured and began to include topics such as gas laws, kinetics, calorimetry, and equilibrium. Significant figures had become well established in both the lecture and laboratory. The typical lab began with an introduction which briefly discussed content. Detailed instructions gave a step-by-step procedure. Data was collected and calculations resulted in the determination of an unknown, which, of course, the instructor knew. This type of lab was praised because it was short, efficient, easy to grade, easy to follow, and easy for graduate students to teach.

The next decade saw a gradual change in the students enrolled in general chemistry. Most of the students were not going into research so chemistry was perceived as an unnecessary subject due to its supposed irrelevancy. The students seemed to dislike chemistry more each year and enrollment began to decrease steadily. Professors often thought these new students were less apt at critical thinking and problem solving.

Some educators blamed the growing problem on the laboratory and criticism against the cookbook lab increased. The fill-in-the-blank data and results sheets were blamed for reducing student decision making ability. Students did not have to judge the validity of data nor did they need to know how to manipulate the data to yield results. The emphasis on how to perform the lab rather than on why the lab worked was also criticized.

In response to such criticism, alternative labs were developed and researched. The literature from the 1970's to the present contains many examples of these alternative labs such as open-ended projects, discovery labs, and guided-inquiry labs. Many of these are similar to the labs supported by Carmody and Schlesinger in the 1930's. Most of the arguments supporting discovery labs still exist today. It is generally agreed upon that these labs are more difficult and are often frustrating. But proponents argue that they are more interesting and are better at promoting critical thinking skills and problem-solving ability. These chemistry educators want their students to learn more than how to follow directions

Proponents of discovery type labs have different objectives for the general chemistry laboratory. These include creativity through experimental design, appreciation of science through development of logical thinking skills, basic laboratory technique, ability to communicate results, and the ability to recognize a problem and the data necessary to solve it (Venkatachelam & Rudolph, 1974). Richardson and Renner (1970) opposed cookbook or verification labs because they believed the students did not have enough background in chemistry to follow a step-by-step procedure with understanding. They criticized time-consuming experiments because they did not allow pause for thought. They believed that students too often left the laboratory without knowing the purpose. In a comparison study, Richardson and Renner found that students in an inquiry lab achieved significantly higher on tests than students in a verification lab.

Pavelich and Abraham (1979), a well-known team advocating inquiry labs, believed the inquiry lab was much better at developing technique and scientific thought. They admitted the inquiry lab was not without problems, but believed it was a viable alternative which should be tried in general chemistry labs.

The 1980's saw great discussion on the "learning cycle lab," a variation on the discovery lab. The three steps of the cycle were exploration, invention, and application (Ryan, Robinson, & Carmichael, 1980). Exploration was data acquisition, invention was creative analysis of the data, and application involved answering related higher-level questions. They also advocated that the laboratory precede the lecture so that the concrete experience could lead into the abstract lecture. Learning cycle advocates claimed attendance raised when this method was used.

In his criticism of verification labs, Pickering (1985) said unfortunately "the point of student labs is to verify the already known, and woe to those whose data don't agree" (p. 874). He believed lab should be approached as a puzzle, emphasizing logical deductions from data. "Lab is not about illustrating principles, nor mastery of finger skills, nor even inventing new procedures. Lab is to teach the art of thinking from data" (p. 874).

Another common response to verification labs frequently seen in recent literature is directions on how to change these labs to a guided-inquiry format (Allen, Barker, &Ramsden, 1986). These educators noticed that all commercially available lab manuals with one exception were verification labs.

So in order to increase motivation, intellectual stimulation, and thinking skills, these chemistry teachers gave general instructions on how to change the existing labs.

Despite all the research and reporting of discovery labs, they are not in wide use. It is interesting to note that the recent literature contains many studies and reports on discovery labs while virtually none on verification labs. But when a method is already widely accepted and used, it does not need to prove itself. It is the proponents for change that must prove their methods.

The lab of the 1990's continues to be of the cookbook variety with little change since the 1960's. Safety is emphasized more and hazardous chemicals have been removed, but today's labs are still very structured and detailed with fill-in-the-blank data sheets. The push toward discovery labs continues but the future remains uncertain as to whether this method will ever be widely used. An upcoming player in the laboratory is the computer. The developing interest in utilizing computer simulated labs may greatly change the general chemistry lab in the next decade. However, it seems clear that the question about the purpose of the laboratory will not be answered soon.

Cooperative Learning

Cooperative learning is a teaching strategy which places students in carefully prestructured groups to complete a given objective. The small groups are organized so that the students work together to maximize their own and each others' learning (D. W. Johnson, R. T. Johnson, & Smith, 1991). Cooperative learning is not simply "group work" occurring whenever students work together. Nor is it group work where one student does all the work or where one student does no work.

Cooperative learning occurs when group members need each other to complete the given task (Nurrenbern, 1993). The group must be interdependent, with each student being held accountable for his or her share of the work. Cooperative learning is active rather than passive because learning is what the student does rather than something done to the student.

Cooperative learning has existed in many forms for centuries with periodic increases and decreases in popularity. Cooperative learning was most widely used in the early 1800's, then rose again to a lesser degree at the turn of the century. For the past fifty years, it has been the least used teaching method despite being the most researched method (Johnson et al., 1991). Now cooperative learning is on the rise again.

Three possible types of student-student interactions exist in the classroom: individual, competitive, and cooperative. Individualistic methods place the student in isolation and grades are based on past performance and improvement. Competitive methods place the student in a "win-loose" atmosphere where only the top few students succeed. Grades are assigned on a norm or a bell curve based on the class average. Students are glad when other students fail because then they succeed by comparison. Students often feel they cannot compete and therefore do not even try. Cooperative methods place the student in a "win-win" environment because the grading policy rewards cooperative efforts and de-emphasizes competitiveness (Nurrenbern, 1993). Cooperative groups continue to work on the task until all members are successful. One student's success will help the group therefore students are glad when other students succeed. A cooperative group must "sink or swim together."

How do cooperative learning groups differ from traditional groups? Traditional groups have one strong leader whereas cooperative groups have leadership duties more evenly distributed among the group members. The group rotates these duties so that everyone participates equally. In traditional group work social skills are assumed, but in cooperative groups these skills are addressed as new information which the students must learn. Traditional group work is usually given one group grade so that loafers could receive more credit than they deserve and yet hard workers could be penalized. Cooperative group members are assessed individually. Traditional groups do not contain peer review while cooperative groups incorporate peer grading. This serves to motivate students because they desire to be seen favorably by their peers. In traditional group work, the teacher rarely intervenes. In cooperative learning, the teacher constantly monitors student progress and intervenes often.

Many educators are skeptical of cooperative learning because it has been tried in the past and almost disappeared. Since the 1930's, competitive methods have dominated the educational system. Why should cooperative methods work now? The current resurgence of cooperative learning is different from past attempts because of the new emphasis placed on five elements. These five elements necessary for effective teaching are positive interdependence, face-to-face promotive interaction, individual accountability, social skills, and group processing (Johnson et al., 1991).

The element of positive interdependence assures participation from every group member by dividing the responsibility so that success is only possible when each member contributes to the group. Members are assigned roles so that each member's contribution is unique, distinct, and essential for completion of the objective. Many roles are defined in the literature or the teacher can create roles for the specific task (Johnson et al., 1991). The checker makes sure all group members understand what is happening. The researcher collects resources and materials. The recorder writes everything down. The observer makes sure all group members are on-task. The elaborator connects current information to previous knowledge. The summarizer is prepared to report the group's progress to the teacher at any time. Sharon Sherman (1994) suggests the roles of principle investigator, materials manager, and recorder for science classes. The principal investigator is essentially the organizer and leader. The materials manager is responsible for obtaining equipment and chemicals. The recorder writes down all measurements and data. Members can rotate roles daily or by task as determined by the teacher so all students eventually participate equally as positive interdependence requires.

The element of face-to-face promotive interaction requires students to exchange information. Students share any background knowledge already acquired relating to the problem. As students complete their individual work, they must teach the other group members what they have learned. Students give each other feedback and discuss the new knowledge until a consensus is reached. In the best case, students challenge each other, thereby forcing more research and investigation into the problem. By the conclusion of the assignment, each member has acquired knowledge from every group member contributing to a larger sum of knowledge than individual effort could acquire.

The element of individual accountability ensures that each participant receives fair credit for his or her efforts through individual assessment. This assessment can take on many forms such as individual written tests, individual written reports, teacher observations, or oral examinations. The practice of individual assessment discourages free-riders which are often seen in group assessment. Redundant efforts are avoided under individual accountability because each member is responsible for a specific and unique contribution. Slavin (1994) suggests grading cooperative efforts according to individual improvement so that students are compared only to themselves and not others.

Social skills, such as teamwork and communication, are an important element in cooperative learning. High grades do not necessarily translate into a successful career. Joining the workforce requires one to be able to work with others and to be an effective communicator; however, these skills are not taught in school. Rarely does an individual work alone or compete with colleagues. Johnson and Johnson (1991) believe academic learning is greatly enhanced and worth more if students can work sociably with others and communicate their knowledge well. Cooperative learning develops supportive, cooperative, and communicative skills in students.

Group processing is the fifth element in cooperative learning. Since learning is more student dependent than teacher dependent, it is important for the students to reflect on their behavior. At the end of the class, the group gives itself feedback by discussing which activities were helpful and which activities were unproductive. The group can then decide how to improve their performance for the next class. Group processing enables the group to become more efficient and to maximize learning.

Johnson and Johnson (1991) describe three types of cooperative learning groups. Informal groups are used during lectures and exist for only a few minutes. Informal groups can be interspersed throughout a lecture to allow students to cooperate on a problem, a vocabulary definition, or other short task. These groups can be used to get rid of note-taking without thinking.

Formal groups are assigned by the teacher and exist for one or two entire class periods. Formal groups can work on an in-class assignment to be turned in at the end of the period. Formal groups could also work on a short homework assignment to be briefly presented at the next class meeting.

Base groups are long-term groups which last several weeks or even an academic year. Base groups provide not only academic support but psychological support as well by making students feel they "belong." Base groups result in positive student relations and healthier psychological adjustment. They serve to motivate students and increase student attendance. Base groups often meet outside of class to study together and support each other.

The formation of groups can be a difficult task for the teacher. Students should not be allowed to pick their group members because homogeneous groups result and less on-task behavior is observed. All girl and all boy groups will encounter gender problems. Racial tension could result from all white, all black, and all Hispanic groups. Heterogeneous groups can actually lead to improved racial relations (Slavin, 1994).

Most researchers agree that groups should be heterogeneous and contain two to six members. Sherman (1994) suggests balancing groups by gender and race. Slavin (1994) suggests balancing groups by placing high, average, and low ability students in each group. Heterogeneous grouping combines a wide variety of backgrounds and perspectives together which aids creativity and development of alternative plans.

The instructor's role in cooperative learning is quite different from the typical leadership role of direct teaching methods. The teacher is no longer the learning source but rather the learning facilitator. After forming cooperative groups, the teacher specifies the task. Academic and social objectives must be clearly explained. The instructor may point out critical features in the task, give hints, and define the criteria for successful completion. After answering questions, roles are assigned to each member and the group begins work.

For the remainder of the class, the teacher monitors group progress and does not grade papers or read a book. The teacher walks through the class asking students what they are doing and why. This provides students with immediate feedback and keeps them on-task. Students first seek help from their group, and then ask for the teacher's assistance. Much practice is necessary for a teacher to learn when to intervene. Beginning facilitators often feel somewhat helpless when first releasing control of the classroom to the students.

Before students leave, the instructor should check on their progress and answer questions as well as ask questions to determine individual participation. The last duty of the teacher is to evaluate student progress and to assign individual grades.

There are many advantages of cooperative learning over individual and competitive methods (Johnson et al., 1991). Research has shown that cooperative methods increase productivity, motivation, attention, retention, and achievement. Psychological benefits include higher self-esteem, lower stress, lower anxiety, and the development of a more positive attitude. Group work promotes social skills and decreases the fear of public speaking. Decision making, problem solving, and critical thinking skills are enhanced. Students become more effective exchangers of information and learn how to seek and give help when needed. One last advantage of cooperative learning is the fact that students enjoy and prefer it over other teaching methods (Nurrenbern, 1993).

Sue Nurrenbern warns, however, that cooperative methods will not solve all classroom problems or create total equality. Problems do occur in the groups such as arguing, timid members not participating, or over-achievers doing all the work. Elizabeth Cohen (1994) defines a status problem as unequal participation among group members. Usually a high ability student attempts to dominate the work while a low ability student sits back and watches. Cohen describes two strategies for combating status problems.

The multiple abilities treatment can prevent status problems when the students are aware that many different abilities are necessary to complete the task, not just academic knowledge. Manual skills, organizational skills, and visual skills are also desirable. Creativity, inventiveness, and public speaking skills can contribute to the group. Assigning importance to such skills can allow lower academic students to feel needed and competent. They realize their participation can be as valuable as the higher academic students.

Assigning competence to uninvolved students can also stop status problems. If the teacher can praise a student in front of the other students, the group's expectations will rise for that student. Public recognition may be all that is needed to include an inactive student in the group.

Cooperative learning can be implemented in the classroom by many different methods. Of interest to this study is the group investigation method. Sherman (1994) describes this method as the process by which a team of students identify a problem, conduct an experiment, and report the findings to the rest of the class. Each group should have something unique to report. Cohen (1994) believes the best problem for the group investigation method is an open-ended task which has many possible solutions. Therefore, different groups may have different solutions which will have to be justified to the rest of the class during presentations.

Y. Sharon and S. Sharon (1994) describe four significant features of group investigation. The investigation must be an inquiry in which the instructor challenges the students with a multi-faceted problem. Interaction must take place as students discuss, exchange, and debate ideas. Interpretation occurs as the group negotiates all the data into a final group consensus. Intrinsic motivation is present because students enjoy having control over their learning.

Successful implementation of the group investigation method involves six key steps (Y. Sharon & S. Sharon, 1994). The first step is organization. An interesting, relevant problem should be presented which has no single correct answer. Resources of varying difficulty should be available. Immediate questions should be answered so the students clearly understand the problem and know what to pursue next. Planning then occurs. Students assign roles, divide the labor, and brainstorm. The third step is execution which takes many class periods. Students conduct experiments and record, discuss, and analyze the data. Students must decide if more information is necessary. Teachers should encourage groups to have many activities going simultaneously to allow maximum efficiency and participation. Next the students must plan their presentations. Students must decide what information is most important to share and how to share it with the class. A time limit needs to be established by the teacher and every member should participate. The fifth step is the presentation. A schedule must be followed with clear rules of proper conduct. Questions should be allowed and each group should be evaluated by the rest of the class. The last step is the teacher evaluation. Individual grades can be given for a test, essay, or report.

One last hint given by Sharon and Sharon (1994) is to precede a complex group investigation by a smaller project. This will allow the groups to acquaint themselves with a cooperative experience.

The group investigative method closely resembles what actually occurs in many science laboratories. Implemented properly, this cooperative learning method could teach students the reality of laboratory research.

Qualitative Research

Qualitative research, or ethnography, is social research that explores human behaviors in a natural setting. Qualitative methods include case studies, participant observations, field studies, and naturalistic inquiries. Many subjects can be studied through qualitative research such as culture, psychology, sociology, and education. In education, qualitative studies often examine actual classroom behavior in order to improve instructional methods.

Denzin and Lincoln (1994) define qualitative research as a multi-method, interpretive naturalistic approach to studying subject matter. The use of multiple methods, called triangulation, allows the research to be credible because information is found from more than one source. Atkinson and Hammersley (1994) define ethnography as social research that investigates a small number of cases in order to analyze human actions.

Bogdan and Biklen (1992) further describe qualitative research by explaining its five key features. First, the research is conducted in a natural setting which is the main source of data. Second, the research is descriptive using detailed written words instead of numbers. Statistics have little meaning in qualitative research. Third, the research is concerned with processes rather than simply the outcomes. Fourth, data is analyzed inductively. Qualitative research does not begin with a hypothesis which needs to be proved or disproved. The researcher does not seek out specific data to support a preconceived theory. Instead, data is first collected, analyzed, and then theories emerge through generalization. Fifth, the human subject perspective is essential. Selected participants involved in the study, called informants, are often questioned in order to examine and learn from their personal thoughts.

Goetz and LeCompte (1984) agree that qualitative research must be inductive. The researcher enters the natural setting unsure of the final outcome. Preconceptions can actually interfere with the observations if the researcher is biased. The researcher should first examine all phenomena impartially and then develop theories to explain the observations.

Qualitative research proceeds in four overlapping steps which require large amounts of time. A qualitative study can last several months or years. First, the experimental design must be defined. Then data is collected from as many sources as possible. The data is analyzed both during the observation period and afterwards. Finally, the conclusions are reported.

In qualitative research, the experimental design is not planned in detail in advance. It must unfold and develop during the research. The focus of the research may change several times during the experiment as new theories emerge and old ones are discarded. Initial ideas and plans are often thrown aside after the research begins.

The researcher should approach the setting as a clean slate, wiping out preconceptions. A detailed procedure should slowly evolve as the research proceeds. The researcher must be patient and flexible. It may take weeks for a focus to emerge, and even then it may change further.

Before research begins, there are a few necessary steps to be taken (Lincoln & Guba, 1985). A subject of inquiry must be determined. A phenomenon is usually going to be explained or evaluated. The goal of formative research is to improve something. Summative research seeks to assess something's impact on society.

Once the subject matter has been identified, data collection methods must be determined. Times, places, and participants must be located which will allow the researcher to examine the chosen phenomenon. The researcher must contact the participants and negotiate consent to enter the setting.

The researcher must plan how to record and analyze the data. These steps do not occur at a single point in time but will occur throughout the study. Finally, the researcher should become familiar with the setting or field site.

Once the study has begun, the researcher must strive to build and maintain the trust of the participants. Anonymity and confidentiality must be promised in order to receive credible data.

Validity is very crucial to qualitative research (Lincoln & Guba, 1985). Observers and participants should not be changed during the study. External events that could affect the study should be avoided or reported. In order to generalize or transfer results, the participants should reflect a normal population, not an unusual group.

Reliability is achieved when the study is duplicated with similar results. The research is most useful if it is dependable, predictable, and consistent among similar settings.

Objectivity can be obtained by triangulating data. This involves multiple agreement from more than one source. Validating conclusions in this manner decreases the chance of observer bias.

Credibility is maintained by observing the setting more than once and by prolonging the study until the phenomenon is over or no new data can be recorded. The observer should record his or her own feelings and ideas. Qualitative researchers should strive for validity, transferability, reliability, objectivity, and credibility.

The researcher must determine what his or her role will be in the setting. The complete observer or non-participant does not interact with the participants. Goetz and LeCompte (1984) report that one advantage of this role is that the researcher does not influence the participants. However, the researcher may not perceive the true participants' perspective which is crucial. At the other extreme is the complete participant, who appears no different from the subjects. The problem encountered in this role is that the researcher often "goes native." The researcher becomes so involved with the subjects that it is impossible to distinguish him or her from the subjects and objectivity is lost.

Bogdan and Biklen (1992) suggest staying in between the two extremes. They believe the researcher should interact with the subjects without full participation. The researcher can talk to, joke with, and help the subjects for the purpose of data collection. Establishing a good rapport is important so that the participants will share their honest feelings. The researcher must be discreet. He or she should never share subjects' remarks with others or leave notes lying around where someone could find them.

Once the study has been initiated, data collection begins. Data can be collected through field notes, video tape, audio tape, interviews, informants, and documents.

Field notes are a written record of events and often serve as the main source of data. Events, behaviors, dialogues, settings, and facial expressions are recorded in detail as they are observed. Because field notes will always be somewhat influenced by the observer, personal feelings, ideas, and speculations should be recorded to control bias. Field notes allow the researcher to capture momentary inspirations and insights because the researcher can make notes to him or herself. These fleeting ideas would be lost if video tape were the only source. The researcher can look back during the observation period in progress to review previous notes. This would be impossible with recording devices. Field notes also keep the observer alert because note taking is continuous.

Field notes usually begin with the date, time, and place. During the first several days of field work, the notes are long and unfocused as everything is written down. These days are confusing, awkward, and even overwhelming until themes and patterns emerge.

Recording devices can be used in qualitative research. If these are the only data source, however, problems can occur. Technical problems such as running out of tape or dead batteries can ruin a day's research. Audio tape cannot capture facial expressions. Sometimes participants are threatened by being recorded and this influences their actions. However, tapes can recall dialogues and multiple events perfectly. Taping is most useful when supplemented by field notes.

Formal and informal interviews serve to capture the participants' view. Formal interviews are scheduled with prepared questions. Informal interviews occur spontaneously when the researcher simply talks to or questions a participant during a regular observation period.

Informants are designated participants with whom the researcher consults on a regular basis. Informants provide an "inside view" that the researcher cannot otherwise obtain without going native. These participants can be chosen or they could volunteer. They should reflect a diverse sample of the participants if possible. Informants should be willing to share their thoughts and feel comfortable with the researcher.

Documents, surveys, and other written material can be used as data. Student records, exams, course materials, and questionnaires can be consulted. The more sources of data, the more credible the study.

Data analysis is an on-going process as the researcher seeks to make sense of all the field work. Goetz and LeCompte (1984) describe the constant comparison technique for data analysis. Events are constantly compared with previous events to discover relationships, themes, patterns, and trends. Hypotheses that emerge become a focus for future observations.

During the analysis, decisions are made to narrow the study (Bogdan & Biklen, 1992). Future sessions are planned in light of previous observations. Emerging themes can be discussed with the informants. The data should be reviewed after every observation period.

Once the study is over, the monumental task of organizing and categorizing the data is completed. The field notes and all other data should be arranged and grouped into categories. Field notes should be coded according to the final themes. This task can seen overwhelming due to the hundreds of pages of data.

When the data is finally coded and separated into themes, these are reported. The introduction should describe the phenomena studied, the setting, the participants, and other relevant background. The methods for data collection and analysis should be described. The researcher's role and personal feelings should be written. The core of the report attempts to recreate the setting by describing the events and actions in detail. The researcher should attempt to explain all observations. The conclusions should be supported by observations. The evaluation or assessment of the phenomenon studied must be stated with implications, modifications, and future research required.

CHAPTER III

LABORATORY COURSE DESCRIPTIONS

The Modular Laboratory Course

The regular general chemistry laboratory course, CHEM-1107, at Texas Tech University consists of ten traditional modular experiments. The course meets once a week for three hours and students receive one hour of college credit. The course lasts twelve weeks, then all sections meet one evening of the thirteenth week for a departmental final. The first week's lesson is on safety, course policy, and contains an introductory exercise. The next ten weeks consist of ten independent laboratory experiments. Each experiment contains a prelab, a data analysis and calculations section, and a postlab. Quizzes are given every other week. The twelfth week includes the last quiz, a check-out procedure, an evaluation, and a review for the final exam. A typical course schedule is in Appendix A.

The course grade is based on the prelabs, data, calculations, postlabs, quizzes, and the final exam. Students work independently most of the time, but some experiments require working in pairs. All of these classes are taught by teaching assistants (TAs) who are usually first- or second-year graduate students. A typical class begins with a prelab discussion led by the TA, then students are dismissed to work and leave when they are finished. The course is held in a laboratory with four benches, six students per bench. There are two hoods, a whiteboard, and an adjacent balance room.

The modular labs can be called cookbook labs because complete instructions are given step-by-step. Students are directed where to put every measurement on their data sheets and are given all equations for their calculations. Students do not keep a laboratory notebook and do not write formal lab reports. The content and explanation behind the lab procedure is written in the lab module, but since it is not necessary for successful completion of the experiment, students often neglect this information and take "the path of least cognitive resistance." Often, only the highly motivated students learn why the lab procedure works to find the solution. The grading system emphasizes using the correct mathematical application to arrive at a correct answer. Emphasis is placed on completing the lab, rather than understanding the lab.

The ten experiments include such topics as chromatography, graphing, density, displacement reactions, acids, stoichiometry, gas laws, a sequence of chemical reactions, enthalpy, and freezing point depression. The final exam is multiple-choice. The final exam grades are generally much lower than would be predicted from the other lab grades. This could indicate that the students did not truly learn the material, did not bother to study, or that knowledge obtained from these cookbook labs is soon forgotten.

The Project Laboratory Course

In response to the short comings of the modular laboratory, an alternative course was taught in six sections of CHEM-1107 in the spring of 1994 according to the plans of the general chemistry laboratory directors group. After evaluating this trial semester and making any appropriate changes, the project lab may completely replace the modular course in future 1107 courses.

The project lab met once a week for three hours for thirteen weeks. This lab had neither quizzes nor exams. The course was conducted in exactly the same setting as the modular course and was also worth one hour of college credit. The three experiments took the form of longer, multi-faceted projects, which lasted more than one class period. The projects were completed by cooperative learning groups rather than by individuals.

The first week was devoted to safety, course policy, orientation, group formation, and the assignment of Project One. Project One occurred during the second and third weeks. Project Two took place during the fourth to eighth weeks. Project Three was conducted during the ninth to twelfth weeks. The thirteenth week consisted of checking out, evaluations, and the last oral presentations. The course schedule, general information, and policy is in Appendix B.

Grades were based on preliminary proposals, written reports, oral presentations, lab technique, lab notebooks, and peer evaluations. Preliminary proposals were written plans developed by the group for their course of action for that lab period and were collected at the beginning of the class. Written reports were formal and consisted of a title page, introduction, experimental section, results, discussion, conclusions, and references. Detailed instructions were given to the students regarding the written reports and can also be found in Appendix B. Oral presentations were made by the group on the last day for each project. Oral reports were graded on delivery by each member, visual aids, incorporation of background material, content, organization, and overall impression. Lab technique was observed by the instructor. Lab notebooks were required in the course and consisted of carbonless duplicate pages so that the students could hand in a copy at the end of the period. Students were instructed to record every event, procedure, and measurement directly into their notebooks. Peer evaluations occurred at the end of each project. Each group member anonymously graded their partners on participation and contribution to the group. These evaluations were collected by the TA.

A typical working day in the project laboratory began with the TA collecting the preliminary proposals. These were quickly looked over and handed back to the students with any necessary changes due to unavailable chemicals or equipment. There were no prelab discussions over content or procedures. After any announcements, the students were allowed to begin work. Students were free to leave when they finished, but generally remained the entire class period. Occasionally a group went to the library for additional resources, but many textbooks and lab manuals were available in the classroom.

On days designated for oral presentations, the class began with the TA organizing the students for the presentations. An overhead projector and whiteboard were available for the students' use. Each group presented their experience in random order with questions, if any, being entertained after the delivery. When all the groups had presented, the next project was assigned so students could prepare for the next class meeting.

Project One was entitled "The Emir's Sand" and is found in Appendix C. Project One was purposely short and relatively simple because most students were not acquainted with cooperative learning and needed practice to operate productively in their groups. Students had to learn how to plan an experimental design, divide the labor, safely conduct themselves in the laboratory, and evaluate their data as well as learn the chemical concepts in the project. These students had only been in chemistry lecture for two weeks and may never have been in a laboratory. As a result they had little or no foundation upon which to build. The problem in "The Emir's Sand" was to separate a mixture of salt, air, and sand into its component parts. Students developed a procedure for quantitative separation of the salt from the sand sample. Students also decided if the air could be neglected.

Project Two was called "Determination of Phosphoric Acid in Colas." A complete description of this project is in Appendix D. The overall task was to analyze cola samples for phosphate ion by spectrophotometric means. Students first learned how to operate the Spectronic 20 instrument. They had to discover the relationship between the color of a solution and the wavelength of absorption by experimenting with food dyes. The students were also to discover the relationship between absorption and concentration. The students then determined the concentration of an unknown solution before being allowed to proceed any further. This demanded that the students prepare several solutions of known concentration and plot a calibration curve. Students then prepared another curve from known concentrations of phosphate ion. The students had to degas and decolorize their cola samples in order to analyze them for determination of the phosphate ion concentration.

Project Three was named "Characterization of Industrial Inorganic Chemicals" (see Appendix E). The problem in this project was to identify sixteen inorganic compounds through qualitative analysis. Gases, solutions, and solids were represented in the unknown samples. Students had to research each chemical to determine unique physical and chemical characteristics for each. Students then planned a scheme for identifying each compound. Each unknown chemical required a confirmatory test to verify the identification.

CHAPTER IV

PARTICIPANTS

The names of all the participants have been changed. Fictitious names will be used for all students and TAs.

Evan

Evan is a first-year analytical graduate student. In the fall 1993 semester, he taught the CHEM-1107 modular laboratory course. In the spring 1994 semester, he was assigned to the 1107 project laboratory course. As an undergraduate chemistry major, Evan taught six semesters at a small state university. He taught general chemistry, analytical, and instrumental laboratory courses before arriving at Texas Tech University.

Evan believes laboratory courses should reflect the reality of working in a research lab. Real research involves tedious work, some failures, as well as some successes. Not all research experiments work according to plan and students should learn this. Evan believes the laboratory course should teach lab techniques and skills such as making solutions, and accurately measuring weights and volumes. He believes content knowledge should be taught in the lecture and not in the laboratory. The lab's focus should be on practicing technique and applications.

Before teaching the project lab course, Evan believed it was an interesting and good idea. However, he was doubtful that it could be as good as the modular laboratory course. He was partial to the traditional course because that was the method he had successfully learned from as an undergraduate and saw no real problems with it. But he was excited about teaching the project lab because it was different. He entered the project lab thinking it would be fairly easy for the students and that it was rather "watered down." Otherwise, he had no preconceived expectations. In fact, he was not really sure what to expect.

When asked what his goals were for this lab, Evan replied to teach proper techniques. When asked how he perceived his role, he answered, "a watchdog." He explained that he would be responsible for safety and for fixing major problems if any arose. He planned to require students to gather information first before he would help them. He wanted to answer specific questions, not general questions. In preparation for the project class, Evan read the student handouts. Other than that, Evan planned to be open-minded, flexible, and to "wing-it."

Evan's teaching style is rather brusque, blunt, and authoritative. He is usually serious, with a bit of dry humor now and then. He is not very personal with his students and so retains an authority image. His classroom is quiet, orderly, and very structured. His students do not avoid him, yet they do not discuss daily life or small talk with him. His students like him but do not treat him as a fellow college student.

Nick

Nick is a second-year organic graduate student. He taught the modular CHEM-1107 course three semesters before he was assigned to teach the project laboratory. Nick did not have any previous teaching experience before he came to Texas Tech University and does not have a philosophy of education at this time in his career. He does enjoy teaching and relies on TA training and TA meetings to guide his teaching efforts.

Nick was very excited about teaching the project laboratory course and approached it with a very positive attitude. He believed it would be a great course as well as lots of fun. He believed that students would learn more knowledge and would retain it longer than students in the modular lab. He also believed it would be much more difficult for the students. It would be their "hardest lab course ever."

In his journal before the lab began, Nick wrote that this lab was "total immersion" because the students were entering a foreign environment full of the unknown. "By removing all of the recipes and most of the guidelines, the students will be forced to (1) identify the problem, (2) propose possible solutions, and (3) test their hypothesis." Nick believes that a formal education consists mainly of "collecting and regurgitating information while the most important part of learning--integration and conceptualization--is left mainly to the student to develop on his own." Nick complained that even as a graduate student he looks to professors and books for all the answers because that is what his undergraduate experience had trained him to do.

When asked if he had any particular goals for his students, Nick said he hoped to develop their reasoning ability by making them think for a change. He realized that the laboratory's success or failure would depend largely on his ability to motivate the students. He felt that this would be the most difficult part in his attempt to teach the project laboratory course.

Nick originally thought his role as the instructor would be that of a guide, and not a teacher. He planned on sitting back, observing his students, and watching for safety. He had decided to let the students stumble and then to help them solve their problems through guided questions. He wanted his students to think of him as a helper and not an authority figure. Nick's preparation for the project lab consisted of nothing more than reading the student handouts. He did not really know how else to prepare for this flexible course.

Nick's teaching style is extremely relaxed. He approaches his students as a friend, talking about his personal life and joking with them. He projects a very concerned and caring attitude. His students treat him more like a fellow student than a teacher, often talking about their own daily lives. It is not unusual for Nick to interrupt his class with a spur of the moment announcement. His classroom is noisy, sometimes disorderly, but always has an open and friendly atmosphere.

The Students

The students who take CHEM-1107 are typically freshman and sophomore science, engineering, and pre-health majors. Occasionally there are juniors, seniors, and non-traditional students. Nineteen sections of CHEM-1107 were offered in the spring 1994 semester. Students enrolled in the section of their choice during the registration process without knowing some sections would be the experimental project laboratory course. The experimental sections were randomly chosen by designating one laboratory classroom as the project room. Six sections were scheduled in this room. Nick and Evan were assigned three sections each.

In order to enroll in CHEM-1107, students must have either already passed the corresponding lecture or be concurrently enrolled in it. In order to take the lecture, students must have had chemistry in high school or CHEM-1301, the introductory chemistry course.

Of the three hundred forty-two students who completed CHEM-1107 in the spring 1994 semester, one hundred five were in the project sections. Evan had a total of fifty-six students and Nick had forty-nine. The researcher observed one of Evan's sections and one of Nick's sections. In Evan's observed section, there were sixteen students: one female and fifteen males. Eight students were minorities and none were non-traditional. In Nick's observed section, there were twenty students: ten females and ten males. Four students were minorities and two were non-traditional students.

The Informants

Informants were utilized in this study to gain additional information from the student perspective. The observer asked the class for volunteers who would share their honest feelings and ideas about this course every class period. The observer asked for a science major who liked chemistry and a pre-health major who would not be taking this course except that it was required.

In Evan's class, Michael and Vincent eagerly volunteered. Michael is a freshman chemical engineering major who enjoys science. He is not scared of chemistry and expected an A in the course. Michael's first impression of the project laboratory was very positive. He thought it sounded fun and liked the idea of group work. Vincent is a freshman pre-med major who does not consider himself a scientist and yet is not scared of chemistry. He does, however, hate chemistry and hoped for at least a C in the class. His first impression of the lab was quite negative. He believed it would take up too much time, and thought meeting outside of class with his group absurd. "Library research, give me a break, for a one hour lab? Oh man!"

In Nick's class, Shawna, Penny, and later Liz volunteered. Shawna is a sophomore chemistry major who had taken the lower level general chemistry lecture and lab course as a freshman. She enjoyed these courses so much she changed her major to chemistry, and had to take the science majors general chemistry course. She was excited about the project laboratory, and thought it a great idea since "anyone can follow a procedure." She believed this type of course would better indicate "if chemistry is your thing." Shawna expected an A in the course and looked forward to the creativity this lab would require. Penny is a freshman physical therapy major who is terrified of chemistry. She likes neither science nor math. She thought group work sounded like fun but was skeptical of the course format. Penny simply wanted to pass the class. During the fifth class period, Liz, a freshman zoology major, asked if she could share her opinions and continued to do so to the end of the course.

The Observer

I am a second-year chemistry education graduate student. I have taught the second semester general chemistry lab, CHEM-1108, six semesters and the first semester lab one semester. I enjoy teaching and want to teach chemistry at a large university after obtaining a Ph.D.

I believe a general chemistry laboratory course should demonstrate how information can be obtained through research. I believe all the steps involved in research should be taught to the students, not just following a procedure and calculating results. These steps include understanding that a problem exists and that information must be found to solve it. Students should be required to decide what information is necessary and how it can be discovered. The students should learn how to plan an experiment, conduct the experiment, and collect data. The students need to be able to judge if their data is reasonable and valid. They must then decide if more information is necessary, or if they have all the information they need to solve the problem. Finally the students analyze their data and come to a conclusion.

My educational beliefs regarding the traditional verification lab have changed greatly since I began teaching this type of lab. As a student, I thought these labs were wonderfully organized, logical, good demonstrations of chemistry in action, and I learned a lot from them. But I am one of those students who dislike following directions without understanding and therefore taught myself what was missing from the traditional labs in order to learn. As a teacher, I realize that many students do not teach themselves and thus learn very little information from a verification lab. It seems only the high achieving students gain significant benefits from these labs because they are the only students who take time to reason through the procedure on their own. Only they have enough intrinsic motivation to take time and effort to understand the experiment completely. But these are the students who know how to learn on their own and would learn no matter the situation. Most students do not know how to learn on their own, and since the modular labs do not teach, they only direct, students do not learn from them.

The students I have worked with often cannot identify the problem or purpose of the traditional laboratory experiment. My students do not know why the procedure works to solve the problem. They do not know if their data is reasonable and cannot explain their observations. They do not place any significance on their answers. For example, many of my students calculate a molecular weight to be less than one. I find it incredible that a student cannot realize that a molecular weight of 0.0217g/mol is absurd.

I would prefer to stress why a procedure is followed, not how to follow a procedure. In the traditional lab, a teacher cannot distinguish between a student who truly understands, and one who simply followed directions without understanding. Students realize this so why should they take time to understand if they can still get the correct answer. I would also like students to understand the big picture including the content knowledge involved in the experiment. If the chemical concepts or background knowledge required in the lab has not been taught in lecture, then the lab must provide this knowledge. Without it, the lab is a meaningless exercise in following directions.

For these reasons, I was interested in the project laboratory course as an alternative approach to the general chemistry lab. The project lab comes closer to fulfilling my personal teaching goals and beliefs than the modular traditional lab.

However, I did approach the project course with skepticism. By removing the TA led pre-lab discussion, I felt that many students would not have the content knowledge to survive in this discovery learning situation. By reducing the number of experiments from ten to three, I wondered if students would learn much chemistry. I was also quite skeptical of group work as my own experiences with working in groups were nothing less than awful. I recall having to do all the work myself because my partners were satisfied with work that did not meet my standards. Yet my group members and I received the same grade which I felt was unfair. I had never participated in or seen group work at the college level and doubted it could be implemented fairly.

However, I was very excited that the project laboratory would finally challenge students to develop problem-solving skills and higher thinking skills. I hoped to see general chemistry students display logical and deductive reasoning. I was certain students would show more understanding of chemistry and be able to judge their results for validity. I believed the project lab had weaknesses, but thought overall it had the potential to be a better course than the modular lab.

CHAPTER V

METHODOLOGY

Data Collection

Data was collected on the CHEM-1107 project laboratory course during the entire spring semester. Two of the six project lab sections were observed by the researcher. One section was taught by Nick and the other by Evan.

The main source of data was field notes written by the observer. The field notes included TA actions and verbal comments, including personal remarks to the researcher. The notes also described student actions, behaviors, dialogues, and events of interest. Many informal interviews occurred because students shared their personal thoughts and comments often during the class periods.

Informants were asked to volunteer on the first day of class. The researcher asked for a science major who liked chemistry, and for a pre-professional health major who did not like chemistry. All of the selected informants volunteered and seemed willing to discuss their views. Informants were questioned at the end of every lab period to verify the researcher's ideas and emerging theories. Informants were also asked to give their own comments.

The TAs were asked to keep journals during the semester in order to record their thoughts and ideas. These journals were given to the researcher at the end of the semester. Two formal interviews were scheduled separately for Nick and Evan after the course was over to obtain their final comments. Weaknesses and strengths of the course were discussed as well as suggestions for improvement.

Documents such as the course syllabus, all student handouts, and project directions were obtained as data. Final course evaluations and quizzes were also used as data. The quiz contained three questions which also appeared on the regular 1107 course final exam. The regular lab's final exam statistics were made available to the researcher to compare with the quizzes given to the project laboratory students.

Data Analysis

Data was continuously analyzed according to the constant comparison technique. The field notes were reviewed after each observation to look for patterns and trends. Emerging theories and hypotheses were formed and became focal points so that subsequent observations were guided by previous class periods. The observer's feelings and ideas were recorded to maintain credibility.

To verify the researcher's ideas, the informants were questioned about possible conclusions to determine the student perspective. After the course, the TAs were formally interviewed to further comment on the researcher's conclusions. By triangulating the data in this manner, objectivity was established because observer bias was decreased.

When the project laboratory course concluded, all of the data was reread and coded into categories. The categories were the TAs, the students, TA-student interactions, student-student interactions, group evolution, the projects, the quiz, and the course evaluations. Conclusions in each category were found. Observations, student remarks, and TA thoughts were found to support the conclusions. Multiple agreements among the various data sources were located to further support the conclusions. After all the data was analyzed and categorized, writing began.

The Researcher's Role

I was introduced to the students on the first class day after Nick and Evan had introduced the course. Nick and Evan told their classes that I was going to evaluate the course. I told the students that I was a graduate student studying chemistry education. I told them I was interested in the new chemistry lab course and I wanted their input. I asked them to come and talk to me if they had any complaints or comments about the class. I then asked for volunteers to share their views with me each class period.

I did not become a participant and did not conduct any experiments myself. Neither did I remain a complete observer. I often spoke to and joked with the students. They perceived me as a friend and not as a teacher or an authority figure. The students often did things in my presence that they would not have done if the TA had been watching. In the balance room, students touched chemicals and told me "Shhh." Vincent punched out the face plate of his goggles and told me to watch how long it would take Evan to notice. Occasionally, a student would come to me for help while the TA was not looking as though this action would be considered cheating.

During the class periods, I usually sat in the middle of the classroom where I was elevated and could see all the students. Usually once or twice a period, I walked through the classroom to ask students how they were doing. The students appeared to trust me because they sometimes spoke harshly against their group members, the course, or even the TA. At the end of the period, I talked to the informants.

If the TA ever left the room, the students often came to me to complain. It took the students many class periods to realize that I knew chemistry. Even then, the students rarely asked me chemistry related questions about their projects. Most of our conversations were about the educational aspects of the course.

CHAPTER VI
DISCUSSION

Evan's Perspective

Evan set a serious and fairly formal tone in his lab on the first day that would last the rest of the semester. He seated the students alphabetically, passed out the syllabus, and gave a typical safety lecture. Then he read the student handouts verbatim to the class. Students were placed in groups of threes or fours according to the seating arrangements, and then given the remainder of the class period to discuss Project One. In his journal after the first week, Evan wrote that the students seemed excited about the course. He believed they felt the lab would be easy and developing their own procedures would be simple.

After the second week of the project lab, Evan admitted that the class was going much smoother than he had expected. He was surprised that the students relied on information from within their own group rather than other groups. He wrote, " this was unexpected as I thought one group would lead the experiment and the other groups would copy what they were doing." He was surprised at how prepared and resourceful the students were for the lab. Many students had gone to professors and library books for ideas. The preliminary proposals contained many complicated procedures. He felt the biggest problem was that the students did not know what equipment was available or where it was located. He also felt the preliminary proposals could be more detailed rather than just a broad summary of the students' plans.

On the second day for Project One, Evan positioned his class around the whiteboard and encouraged student questions for the first oral presentations.

After all the groups had presented, Evan told the students how he would approach the problem himself. This was of extreme interest to the students because they were very attentive and asked Evan several high-level questions. Evan felt the oral reports were rather poor. He was distressed by what he considered to be irrelevant remarks such as "we learned it is important to work together as a group" and "we learned how to use lab equipment." Therefore, Evan feels more explicit directions should be given for the oral presentations to avoid such non-chemistry related statements. He also noticed a complete absence of error analysis and a lack of visual aids. Evan felt that the first group to present set the pace and that the other groups copied their style.

The first written reports were also poor in Evan's opinion. He complained that the students did not follow the directions, had little organization, and used first person. Evan suggests telling the students to use third person past tense in their reports and did this with his classes. The written report instructions in the student handout did state that third person should be used.

Evan did not have any general comments and did not write in his journal for the next several weeks. He was very busy preparing for his first literature seminar and studying for his graduate courses.

Evan saw great improvements in the second set of oral presentations and written reports. Halfway through the oral presentations, Evan directed three questions to the entire class which initiated a heated discussion. This was the best interaction of the day because students were challenged to critically judge their work. Evan was pleased that the presentations focused on just chemistry and not other aspects of the project course. More visual aids were used and error analysis was at least mentioned. Evan noticed a more relaxed atmosphere as students joked and asked each other questions.

The written reports definitely improved in style and organization according to Evan. All of his suggestions had been followed this time and only a few students used first person. Evan's biggest complaint with this set of reports was that students did not mention the problems they encountered and how they corrected them.

During Project Three, Evan perceived that the students were working much more efficiently in their groups. The groups were finally dividing up the labor into individual trials so that many groups finished early. He also noted that laboratory techniques had greatly improved.

Evan was quite impressed with the last set of oral presentations and written reports. He felt the students were more sure of themselves in front of the class. Questions were more common than before and the students even argued with him about certain procedures. He believed the students were finally becoming confident and comfortable in front of the class.

Evan wrote that the written reports "were well structured, read like they had been practicing scientific writing for sometime--did not sound like freshman chemistry--much more advanced." Evan believes that the writing skills acquired in his class will prepare these students for upper level science courses.

After the project laboratory course was over, Evan made several suggestions for future classes. First, he believes the instructor must know exactly what to do. He suggests weekly TA meetings with very involved discussions. Second, he would like to require visual aids in the oral presentations because when such an aid was used, the presentations were much better. He would like the grading system to place more weight on the written reports and less emphasis on group grades. Finally, he thinks the preliminary proposals should include a detailed procedure and the lab notebooks should include an apparatus diagram.

In a formal interview after the lab course, Evan said he still prefers the modular lab course because he believes it teaches more chemistry. But he admitted that the information acquired in the project laboratory would probably be retained much longer. Evan believes that the project lab teaches procedure development, problem solving, research skills, organization, and cooperative skills. The student role is more active since the students determine their own learning. Evan credits the project lab with more critical thinking and says there is "definitely more thinking in general." The lab overall was better than what he expected and the students did learn proper techniques.

Evan believes the project lab's success depends more on the TA than in the modular class. More preparation is required than what he originally thought. He suggests future TAs develop many plans of action for a lab and think through each of them. He warns other TAs to be prepared to change the students plans if they are unrealistic or too long. He believes the TA must be outgoing, willing to answer questions, very patient, and flexible. He thinks the TA should reveal any unknowns to the students after the oral presentations and discuss why their results may differ.

Evan admitted that the oral presentations got boring and repetitive but believes the students need the practice of public speaking. He believes visual aids and TA questions may help break the monotony. Evan believes the written reports are of utmost importance and would not change them. Evan also likes the peer evaluations and would not change them either. He would change the attendance policy to be more strict by permitting only one absence because attendance problems arose.

Evan said groups of three or four students worked best. Five would be too many and two would be too few in a group. He thought the co-ed groups worked best together. He said that the males had better techniques while the females had better writing skills. Evan believes that A and B students benefit the most from the project lab while C and D students remain uninvolved and "tag-along." If he could, Evan would place the C and D students in the modular lab so they would be forced to do individual work. Evan said he knew the lab was progressing well when he observed groups debating among themselves. He said a warning sign was an isolated student which required TA intervention to correct. Overall, Evan enjoyed teaching the project laboratory course and believes with a few changes, it could be implemented successfully on a large scale.

Nick's Perspective

Nick began his class with a friendly, relaxed, and somewhat unorganized discussion of the project lab in general. Nick really stressed the more attractive features of the lab course such as no quizzes, no tests, and only three experiments to make the students believe they were in a great class. His introduction was very humorous and captivating. He eventually discussed all the details in the student handouts and placed the students in groups of fours or fives based on their alphabetic seating arrangements. Nick displayed confidence, enthusiasm, and made the students laugh. Yet his instructions were sometimes vague and confusing.

After the first week, Nick thought that the students feared the lab reports. He wrote in his journal that when he mentioned the reports he could "see the fear in their eyes." Only four of his students had ever written a lab report before.

This worried Nick since the report was a large percentage of their grade. He suggests having an actual lab report, not just directions, posted in the classroom for the students to browse through.

After two weeks of the course, Nick was surprised at how much thought and effort the students were putting into the class. He noted that most errors were due to a lack of exposure to laboratory equipment. To remedy this, Nick suggests future labs spend some time on the first day acquainting students with common lab techniques such as weighing samples and lighting Bunsen burners. Another problem noted was students getting "locked" into one specific method. If a problem with that method became evident, the students stalled, unable to adapt. Nick was very pleased to notice self-satisfaction and confidence in the students when they were successful.

Nick did notice some groups having many problems. These students were not prepared, did not seem excited, and showed no creativity. He decided these groups were all younger freshman and part of their problem was poor group functioning and lack of communication. He contemplated rearranging one group in particular who appeared to do nothing but argue unproductively. Nick was also worried about the very quiet groups as he could not assess their progress. He decided he could only wait and see what they had accomplished in their oral presentations.

The first oral presentations did not go very well in Nick's opinion. After all the groups presented, Nick tried to summarize the experiment by asking several questions. Only two students responded while the class as a whole appeared tired, bored, and disinterested. Regarding the written reports, Nick said "they are pretty bad, but not because the students aren't learning. Most just don't pay attention to the rules of writing." Nick decided the written guidelines for the reports were not enough to produce quality work, and that he must orally go over what he expected from them.

Over the next several weeks Nick saw a transformation occur in his students. Group participation and organization increased. He felt that every student was involved in the laboratory to some degree. He noticed that definite leaders had emerged in every group and were organizing and delegating authority. The second set of written reports was much better according to Nick. Most students showed definite improvements in organization and communication. However, Nick believed that the oral presentations were boring and repetitive. He felt that doing a written report and an oral presentation was "overkill" and took too much time. Therefore, he told the class to limit their presentations to fifteen minutes, to show only one calculation, and to stress something they as a group did different from everybody else.

In his interview after the project laboratory course was over, Nick suggested changes in the oral and written reports. To avoid repetition, which is extremely boring, Nick said each group should be assigned a different part of the experiment to present orally. He felt the students did not really listen anyway, but nevertheless, thought the oral presentations were important to force each student to speak in front of the class. Another possibility is to require each group to present only once instead of three times. Nick believes oral presentations are most beneficial when students ask each other questions and debate issues. However, he admitted it was very difficult to get the students to interact in this manner. Nick complained about grading the written reports and wished they could be shorter. But he did agree they are an absolute necessity in the course.

Nick realized by the end of the project laboratory that his role as the instructor was very different than he had expected. He had to help the students much more than he originally anticipated and often influenced them through guided questioning. Nick also realized that more TA preparation is necessary. He suggests that future TAs be prepared to give the students more information and more feedback than he did. He believes that the TA has more influence over the project laboratory course than the modular course, and that a "deadbeat TA" will seriously damage the class.

Among the changes Nick would make in the project lab is a longer introduction section with exposure to lab equipment. He would not require preliminary proposals at all and would stress the peer evaluations more. Nick believes group sizes of three, four, or five students are all acceptable but said all female groups were trouble. The females did less work than the males, showed less understanding, and spent a lot of time talking about their personal lives in his opinion.

Nick was very liberal in his attendance policy. He believed if an entire group wanted to skip a day it was acceptable. He also thought if a group excused a member's absence, then that member should not be penalized. He explained this policy by stating that if a member was not excused by the group, then "he will get nailed by the peer evaluations." Thus, Nick believes peer grading serves as an incentive to attend class.

Overall the project laboratory did not meet Nick's high expectations. Although the class was not as good as he had hoped, it was certainly not bad. He believes the modular lab teaches more chemistry but said "face it, neither really teaches much." He felt one of the project lab's strengths was that it gave students a better view of reality. He believes C and D students will benefit most from the project lab because of the cooperative atmosphere. When asked about the A students, he replied they will learn no matter what type of lab they take, and so are not really of concern. Nick believes the best aspect of the project lab is that it "definitely brings out more higher level thinking." The students must be more responsible in the project laboratory and they must learn how to learn. As Nick's primary goal was to promote thinking, he concludes that the project lab was a success and can be implemented full scale next semester.

The Students

On the first day of the project laboratory course, the students were very quiet and seemed unsure about the class. Some students frowned; others looked bewildered and confused. Many students were bored, disinterested, or had completely blank faces. Many students appeared scared although none raised their hands when asked by the TA if this lab seemed scary. Only three hands went up when asked if the course sounded fun. Only five students acted interested and responded to the TA by nodding their heads and changing their facial expressions. One student later said this type of lab would make students think, it would be more interesting than the typical lab, and more chemistry would be learned.

The second class was very interesting as it became obvious that the students had no idea how to conduct themselves in a laboratory. Problems arose over simple procedures that a chemist might assume to be common sense or obvious to anyone. The students spent a large amount of time just finding their way around the laboratory looking for the balance room, sinks, Bunsen burners, ring stands, and other equipment. The students did not know what equipment could be checked out from the stockroom or where it was located. The students could not turn on or tare the balances. The balance room was in complete disarray as students did not use weighing paper and put chemicals directly on the pan. To separate a filtrate and solid, one student held a piece of filter paper while another student poured the solution through it. Beakers were hand held while students waved the Bunsen burner back and forth under them. Of course, just lighting the Bunsen burner was quite a task. Students basically could not use funnels, balances, and Bunsen burners without instruction.

Yet many positive activities were also observed. One group took over the whiteboard to draw their apparatus set-up and to organize their procedure. Most students meticulously cleaned all their glassware without being told. One group discussed a similar agriculture lab and applied that knowledge to the current problem. Another student used the second whiteboard to convince his group to follow his ideas.

Shawna, the chemistry major in Nick's class, said she enjoyed this day in the laboratory, especially the group work. She liked hearing other students' views and opinions and felt that more ideas and alternative plans were generated than if she had worked alone. She liked this lab better than the modular lab she had taken the previous semester. She enjoyed Nick's teaching style very much and said he helped the group by being enthusiastic. She did mention that she felt pressed for time because it took longer than expected for her group to get organized.

Penny, the physical therapy major in Nick's class, neither liked nor disliked the class. She thought it was good because she had to think, she had learned some chemistry, and she liked hearing her group's opinions. However, she felt that more feedback was needed from Nick and was afraid they had gotten off on the "wrong track." She believed the day had been completely unorganized. Another student commented that making up the procedure was much better than reading a long boring one. This student enjoyed figuring out the lab for himself and was glad no one was telling him what to do. He said, "I finally understand the 'why.' In a traditional lab I never know why we do things."

Vincent, the pre-med major in Evan's class, hated the lab but admitted meeting outside of class was not as bad as he thought it would be. He did like working in groups, but said this lab was too time consuming. Michael, the chemical engineering major in Evan's class, had enjoyed the day. He said he hated following directions so was really glad to create his own procedure. He said his group worked well together and each member had a role. He said four opinions was better than one and he liked debating those opinions until everyone agreed. He said Evan had helped just enough without "spoon feeding" them. Another student mentioned that her group had decided to let the majority rule whenever they disagreed. This student said that she felt nervous whenever Evan was near and did not like him observing their work.

The third lab day was scheduled for oral presentations. Overall, they were quite poor. The students displayed no public speaking skills and the talks can only be described as boring. The students were extremely nervous, which is understandable, but the TAs could have improved their presentations with a few simple comments. Most students spoke too quietly to be heard, spoke facing the whiteboard, read directly from papers, looked at their feet, or did not stand in front of the class. These problems could be simply corrected. Most groups did not use any visual aids and the TAs asked them to at least write something on the board. Some students did occasionally look at the TA, but rarely did a student look at another student.

It appeared that most groups were not interested in listening to the other groups. If a group had not presented yet, they read their own notes. If a group had already presented, they relaxed and ignored their surroundings. One group did use a single transparency and it was only at this point that all the students paid attention. Overall there was little interaction between the students. A total of ten questions were asked by students in both of the observed labs. Only during one presentation did a discussion take place, but it was TA initiated.

There was a slight difference between the two classes. Nick's class gave their presentations in a slightly more relaxed tone than Evan's class. Evan's students were more formal and detailed. Although they were just as boring, Evan's students were more organized and covered more content. It seemed the students imitated their teacher to some degree.

Shawna said she liked the oral presentations because she could see what other groups had done. However, she felt more guidelines were necessary such as a time limit and how in-depth or detailed the talks should be. Penny liked the practice of public speaking and definitely preferred the oral report to the written report. Vincent thought the oral presentations were unnecessary and thought the class period could be better utilized. Yet he did think the practice on public speaking was advantageous. Michael said it was very hard to face the class. He kept wanting to turn around and write on the board. He believed it was a necessary part of the class though, because it benefited him to hear other approaches and ideas. Michael wished the presentations could be recorded on video tape so he could see himself and learn from his mistakes. He also thought more directions were needed for the oral reports to guide included content and detail.

By the fourth week, the students were beginning to function more efficiently in the laboratory. One group began the class by looking at the Baker safety poster guide to labels on chemicals. This led them to the Material Safety Data Sheets (MSDS) to find information on a particular chemical. Students were using the reference books more often so it appeared they were developing research skills. They still cleaned all their glassware and usually left the classroom very neat. Penny mentioned she was developing problem-solving skills, something she had never had to use before. Another student said she was learning more knowledge than she would with additional instruction. She explained this seemingly contradictory statement by stating that the more instruction she received, the less she had to think.

A comfortable and relaxed atmosphere had developed by the fifth week. Students were volunteering their opinions more often. Many students were becoming careless about wearing their goggles and many students chewed gum. More off-task behavior was observed than in previous classes such as personal small-talk and a fifteen minute hair braiding session. The females explained to the TA that it was necessary to pin up their hair. Students often looked around the room to locate the TA to make sure he would not see their off-task behaviors. Many students were absent this week and that seemed to hinder their group's functioning. One group had two students absent and the two students present appeared to have no incentive to work without them. These two students were very mad that their members were gone without even calling and so felt it unfair to be expected to work without them.

Generally technique had greatly improved. Students used droppers to make sure the meniscus of their solutions was exactly at the mark. Glassware and desktops were always clean. Students used funnels correctly. However, weighing technique was only slightly improved and the balance room was often very messy. Perhaps this was because the TAs never went into the balance room. Students often looked up information in the MSDS notebook. Two groups had finished their day's work early and were discussing if they should repeat anything. This was the first time students were observed judging their techniques and data for validity. One group decided to perform an extra trial. This was an unexpected behavior because students in the modular course rarely consider doing more than the absolute minimum.

At the end of the fifth period, Yolanda, a pre-physical therapy major, said she was enjoying the class except that some of her group members had missed their scheduled meeting at the library. Then in class that day, one student was again absent. She also expressed her displeasure with the lecture course by stating, "In lecture, there's no thinking. Information is just heaped on you. In here I like that I get to think at my own pace."

Liz also expressed problems with her group since they were "well, you know, kinda, not too smart." She wished her group was smaller in size because she and one other student did all the work while the other two members watched. She also said one person usually missed their night library meetings. She thought she would probably get more out of the modular laboratory course. She did not like this much freedom and would have preferred a more structured course. Liz believed the TA should help more and not sit at his desk.

Another student complained that the project laboratory required too much time to be worth only one hour of credit and it did not relate to the lecture. Michael enjoyed the lab period except that one member was absent from his group. Vincent complained that he felt very isolated. He said he could not ask other students for help since every group had their own procedure. He said that the TA would not help him either, so he was very frustrated. He also complained that his friends in the modular lab never stayed the entire three hours while he always did.

The sixth week saw few changes in student behavior. The students were perhaps more on-task as Project Two was ending soon. Students still cleaned their glassware and lab space. Once again students were observed holding the Bunsen burner under the beaker and waving it back and forth. Some students were very upset to find dirty equipment in their drawers. One student admitted they had planned for two members to be absent since Nick did not care as long as their group excused them. Liz had a much better day because all her group members were present and participated. Shawna had been absent the previous week and said it was very difficult to get caught up with her group. She had to rely on them to be patient with her and help her with the experiments she had missed. Vincent said the course was getting worse. He was having a hard time knowing what to do. He complained again that Evan would not help him.

The seventh class day was rather quiet, serious, and more organized than previous lab periods. Students were very careful regarding volume measurements and exhibited good pipeting techniques. One group had a minor explosion as a beaker burst while being heated, but they quickly cleaned it up properly. One group was writing chemistry on the whiteboard. Students were still very conscientious about cleaning up after themselves.

The eighth week was set aside for oral presentations. Overall, there was not much improvement. It was noticed that the older, non-traditional students really concentrated on clearly communicating their experience and put forth more effort than the younger students. Although the presentations were still boring, more students were attentive. More visual aids were utilized this time, such as a poster and two overhead transparencies. The students paid more attention when a visual was displayed. Delivery style did not improve at all as students still read directly from their notes, spoke monotone, looked at their feet or the TA, and spoke facing the board. Student questions were very minimal and debates essentially nonexistent.

Before the ninth class period, which began Project Three, five students were encountered outside the chemistry building and they complained that the reference books in the library were all checked out. However, all five agreed that they liked this lab better than a traditional lab because they enjoyed getting to think for themselves. Nick's ninth laboratory class was very short because all the students left for the library to do research. However, Evan's class lasted the entire period. Evan left during his class for about thirty minutes to set up a classroom for his seminar. Once he had departed, several students said they were lost but too scared to tell Evan or ask for his help. Since Evan was a rather formal teacher and was perceived as an authority figure, the students were hesitant to admit their problems to him. This class period seemed very unorganized, the students were frustrated and tempers were high. Many students admitted they had come to class unprepared, without a plan, and that this was a mistake because they were wasting time. Many of these students still needed to do research like Nick's class, but were too afraid to leave.

The tenth week proved to be much more productive because the students came prepared for class. All the students seemed busy and plans were being formulated. One group asked how to properly dispose of their waste. Overall, the students appeared to be very safety conscious regarding the many different chemicals used in Project Three. Many students used the

MSDS notebook or looked at the Baker safety poster. The poorest technique observed was wasteful usage of pH paper. The students placed several inches of this paper into the beaker and stirred it with the solution. Neither TA noticed this and so both classes ran out of pH paper. Another problem was that despite instructions to take only two milliliters of a sample, students were taking about twenty to fifty milliliters at a time.

The eleventh class of the project laboratory course was not observed. The twelfth lab period was the last working day for the project laboratory course. The change in the students' conduct since the first week was remarkable. The students were organized, competent, and handled chemicals correctly and safely. This lab period had a calm and relaxed atmosphere. Most students finished early and cleaned thoroughly before leaving.

The last class day consisted of a check-out procedure, evaluations, and the last oral presentations. Despite the student improvement in the laboratory and written reports, the oral reports were still very poor with no attention paid to public speaking skills. Once again, the presentations were repetitive, boring, and monotonous. Nick's class was extremely unorganized and informal in their presentations. His students literally ran out of the classroom in joy that the course was over. Evan's class was more organized and professional in their talks. But their delivery style was just as poor as Nick's class. Evan's students left in a more dignified manner. Only Vincent stayed late to share his final comments. His biggest gripe about the course was that he never had enough information to begin solving the projects. He complained that Evan would never help him and thus without any direction he "wasted a lot of time fumbling around." A summarization of the final comments from the student course evaluations will be presented later in this chapter.

Student-TA Interactions

Periods with no interaction between the students and TA were more common than interactive periods. In both Nick and Evan's classes there was a prevalent atmosphere of "you're on your own." Despite the TAs' call for questions, the students were hesitant to approach them when they were seated at the TA desk. When the TAs approached the students more directly, the resulting interactions were very beneficial to the students.

During the second class period, the students did not approach Nick often, therefore, he left them alone assuming they were proceeding without any problems. Evan's class was similar until the last hour when one group needed help with the operation of a centrifuge. This started a chain reaction among the groups and Evan was kept busy answering questions until the end of the period. Evan helped all the students and a good rapport developed between him and his students. Evan even stayed after class and allowed one group to finish when he could have said that the lab period was over.

Nick asked several questions during the third class period of oral presentations when the students did not ask their own questions. Most of these questions were not answered and extremely long wait times followed which created an uncomfortable atmosphere. Nick's questions clearly scared the students and appeared to embarrass them. The questions usually pointed out errors in their procedures, and Nick's tone implied that their errors were obvious. These criticizing questions served as negative feedback and the students appeared disappointed and upset at Nick's reprimands. Nick did not ask any simple content questions which the students could answer to build up their confidence.

Some errors might be corrected privately rather than embarrassing the students in front of the class, while other errors that could promote misconceptions could be corrected later to avoid association with a specific group. If an error demands immediate correction, it should be handled in a tactful manner that does not degrade the students.

Nick appeared to lose patience with one group and spoke in a rather condescending tone. Elaine, a chemistry graduate student and friend of Nick's, was present for the oral presentations and also asked the students very difficult questions. Her questions went unanswered as well and the students seemed unsure and nervous at her presence. However, after criticizing every group, Nick told the entire class they had done a good job and then gave very positive feedback. He further explained some common problems and how they could be avoided. The students looked relieved and the class ended on a positive note.

Immediately after Nick's class, several of his students expressed their anger that Elaine had been allowed to ask them such hard questions. They felt that she had made them look stupid because they could not answer her questions. One female student said she did not need any help looking stupid because she did it well enough on her own. They did not think it fair for another graduate student to observe them and hoped she would not come again.

Before his oral presentations, Evan told the students to think of questions to ask each other. It was noticed that Evan frowned during the rest of the class so the students avoided looking at him and looked at the floor, their notes, or the observer. Evan asked each of the first two groups a question and very politely corrected one error. After that, he did not ask anymore questions. When the class was over, one group privately told Evan they wanted one member removed from their group. This member did not participate, attend outside class group meetings, and had arrived at class too late to participate in their oral presentation. Evan discreetly took the student into the hall and told her she had a chance to start over with a new group. He said that she really needed to cooperate with the new group and work hard on Project Two.

Nick's fourth class period began with a short lecture on how to make solutions. Then he left the classroom for one hour to attend a business lunch. The observer had previously agreed to watch his students for safety. When he returned, there was basically no change in student behavior because he sat at his desk. Penny complained that she needed more direction from Nick this day.

Evan's class began without a content lecture. One group asked a question to which Evan replied, "That's what you figure out." However, after forty-five minutes Evan felt the need to clarify a few problems and gave the students general directions on the operation of the Spectronic 20. This helped immensely because all the students began their work with renewed energy. Once again this involvement of Evan sparked a reaction among the students and Evan was flooded with questions. In his class, the students seemed very hesitant to approach him until he "broke the ice." It was as though the students had to first judge if he was willing to help them that day or not. Soon the class was organized, cooperating efficiently, and following a plan.

The fifth week in Nick's class began with directions on how to use the Spec 20 and then Nick sat at his desk to grade papers. After fifteen minutes, Nick realized his instructions had been incorrect, changed the directions, and resumed grading. He graded papers for two hours. During this time, the observer walked through the classroom and many students said they were lost and needed help. One student asked if Nick was mad at them. The students were much more likely to ask questions if the TA was walking around the lab and not sitting in a corner reading or grading. Even the most friendly TAs appear unapproachable when they sit with their backs to the students. Another problem noted in Nick's classroom was the fact that Nick never took roll and rarely called the students by name. He was not aware of who was present or who was absent. After two hours, Nick got up and walked through the classroom. The groups that were really lost avoided talking to him, but the groups that were proceeding fairly well asked him many questions basically to confirm what they already knew.

Evan's class began with a discussion on how to dilute solutions of known concentration. This gave the students some direction and organization. After a while, it was also noticed in Evan's class that the groups having the most difficulty avoided him. Since they were not asking for help, the TA assumed they were proceeding on track without any problems. The noisy, active, outgoing groups received most of the TA's attention, but most of their questions just reassured them of their progress. After two hours, Evan again called his students to the board for a content discussion on Beer's Law. This served to refocus some of the groups on-task. Michael felt that Evan had helped them just enough, without giving too much away which he thought bad. Vincent wanted more help from Evan.

Nick told his students at the beginning of the sixth class that they needed to divide their work in order to finish on time. He said, "all four of you can't just stare at the same thing. You must organize yourselves and hustle." He also announced that Project Two would be extended one week. The class was more quiet than usual and there were only three questions asked of Nick. The most exciting event of the day was a beaker breaking which Nick cleaned up because he was doing nothing else. Evan's class also had little interaction on this day. Mostly Evan was heard telling students to put on their goggles.

The seventh week began with Nick visiting each group to check on their progress. This allowed the students to get organized quickly and gave each group a goal. However, Nick did not assess the students again for an hour. Near the end of the class, panic struck the students as they had to finish the project. Nick made several last minute comments and suggestions which basically added to the frenzied atmosphere.

Evan's class began without any assessment or comments and therefore it took his class longer to get started. Evan finally asked one group if they knew what they were doing. They replied rather sheepishly, "Nope." This class was very quiet and did not have the interaction or hurried pace seen in Nick's class.

Nick started his second set of oral presentations by relocating the students to a small lecture room. This room was much more appropriate for speaking and forced the presenters to stand in front of the class rather than hide behind lab benches. Nick did not ask every group a question as he had previously, and the questions he asked were much simpler. After the class, Nick said it was very hard to think of questions to ask the students, especially the later groups because by then the most obvious questions had been answered.

Evan's class remained in the laboratory which was not ideal for presentations. Evan did not ask a single question in the session directly to a group, but rather addressed three questions to the entire class. Evan's interaction with his class was markedly minimal.

Nick's ninth class began with a TA led discussion over written reports. He wrote a cake recipe on the board with unitless measurements and vague instructions such as "heat the batter" without a temperature or time. He emphasized the importance of units and specific directions. He told the students to keep track of such details in their notebooks so that writing the report would be easy. None of the students was ready to start work on the third project, so after his talk, they all left for the library to conduct research.

Evan's class started with him collecting the preliminary proposals. It was realized that Nick's class did not write proposals anymore. Evan received notice that the problem student, who previously had been transferred to another group, had dropped the course. Evan's class was very quiet without any TA intervention. Both Vincent and Michael complained they were having a hard time getting started on the new project. Evan could have approached each group to help them begin because it was obvious every group was having difficulty.

Nick gave hints on how to distinguish between four different acids at the beginning of the tenth week. He strongly encouraged questions but unfortunately the students did not respond. The material about acids was presented a little over their heads because they had not studied that chapter in lecture yet. Nick kept saying that this was so easy, but it was not for them. The students who did not understand possibly felt unintelligent or even stupid as Nick was almost condescending to them. He told the students that H_2SO_4 would take twice as much NaOH as HCl to turn phenolphthalein pink. Likewise, H_3PO_4 would take three times as much. He said, for example, if hydrochloric acid took five milliliters of sodium hydroxide, then sulfuric acid would take ten milliliters and phosphoric acid would take fifteen milliliters to turn the indicator pink. When the volumes of base required were not exactly in a 1:2:3 ratio, the students were very confused and did not really understand this concept.

Nick also discussed other characteristics of chemicals such as color, physical state, and solubility to aid their qualitative analysis. Overall, this short content discussion helped focus the students on what to do and helped them realize that they needed to develop a separation scheme to gradually narrow down the identifications. The students worked quite well during the remainder of the class period with clear goals and purposes.

Evan held a similar discussion with his class. He also helped the students by clearly defining the problem to be solved and the desired outcome of this project. Unfortunately, after this brief introduction, Evan graded papers for the remainder of the class and the students worked without any guidance or feedback.

Nick's eleventh class began with polite reminders to clean up after themselves. Many students were absent. The remainder of this class and Evan's entire class was not observed.

Nick had a very successful twelfth lab period. He helped students with the unknown gases. Nick inspected the entire classroom and this action invited many questions. In fact, students were calling for him every ten minutes. Nick was extremely busy helping the students the entire class period. The students were on-task the entire day and much was accomplished with Nick's constant surveillance, help, and feedback.

Evan apparently had a productive class the previous week when the observer was not present because most groups were already finished and left early. The few remaining groups finished quickly. Many students stayed and talked about chemistry with Evan. This was the first time Evan was observed interacting with his students on a personal level. Their discussion was about carbonation in beverages, including beer and wine, and appeared quite interesting to the students.

The last class period was the third set of oral presentations and evaluations. Different parts of the project were assigned to different groups by Nick. This allowed each presentation to be unique and student attention was a little higher than previously. No questions were asked by Nick; however, he provided a good summary of Project Three at the end of class with a comparison of each group's results.

Evan had each group present the entire experiment so his class was much longer and more repetitive than Nick's class. Evan asked questions of the outgoing groups but the quiet groups received little TA attention. By the last presentation, no one was paying attention, including the TA. The class then evaluated their peers, something Nick had forgotten to do. Evan led a half-hearted summary discussion of the project, and the class was dismissed for the last time.

Group Evolution and Student-Student Interactions

The project laboratory course is designed to place students in cooperative learning groups. These groups should differ in practice from traditional groups. Each student should contribute something unique and important to the group. This can be accomplished by assigning student roles to each member. The roles in the project course were team leader, assistant team leader, record keeper, and counselor (see Appendix B), and were rotated after each project. Individuals were assessed, instead of the group as a whole, through lab notebooks, technique, written reports, and peer evaluations. More emphasis was supposed to be placed on social skills such as communication, organization, leadership, and conflict management. It does take practice for a teacher and the students to truly implement cooperative learning. Without the instructor's monitoring and intervention, ordinary group work could result with unequal participation and poorly functioning groups.

Nick placed his students in groups of four or five members. After a few students dropped the course, there were five groups total. One group had three members, three groups had four members, and one group had five members. Evan also had five groups total. Four groups had three members, and one group had four members. Most students really liked the idea of teamwork and thought it would be more fun than working alone. On the first day, the groups were rather quiet and timid. The students sat together but read the handouts silently to themselves. Conversations were rather forced and awkward.

On the second day, the groups were quite disorganized and it took almost forty-five minutes for all the students to get involved. After one hour the groups were functioning well although conversation was at a minimum. No leaders were yet apparent but almost every student was busy. Participation was seemingly equal without any inactive observers, which was surprising. Two hours into the class period, personal conversations had begun because students were acquainting themselves with each other. During the last thirty minutes of class, activity increased dramatically and all students were occupied in order to finish Project One. Only one group did not finish during the class period, but they stayed late and worked out their problem without much TA intervention.

The first oral presentations resulted in few student interactions but the students still seemed somewhat uncomfortable with each other. In Nick's class a total of eight questions were asked by the students during all five presentations, none of which initiated a discussion. In Evan's class, a total of nine student questions were asked. One question did begin an interesting debate that attracted most students' attention. When Project Two was handed to the students, half of the groups left immediately. Some groups began making plans. Two groups looked over the Spectronic 20 instruments and one group got into a big argument related to the chemicals to be used next week. It appeared that the groups with an extremely outgoing person were establishing that person as the leader no matter which role was officially assigned to that person. The groups without a natural leader were still very much equal in participation but took longer to organize themselves.

The groups began Project Two by reading their handouts silently for about twenty minutes. After one hour, the confused, blank faces had disappeared and all the students were focused on the Spec 20s. In general, one person in each group read the instructions, one person operated the instrument, and the others watched. One female student said her group did not like her and kept sending her to get chemicals and other such trivial errands. She concluded that her group thought she was stupid. Most groups were very serious and frustrated. Even though this was the second project, getting started was very difficult. Organizational skills were not well developed in the groups yet. After two hours, most groups had at least a weak leader directing the group. Few students were not involved, and there was cooperation and a sense of purpose in each group. However, one student did complain that he had no idea as to what was happening. He said his teammates just ignored him and worked without his participation.

The first thirty minutes of the fifth class period were spent quietly talking in the groups. Each group seemed to have one person organizing and explaining. After forty-five minutes, most groups had started work. The groups with three members had every student busy. The groups with four or five members had inactive students. Each group still ignored the other groups and behaved as though they were the only students in the laboratory. It was surprising that the confused groups did not "spy" on or ask help from the other groups. After two hours, the energy and activity increased greatly as a last minute rush to finish began. The classroom became noisier and all members were doing something even if it was only cleaning.

Both Nick and Evan's classes developed the same daily activity patterns as routines became established. In general, the first thirty minutes were very quiet while the groups planned. The next fifteen minutes consisted of dividing the labor and could be called, "ready, set, go!" The next thirty minutes were highly active with most students on-task. In the next hour routine set in, activity levels dropped, some students became frustrated or bored, and more students were off-task. Then the last thirty minutes appeared to be a high intensity rush to finish with all students actively engaged.

The sixth class period was very similar to the fifth week. The group with five people in Nick's class seemed to have trouble communicating. Two pairs existed within this group with the fifth member basically uninvolved. The groups with four members were largely in two pairs with one pair always busy and the other pair often off-task. Only the three membered groups had all members occupied most of the time. In the smaller groups of three, each member was more crucial to the group's functioning and they could not afford to have one member off-task. Usually the students were off-task in pairs because it takes two to have a conversation. This was very improbable in a group of three unless all three were off-task because one person was unlikely to work alone.

However, a group of four could have two members off-task because there would still be two members left to work together.

In general, groups were still ignoring other groups. The group that had previously stayed late did so again. This week each group had a clear leader, or two leaders. Most students still said group work was fun and it was often what they liked best about the course.

The seventh class period reached a high activity level faster than in previous classes because it was the last day for Project Two. It was apparent that the students had prepared well for the period. In thirty minutes, the laboratory was very energetic with most students busy. After one hour, the pace had slowed down and a few students were off-task. For the first time, groups cooperated with other groups by sharing cola samples. One group had only one member present who said the other members were excused. It seemed that students took advantage of the fact that attendance was not officially taken in Nick's class.

After one and a half hours, each group had at least one member observing and not actively involved. In a group of two non-traditional males and two freshmen females, the males were doing all the work while the females chatted. As observed earlier, the older students appeared to work harder than the younger students in general. It seemed that the freshmen took advantage of this fact because they let the two males do most of the work. Nick also noticed that the older students put forth more effort than the traditional students. Nick, however, believed the off-task behavior was because the freshmen were females.

The second class of oral presentations began with Nick announcing that an absent student could receive the group's oral presentation grade if the group excused the absent member. This really allowed students to take advantage of their group because the students were unlikely to betray their members. Evan never mentioned how he handled absences. Nick's class asked seven questions total and Evan's class asked three questions total. None of these questions led to any significant discussions. It was noticed that the older students took longer to present and they seemed to choose their words more carefully.

The ninth class period was the first day of Project Three. Nick's students admitted they were not prepared, not ready to work with the chemicals, and departed for the library. Evan's class, however, remained the entire period. For the first hour, the groups sat together quietly talking and looking in reference books. For the last two hours, the groups quietly conducted experiments in a very haphazard fashion without any organization. Definite leaders were seen in each group from the very beginning of Project Three. These were the same leaders that gradually rose in Project Two, so it seemed that the assignment of a leadership role was either ignored or in practice did not work. In fact, the roles had not been mentioned by either TA since the first project.

This day was the worst for group organization and cooperation because all the groups constantly argued unproductively. One student was heard calling another student "stupid." The class had obviously not prepared and most efforts were fruitless. Vincent admitted his group had not reached any conclusions and felt they had wasted their time. Michael also complained that his group had spent their time unwisely and had not cooperated with one another. Most students agreed that their time was wasted because they were not prepared for class.

Students were still not prepared for the tenth class meeting. It took over an hour for the groups to begin work. One of Nick's groups had only one person present so that student left, refusing to work alone. In Evan's class, a similar situation occurred, but this student remained and worked alone the entire class period. After an hour and a half, all but one group had chemicals at their desks and were conducting experiments. Interestingly, each group was working on something different so each group had created an unique plan. The groups were very quiet. It seemed the leaders were constantly explaining to the other members as though they were the only member who understood. As a result, only one experiment was conducted at a time with the leader in charge while the others assisted or observed. One group left early without ever getting any chemicals out and explained that they still needed to do research. The group with the non-traditional students appeared to be progressing slower than the other groups but they were more organized and methodical. During the last fifteen minutes, two groups conferred with each other.

The twelfth period was the last working day for Project Three. Fifteen minutes into the class, all the groups had chemicals at their desks and were working. It was obvious that every group had prepared for this class and they were organized immediately. Many groups were working together. One student from the group of five said that there was never enough work planned for all five members to be involved and that one student was usually doing nothing. One student said that cooperating with another group helped immensely.

During the last oral presentations, only one student asked a question in Nick's class. In Evan's class, three questions were asked by the same student.

Most students obviously just wanted to finish this class and therefore said as little as possible.

Project One

"The Emir's Sand" (see Appendix C) was passed out to the students on the first class day. Most students thought it was an interesting and yet easy problem to solve. A few students thought it would be harder than it first appeared. Some students commented that they would really have to think about Project One in order to solve it. Many of the first suggestions were quite bizarre such as measuring "air differences by a vacuum tube" and using conductivity meters. One student said boiling the sand would make the salt stick to the sides of the beaker. Another student said the salt could be "evaporated off of the sand." Finally one student was heard asking what salt was to which another replied, "NaCl."

Project One was scheduled to be completed in one lab period and all but one group did finish in time. Many students spent a lot of their time locating equipment and becoming familiar with the laboratory. If the introductory day addressed these issues, students could spend more time on actual experimenting for the first project. The biggest problem the students encountered in Project One was using large samples which took a long time to filter. Many groups started over with much smaller samples. Three different truckload samples were available to the students yet one group used only one sample and several groups used three samples from the same truckload.

Another problem encountered was whether to find the percent salt by volume or by weight. Students did not understand that thirty percent by volume does not equal thirty percent by weight. Students who tried to measure air space by water displacement did not know whether to use a sample with or without salt. Both TAs later told the students how much one truckload weighed although this information is unnecessary to solve the project.

One student commented that he really did not learn chemistry in Project One, but rather how to function in a group and how to think logically. Vincent thought Project One was "kind of dumb--no purpose" but that it was fun. Michael believed he had learned chemistry and although it was easy, Project One made several points on how to conduct research. Penny felt she had learned little chemistry but did have fun being creative.

Nick wrote in his journal that determining the salt in the sand was not really a problem for the students. The students knew what needed to be done, but did not know how to go about it. He did not like the fact that many students said air was negligible without explaining why. Later when Nick was interviewed, he felt that Project One resulted in group development, higher-level thinking, and good laboratory practice. He recommends no changes in "The Emir's Sand."

Evan agreed that Project One was a good introduction to laboratory research. He was pleased that the students had to go through all the steps of problem solving. He felt his students had learned basic lab procedures such as sampling, weighing, taking measurements, and working with glassware. He was surprised at how much chemical knowledge the students gained from such a simple exercise. His students also learned how to plan, how to work in groups, and how to operate in a laboratory. Evan suggests keeping "The Emir's Sand" as the first project without any changes.

Project Two

The "Determination of Phosphates in Colas" (see Appendix D) was originally scheduled for three weeks but had to be extended for one week due to unforeseen complications. Originally it was planned for the students to learn how to operate the Spectronic 20 instruments on their own given a condensed instruction manual. This simple task for chemists proved to be nearly impossible for the students and left them completely bewildered and frustrated. Most students focused on the instrument and neglected the chemistry. In fact, many students believed that the purpose of Project Two was to correctly operate the Spec 20. The students had not studied light, wavelength, or absorption in the lecture so the content was completely foreign to the students. Yet the project never explained these concepts. The amount of research necessary just to understand the background knowledge required for the experiment proved to be insurmountable.

Nick's first lab period for Project Two was largely a waste of time. The students did not know enough to even get started analyzing the relationships between concentration, absorption, color, and wavelength. The students basically played with different dye solutions in the instrument, took various readings, but could not interpret any of their findings. The students became restless, frustrated, and temperamental. Many of the dye solutions were so concentrated they were off-scale, yet the students interpreted zero percent transmittance to mean that the color did not absorb at that particular wavelength.

Evan gave his class directions so every group knew they were to find the wavelength of maximum absorption for the four food dyes. Yet the students did not seem to realize why the different colors absorbed at different wavelengths.

Some students did not understand the meaning or the significance of the wavelength of maximum absorption. Most students saw no purpose in this exercise and could not relate this information to the rest of Project Two. The students said they needed more information and directions to get started on this project. They felt unfocused and lost without any purpose. Penny felt she had wasted three hours and did not understand what she had done.

During the next lab period, students were supposed to make several solutions of known concentrations, construct a calibration curve, and determine the concentration of an unknown solution provided by the TA. Nick did not specifically explain this to the students and many groups never figured out what they were supposed to be doing. Students saw no connection between the previous class and the current class. Calibrating the Spec 20 instruments became a major problem as even the TA was unsure of the correct procedure.

Evan did tell his students to make five solutions with concentrations between 0.500 and 0.00100 M. Despite this piece of information some groups were still confused. Students did not know how to pick the appropriate wavelength, which should have been learned the previous week. One group did not understand that the wavelength should be held constant while generating concentration-absorption data and kept changing it with each determination. Other groups never realized that the data should be plotted. With thirty minutes remaining, Evan told the class how to use their data to find the unknown's concentration. So the students quickly plotted curves, took an absorbance reading of an unknown, and found its concentration. However, this was probably done without understanding. Students did not recognize how any of this related to the colas. The students did not see the big picture because they were so focused on the instrument's operation. Even graphing was a problem for a few students. One student had his abscissa marked off in units of 1.365 because he said this number was one of his absorbance readings.

Overall, the students did not see the final goal for Project Two. The students had trouble relating the different parts of the project together. Most students did not know if they were on the right path since the TAs rarely checked on them. One student said she learned how to make solutions. Other than that, she was not sure about anything. She saw no relation between making solutions and the colas. She asked "what do the colas have to do with this anyway?" Liz was very frustrated because she felt there was not a clearly stated purpose. The only thing she had learned was how to make solutions. She said the previous week had been a complete waste. Michael appeared to have some grasp of Project Two because he said he understood how to find an unknown solution's concentration. He was the only informant who said he was enjoying Project Two. Vincent felt that this project was too long. He suggested shorter labs with more direction, TA checks on progress, and more goals so that he would not waste entire days as he was now. He did, however, enjoy the arguing that continually occurred in his group because he liked debating.

On the third day for the second project, most of Nick's students still had to find the unknown concentration before proceeding to the cola samples. Nick already knew they would need an extra day to complete Project Two. Once the unknown's were determined, Nick told the students how to decolorize and degas the cola samples. Nick noticed that the students used the equation, $M_1V_1=M_2V_2$, without understanding. He believed the students could only calculate the molarity of diluted solutions from concentrated solutions but not vice versa. The students seemed very confused about the ammonium vanadomolybdate solution and did not comprehend its purpose. Questions that should have been answered before this day were just now surfacing, such as which wavelength to use.

Evan's class began with instructions on how to prepare the colas for analysis. These directions differed from Nick's. Each group bought a cola and then the entire class shared so that all five groups had five different cola samples. None of the students understood why charcoal was used to remove the cola color. Most students were following directions without comprehension. One student asked Evan if he had one-hundred milliliters of a 0.100 M solution and poured ten milliliters of it into a test tube, what would the concentration be in the test tube. Evan did not answer that question.

Soon, the groups were progressing fairly well with the cola samples. However, none of the groups realized that they did not have any knowns with which to compare the cola samples. Vincent's group thought they were finished after recording absorbances for the five cola samples. When asked what the concentration of phosphate ion was, Vincent replied with the absorbance value. When told that his reply was the absorbance, he was utterly confused. So Evan also had to extend Project Two another week.

Now that all the students were finally working with the cola samples, they did not seem able to transfer knowledge gained from the previous weeks to the current week. Students could not see how using the dyes applied to the colas. They could not make connections between the different parts of the project. Most did not see that the unknown determination was to learn and perfect the technique and allow them practice for the phosphate determination. Many students were confused and frustrated. Liz finally felt she understood the purpose of Project Two and enjoyed the day. She said understanding the purpose and having some direction made all the difference. Shawna complained that this project was simply too difficult. She said too much time had been spent researching the material and that too many outside sources had to be consulted before the project made sense. Michael did understand the project but said the handouts could be better written with more detail. He commented that group work was the best part of the lab. Vincent stated that when a group "got stuck" in the lab, they were in serious trouble since the TA would not help. He said his group desperately needed more direction.

On the last day for Project Two, another student mentioned problems with references. This student said specific sources should be suggested because what her group had located in the library was too vague or general to be of any assistance. Most of the groups had problems decolorizing their cola samples despite Nick's step-by-step instructions. Since Nick had never tried this himself, he did not know how to help. The students followed Nick's instructions without any questions as though the explicit instructions suppressed their own thinking. Only three groups produced colorless samples, therefore, they shared with the entire class. Liz was very glad that this project was over. She felt it was too long and she had lost focus along the way. She suggested shorter projects so that more concepts could be experienced. She believed spending one entire class period on how to operate the Spec 20 was wasteful.

Evan's class began with a discussion on how to dilute solutions. It appeared that the students did not comprehend this concept very well. Since this class had already prepared the cola samples, they only needed to prepare solutions of known phosphate ion concentration. All of the students were able to leave early.

The oral presentations focused on instrumentation and solution preparation. Very little was mentioned about content knowledge. Some students wondered what the actual phosphate ion concentration was in the various colas but neither TA knew. One student said the caramel color was removed from the cola samples because the Spec 20 could not detect brown light. Another student said the colas were degassed to remove air pockets which interfered with absorbance readings. Vincent was glad Project Two was over because he "hated it." Michael was proud of his group's performance on the lab and felt they had done a good job.

Nick's journal entries revealed his frustration over this project. He concluded it was too difficult for the students to learn how to use a strange piece of equipment and said next time just to show the students how to operate the Spec 20. He also wrote he never imagined a calibration curve could be so difficult to understand. He decided "the ordeal with the Spec 20 is just too much. Their focus on the machine seems to be outweighing their focus on the main idea."

After reading several written reports, Nick wrote that the students did not really grasp what they had done. He reported ten students never even mentioned the concentration of phosphate ion in their cola samples, yet they did give the absorbance readings. One student had written that finding the wavelength of maximum absorption was the purpose of the experiment.

Nick said in his interview that not enough information had been given to the students to satisfactorily complete Project Two. He believed the students' ability had been over estimated and that too much was expected of them in too short a time. He thought the only chemistry learned was how to make solutions. He believed his students focused too much on the Spec 20 instrument and doubted they could even write the formula for phosphate ion. His final comment regarding Project Two was "chunk this lab."

Evan wrote in his journal that his students did not comprehend the concepts in this project. He felt he had to explain too much to the students in order for them to complete the lab. In his interview, Evan flatly stated, "it was too complex and too hard." He thought his students had learned Beer's law and could explain the relationship between absorbance and concentration. He did not believe that his students understood how to dilute solutions. Evan said Project Two was beyond repair and could not work even with major changes. He concluded that it should be dropped and replaced by another project.

Project Three

The first class period for "Characterization of Industrial Inorganic Chemicals" (Appendix E) initially began smoothly without any student complaints or major problems. Many groups left to go to the library while other groups began testing the unknowns. The students apparently had no trouble finding in C & E News the sixteen chemicals to be identified. The groups who remained to work in the classroom were very unorganized and grew frustrated by the end of the class period because most had only identified one chemical. It was apparent that most students were trying to identify the unknowns without adequate research. Michael was very negative about this project because he said it was very hard to get started. He was already worried about finishing the lab on time.

The next class period was much more productive. Most groups had developed a scheme for placing the chemicals in groups which then would be broken down into smaller groups until each chemical's identity was discovered. One group said this project was fun once it had been started. Liz thought this project was the best. She said the purpose was clearly explained and she knew what the final goal was. She thought this project related to real life much better than the other projects. Another student compared Project Three to a puzzle and said she wanted to solve it. Vincent said he could not interpret his test results because he kept getting conflicting readings. He said he had asked the TA for help, but the TA had said to read. Vincent knew he needed more information but did not know where to find it. He was very frustrated and thought this project was the hardest of the three.

The students were more positive by the last day of Project Three. Most students agreed that identifying the first few chemicals was extremely difficult and slow, but after that the experiment really "took off" and "started to roll." The most common complaints about Project Three were that locating sources for identification tests was difficult and that organizing had taken too long. Most students seemed pleased when a chemical was identified and some students were very excited. The students appeared to completely understand what was expected of them, therefore their work was focused and they did not get side tracked.

One student who usually displayed indifference to the lab said this project was fun. One student said, "Now I understand what chemistry lecture tells me. I have to see it to understand. It makes sense now." This student referred to the various types of reactions that had been studied in lecture such as precipitation, double displacement, and oxidation-reduction. Michael liked this project the best and was proud his group had identified all sixteen chemicals. He said this project was hard but that he had learned more chemistry from it than the other projects. Vincent was upset that the regular general chemistry labs were already finished. He thought the projects took too long. Another student agreed that this project was hard but said he had learned a lot of chemistry. His last words were, "I feel that Project Three is more pertinent to real life. And, at least I liked it."

At first Nick thought Project Three would be too difficult for the students without his constant guidance. However, the students proved him wrong by finding ideas and good identification tests on their own. What frustrated Nick most was that the students would not adapt if their results differed from their predictions. He wrote that one group insisted that a chemical was contaminated because it did not react as they thought it should. Nick liked Project Three because it contained a lot of chemistry and promoted higher-level thinking. He said the students must be told to prepare a "plan of attack." He felt that organization and logic played a significant role in this lab. He decided this project was not as hard as he expected and with minor changes should remain a part of the course.

Evan enjoyed Project Three because the students knew exactly what to do and they researched specific procedures to follow. He believed this project coordinated well with the lecture as the students were able to experience the same reactions they had studied. He felt his students had learned such concepts as precipitation, solubility, physical states, chemical properties, properties of acids, and metal characteristics. He recommends leaving Project Three as it is and including it in all future project laboratory courses.

Quiz

On the last day of the project laboratory course, all six sections were given a three-item, multiple-choice quiz (see Appendix F). Nick informed his class that the quiz would be used for comparison purposes only, while Evan said the quiz would count in their final grade. After the quiz, Evan announced that it would not really be graded. The students were very quiet and serious while taking the quiz and no cheating was observed.

The same three questions appeared on the final exam for the regular course. These three questions were selected for comparison because both courses had covered the concepts. Both Nick and Evan agreed the questions were fair. The results of the quiz appear in Table 1.

Table 1. Quiz Results

Question	% Correct		
	Nick's Classes	Evan's Classes	Modular Classes
1	40.8	39.3	27.4
2	49.0	62.5	50.2
3	32.7	37.5	41.8

Nick had forty-nine students take the quiz, Evan had fifty-six students take the quiz, and two hundred thirty-seven students in the modular course took the final exam. Due to the several different variables in the testing procedure, the results cannot be evaluated for statistical significance. The students in the modular course had the chance to study for the final exam. The questions of interest were interspersed in the twenty-five question final and the students knew every question would figure into their grade.

The project course syllabus and the TAs had informed the project students that there were no quizzes or exams so these students did not prepare for the unannounced quiz. Nick's students knew the quiz would not be graded but Evan's students had just been told it would count in their grade so they might have tried harder than Nick's classes. The students in the modular course had more opportunity and motivation to succeed on the questions than the project lab students.

Although the comparison cannot be conclusive, it appears that the students in the project laboratory course did achieve higher on the first question involving diluting a solution. Evan's students performed best on the second question which required predicting the error in a molarity calculation. The students in the modular course did slightly better on the double displacement reaction in question three. Overall, it appears the project course provided a comparable learning opportunity for the concepts of solutions and reactions.

Course Evaluations

On the last day of the project laboratory course, students completed a course evaluation (see Appendix G) after the quiz. The results are reported in Appendix H. Responses were scored: strongly agree = 5, agree = 4, neither agree nor disagree = 3, disagree = 2, and strongly disagree = 1. In the following discussion, Nick's mean class score will be given followed by Evan's.

The highest scoring item (mean = 4.71, 4.07) stated that the course effectively challenged students to think. The lowest scoring item (mean = 2.98, 2.48) said the amount of work required was reasonable, which is a very common complaint about all laboratory courses. Students believed that they had learned a lot of chemistry (mean = 4.04, 3.37). Students also believed they had learned how to research chemicals (mean = 4.35, 3.87) and how to work safely in a laboratory (mean = 4.40, 3.94).

The students thought group work was an important part of the course (mean = 4.31, 3.91). However, they neither agreed nor disagreed that the oral presentations were important (mean = 3.19, 2.96). There were no complaints about the grading system and students said it was fair (mean = 4.24, 3.63).

When asked if the project directions were clear, the students were undecided (mean = 3.50, 2.74). Specific resources may need to be suggested because the students did not agree with the item that said resources were easily found (mean = 3.22, 2.76). Nick's class did agree that skills acquired in this course would aid them later while Evan's class was not sure (mean = 4.27, 3.22).

When asked if they would prefer to take the project lab course instead of the regular course, the students were slightly in favor of the project lab (mean = 3.76, 3.39). Project One was the most popular lab in both Nick and Evan's classes while Project Two was the least liked lab. When it was stated that the course was enjoyable, students were rather neutral (mean = 3.80, 3.11). Some students really enjoyed the class while others hated it.

The last statement on the evaluation form called for written comments. Approximately one-third of the students contributed their personal remarks. Thirteen students believed the course required far too much time and effort to be worth only one hour of credit; however, this is said of most lab courses. Many students said the time spent on library research, outside class meetings, writing reports, and preparing for oral presentations was entirely too much. One student spent more time on lab material than lecture material. Two students said they spent ten hours a week on this course and thought that was ridiculous. Another wrote preparing for an oral presentation while also writing the report was too much to handle.

Another common complaint was that the project directions were vague, ambiguous, and misleading; therefore, more informative instructions and clearer explanations were needed. One student felt he or she was always working without any direction. One student thought even the TA did not know what to do. Another student wrote that the projects were "just thrown at us...nothing was ever explained." Many students wrote that more information was needed to begin each project. One student suggested giving students a reference list of books or authors that could be consulted. Another student said "I feel like a lot of time was wasted trying to figure out what we needed to do."

Many students complained that their knowledge of chemistry was insufficient to understand the projects. One student was very frustrated because he or she felt like "we were expected to know a lot more than we already did." Several students wrote they had never taken chemistry before, so this made the course too hard. Perhaps these students did not know that high school chemistry or CHEM-1301 was a prerequisite. One student did not like the course because it was assumed that students already knew how to work in a lab. Another said the project course was inappropriate due to little chemistry background, little help from the TA, subjects too advanced for the students current knowledge and experience, and no correlation between lab and lecture. Students in the regular lab course also often say that the lecture and lab do not coordinate well.

Comments such as "this lab was too hard!" and "labs were too complicated" were common. One student felt the course was unorganized and claimed it would be much "more fun and educational" if it became organized. A few students thought the course appropriate for chemistry majors only or for junior and senior level courses only. One student felt that motivation played a significant part in the course and without it, nothing would be learned. One student wrote the lab taught only confusion.

Many students wrote their opinions regarding group work. One student suggested changing groups after each project and thought the peer evaluations were a great idea. Another student thought movement from a group should be encouraged if a student was unhappy. "Group work ended up being a nightmare!" stated one student who wrote two of his or her partners never did much, missed meetings, and missed classes. This student thought groups should consist of only two members so that one or two students did not carry the entire group. One member of a group of five students wrote that their group often had members not doing their share. One student said it was hard to "work beyond the other's grasp of chemistry." One student wished that the groups had more opportunity to learn from each other. Another student also wanted to change groups to prevent one group from always lagging behind and to allow students the chance to work with a greater number of people. Scheduling outside class meetings was another problem with group work and one student wrote conflicting schedules made this impossible in their group. On the other hand, one student admitted that he or she would have dropped the course if not for the group work.

Other suggestions were to "cut out the orals" because they were wasteful. This student thought instead the TAs should explain their own solution for each experiment. Two additional students wrote that the oral presentations were not beneficial. One student wanted more shorter projects. One student specifically wrote that Project One was not challenging and too simple. Another student said for Project Three, the groups should receive the chemicals they asked for because the handout stated this would be done. One concerned student said that students will pass along their work so the projects should be switched or else the entire purpose of the course will be defeated.

One of the most negative comments stated, "Please don't make any other students go through this lab. I learned how to B. S. my way through lab reports and oral reports and how to copy answers. We didn't learn anything about chemistry because the lab did not teach chemistry." Another wrote, "Nobody should go through the hell we have...This is the worst and most boring class ever!"

Despite all the negative feedback, some evaluation comments were extremely positive. Some of these read, "I learned a lot more than being in a regular lab," "this class is effective," "I learned much," "the lab [is] pretty cool and challenging...this is good." The course was often described as interesting, fun, challenging, and okay. Phrases such as "made me think" and "lots was learned" appeared several times.

One student was glad not to have a different experiment each week. One student felt the lab was well constructed, required thought, and taught a lot of chemistry. One student felt learning to work with others and developing presentation skills was good. One student wrote, "this lab was a step above other labs." One of the best comments was, "all the labs should be like this because they teach a student to think on his own and stretch his knowledge and abilities to the limit."

Many students wrote they thoroughly liked and enjoyed the lab, and thought it extremely challenging. One student believed the course was "definitely much better than the mundane, dull method of other labs." A very proud student wrote, "Overall I was impressed with how much was taught and how much I learned on my own in this lab!!!"

CHAPTER VII

CONCLUSIONS

The TA

The TAs in the project laboratory course play a very significant role despite the fact that the role is not primarily a teacher, but rather a facilitator. The TAs must understand that although they will not be the center of attention as instructors, they will have duties to perform that will require preparation. A large amount of introductory information about the course was given in the student handouts used in Nick and Evan's classes. These handouts, or similar ones, should be carefully read by the TAs.

The TAs need to know exactly what their role should be in the project course. To accomplish this, the TAs must be knowledgeable about cooperative learning methods. The TAs will then be aware that some goals of the course are not necessarily chemistry related. Goals such as effective communication, student cooperation, organization, problem solving, higher thinking, and improvement in oral presentations are important and valuable.

The TAs need to understand group dynamics so that they can monitor group progress and intervene when necessary. The TAs should actively participate in the class rather than remain aloof and sit at the TA desk. The TAs must learn how to question the students regarding their work and learn how to help the students through guided questioning techniques. The TAs should not neglect the students leaving them completely without guidance, nor should they give the students step-by-step directions. It is a fine line between not helping enough and helping too much, and only by practice will the TAs learn to walk this line.

The TA should interact with the students several times during a class period. If the TA constantly monitors the class, the students will receive the necessary feedback that was lacking in Nick and Evan's classes. One of the TA's duties could be to check with each group once an hour. This will allow the TA to assess the groups' progress, individual participation, and individual technique. The TA can ask a different group member each visit what he or she is doing and why. If the students know that the TA will eventually be asking each of them about their work, each student might remain involved and on-task.

To keep track of whom the TA has talked to and what each group actually did, the TA could keep a file for each class which charts each group's progress. This would help the TA remember which students displayed understanding, which were active, which were tardy or absent, and would serve as a valuable reference when grading the written reports.

When questions arise, the TA should help the students discover a solution by guiding the students with questions. If the students are way off track and conducting a futile experiment, the TA should intervene. By asking the students why they are doing something, the TA can guide them to the realization that their task will not produce relevant or valid information. This will prevent students from wasting an entire day as was observed in Nick and Evan's classes.

The TAs need to understand the project's content and be knowledgeable of the chemistry and instruments involved. To prepare for each project, the TAs should brainstorm many possible solutions and research the chemistry involved. Many students will not attack the problem in the same manner that the TA might. To prepare for this, all the TAs teaching the project laboratory should meet together to discuss their different solutions. The TAs can share the pros and cons of each method and dispel any misunderstandings. Research, if needed, could be evenly divided among the TAs. The TAs could actually conduct the experiments which are unfamiliar.

At the end of each project after the oral presentations, the TAs should share how they would have solved the problem. If there are unknowns involved, the TAs should tell the students their identity. If the students are measuring an unknown value, the TAs should reveal the actual answer.

The TAs should always attempt to be positive, friendly, and enthusiastic while monitoring the class. The TAs should establish an open and concerned atmosphere, displaying willingness to help every student. Attention should not focus only on the noisy, outgoing students but also on the quiet, reticent students. Praise should be awarded to deserving students to boost confidence, and feedback should be given often to promote motivation. Errors or inappropriate actions can be corrected without embarrassing or "talking down" to the students.

The biggest problem seen with Nick and Evan's teaching style was that they did not interact enough with the students. It was common for no interactions to occur for periods as long as an hour. Both TAs seemed to believe that it was their job to leave the students alone and allow them to make mistakes. Rarely did either TA intervene without a student first asking a question. Both TAs seemed to feel that their primary duty was to grade written and oral reports. During working lab periods, both Nick and Evan appeared unsure about what to do and usually remained near the TA desk waiting for the students to come to them.

Both Nick and Evan had friends visit them during the project lab. This probably occurred because both TAs usually felt like they had little to do. Elaine visited Nick during the oral presentations and Clayton visited Evan briefly on three different occasions. Elaine greatly disturbed the students because she participated by asking questions. Clayton did not disturb the classroom visibly but may have prevented Evan from watching and interacting with his students. Future TAs should be specifically told to avoid such behavior because it could interfere with facilitating the course. Since the role of facilitator is new to most TAs, explicit directions need to be given to help clarify this position.

Overall, the TAs in the project laboratory course should understand cooperative learning, actively monitor the class, be aware of each student's progress, provide constant feedback, guide students through questioning techniques, understand the chemistry content, provide closure to each project, and promote an open environment. All of these duties will not come easily to the TAs since most graduate students have never participated in a cooperative learning experience. Most TAs will feel uncomfortable in their new role as facilitator and they should know that this is a normal reaction. It will take time, practice, training, and preparation in order to successfully facilitate a project laboratory course.

The Students

The students taking the general chemistry laboratory course at a large university usually represent a very diverse population as in Nick and Evan's classes. The students will be different ages, have different backgrounds, and have different abilities. It should not be assumed that the students remember previous chemistry knowledge, have adequate familiarity with lab work, or have ever learned in a cooperative setting.

The cooperative format of the project laboratory may be completely foreign to most students. A brief introduction to cooperative learning, like Nick and Evan conducted and what appeared in the student handouts, is important so that the students understand what will be expected of them.

To avoid the confusion observed during the initial days of Nick and Evan's classes, the course introduction should be expanded upon to include a laboratory equipment overview. The students should be shown how to operate a balance and how to correctly weigh a sample. The students should be shown all the available equipment in their drawers and in the classroom. Examples of commonly used stockroom equipment can be displayed for the students. The TA can explain when to use various glassware such as when a beaker is sufficient versus when a volumetric flask should be used. Common techniques such as suction filtration, pipeting, and lighting a Bunsen burner can be demonstrated and practiced.

One of the most noteworthy characteristics of the students in the project laboratory was their display of higher-level thinking. Students debated different procedures and judged the validity of their data. Students were observed teaching other students. Students discussed and argued about chemistry. The students were creative and resourceful in their planning. Most students did develop problem-solving skills and many exhibited logical thought processes. Although the students were faced with fewer chemistry concepts than in the regular course, the students showed better understanding of the chemistry involved in the projects.

Most students attempted to maintain a very safe and clean working environment. The students often researched chemicals for hazards by looking at the Baker safety poster or in the MSDS binder. Some students asked about proper waste disposal. Almost all the students kept their glassware clean and became upset if they discovered dirty equipment in their drawers.

Laboratory technique improved greatly by the end of the course. Most techniques developed through practice and common sense because they were rarely demonstrated. Students became especially careful about volume measurements. Droppers were often used to bring solution volumes to mark.

Group work resulted in both positive and negative outcomes. Some groups never functioned as a true cooperative group and characteristics of traditional group work were observed. Such characteristics included not penalizing absent students, not enforcing student roles, not providing constant feedback, forgetting group processing through the peer evaluations, not acknowledging social skills as important, and not rearranging problem groups. One possible reason for the traditional group work was because the TAs did not closely monitor the class and did not intervene when necessary.

A few groups never developed positive interdependence because participation was sometimes unequal. During Project One, participation was roughly equal because the students were unfamiliar with each other and a natural leader had not yet emerged. By the end of Project Two and throughout Project Three, it seemed that participation was more unequal with much off-task behavior. With the emergence of a leader, some of the other students "relaxed" and became less active.

This occurred in Liz's group. Liz was a natural leader but had difficulty delegating work. Two of her group members became quite content to leave the work to her. The TA should intervene when such a situation is observed. The TA can enforce roles to encourage equal participation. The TA could also ask questions of the inactive students. As a last resort, the groups could be rearranged because once in a new, unfamiliar group, it seems that equal participation is likely. However, this problem only affected a few groups. Most groups did maintain equal participation even with a strong leader.

Although groups were randomly formed by alphabetic seating arrangements and not by self-selection, problems did occur with homogenous groups that seemed to lack creativity and variety in their efforts. Problems occur because such groups have a similar mind set and suffer from a lack of diversity. Vincent's group did not contain a high-ability student. Another group often stayed late because all three male members were slow and cautious workers. Both of these groups were consistently behind the other groups. Such homogenous groups should be rearranged if possible. The slow group had difficulty generating ideas and Vincent's group had serious problems with content knowledge.

One aspect of cooperative learning that was largely ignored was the assignment of student roles. The TAs never mentioned the roles after Project One or checked to see if each member was fulfilling his or her role. Neither TA seemed to believe the roles were important and probably did not know their purpose. Future TAs should be taught why roles are important in cooperative learning.

The particular roles initially chosen for the project laboratory course seemed reasonable in writing, but after observation, appeared to be inadequate in practice. The roles chosen were somewhat intangible and therefore difficult for the TA to monitor and assess.

The role of Team Leader is basically meaningless because the natural leader in the group will lead no matter who officially has the role. The leader in Project Two was the same leader in Project Three. At the college level, leadership ability cannot be suppressed nor created by mere assignment of the role.

Assistant Team Leader, similarly, is also meaningless in practice. The ability to coordinate an oral presentation probably should not be assigned, because in actuality, it will not be followed. This duty will naturally fall to a student who has given speeches or likes public-speaking. However, the assignment of writing the preliminary proposals is possible and should remain in a role.

The role of Record Keeper is largely irrelevant because all members should record everything in their own notebook. Responsibility for informing an absent member about progress made will fall to whomever the absent student chooses to ask. Such student interaction cannot really be assigned.

Team Counselor is also difficult to assign to a student. This falls naturally to a student whose personality needs cooperation and harmony among workers. If a student disagrees with the group, it is really her or his responsibility to inform the group. This role in particular is very hard for the TA to enforce and assess.

Roles should be assigned that do not rely on a particular type of personality. Roles should involve a tangible task that any of the students could perform without attempting to change their natural characteristics. The TA should be able to actually observe the task in order to assess if the group is functioning satisfactorily and equally. The fulfillment of the roles should also help the TA assess individuals. The roles should exist so that rotation does not challenge the natural operations of the group. Each role should require understanding of what the group is doing.

Possible roles are Planner, Checker, Chemical Researcher, and Presenter. The Planner would be responsible for writing the preliminary proposals and explaining the proposed daily course of action to the TA. The Planner would check in with the TA at the beginning of every working laboratory period. This would ensure that the Planner understood what the group intended to do every day.

The Checker must officially check-out daily with the TA. She or he would tell the TA that the group is leaving and would summarize what was accomplished during the period. The TA could probe this student's understanding to ensure that the Checker was actively involved.

The Chemical Researcher would be responsible for safety information on every chemical to be used on a particular day. To enforce this role, the TA could ask each researcher at some point during the three hour class period what chemicals the group was using, their safety hazards, and why these chemicals were being used. In order to answer, the researcher would have to know what each chemical's purpose was in the experiment. This would ensure that the Chemical Researcher understood what the group was doing.

A fourth possible role is the Presenter, who would be responsible for the visual aid(s) to be used in the oral presentation. This person would explain the information on the visual aid during the presentation. For a three-member group, the Chemical Researcher or Presenter role would become the entire group's responsibility.

These roles could be assessed by the TA, they would promote student-TA interactions, and might motivate the students to remain involved and active in their group's work. The roles should still be rotated after each project.

Group size was clearly a factor in efficient group functioning. The group of five students was obviously too large because one or two members were often off-task. Communication and organization became a problem in this group because rarely was there enough planned at one time to merit five people's participation. Groups of four also had off-task behavior because a pair would engage in personal conversations. The groups of three members were on-task more than the other groups. No differences were observed between the quantity of work produced by different sized groups. No complaints were made about a group being too small. It appeared that three students performed the experiments as well as four or five students.

A group size of three members seems to be most satisfactory for the project laboratory course. Groups of four could be assigned if there are students left-over after assigning students in groups of threes. The TA will have to use his or her best judgment in reassigning students if a member drops the course. It is probably possible for a group of only two members to successfully complete the projects.

Group work was most efficient after Nick or Evan held a brief content discussion and when they actively monitored the classroom. When possible, the TA should begin class with a discussion, instructions, or with a brief review of the goals and what should be accomplished on that day. During the class period, the TA should remain an active part of the lab to monitor on-task behavior. These practices were observed to focus the students and initiate activity quicker than when the TA said nothing at the beginning of the period. It seemed as though the students needed the TA to begin the class with a few words.

Absences were a large problem for the groups. Nick's policy was clearly an error because the threat of a poor peer evaluation did not seem to discourage absences. As stated in the course policy, two unauthorized absences should result in a grade of F. It should be stated that the group, however, is not the authority excusing the student. To enforce this policy, the TA will need to take some form of roll.

The slowest and most unorganized days in the course were the first days of each project. This appeared to be largely due to lack of preparation. It appeared that after finishing a project, no work occurred before the next class despite the next project already being assigned and handed out. Some frustration is of course normal when beginning a complex task, but if research time was incorporated into the class, time might be better utilized. After the oral presentations, at least one hour of class time remained in both Nick and Evan's classes. If the students remained in the lab to begin research for the upcoming project instead of leaving, considerable preparation could occur. At the end of the period, the new Checker could inform the TA of their ideas. This would allow the students to know they were on the right track and they would know what to do next. Perhaps the next class period would not be so unproductive even if no further work was completed.

According to the students, group work was quite enjoyable and preferable to working alone in a laboratory course. Many students enjoyed working at their own pace and the freedom encountered in the class. When equal participation occurs, absenteeism declines, heterogeneity exists, and feedback is constantly received, cooperative learning is successful.

Project One

"The Emir's Sand" was an excellent choice for the first project which introduces the students to cooperative learning, the laboratory, many chemistry techniques, and problem solving. In addition to solving the first project, students had to get acquainted with each other and learn how to function effectively as a group. An extremely difficult project would have made this overwhelming. Most students had not worked in groups for several years and "The Emir's Sand" allowed students to readjust to this method.

Since the first project was not complex, the students were able to focus much of their attention on their new surroundings. The students learned where to find equipment, and how to use common research apparatus such as Bunsen burners and suction filtration systems. The students learned how to weigh samples, measure volumes, and check out stockroom equipment.

Perhaps most important was that students began learning how to conduct research. The students had to identify a problem, understand the concepts involved, and determine what information was needed. Then they had to plan an experiment to obtain the necessary data, conduct the experiment, interpret the results, draw a conclusion, and trouble shoot problems.

Most students readily understood the objective of Project One. Many students soon realized that salt is soluble in water while sand is not. Yet applying this knowledge in order to separate the sample was not easy. Students learned characteristics of salts and were introduced to solubility. Some students learned the difference between percent volume and percent weight. Other students learned that using several different samples is better than one sample. Some students learned that a small sample is easier to handle than a large sample. Many students learned how to measure volume by water displacement.

Most of the students enjoyed Project One. Forty-two students replied on the course evaluation that they liked it the most. Only eleven students said they liked it the least. Both Nick and Evan believe "The Emir's Sand" should remain the first project in the course. Although it is not challenging in its chemistry content, many research and laboratory process skills were learned. "The Emir's Sand" was a good introduction for the project laboratory course.

Project Two

"Determination of Phosphates in Colas" first appeared to be quite suitable for the project laboratory course, but in practice, it was too long and complicated for the first semester general chemistry students. Almost all of the chemistry content knowledge required in the project had not yet been covered in the lecture. Requiring the students to learn about light, absorbance, and wavelength on their own as well as designing the experimental procedure was more than they could handle at their level.

Having the students learn how to operate the Spectronic 20 on their own required much more work than originally anticipated. Despite an entire day spent with colored dye solutions, few students drew correct conclusions about the relationships between absorbance, concentration, wavelength, and color. Since most students did not understand the concepts, inductive reasoning was impossible. Either a content lecture or detailed instructions would be necessary to teach most students about the Spec 20.

Many students focused on the instrumentation to the exclusion of the chemistry content. By the end of the first day on Project Two, most groups could take absorbance readings; however, the data meant little to them. The majority of students entered the next phase of Project Two with confusion, misconceptions, and little understanding.

The next phase of Project Two required the preparation of solutions of known concentration. After the TAs instructed the students about diluting solutions, the students did seem to understand the concept of molarity. Many students followed the step-by-step instructions given in the handout for preparing their solutions. Most groups found calibration curves in their textbooks or other reference books and used this information to plot their data. Then the unknown sample's concentration was determined. It appeared that most students followed instructions for this part of Project Two and did not truly understand what they were doing. Most students saw no connection between the day spent with the dye solutions and this part of the project.

The last part of the project consisted of following directions with little understanding. The TAs gave the students step-by-step instructions for degassing and decolorizing their cola samples. Students followed directions for preparing solutions of known concentration, plotted a calibration curve, and found the phosphate ion concentration in their samples.

Overall, most students did learn how to make solutions. But the students remained confused about the other aspects of the experiment. The students lost sight of the main goal in Project Two because of the instrumentation. Basically, solution preparation could be learned in a simpler project that does not confuse the students.

The "Determination of Phosphates in Colas" is not a suitable lab for the CHEM-1107 course. In order to make this project understandable, so much instruction would have to be added that the project would end up being a traditional cookbook experiment. The students would follow instructions without necessarily understanding what they were doing.

Project Two should be replaced by one or two experiments. Project Two lasted five weeks total. Two shorter experiments, one lasting two weeks, and another for three weeks, could be used instead. It was very difficult for the students to link all five days of the experiment together. Since these students are just in the middle of their first chemistry semester, shorter labs might be easier for them to follow.

Both Nick and Evan agree that "The Determination of Phosphates in Colas" was a failure. On the final course evaluation, twenty-seven students liked it the most, but fifty-eight students liked it the least. Project Two was largely responsible for many complaints on the course evaluations regarding insufficient background knowledge, confusion, and unclear directions. It should be replaced in future project laboratory courses.

Project Three

"Characterization of Industrial Inorganic Chemicals" very closely resembled true laboratory research. This project required careful planning and research in order to develop a scheme for classifying and identifying the unknown chemicals. Initially, the students went through a period of frustration as this scheme slowly evolved. Then near the end of the experiment, the students had great success in correctly identifying the unknowns.

This project related most closely to the lecture because the students had studied acid-base, precipitation, single displacement, oxidation-reduction, and double displacement reactions. Now the students were able to see examples of these reactions. This project had a very clear and defined purpose of which the students never lost focus, thereby allowing them to successfully work towards the goal of identifying the chemicals.

One problem arose concerning the statement in the handout which said chemicals would be provided if the students requested them a week in advance. Some students did not receive their requested chemicals so this statement should either be omitted or followed in the future. Other problems arose regarding the oxidation and reduction tests in the handout. Students were confused as to what a positive test looked like. Perhaps an example could be shown to the students or the directions written more clearly. Many students thought all their tests were positive.

Other problems were wasteful use of pH paper and taking large samples. The TAs could easily solve these problems by telling the students to dot the pH paper with a stirring rod and reminding them to take small samples. Some students had problems finding references for this project. Perhaps a list of possible books could be posted for the students.

Project Three motivated the students because it was satisfying to identify an unknown chemical. Many students were proud of themselves after this project. Project Three seemed to create a positive atmosphere in the classroom in comparison to Project Two. This lab should remain in the project course because it ended the class positively with students feeling as though they truly learned and accomplished a great deal.

Both Nick and Evan would like to see "Characterization of Industrial Inorganic Chemicals" remain a part of the project laboratory course. According to the course evaluations, thirty-three students liked it the most and thirty-one liked it the least. This project in particular encouraged logical thinking and problem solving.

Oral Presentations

The oral presentations were a surprising disappointment. What could have been a highly thought provoking and interactive activity turned out to be dull and repetitive. The students' monotone delivery style could make even the most interesting talk boring. However, the oral presentations should not be discontinued, but rather significantly modified.

The students need more directions regarding the oral presentations. A time limit such as fifteen or twenty minutes should be given so that students know how much preparation is needed. Students need to be told either to summarize their experiment or to give explicit directions with measurements. The students also need to be informed on how to deliver an oral presentation. Common sense practices such as speak loudly, face the audience, do not read, do not speak in a monotone, and act interested should be told to the students and corrected if not followed. These speaking skills will likely benefit the students later in their careers.

Visual aids should be required otherwise most groups will not use them. The students' interest was clearly peaked in Nick and Evan's classes when visuals were presented. Such aids also help to prompt the presenter regarding what to say. Each group member should participate in the presentation so the practice of dividing it by roles should continue.

Unfortunately, in Nick and Evan's classes, many groups did not have to answer a single question after their presentation. Since the students were hesitant to ask questions on their own, each group should be required to ask one question after every presentation. This would encourage the students to pay attention to other groups, and would allow each group practice in answering questions.

The TAs should also be required to ask a few questions of each group. These questions should not all be difficult because the groups might not be able to answer any of them. This would only discourage the students and destroy their confidence. Rather, some easy questions should be asked as well which the students can answer to build their confidence. Perhaps two easy questions with one higher-level question could be posed to every group by the TA.

Another problem with the oral reports was repetition. Since the introduction, problem, and background material was the same for every group, perhaps only the first group presenting needs to include this information. What is of most interest is the different methods used by each group, not the similarities. If the TA is charting group progress, she or he could pick out unique activities for each group to stress in their presentations. By presenting unique procedures, questions would be generated because the other students would not have performed that particular procedure and they might challenge its validity. Another way to reduce repetition is to divide up parts of the experiment. For example, in Project Three, one group could report the gases, one the solids, and another the solutions. This would allow more time to be spent on each part of the experiment rather than every group briefly discussing all the parts.

By requiring visual aids, asking more questions, reducing repetition, and teaching students better delivery style, the oral presentations will be an interesting and worthwhile learning experience.

Feasibility

The project laboratory course can be an alternative choice for general chemistry labs in large universities. After the appropriate changes to this pilot study, the resulting course can be successfully implemented at a large university. According to the course evaluations, the students did enjoy it in general, and preferred it over a traditional lab course.

Nick and Evan believed their role was basically to observe the students and to help them only when absolutely necessary. This approach clearly did not result in positive outcomes. Both Nick and Evan are considered to be excellent TAs because they relate well to the students, have natural teaching instincts, and have enthusiastic, outgoing personalities. Unfortunately, not all graduate students have these abilities. Many graduate students have no teaching experience, do not communicate well, and have no desire to teach in their career. These TAs will need more instruction on how to facilitate the project laboratory course.

The TAs will need a training session to acquaint them with cooperative learning. The TAs will need to become familiar with the projects, perhaps by conducting some experiments themselves. They will need to know how to effectively give oral presentations in order to teach this to the students. The TAs need to be kept on-task to discourage them from reading or grading papers during their class. By charting group progress and checking on each group every hour, the TA will be much more active in the course. This will decrease student complaints about not knowing what to do, vague instructions, and little TA assistance. With this TA feedback, the students will not feel lost and helpless like Vincent did.

The groups need to be more closely monitored and even rearranged if problems occur. Smaller group sizes will help increase individual participation. Attendance should be checked to reduce absenteeism. Daily check-outs should occur to be sure the groups are progressing well with the proper goals being reached. This will decrease student complaints regarding group work.

If Project Two is replaced, student complaints about insufficient background knowledge should decrease. Many of the complaints about confusion, ambiguous directions, and not knowing the purpose of the project will disappear. If Project Two is replaced by two experiments, there would be four projects in the course. According to the existing guidelines, this would require the students to write four formal reports and to prepare four oral presentations. This is too much work for an one-hour credit. Instead, either a written or oral report should be required for each project. For Projects One and Three, half of the groups would write a report while the other half gave oral presentations. The reverse would occur for Projects Two and Four. The result would be two written reports and two oral presentations total per group. Four projects will enable students to experience more chemistry and with the shorter projects, goals may be more clear. This will decrease the work required for the course and complaints about the amount of time spent outside of class should diminish.

Changing the oral reports may change the students' opinion that the oral presentations were not important as expressed in the course evaluations. By providing proper delivery instructions, the students will learn a valuable skill for later use and the talks will be more interesting. Visual aids will increase attention. Requiring questions will force the students to learn more. If the groups are giving only two oral presentations for the four projects, only one-half of the class will be presenting each project. Only three or four groups will present on one day instead of six or seven. This will reduce repetition and boredom. If the TAs chart each group's activities, they can find unique work to stress to also prevent repetition.

Time will also be decreased for the oral presentations if only one-half of the class is presenting. Three or four groups will take about an hour to present. After the TA sums up the experiment, the remaining class period should be used to begin research on the next project. When the groups check out, the TA can clarify any problems and make sure the students know what to do next. By incorporating research time into the class, complaints about outside work should decrease.

By modifying the TA's role, deleting Project Two, reducing the work to two written reports and two oral reports, most of the student complaints will diminish. The biggest problems according to the students were: too much time required; too much work; vague directions; little background knowledge; and group inequalities.

Many elements in the project laboratory course were successful and should not be changed. Both Nick and Evan were friendly, invited questions, and seemed willing to help, although the students rarely asked for it. Future TAs should strive to be enthusiastic and should appear willing to help all of the students, even the quiet ones.

The course does promote higher-thinking skills and the students did exhibit problem-solving ability. As seen by the quizzes, the students performed as well as the students in the traditional course, therefore chemistry content was learned. By working in cooperative groups, the students learned organization, communication, and teamwork skills that will help them in the future. The students did learn how to conduct research, safely work in a laboratory, and perform fundamental lab techniques.

Writing formal reports is more desirable than fill-in-the-blank answer sheets as students learn how to communicate their ideas and conclusions.

Being able to write reports will be helpful in most future classes and careers. Both Nick and Evan noticed great improvement in the written reports so the students did learn writing skills. Oral presentation skills will also help students in future classes and careers.

The introductory handouts were very helpful if the students and TAs read them because they provided information on cooperative learning, safety, lab notebooks, roles, grades, and written reports. This handout with more information on the oral presentations will be a valuable resource which the TAs will need to discuss with their students. The peer evaluations should remain a part of every project.

With the discussed changes, all of the student and TA complaints have been considered. Some students simply dislike chemistry and this will not change. Other students will not put forth effort no matter how hard the TA tries to motivate them. Problem students will still exist. However, most students will benefit greatly from the course if they give it a chance. As seen in Nick and Evan's classes, many learned more than they thought possible and were proud of their accomplishments. After training, the TAs will more clearly know how to facilitate the course. Although no course is perfect and complaints will persist, the project course has the potential to be at least as effective as the traditional course. With modifications, the project laboratory course could be an enjoyable learning experience for the students led by competent graduate students.

REFERENCES

Adams, C. S. (1942). The importance of lab work in general chemistry at the college level. Journal of Chemical Education, 19, 266-270.

Allen, J. B., Barker, L. N., & Ramsden, J. H. (1986). Guided inquiry laboratory. Journal of Chemical Education, 63, 533-534.

Atkinson, P. & Hammersley, M. (1994). Ethnography and participant observation. In N. K. Denzin & Y. S. Lincoln (Eds.), Handbook of qualitative research (pp. 248-261). London: Sage.

Barger, T. M. (1935). Effectiveness of the individual laboratory method in science courses. Journal of Chemical Education, 12, 229-232.

Bogdan, R. C., & Biklen, S. K. (1992). Qualitative research for education: An introduction to theory and methods (2nd ed.). Boston: Allyn and Bacon.

Bowers, W. G. (1924). The advantages of laboratory work in the study of elementary chemistry. Journal of Chemical Education, 1, 205-209.

Bradt, W. E., & Smoker, E. H. (1929). More effective individual laboratory instruction in general inorganic chemistry. Journal of Chemical Education, 6, 1933-1939.

Carmody, W. R. (1935). Elementary laboratory instruction. Journal of Chemical Education, 12, 233-238.

Cohen, E. G. (1994). Complex instruction: Higher order thinking in heterogeneous classrooms. In S. Sharan (Ed.), Handbook of cooperative learning methods (pp. 82-96). Westport, CT: Greenwood.

Deming, H. G. (1948). Guinea pigs in the classroom. Journal of Chemical Education, 25, 445-449.

Denzin, N. K., & Lincoln, Y. S. (1994). Handbook of qualitative research. London: Sage.

Gabriel, H. (1956). Quantitative work in freshman chemistry. Journal of Chemical Education, 33, 42-44.

Goetz, J. P., & LeCompte, M. D. (1984). Ethnography and qualitative design in educational research. Orlando: Harcourt Brace Jovanovich.

Jackman, L. E., Moellenberg, W. P., & Brabson, G. D. (1987). Evaluation of three instructional methods for teaching general chemistry. Journal of Chemical Education, 64, 794-796.

Johnson, D. W., Johnson, R. T., & Smith, K. A. (1991). Cooperative learning: Increasing college faculty instructional productivity. Washington, DC: George Washington University.

Lincoln, Y. S., & Guba, E. G. (1985). Naturalistic Inquiry. Beverly Hills: Sage.

Lucasse, W. W. (1928). The possible over-emphasis of laboratory instruction in higher institutions. Journal of Chemical Education, 5, 142-150.

Nechamkin, H. (1952). Laboratory meetings should teach too. Journal of Chemical Education, 29, 92-94.

Noll, V. H. (1929). The results of certain experiments in the teaching of chemistry to college students. Journal of Chemical Education, 6, 1740-1747.

Nurrenbern, S. (1993, January) Cooperative learning. Connecting with Chemistry, pp. 5-6.

Pavelich, M. J., & Abraham, M. R. (1979). An inquiry format laboratory program for general chemistry. Journal of Chemical Education, 56, 100-103.

Payne, V. F. (1932). The lecture-demonstration and individual laboratory methods compared. Journal of Chemical Education, 9, 932-939.

Pickering, M. (1985). Lab is a puzzle, not an illustration. Journal of Chemical Education, 62, 874-875.

Richardson, V., & Renner, J. W. (1970). A study of the inquiry-discovery method of laboratory instruction. Journal of Chemical Education, 47, 77-78.

Ryan, M. A., Robinson, D., & Carmichael, J. W., Jr. (1980). A piagetian-based general chemistry laboratory program for science majors. Journal of Chemical Education, 57, 642-645.

Schlesinger, H. I. (1935). The contribution of laboratory work to general education. Journal of Chemical Education, 12, 524-528.

Sharan, Y., & Sharan, S. (1994). Group investigation in the cooperative classroom. In S. Sharan (Ed.), Handbook of cooperative learning methods (pp. 97-114). Westport, CT: Greenwood.

Sherman, S. J. (1994). Cooperative learning and science. In S. Sharan (Ed.), Handbook of cooperative learning methods (pp. 226-244). Westport, CT: Greenwood.

Slavin, R. E. (1994). Student teams achievement divisions. In S. Sharan (Ed.), Handbook of cooperative learning methods (pp. 3-19). Westport, CT: Greenwood.

Smith, H. R. (1926). Achievements of pupils in laboratory instruction. Journal of Chemical Education, 3, 307-312.

Stubbs, M. F. (1959). Qualitative analysis in the general chemistry program. Journal of Chemical Education, 36, 387.

Thomas, W. B. (1943). Laboratory work and the scientific method. Journal of Chemical Education, 20, 379-380.

Venkatachelam, C., & Rudolph, R. W. (1974). Cookbook versus creative c chemistry. Journal of Chemical Education, 51, 479-482.

Walter, R. I. (1968). Laboratory experiments for the introductory chemistry course. Journal of Chemical Education, 45, 672-673.

Xan, J. (1954). Laboratory teaching. Journal of Chemical Education, 31, 519-520.

APPENDIX A

THE MODULAR COURSE SYLLABUS

Chemistry 1107 -- **GENERAL INFORMATION** -- Spring, 1994

Section: ______________ Teaching Assistant: ____________________

Room: ______________ Drawer Number: __________________

Required Materials

1107 Laboratory Module Packet, Chemical Education Resources, Inc.
--available at the bookstores

Laboratory safety **GOGGLES**
--available at the 2nd floor stockroom or in the bookstore

Grading

Pre-lab questions	(11 x 10 pts)	10%
Lab reports	(11 x 40 pts)	60%
Quizzes	(6 x 20 pts)	15%
Final-comprehensive	(25 pts)	15%

Grades are based on a straight percentage--there is no curve.

Important Places

General Chemistry Office -- CH 109

--If you need to contact your TA outside of her/his office hours, you may leave a message or an assignment with Ms. Guerra, the general chemistry secretary, who will see that your TA receives it. The General Chemistry Office is open 8:00 am to 12 noon and 1:00 pm to 5:00 pm, Monday through Friday. Our telephone number is 742-2081.

--If you are having a problem with your TA that the two of you cannot resolve, you may address the issue with Dr. Metz, the general chemistry coordinator. She has office hours Monday through Friday 1:00 pm to 2:00 pm or by appointment.

Help Room -- CH 116

--A teaching assistant is available to help you with problems you are having with lab or lecture material. Hours are posted on the door.

Bulletin Board -- outside CH 209

--After each quiz week, copies of the TA quizzes are posted here until the next quiz week. The lab final is based on these quizzes. Check the bulletin board after each quiz week.

Students with Disabilities

Any student who, because of a disabling condition, may require some special arrangement in order to meet course requirements should contact the instructor as soon as possible so that the necessary accommodations can be made.

Pre-Lab Questions

Each experiment has pre-lab questions (found on the last sheet of the module) designed to help you prepare for lab each week. Your TA will collect these questions at the start of lab each week. Any papers turned in after class begins are considered late and will not be graded. These assignments are worth 10 points each.

Reports

A lab report consists of the data, detailed calculations, analysis, and post-lab questions for an experiment. Reports are due at the start of the next lab period. Any papers handed in after class begins are considered late and will be docked 5 points per each weekday late. If you are absent from lab, your lab report is due in the General Chemistry Office by noon the next day or it is considered late.

Quizzes

Quizzes are given every other week (see attached schedule) at the start of class. If you are late for a quiz, you will not be given extra time. If you should miss class the week of a quiz, you have until the next class to see your TA for a make-up quiz; after that time you will not be able to make up the quiz.

Final

A comprehensive final exam is scheduled for Thursday, April 28 from 7:00-8:30 pm. If you have a class scheduled at this time, please notify the general chemistry office one week prior to this date. If you have other conflicts, resolve them. The final consists of 25 multiple-choice questions: 2 from each experiment, 2 on safety, and 3 on general knowledge and/or course policy. The questions on safety and the experiments are based on the TA quiz questions from the semester. After each quiz week, copies of the TA quizzes are posted, for 2 weeks, on the 1107 bulletin board outside CH 209.

Make-Up Lab

Due to the abuse of Make-up Lab privileges by students during previous semesters, it is necessary for the General Chemistry Office to verify the absence from your regularly scheduled lab. Before a permission slip is issued, you must provide written documentation of your absence, e.g., letter (on letterhead) from faculty sponsor of a field trip, release form from hospital, obituary notice indicating your relationship to the deceased, letter (on letterhead) inviting you for a company interview/plant trip, prescription bottle dated the day you missed lab, or police accident report. If you do not have such written documentation, you may not go to Make-up Lab. *Please note*: 1) Thompson Hall does not issue written statements for visits and 2) academic deans send letters only when an illness requires an absence from class for more than one week.

Each experiment done in the Make-up Lab is docked 5 points.

No permission slips are given after 12 noon on Friday. If you lose your permission slip, we will not issue another.

Make-up Lab meets Friday afternoons from 2:00-5:00 pm in CH 116.

You have only two opportunities to make up a missed experiment -- the Friday of the week the experiment is scheduled or the following Friday.

If you attend Make-up Lab on the first make-up date, your lab report is due the following week at your regularly scheduled lab. If you attend Make-up Lab on the second make-up date, your lab report is due the following Monday in the General Chemistry Office by 12 noon. Reports not turned in at these times will be subject to the regular late lab report penalty.

Lab Accidents

Any student involved in a laboratory accident (e.g., cuts, burns, inhalation of fumes, chemical spills), is taken to Student Health Services (Thompson Hall) for treatment. If further treatment is necessary, you will be sent to the University Medical Center (or another hospital). The university does not cover your expenses at UMC (or other hospitals) or any other medical expenses incurred.

Lab Drawer

Because several students are assigned to the same lab drawer, you must check the contents at the start of lab each week. If items are missing, see your TA immediately about replacements. Before leaving the lab, check that all items are in your drawer and the drawer is locked. If the next student to use your drawer finds any missing or broken items, you will be charged for them. Any items checked out by you from the stockroom, which are broken or not returned, are also charged to you.

Bar Codes

In order to checkout equipment from the stockroom, each student is issued a bar code. The bar code is scanned when you check out an item and again when you return it. If you fail to return an item or have another student return it for you, you are automatically billed for the item. This is an example of a student bar code:

General Policies

If you drop CHEM-1307 lecture you must also drop CHEM-1107 lab. After you officially drop these courses at the Registrar's Office, notify the stockroom where you checkout equipment in order to avoid unnecessary lab breakage and check-out fees.

Save all of your graded quizzes, pre-lab questions, and lab reports until after you have received your course grade from the registrar.

Texas state law requires that everyone working in a chemical laboratory wear safety **GOGGLES**, not glasses, at all times. Long pants, shirts with sleeves, and shoes (no open-toe shoes, sandals, etc.) are also required in the lab. Students not wearing safety goggles, long pants, and/or shoes will be told to leave the laboratory. *A make-up lab slip will not be issued for work missed.*

ACADEMIC DISHONESTY WILL NOT BE TOLERATED IN THIS COURSE. Any form of copying on quizzes or lab reports, altering information, forging signatures, or using cribs will result in judicial proceedings in accordance with Texas Tech University's policy on academic dishonesty.

Chemistry 1107 -- **LABORATORY SCHEDULE** -- Spring, 1994

Dates	Experiment	Number*
Jan 17-20	No Lab	
Jan 24-27	Check-in	Handouts
	Laboratory Techniques: Safety Precautions	TECH-430
	1st Day Exercise	Handout
	February 2 -- Last day to drop without course appearing on transcript.	
Jan 31 - Feb 3	***Quiz 1: Safety and Course Policy***	
	Separating and Identifying Food Dyes by Paper Chromatography	ANAL-372
Feb 7-10	Graphical Representation of Data	MISC-327
Feb 14-17	***Quiz 2: Chromatography and Graphing***	
	Relationship Between Mass and Volume	PROP-300
Feb 21-24	Identifying Six Solutions by Their Interactions	REAC 405
	February 28 -- Last day to drop a course and receive an automatic W.	
Feb 28 - Mar 3	***Quiz 3: Density and Six Solutions***	
	Acid Content of Fruit Juices	ANAL-427
Mar 7-10	Studying the Stoichiometry of the Reaction of Nickel(II) Ion and Hydroxide Ion	STOI-401
Mar 14-17	*Springbreak -- No Lab -- Enjoy!*	
Mar 21-24	***Quiz 4: Fruit Juice and Nickel Hydroxide***	
	Evaluation of the Gas Law Constant	PROP-332
Mar 28-31	A Sequence of Chemical Reactions (Copper Cycle)	REAC-309
Apr 5-11	***Quiz 5: Copper Cycle and Gas Laws***	
	Enthalpy of Formation of Ammonium Salts	THER-185
Apr 12-18	Determination of Gram Molecular Mass by Freezing Point Depression	PROP-334
	April 22 -- Last day to drop a course with a W or WF.	

Apr 19-25	***Quiz 6: Enthalpy and Freezing Point*** TA Evaluation Check-out Review for lab final
Apr 28	***LAB FINAL*** (Comprehensive) 7:00 - 8:30 pm

*Refers to the Chemical Education Resources module number.

APPENDIX B

THE PROJECT LABORATORY

COURSE SYLLABUS

Chemistry 1107 -- **Project Laboratory Policies**-- Spring, 1994

Section: ____________________ Teaching Assistant: ______________________

Room: ____________________ Drawer Number: ______________________

Required Materials

Laboratory safety **GOGGLES**
--available at the 2nd floor stockroom or in the bookstore

Laboratory Notebook
--available at the bookstores

There is no formal laboratory manual for the course. This handout serves as an informational and resource packet. However, you are required to purchase a lab notebook for recording your experimental observations and data.

Grading

Preliminary proposal	15% (group grade)
Final report	45% (individual grade)
Technique and lab notebook	15% (individual grade)
Oral report	15% (group grade)
Peer evaluation	10% (individual grade)

Save all of your written and oral evaluations until after you have received your course grade from the registrar.

At the end of the semester each of you will evaluate the other members of your group (anonymously). This peer evaluation will be worth 10% of the total laboratory grade and will reflect such factors as attendance and contributions to the group as a whole.

Important Places

General Chemistry Office -- CH 109
--If you need to contact your TA outside of her/his office hours, you may leave a message or an assignment with Ms. Guerra, the general chemistry secretary, who will see that your TA receives it. The General Chemistry Office is open 8:00 am to 12 noon and 1:00 pm to 5:00 pm, Monday through Friday. Our telephone number is 742-2081.

--If you are having a problem with your TA that the two of you cannot resolve, you may address the issue with Dr. Metz, the general chemistry coordinator. She has office hours Monday through Friday 1:00 pm to 2:00 pm or by appointment.

Help Room -- CH 116
--A teaching assistant is available to help you with problems you are having with lab or lecture material. Hours are posted on the door.

Students with Disabilities

Any student who, because of a disabling condition, may require some special arrangement in order to meet course requirements should contact the instructor as soon as possible so that the necessary accommodations can be made.

Lab Accidents

Any student involved in a laboratory accident (e.g., cuts, burns, inhalation of fumes, chemical spills), is taken to Student Health Services (Thompson Hall) for treatment. If further treatment is necessary, you will be sent to the University Medical Center (or another hospital). The university does not cover your expenses at UMC (or other hospitals) or any other medical expenses incurred.

Lab Drawer

Because several students are assigned to the same lab drawer, you must check the contents at the start of lab each week. If items are missing, see your TA immediately about replacements. Before leaving the lab, check that all items are in your drawer and the drawer is locked. If the next student to use your drawer finds any missing or broken items, you will be charged for them. Any items checked out by you from the stockroom, which are broken or not returned, are also charged to you.

Bar Codes

In order to checkout equipment from the stockroom, each student is issued a bar code. The bar code is scanned when you check out an item and again when you return it. If you fail to return an item or have another student return it for you, you are automatically billed for the item. This is an example of a student bar code:

Attendance

Attendance in this lab is required. If you have to miss a lab for some reason you should inform the members of your group and your TA. Your group members will decide how to deal with your absence. They may request that you do extra work, such as library research for the group project. There is no make-up lab for this section. If you have two or more unauthorized absences, you will earn an F for the course.

Withdrawal from the Course

If you find that you must withdraw from the course, please inform your TA and the members of your group, so they may make arrangements to accommodate your loss from the group. Please make every effort to show consideration for the group members who are staying in the course.

If you drop CHEM-1307 lecture you must also drop CHEM-1107 lab. After you officially drop these courses at the Registrar's Office, notify the stockroom on your lab floor in order to avoid unnecessary lab breakage and check-out fees.

General Policies

Texas state law requires that everyone working in a chemical laboratory wear safety **GOGGLES**, not glasses, at all times. Long pants, shirts with sleeves, and shoes (no open-toe shoes, sandals, etc.) are also required in the lab. Students not wearing safety goggles, long pants, and/or shoes will be told to leave the laboratory. *A make-up lab slip will not be issued for work missed.*

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Schedule

Jan 17-20	No Lab
Jan 24-27	Orientation to Project laboratory Check-in Safety Formation of Groups Assignment of Project One
Jan 31-Feb 3	Project One
Feb 7-10	Individual written reports due for Project One Group oral report due for Project One Assignment of Project Two
Feb 14-17	Project Two
Feb 21-24	Project Two
Feb 28-Mar 3	Project Two
Mar 7-10	Individual written reports due for Project Two Group oral report due for Project Two Assignment of Project Three
Mar 14-17	Springbreak--No Lab--Enjoy!
Mar 21-24	Project Three
Mar 28-31	Project Three
Apr 5-11	Project Three
Apr 12-18	Project Three
Apr 19-25	Individual written reports due for Project Three Group oral report due for Project Three Check-out TA Evaluation Course Evaluation

Chemistry 1107 -- Project Laboratory General Information-- Spring, 1994

Introduction

The format of the chemistry laboratory this semester will probably be different from the one to which you are accustomed. Instead of performing one lab exercise per week on an individual basis, you will become a member of a group of students who will work on an assigned open ended problem for a number of weeks. This semester your group will complete three projects, rather than the ten pre-prepared experiments in the other 1107 sections.

The idea behind this type of laboratory is to give you a more realistic experience in the laboratory. Real scientists do not have a recipe for each experiment they perform. Rather they devise their own experiments to test their hypotheses and gather as much data as they can. In the "real world" there is no one right answer and so it will be in your laboratory experience. You will not be graded on how close you come to a "right answer" but rather on how you plan your experiments, evaluate your data, and present your report. It is unlikely that the lab will coordinate topics with the lecture portion of the course. However, you will need to apply knowledge gained from lecture and learn new material on your own. In this lab course we are more concerned with your learning how to think through problems, a skill which will serve you well in any field.

As already stated this course is probably quite different than those you have had in the past. Although you may feel somewhat unsure of what to do initially, remember that your group is there to help. You are all in the same boat and can look to each other for help. We hope that you will find these labs fun, interesting and intriguing, and if past experience is anything to go by this will be true. Remember there is no one right answer for any of the projects you will be assigned. There is no set amount of material to be covered, and there is no point at which you should stop and say you have done "enough". Each group in your section will have different outcomes to the same project. It is up to your group to define the problems you are given and determine how far you will go to obtain the solutions.

A word about the things you will learn in this course besides chemistry. A recent survey of major business and industrial firms concluded the workplace basics to learn in school are:

- learning how to learn
- listening and oral communication
- competence in reading writing and computation
- adaptability based on creative thinking and problem solving
- personal management characterized by self-esteem, goal setting, motivation, personal/career development
- group effectiveness characterized by interpersonal skills and teamwork
- organizational effectiveness and leadership

(American Society for Training and Development and the U.S. Department of Labor 1988))

Unfortunately many of these things traditionally are not taught in colleges and universities. However, if you, as a student, are to reach the workplace well equipped to cope with the "real world" you must have the opportunity to practice some of these skills. Learning these skills will be one of the major goals of this laboratory in addition to learning laboratory skills and chemical concepts. You will be presented with problems which you must solve in the context of the general chemistry lab. When you begin this process it is very likely you will feel some frustration, and perhaps get discouraged, but remember: *Being Temporarily Perplexed Is A Natural State Of Problem Solving.*

The feeling you get when faced with a new problem and do not know what to do is quite normal, the key here is that the feeling is temporary and as you get into the project you will begin to feel more confident, and by the end of the course you will have learned a set of problem solving skills that you can carry with you the rest of your life. The time you spend at the beginning of each of your projects floundering is not time wasted. Rather, research has shown that this time is essential to successful problem solving and sometimes is given the term creative floundering. After all, if you knew immediately how to solve a problem, then it would not really be a problem in the true sense, merely an exercise.

This lab course will present you with some problems that you may not be able to solve by yourself and that brings us to the other rather unique aspect of this course; which is that you will be assigned to a group of students, sometimes known as a cooperative learning group.

Cooperative Learning

Cooperative learning is the name given to a style of learning that has become quite prominent during the last few years. There is considerable evidence to show that the outcomes from cooperative learning are very positive for the student. Research has shown that students learn better with more understanding, that they develop interpersonal skills and that they enjoy the course more when it is conducted in this manner.

Cooperative learning is not simply placing students in groups and having them work side by side on a problem or having the best student do the work while the others watch. The elements of cooperative learning are:

1. **Positive Interdependence.** That is we all sink or swim together. Everyone in the group should pull their weight. Everyone has something to contribute and is able to contribute under this system. The more you put into the groups efforts the more you are rewarded at the end not only in terms of the grade you earn but also the skills you learn and the satisfaction you gain from your accomplishments.

2. **Individual accountability.** Although the projects are carried out by the group, the evaluation of your performance is individual. You are graded individually on your lab reports, lab technique and peer evaluation. Only a minor component of the grade is a group grade. This is for two reasons, (a) to discourage "hitch hikers" that is students who do not contribute to the group and (b) to ensure fairness so that each student gets the grade s/he earns rather than the grade someone else earned, be it higher or lower.

3. **Social Skills.** Groups cannot function effectively if students do not have or learn leadership, decision-making, trust building, communication, and conflict management skills. During the semester you will be assigned different roles with different responsibilities. These roles will be rotated after each project so that you will have a chance to assume different roles.

Conflict Management

When people work in groups it is important that they be able to communicate with each other without conflict. It is inevitable that sometime during the course of the semester one of your group members will say or do something that will annoy you or with which you disagree. So it is important to bear in mind the following:

Be critical of ideas not people. When you are discussing your plan of action for the project it is almost certain that conflict will arise. If someone has an idea that you think is stupid, it is okay to criticize the idea (it may not be wise to call it stupid), but if you criticize the person it is almost certain to cause hard feelings and affect the functioning of the group.

Try to avoid win/lose situations. The goal of this lab course is to develop problem solving skills, not to engage in conflicts where one person's ideas dominate.

During this lab you will also learn or be given the opportunity to practice your oral and written communication skills, since you are required to produce both written and oral reports on the projects.

Group Roles

The following roles are assumed by different group member for each project.

Member A - Team Leader: responsible for overall supervision of the team and ensures that all members contribute equally.

Member B - Assistant Team Leader: assumes functions of Team Leader when s/he is absent and is responsible for coordinating the group's oral presentation and written proposal in a way that it reflects the thinking of all team members.

Member C - Record Keeper: keeps records of all discussions, coordinates the group's written proposal, and is responsible for informing absent team members of progress made.

Member D - Team Counselor: assumes role of Member C if s/he is absent and is responsible for making sure all team members agree on proposed course of action.

Note that although much of your project will be designed and carried out by the group members, your grade will be mainly determined by your individual efforts, therefore it is important that you do not let the other members of the group do your work and that you participate to the fullest extent. As you plan your experiments it is important that everyone is has a task most of the time. The idea is not that one of you will do the experiment while the others watch, but that each of you will contribute to the overall goal. This might mean that some of you will do duplicate experiments or each member of the group might perform a given experiment under a different set of conditions.

Safety

Safety Rules

1. Eye protection is required at all times in the laboratory and where chemicals are stored and handled. Only safety **GOGGLES** (not glasses) are approved for the general chemistry laboratories. Wearing contact lenses in a chemical laboratory can be harmful to your eyes. Contact lenses should be replaced by prescription glasses except in the rare case where this is not possible.

2. Eating, drinking, and smoking are not allowed. Do not taste anything in the laboratory.

3. Unauthorized experiments are prohibited.

4. Horseplay, pranks, or other acts of mischief are especially dangerous and are prohibited.

5. In case of fire or accident, call the instructor at once.

6. You must go to Student Health Services (Thompson Hall) for treatment of cuts, burns, inhalation of fumes, or other laboratory related accidents.

7. You must wear shoes in the laboratory. Open-toed shoes or sandals are not permitted. Exposed skin is another element of risk. Cotton jeans and long-sleeve shirts are recommended. Shorts are not permitted. Confine long hair and loose clothing.

8. No chemicals or equipment may be removed from the laboratory without specific permission and supervision of the instructor.

Material Data Safety Sheets (MSDS)

MSDS's are safety and waste disposal information sheets for chemicals used in the workplace. Some MSDS's are available in the lab. You are required to check these sheets before dealing with any compound in the lab.

Baker Hazard Codes

These colored hazard codes appear on the label of many of the reagents you will use. They are a quick and easy reference for any health, flammability, reactivity, or other special hazards associated with each reagent. A poster explaining the codes is displayed in the laboratory.

Waste Disposal

After you have finished your experiments you will probably have some waste chemicals and solutions to dispose. **Do not put them down the sink unless specifically told to do so by your instructor.** It is your responsibility to investigate the appropriate waste disposal methods by consulting the MSDS.

Basic Laboratory Etiquette

The equipment you use in this laboratory is used by many other students. **Please leave the equipment and all work spaces as you would wish to find them.**

1. If you find a piece of equipment that is not in good working order, notify your TA immediately so that a work order for its repair is submitted.

2. After you have finished work in the lab, clean off your work area so that it is in good shape for the next person in lab.

3. When obtaining reagents do not take the reagent container to your bench.

4. If you take more reagent than you need, do not put the excess back into the bottle. It may be contaminated at this stage. Treat the extra as waste and dispose of it accordingly.

5. You will be given instructions on how to dispose of waste chemicals on the basis of their toxicity. Do not put anything down the sink unless you are explicitly told to dispose of it this way. Most waste will be placed in labeled containers.

6. When weighing any material on the balances, do not weigh directly onto the balance pan. Weigh your material onto a piece of weighing paper or into a beaker or other container. If you should spill anything into the balance, notify your TA. The balances are sensitive instruments and should be treated with great care.

7. Do not put caps or stoppers face down onto the lab bench because they may become contaminated. Hold the cap or stopper in your hand while you get the material out of the bottle. Replace caps or stoppers on their original bottles to prevent cross contamination.

IF YOU MAKE A MESS CLEAN IT UP OR TELL SOMEONE ABOUT IT. DO NOT LEAVE IT FOR SOMEONE ELSE TO FIND.

The Laboratory Notebook

In contrast to other laboratories you may have experienced, you are required to keep a laboratory notebook for the duration of this course. The notebook should be bound, with the pages numbered consecutively.

The notebook is a day to day record of your activities in the lab. It is the place where you describe experiments and observations, **as you do the experiment**, record your data, and analyze data. Your notebook will be an invaluable tool, when the time comes to write your laboratory reports, because you will need an accurate record of what you did and observed in the laboratory.

All data, results, measurements, etc. are **recorded directly into your notebook** and not on pieces of paper.

The notebook should **not** be a neatly copied reiteration of the laboratory procedure, but rather a record of what you did and observed. Neatness, spelling punctuation and grammar are not essential in this notebook, but it should be possible for someone else to repeat your work by reading your account, i.e., it should be legible and intelligible.

Your lab instructor will read your notebook periodically, in order to see whether you are keeping up with your work, whether you understand what you are doing, and whether you are recording everything you need.

Writing Lab Reports

The following is an outline of the fundamentals of a Lab Report; please read it carefully. The grading criteria for your Lab Reports will refer to the following materials. (A copy of the grading criteria is attached.)

Scientists are investigators who "try out" ideas. They conduct experiments in order to test or prove ideas and they share the results of their experiments in papers and written reports. Reports allow others to learn the results of scientific investigations. Like other scientists, you will be conducting experiments, stating hypotheses, observing processes, recording data, and formulating conclusions. For each project you will write a lab report describing the experiment, summarizing your observations, and explaining your conclusions or judgments about the meaning of what you observed.

Audience: Professional scientists write papers and reports for their own use, for their colleagues, and for the public. When they write, they choose the language, style and format best suited for communication with their readers. In preparing your lab reports, think of the reader as an educated person who is interested in learning about your experiment but who knows less about this subject than yourself. You take the roll of expert; you are in charge of efficient, accurate communication of facts and ideas.

Evaluation: Your lab instructor will actually be reading your papers, commenting on them, and grading them. Your instructor assumes the role of the reader described above. S/he judges how well you communicate necessary background information, as well as the processes and results of the experiment itself. Your instructor also observes how carefully you follow the format for lab reports described in this handout.

General Format: Lab reports must be typed or word processed. They should include tables and illustration where necessary. Lab reports contain the following sections: **title page, introduction, experimental section, results, discussion, conclusion, and references.**

Title Page: The first page of the report is the title page. Include the title of the report, your name, the course number, your section number, the instructor's name, and the date the report is due. Put the information in the order just presented. In the bottom left-hand corner you should also include your group members names. Note: the title of the paper can simply be the name of the experiment, i.e., **The Kinetics of Solvolysis of *t*--Butyl Chloride**, or it can include clues about the hypotheses.

Introduction: The text of the report begins with an introduction. In this section of the paper, identify the experiment(s) and tell the reader in general terms what you intend to do. Include all phases of the experiment(s). Emphasize any unusual or critical conditions.

Point out exactly what ideas or hypotheses you are testing. Explain your reasons for making these hypotheses and make sure the reader understands the purpose of the experiment(s). What you are attempting to test or prove should be clear to the reader. If necessary, include general information which supports the hypotheses or explains the importance of the experiment(s). Tie the experiment to your general course of study by explaining how it confirms or fails to support general laws of chemistry that you are exploring and learning. Briefly discuss how the experiment tests the hypotheses and describe the expected outcome of the experiment.

Even though you are acting as the "expert" for the general reader, you must cite references both to support statements you make about the scientific basis for your investigation and to define sources for specific pieces of data crucial to the experiment. Citations give you credibility, they tell the reader that you prepared properly for the experiment by providing yourself with a basic background and by "checking out" the accepted authorities. These citations should be numbered consecutively in the text and listed in the References Section (see **References**).

Typical sources for your citation include: your text book, other lab manuals you may have consulted, tables of data such as the CRC handbook and chemical catalogs.

Experimental Section: In this part of the report, you give the reader a step-by-step account of the actual experiment. Here, you will do more than simply provide greater detail about the experiment than you did in the **Introduction**. You need to describe your experiment in such a way so that others could read your lab report, follow your lab procedure, and successfully duplicate your experiment. Scientific experiments are not considered valid unless they can be repeated by other experimenters working in other laboratories. In one sense, science has no secrets; scientific theories become established only when they can be repeated or verified by others besides the original investigators. You make this verification possible when you write a complete, accurate description of your techniques. Other investigators may not choose to duplicate your experiment, but they may choose to use your procedure in some similar investigation. The experimental section of your lab report should be usable as a set of directions for other scientists.

A Word About Style

As you are writing, pay close attention to your style. You and your lab partners are not important to the report. In scientific papers, facts and interpretation of facts count more than personalities. The depersonalized writing known as "scientific" or "academic" is most appropriate to your lab report.

What are the common elements of this style? You are writing about the experiment you have already completed -- not one that you are now doing--**use the past tense**.

In a sense, you are telling a story; in another sense, you are providing directions. Rather than telling a story or writing a recipe, you must describe what you did. At the same time, keep the personal element out of the report--**use the third person and passive voice**, for example: "The solution was titrated with 0.350 M NaOH". Do not write, "I titrated the solution with 0.350 M NaOH" or "Titrate the solution with 0.350 M NaOH."

You must be as accurate and specific as possible. Successful scientific description requires exact detail.

Results: In this section you summarize the outcome of your experiment for your reader. This section will consist primarily of **data** (facts and figures) that you gathered in the course of the experiment. Data must be presented in such a way that it is easy to read. You must organize or assemble and label the data for the reader. Numerical data or lists of numbers are usually presented in tables. Relationships between sets of data or factors in the experiment are often shown in graphic form. Graphs, drawings, and sketches are called **figures.** Although tables and figures are labeled on the page with descriptive titles, they are identified in your report by number rather than name. When you discuss tables and figures in the text of this section, you mention Table 1, Table 2, Figure 1, and so on.

Data presentation and text are both required in the **Results** section. It is not permissible simply to list data without providing a written explanation of the data. At the same time, textual explanation or description alone is not adequate.

<u>Preparing Graphs</u>

1. Use graph paper which will give you the accuracy you require. In general, graph paper with 10 mm per 1 cm division is best.

2. Use a ruler to draw the axes and choose an appropriate scale so that the entire area of the graph paper is used to display your data. Mark the intervals you have chosen evenly along the axes.

3. Label the axes and title the graph.

4. If your data generates a straight line, use a ruler to draw the line, this is not a connect the dots exercise.

In some experiments you may use a computer program to generate your graphs, in which case the graphs should still be labeled and named accordingly. Place graphs (and tables) at appropriate points in body of your report; this makes it easy for the reader to use and understand the graphs, charts, tables, etc. If you put the data presentation in a separate appendix, the reader will have great difficulty in understanding the results of your experiment.

Discussion: The discussion section of your report is the most important one for you and your reader. In this section of the report, you interpret the results of your experiment for the reader. You explain what the results mean and you mention any weaknesses or problems in the plan of the experiment or methods you used. You demonstrate not only how successful your experiment was but also tell how well you understood the experiment. The discussion section can be difficult to write, but you will learn more about your experiment and yourself as an investigator as you write it.

Before you begin writing this section, complete both the **Introduction** and the **Experimental** section. Put these sections on the desk together with your lab notebook so that you are able to look at all these sources of information as you write the **Discussion** section. Then prepare to write a rough draft of this section. You can make an outline for yourself by taking the following steps. Using this list as a guide, prepare a comprehensive discussion or explanation of the results of your experiment.

1. Write out your hypotheses again. Look over the tables, figures, and general information you compiled for the **Results** section. Decide whether or not you should accept or reject your hypotheses. Did your experiments support your hypotheses or prove them false?

2. Check the expected results which you described in the **Introduction**. Do your results match your expected results or do they contradict them?

3. Write down the specific data which led you to decide that your hypotheses were correct (or incorrect). List all the data, including actual information you recorded during the experiment.

4. Write down what you know about the principles of chemistry involved in your experiment. How do the results of your investigation fit with accepted laws of chemistry? Identify the sources of your information at this point.

5. List any weaknesses or problems you discovered in your experimental design or procedure. Tell the reader how these problems may have affected the results of your experiment.

6. Review the experiment again. List and discuss any difficulties which arose during the course of the experiment. Be sure to point out to the reader any way in which these problems could have affected the outcome of the experiment.

Conclusion: Your overall conclusions about the project have probably already been mentioned several times in the course of your report. You may have predicted some of the outcomes of your experiments in the **Introduction** and discussed them again as an empirical conclusion (meaning that it was derived from your experiments and observations) in the **Results** section. In the Conclusion section, a brief, single paragraph may be enough to clearly state the outcome of your investigation. The Conclusion section tells the reader what the results of the experiment mean. In a sense, it is a combined summary of the **Results and Discussion** sections. Make sure your stated conclusion clearly matches the actual outcome of your experiment(s).

References: The final section of your report tells the reader where to find any of the sources of information you used in your report. In the body of the your report (particularly in the **Discussion** section), you will have referenced other sources. Each of these references should be numbered consecutively within the text. At the end your report, after the **Conclusion,** include a complete reference list, in numerical order, of the sources used. The reader can use this list to follow up or check out any source you mentioned or to do additional reading.

The format of your references should follow the American Chemical Society style guidelines. For example, in the text of your report you might write: "Similar experiments have been reported by Haight (1) and Vogel (2) and explained by Redington (3)." In the **Reference** section you would list:

1. Haight, G. P. *J. Chem. Educ.* **1965,** *42*, 468.
2. Vogel, A. I. *A Textbook of Quantitative Inorganic Analysis,* Longman: New York, **1979,** p. 358.
3. R. L. Redington (personal communication, January 20, 1994).

For your journals, the order of listing is: Author, Journal, **Year**, *Volume Number,* Page Number. For books the order is: Author, Title, Publisher: City, **Year**, Page. For further information see *The ACS Style Guide: A Manual for Authors and Editors,* Dodd, J.S. Ed, *American Chemical Society,* Washington DC, 1986.

Oral Presentations Guidelines

In this course you are required to give a group presentation for each project. These guidelines are intended to give you some pointers so your presentations are more effective.

1. The presentation is a group effort so you should divide up the material so that each person has something interesting to say. In a group of four people an equitable distribution might be:

Member A:	Introduction, background material, the rationale behind your group's strategy.
Member B:	Continue discussion of experimental strategy, describe experimental setups.
Member C:	Results, what happened, did you have to change your experimental strategies as a result of your initial experiments.
Member D:	Discussion, what did you learn, did your experiments confirm your hypotheses.

This division is just a suggestion, clearly the topics of each person's presentation will change from group to group and project to project.

2. When planning your talk, imagine you are teaching the material to your audience, rather than simply reporting it. Your points will come across better if you make an effort to explain and reach out to your audience.

3. Use visual aids. This can be as simple as writing on the whiteboard or by preparing charts and graphs. Remember a picture is worth a thousand words.

4. Remember, a well-organized presentation is more likely to be remembered and the presenter of a well-organized presentation is more likely to be remembered favorably. If your listeners can see how your points relate to each other and to an overriding theme, those points will carry more meaning. A presentation which has continuity will keep listener attention, will enhance understanding, and will be remembered longer. Ultimately, a well-organized presentation will have more impact than a disorganized one. It has also been shown that a well-organized message reflects positively upon speaker credibility.

Preparing an Experiment

Lets say you have decided on an initial course of action. Before you begin you should be able to answer the following questions:

1. Why are you doing this particular experiment? This will of course depend upon your project and each project may consist of many different experiments. However, you should be able to give an answer to this question at each stage of your project development.

2. What equipment will you need to carry out the experiment? Is it available in the lab? In the building? Can your group make the piece of equipment you need?

3. Which reagents will you need? Are the concentrations of solutions appropriate for the experiment? Will your TA or the prep lab chemist be able to find the right chemicals for you by next week? Do you have an alternative plan if all your reagents are not supplied in time?

4. Have you looked up all the reagents you will use and noted any safety precautions and special disposal instructions?

Lab Report Evaluation

Name: ____

Project Title: ____________________________________

Title **(5 points)**

Identifying report include all information in the required order

Introduction **(15 points)**

Understanding basic concepts (5 points)
General format (5 points)
Quality points (5 points)
Comments:

Experimental Procedure **(15 points)**

Use scientific style (10 points)
Describe procedure so clearly that reader could duplicate the experiment (5 points)
Comments:

Results **(20 points)**

General format (5 points)
Presentation of data (15 points)
Quality points (5 points)
Comments:

Discussion **(25 points)**

Understanding concepts (5 points)
General format (15 points)
Quality points (5 points)
Comments:

Conclusion **(5 points)**

Clearly restate and summarize conclusions
Limit conclusion to summary
Comments:

References **(5 points)**

List all sources
Use proper form for citations and list of sources
Comments:

Overall Quality **(10 points)**

Mechanics of writing
Quality of prose
Coherence
Comments:

Oral Presentation Evaluation

Group members

____

Project ______________________________________

Oral delivery:

	Excellent	Very Good	Good	Fair	Poor
Member A	20	18	16	13	10
Member B	20	18	16	13	10
Member C	20	18	16	13	10
Member D	20	18	16	13	10
Member E	20	18	16	13	10
Quality and Use of Visual Aids:	20	18	16	13	10
Incorporation of Background Material:	20	18	16	13	10
Content:	20	18	16	13	10
Organization:	20	18	16	13	10
Overall Impression:	20	18	16	13	10

Total Points: __________________________

Comments:

APPENDIX C

PROJECT ONE

Chemistry 1107 -- **Project One**-- Spring, 1994

How Much Salt and Air Are in the Emir's Sand?

Introduction

The Emir of Eponema has requested your advice. He has been buying sand from the Queen of Sheba for his glass factory at the rate of ten truck loads each day, every day, for the past twenty years. The Queen has been charging $200 per truck load.

Abdul, the Emir's new science advisor, has alleged that each truck load of sand also contains salt and air. Abdul believes the Emir should not have been paying for the salt and air. The Emir will supply you samples of sand from three different truck loads and would like you to analyze the sand to determine whether he should have money refunded, and if so, how much.

APPENDIX D

PROJECT TWO

Analysis of Colas

Introduction

For this project your group has been hired by the research labs of a major cola company. The company has decided to do a little industrial espionage and look at the formulations of their rival cola products. Many people drink cola to settle an upset stomach because they think the buffering capacity of phosphate will help. For this reason, your company is interested in the phosphate content in the other colas.

Your boss has told you she wants you to analyze as many of the rival cola products as possible and she wants you to use the new fangled Spec 20 spectrophotometer she recently purchased. So your first goal for this project is to figure out how the Spec 20 works. (A manual is provided with each instrument in the lab.) **Make sure you use the same instrument for all your data.**

Part 1: Learning about the Spec 20

There are two aspects of the Spec 20 you will need to get straight before you begin your cola analysis:

1. What is the relationship between the color of a compound and the wavelength of light absorbed? (Several compounds of different colors will be available in your lab for your use.)

2. How does the amount of light absorbed correlate with the concentration of the species in solution, i.e., how can you use the Spec 20 to tell you how much of something is in solution?

After you have investigated these two aspects, your TA will check your Spec 20 technical skills by having you determine the absorbance and molarity of a solution prepared by the Prep Lab. If your measurements are acceptable, then (and only then) your group will be ready to analyze the cola products.

You might want to think about some of the following points when designing your experiments:

a. How will you make up your solutions? Volumetric flasks with 50 mL, 100 mL, 250 mL, and 500 mL volumes are available from the stockroom. (See below and the molar solutions section in your textbook for information on preparing volumetric solutions.)

b. How will you find the wavelength of maximum absorption?

c. If your solution is too strong or too weak to give accurate readings, what will you do to get better results?

d. Is the maximum absorption wavelength of light the same color as the compound itself? Why or why not?

e. What is the process that gives rise to the color of your compounds? Why do we see potassium permanganate as purple, for example?

f. How much waste solution will you generate? How will you dispose of it?

Once you have decided on the relationship between absorption and color you should investigate the relationship between absorption of light and concentration of the solution. You need only investigate this property for one compound.

a. Which wavelength of light will give the best results for your investigation of this effect?

b. There are two scales on the Spec 20, absorbance and transmittance, what is the relationship between the two? Which will you measure?

c. By what factor will you change the concentration as you monitor the absorbance/transmittance of the solution?

d. What method will you use to assess the absorbance-concentration relationship?

Used with permission from Melanie M. Cooper, Department of Chemistry, Clemson University.

Making a Solution of a Known Concentration

a. Decide on the concentration you need. (for example 0.1 M NaOH)

b. Calculate the molecular weight of your solute. (NaOH is 40.0 g/mol)

c. Decide how much solution you are going to make and obtain a volumetric flask for that volume. Volumetric flasks are routinely available in 50 mL, 100 mL, 250 mL, and 500 mL sizes.

d. Calculate the amount of solute you need. If you are making up 250 mL of a 0.1 M solution of NaOH you would need

$$\left(\frac{0.1 \text{ mol NaOH}}{\text{L soln}}\right)\left(\frac{1 \text{ L}}{1000 \text{ mL}}\right)(250.0 \text{ mL soln})\left(\frac{40.0 \text{ g}}{\text{mol NaOH}}\right) = 1 \text{ g NaOH}$$

Notice there is only one significant figure in the answer, but when you weigh out your NaOH you would weigh it out as accurately as possible, since the whole point of making a solution this way is to know the concentration as accurately as possible.

e. Weigh out accurately, on the most sensitive balance available, about 1 g of NaOH. Never place chemicals directly on the balance pan, use a piece of weighing paper, a weighing boat, or a beaker.
You will find it very difficult to weigh out exactly 1.00 g of NaOH and you should not try to do this. It is far better to weigh out an amount close to 1.00 g, for example 1.08 g, than spend an excessive amount of time trying to get exactly 1.00 g. This will mean the solution you prepare will not be exactly 0.1 M in concentration and you will have to calculate the actual concentration later.

f. Place the weighed solute directly into the volumetric flask. Use a funnel so that no solute is lost during transfer. Add solvent until the flask is one-third to one-half full. (If your solute is a liquid, wash out the container you weighed it in and add the washings to the flask, repeat several times.) Swirl the flask until the solute is completely dissolved. Add solvent to the flask until the bottom of the solution meniscus is even with the etched mark on the neck of the flask. It is best to add the last milliliter or two of solvent with a medicine dropper. Stopper the flask and invert it repeatedly to achieve a homogeneous mixture.

g. Calculate the concentration of your solution

$$\left(\frac{1.08 \text{ g NaOH}}{250.0 \text{ mL soln}}\right)\left(\frac{1 \text{ mol NaOH}}{40.0 \text{ g NaOH}}\right)\left(\frac{1000 \text{ mL}}{\text{L}}\right) = 0.108 \text{ M NaOH}$$

Part 2: Determining the Amount of Phosphoric Acid in Colas

Phosphoric acid does not absorb ultraviolet or visible light; however, it can be complexed with a reagent that is colored. The reagent you will use is an ammonium vanadomolybdate solution, which is already prepared for you. This solution complexes with the phosphate ion to give a colored species. You need not concern yourself with the nature of this species, merely know it is colored. Questions you should address are:

1. What color is the complexed phosphate ion solution?
2. Which wavelengths of light will the solution most likely absorb?

3. What wavelength will you use to analyze for phosphate ion?

You will have to construct a calibration curve using known concentrations of phosphate ion. Prepare your solution from KH_2PO_4, and remember it is just the phosphate ion you are measuring. The usual range of phosphate concentration in colas is around 10^{-3} to 10^{-4} M, so make sure you prepare a calibration curve of appropriate concentrations, but also understand the concentration you use will have to have appropriate absorbances. Note: each point on the calibration curve should be made by mixing 5 mL of the ammonium vanadomolybdate solution with 10 mL of the phosphate solution, make sure you include this dilution factor in your calculations. Use 5 mL of the ammonium vanadomolybdate solution diluted with 10 mL of water as your reference.

Before you start analyzing the colas you will need to remove the dissolved CO_2 gas and the caramel color (why?). Treating the beverage with a little activated charcoal should remove the color. You can de-gas the solution by opening the container and letting it go flat over several days or by heating it below the boiling point for about 20 minutes. With the latter method it is important to minimize evaporation. Why? What apparatus setup will you use? Once your cola is ready for testing, follow the same procedure you used on the phosphate standards. You may have to dilute the colas to obtain useful readings.

APPENDIX E

PROJECT THREE

Chemistry 1107 -- Project Three-- Spring, 1994

CHARACTERIZATION OF INDUSTRIAL INORGANIC CHEMICALS

Introduction

The premise for this project is that your group is seeking summer employment with the Environmental Protection Agency (EPA). A chemical land-fill has been discovered in West Texas and the contents of hundreds of containers of chemicals must be identified before cleanup can begin. The EPA will hire your group for the summer, if you can demonstrate to the chief chemist that you have excellent qualitative analysis skills. He has devised the following project as a check.

Each year Chemical & Engineering News ranks the top 50 chemicals produced in the United States. The inorganic chemicals in this list exhibit most of the common types of chemical behavior studied in an introductory chemistry class, e.g., strong acids and bases, weak acids and bases, oxidizing and reducing agents, covalent molecules, and ionic solids. An investigation of their chemical interactions serves as a cumulative exercise of your understanding of the chemical behavior of these types of chemicals.

Because of the lack of facilities for handling O_2 this chemical is omitted from the exercise. Due to time restraints several other compounds (carbon black, K_2O, TiO_2, and Na_2SiO_3) are not included in the experiment. The remaining inorganic chemicals are supplied as unknowns. The unknowns may be gases, solids, or 1 M aqueous solutions. Because sodium hydroxide is caustic and chlorine is poisonous these chemicals are provided as solutions. In addition, pH paper and test solutions of 0.001 M $KMnO_4$ and saturated acidic $MnCl_2$ are provided. Handle all the chemicals cautiously.

Part 1: Library Work

1. Find the most recent issue of Chemical & Engineering News with the Top 50 Industrial Chemicals. [Resources: Uncover found under Journal Articles Indexes on the library's on-line catalog, Periodical Abstracts CD-ROM, or manually searching the 1993 issues of C&E News.]

2. Classify each of the 50 industrial chemicals as either inorganic or organic.

3. Construct a Table of Physical and Chemical Properties for the inorganic chemicals. The table should include the chemical name, chemical

formula, physical state at 25°C, solubility in water, any characteristic odor or color, and its acidity or basicity (i.e., strong acid, weak acid, neutral, weak base, strong base). Include any additional information you think relevant and helpful to the experiment. [Resources: CRC Handbook of Chemistry & Physics, The Merck Index, Lange's Handbook of Chemistry, your textbook and the others in your lab.]

Part 2: Identifying the Unknowns

1. Outline a general procedure for identifying the unknowns.

2. Identify all of the unknown inorganic chemicals. [Resources: qualitative analysis books, an inorganic chemist, your textbook and the others in your lab.]

Part 3: Confirmatory Tests

1. EPA chief chemist knows many of the unknowns can be identified by process of elimination, you must find or develop two chemical confirmatory tests for each unknown. [Resources: qualitative analysis books, an inorganic chemist, your textbook and the others in your lab.]

If you need any special chemicals or equipment, you must submit a list of requested items to your TA *one week in advance.*

Handling Unknowns

Gases: In the hood, prepare approximately 0.1 M aqueous solutions of the gaseous unknowns by slowly bubbling the gas into 20 mL of water for 15-30 seconds.

Solids: Dissolve some solid unknown (approximate volume of a pea) in 20 mL of water. This will produce a solution with approximately 0.1 M concentrations of the ions present in the compound.

Solutions: Dilute a portion of each 1 M solution provided so that you have approximately 20 mL of 0.1 M unknown.

Chemical Hints

a. Colorless crystals may appear white when they are finely divided, i.e., in a powdered form.

b. To test for oxidizing properties add 4 drops of 0.1 M unknown solution to 6 drops of $MnCl_2$ test solution. The formation of a green to brown color upon warming is due to the formation of $MnCl_6^{3-}$. This indicates the presence of nitrate ion or chlorine.

c. To test for reducing properties, add 1 drop of the $KMnO_4$ test solution to 1 mL of 0.1 M unknown solution. Heat in a boiling water bath for a couple of minutes. Formation of MnO_2 (brown) or Mn^{2+} (almost colorless) indicates the presence of chloride.

d. Check a standard qualitative analysis scheme for the test for NH_4^+ .

e. Flame test can be used for Na^+ and Ca^{2+}. Ca^{2+} imparts a dark-red color to the flame of a Bunsen burner and Na^+ an intense yellow-orange. The Na^+ test is very sensitive though; any sodium impurities from dirty glassware could give a positive test.

f. $Al(OH)_3$ will dissolve in strongly basic solution forming $Al(OH)_4^-$.

g. When checking the reactivity of one unknown with another, place 5 drops on of one unknown (0.1 M) in a test tube and add the other unknown one drop at a time until a total of 10 drops have been added.

Qualitative Analysis

The goal of **qualitative** analysis is to find out what is present in a sample of material (as opposed to **quantitative** analysis, which deals with finding out how much material is present). One of the most common types of qualitative analysis is the sequences of chemical tests that are often used to determine the ions present in a sample. This type of qualitative analysis can be performed using small samples and test tubes for reaction vessels. There are a few definitions, techniques, and general instructions which must be understood for this type of analysis.

Definitions

1. **Precipitating Agent -** A substance added to a solution to cause a precipitate to form between it and specific type of ion in solution.

2. **Precipitate -** The solid material that separated out and usually falls to the bottom of the liquid.

3. **Supernatant Liquid -** The liquid left after a precipitate is formed.

4. **Group -** Ions that are related by a common property such as charge or precipitating agent; not necessarily from the same group in the periodic table.

5. **Filtrate -** A liquid that is separated from a precipitate by passage through a filter.

6. **Decant -** To pour off liquid from a solid or another liquid layer so it is not disturbed.

7. **Decantate -** The liquid that is decanted off.

8. **Centrifuge -** A machine using centrifugal force to cause a precipitate to go the bottom of a container.

9. **Effervescence -** To bubble or foam when a gas is released, e.g. Alka-Seltzer.

Techniques

1. For semimicro qualitative analysis, smaller volumes of reagents and test solutions are employed. The separations of solids from liquids are accomplished by centrifugation followed by decantation. Standard 4-in test tube which have a volume of approximately 10 mL should be used.

You should practice estimation of the volumes of liquids in the 4-in tube, since frequently an estimation of volume, rather than a more time-consuming precise measurement, will suffice.

2. Medicine droppers are generally used in adding reagents to test solutions. The dropper in the cap of a reagent bottle should never be laid down; it should be replaced immediately in its proper bottle.

3. For stock solutions not equipped with droppers, pour small amount of the liquid in a test tube and use your own clean dropper to withdraw the liquid from the tube. ***Never put your dropper (or pipette) directly into the stock solution.*** Discard any unused portion of the liquid. ***Never return it to the stock container.***

4. You should familiarize yourself with a dropper so that you can estimate the volume of 1 mL in the dropper and the number of drops per milliliter obtained from the dropper. The number of drops per milliliter will vary with the size of the orifice of the dropper as well as with the density and surface tension of the liquid but for the ordinary-sized dropper orifice with water solutions of inorganic substances, the number of drops per milliliter will be nearly constant.

5. A centrifuge is used to facilitate separation of a solid precipitate from the liquid with which it is mixed. The 4-in test tube will fit into the centrifuge conveniently. ***The tubes should never be full when centrifuging*** since the effective force which causes the solid to settle out from the liquid is directly proportional to the distance from the center of rotation of the centrifuge. In a

nearly filled test tube much of the mixture is so near the center of rotation that sedimentation will be quite slow. With a test tube containing approximately 1 mL of mixture the sedimentation is ***complete in most cases in about a minute.*** Since several students may be using the same centrifuge, it is important not to use it longer than necessary.

When tubes are placed in the centrifuge, they should be place so that ***there is a tube opposite each one to counterbalance it.*** If there is considerable vibration when the centrifuge is operating, it should be stopped and balanced better. Do not stop or brake the centrifuge with your hand. Centrifuges have been known to vibrate off a lab bench. ***Do not leave an operating centrifuge unattended.***

6. After sedimentation in the centrifuge, it is usually easy to decant the liquid from the solid. If the solid is to be washed, the last drop of liquid which clings to the lip of the test tube can be removed with an absorbent strip of paper (paper towel). When wash liquid is added, the liquid and solid in the tube can be mixed with a glass stirring rod.

7. Liquids in small test tubes should not be heated directly over a flame, since this frequently causes the liquid to pop out of the tube. This not only results in the loss of the sample, but also may be hazardous to you and your neighbors. The tubes should be heated in a water bath which may consist simply of a beaker of water over a flame.

General Instructions

1. **DO NOT THROW ANYTHING AWAY** (precipitate, decantate or washings) until you are certain you do not need it.

2. Avoid contamination of reagents.

3. Read labels carefully, use of the wrong reagent may spoil several days work.

4. Read the instruction carefully and follow them to the letter.

5. Make sure reagents are mixed thoroughly. Use a stirring rod to mix after every addition.

6. When the instruction say wash the precipitate with two 5 mL portions of water, this means: add one 5 mL portion of water to the test tube, stir thoroughly, centrifuge and decant off the water. Repeat once more.

APPENDIX F

QUIZ

CHEM 1107 Evaluation Quiz

1. When a student added 40.0 mL of water to 5.00 mL of a concentrated solution, the resulting diluted solution had a concentration of 0.300 M. What was the molarity of the original concentrated solution?

   (A) 0.0333 M
   (B) 0.0375 M
   (C) 0.370 M
   (D) 2.40 M
   (E) 2.70 M

2. When preparing 100 mL of an NH_4Cl solution, a student weighed out 0.53 g of NH_4Cl but recorded 0.35 g. Compared to the actual concentration the calculated molarity is too

   (A) high because the mass used in the calculation was too large.
   (B) low because the mass used in the calculation was too large.
   (C) high because the mass used in the calculation was too small.
   (D) low because the mass used in the calculation was too small.
   (E) More information is needed to answer this question.

3. A solution of $Al_2(SO_4)_3$ was mixed with a $Ba(NO_3)_2$ solution. The product mixture consists of

   (A) $Al(NO_3)_3$ and $BaSO_4$
   (B) $Al(NO_3)_2$ and $Ba_2(SO_4)_3$
   (C) $Al_2(NO_3)_2$ and $Ba(SO_4)_3$
   (D) $Al_2(NO_3)_3$ and $Ba(SO_4)_2$
   (E) No reaction will take place.

APPENDIX G

EVALUATION FORM

CHEM-1107 Project Lab Evaluation

Please rate each statement with the scale:

A - strongly agree
B - agree
C - neither agree nor disagree
D - disagree
E - strongly disagree

1. The information given was sufficient to meet course goals.
2. Project instructions were clear and specific.
3. I understood what was expected of me.
4. This course effectively challenged me to think.
5. I learned a lot about chemistry in this lab.
6. The amount of work required was reasonable.
7. The grading system was fair.
8. Group work contributed significantly to this course.
9. I learned how to find information on chemicals.
10. I learned how to safely work in a chemistry laboratory.
11. The oral presentations are an important part of this course.
12. Resource materials were easily found.
13. If I take CHEM-1108, I would prefer this project format instead of a different experiment each week and quizzes every other week.
14. The skills I learned in this lab, (research, oral presentation) will benefit me later.
15. My background was sufficient to enable me to keep pace with the work load.
16. Overall, I enjoyed this course.

For items 16 and 17, choose:

A - The Emir's Sand
B - Phosphates in Cola
C - Industrial Chemicals

17. The project I liked most was
18. The project I liked least was

Please write any comments you have on the back on this form. Your thoughtful remarks will greatly aid future project lab courses and instructors.

APPENDIX H

EVALUATION RESULTS

COURSE EVALUATION

Instructor:	Nick	Enrollment:	49
Course:	1107	Evaluations:	49
Semester:	Spring 1994		

1. The information given was sufficient to meet course goals.

Mean = 3.84

strongly agree	9	18.37%	xxxxxxxxx
agree	29	59.18%	xxxxxxxxxxxxxxxxxxxxxxxxxxxxx
neither	5	10.20%	xxxxx
disagree	6	12.24%	xxxxxx
strongly disagree	0	0.00%	
Missing Data	0	0.00%	

2. Project instructions were clear and specific.

Mean = 3.50

strongly agree	5	10.20%	xxxxx
agree	23	46.94%	xxxxxxxxxxxxxxxxxxxxxxx
neither	13	26.53%	xxxxxxxxxxxxx
disagree	5	10.20%	xxxxx
strongly disagree	2	4.08%	xx
Missing Data	1	2.04%	x

3. I understood what was expected of me.

Mean = 3.82

strongly agree	7	14.29%	xxxxxxx
agree	32	65.31%	xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
neither	4	8.16%	xxxx
disagree	6	12.24%	xxxxxx
strongly disagree	0	0.00%	
Missing Data	0	0.00%	

4. This course effectively challenged me to think.

Mean = 4.71

strongly agree	37	75.51%	xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
agree	10	20.41%	xxxxxxxxxx
neither	2	4.08%	xx
disagree	0	0.00%	
strongly disagree	0	0.00%	
Missing Data	0	0.00%	

5. I learned a lot about chemistry in this lab.

Mean = 4.04

strongly agree	18	36.73%	xxxxxxxxxxxxxxxxxx
agree	19	38.78%	xxxxxxxxxxxxxxxxxxx
neither	8	16.33%	xxxxxxxx
disagree	4	8.16%	xxxx
strongly disagree	0	0.00%	
Missing Data	0	0.00%	

6. The amount of work required was reasonable.

Mean = 2.98

strongly agree	6	12.24%	xxxxxx
agree	14	28.57%	xxxxxxxxxxxxxx
neither	9	18.37%	xxxxxxxxx
disagree	13	26.53%	xxxxxxxxxxxxx
strongly disagree	7	14.29%	xxxxxxx
Missing Data	0	0.00%	

7. The grading system was fair.

Mean = 4.24

strongly agree	19	38.78%	xxxxxxxxxxxxxxxxxxx
agree	25	51.02%	xxxxxxxxxxxxxxxxxxxxxxxxx
neither	4	8.16%	xxxx
disagree	0	0.00%	
strongly disagree	1	2.04%	x
Missing Data	0	0.00%	

8. Group work contributed significantly to this course.

Mean = 4.31

strongly agree	30	61.22%	xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
agree	11	22.45%	xxxxxxxxxxx
neither	3	6.12%	xxx
disagree	3	6.12%	xxx
strongly disagree	2	4.08%	xx
Missing Data	0	0.00%	

9. I learned how to find information on chemicals.

Mean = 4.35

strongly agree	18	36.73%	xxxxxxxxxxxxxxxxxx
agree	30	61.22%	xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
neither	1	2.04%	x
disagree	0	0.00%	
strongly disagree	0	0.00%	
Missing Data	0	0.00%	

10. I learned how to safely work in a chemistry laboratory.

Mean = 4.40

strongly agree	21	42.86%	xxxxxxxxxxxxxxxxxxxxx
agree	25	51.02%	xxxxxxxxxxxxxxxxxxxxxxxxx
neither	2	4.08%	xx
disagree	0	0.00%	
strongly disagree	0	0.00%	
Missing Data	1	2.04%	x

11. The oral presentations are an important part of this course.

Mean = 3.19

strongly agree	6	12.24%	xxxxxx
agree	15	30.61%	xxxxxxxxxxxxxxx
neither	14	28.57%	xxxxxxxxxxxxxx
disagree	8	16.33%	xxxxxxxx
strongly disagree	5	10.20%	xxxxx
Missing Data	1	2.04%	x

12. Resource materials were easily found.

Mean = 3.22

strongly agree	7	14.29%	xxxxxxx
agree	14	28.57%	xxxxxxxxxxxxxx
neither	15	30.61%	xxxxxxxxxxxxxxx
disagree	9	18.37%	xxxxxxxxx
strongly disagree	4	8.16%	xxxx
Missing Data	0	0.00%	

13. If I take CHEM 1108, I would prefer this project format instead of a different experiment each week and quizzes every other week.

Mean = 3.76

strongly agree	21	42.86%	xxxxxxxxxxxxxxxxxxxxx
agree	10	20.41%	xxxxxxxxxx
neither	8	16.33%	xxxxxxxx
disagree	5	10.20%	xxxxx
strongly disagree	5	10.20%	xxxxx
Missing Data	0	0.00%	

14. The skills I learned in this lab, (research, oral presentation) will benefit me later.

Mean = 4.27

strongly agree	25	51.02%	xxxxxxxxxxxxxxxxxxxxxxxxx
agree	14	28.57%	xxxxxxxxxxxxxx
neither	6	12.24%	xxxxxx
disagree	3	6.12%	xxx
strongly disagree	0	0.00%	
Missing Data	1	2.04%	x

15. My background was sufficient to enable me to keep pace with the work load.

Mean = 3.31

strongly agree	6	12.24%	xxxxxx
agree	19	38.78%	xxxxxxxxxxxxxxxxxxx
neither	9	18.37%	xxxxxxxxx
disagree	12	24.49%	xxxxxxxxxxxx
strongly disagree	2	4.08%	xx
Missing Data	1	2.04%	x

16. Overall, I enjoyed this course.

Mean = 3.80

strongly agree	15	30.61%	xxxxxxxxxxxxxxx
agree	19	38.78%	xxxxxxxxxxxxxxxxxxx
neither	7	14.29%	xxxxxxx
disagree	6	12.24%	xxxxxx
strongly disagree	2	4.08%	xx
Missing Data	0	0.00%	

17. The project I liked most was

emir's sand	17	34.69%	xxxxxxxxxxxxxxxxx
phosphates in cola	18	36.73%	xxxxxxxxxxxxxxxxxx
industrial chemicals	13	26.53%	xxxxxxxxxxxxx

18. The project I liked least was

emir's sand	8	16.33%	xxxxxxxx
phosphates in cola	22	44.90%	xxxxxxxxxxxxxxxxxxxxxx
industrial chemicals	17	34.69%	xxxxxxxxxxxxxxxxx

COURSE EVALUATION

Instructor:	Evan	Enrollment:	55	
Course:	1107	Evaluations:		55
Semester:	Spring 1994			

1. The information given was sufficient to meet course goals.

Mean = 2.78

strongly agree	5	9.09%	xxxx
agree	12	21.82%	xxxxxxxxxx
neither	12	21.82%	xxxxxxxxxx
disagree	16	29.09%	xxxxxxxxxxxxxx
strongly disagree	9	16.36%	xxxxxxxx
Missing Data	1	1.82%	

2. Project instructions were clear and specific.

Mean = 2.74

strongly agree	4	7.27%	xxx
agree	12	21.82%	xxxxxxxxxx
neither	14	25.45%	xxxxxxxxxxxx
disagree	14	25.45%	xxxxxxxxxxxx
strongly disagree	10	18.18%	xxxxxxxxx
Missing Data	1	1.82%	

3. I understood what was expected of me.

Mean = 3.26

strongly agree	6	10.91%	xxxxx
agree	21	38.18%	xxxxxxxxxxxxxxxxxxx
neither	13	23.64%	xxxxxxxxxxx
disagree	9	16.36%	xxxxxxxx
strongly disagree	5	9.09%	xxxx
Missing Data	1	1.82%	

4. This course effectively challenged me to think.

Mean = 4.07

strongly agree	25	45.45%	xxxxxxxxxxxxxxxxxxxxxx
agree	19	34.55%	xxxxxxxxxxxxxxxxx
neither	2	3.64%	x
disagree	5	9.09%	xxxx
strongly disagree	3	5.45%	xx
Missing Data	1	1.82%	

5. I learned a lot about chemistry in this lab.

Mean = 3.37

strongly agree	10	18.18%	xxxxxxxxx
agree	21	38.18%	xxxxxxxxxxxxxxxxxxx
neither	9	16.36%	xxxxxxxx
disagree	7	12.73%	xxxxxx
strongly disagree	7	12.73%	xxxxxx
Missing Data	1	1.82%	

6. The amount of work required was reasonable.

Mean = 2.48

strongly agree	5	9.09%	xxxx
agree	11	20.00%	xxxxxxxxxx
neither	7	12.73%	xxxxxx
disagree	13	23.64%	xxxxxxxxxxx
strongly disagree	18	32.73%	xxxxxxxxxxxxxxxx
Missing Data	1	1.82%	

7. The grading system was fair.

Mean = 3.63

strongly agree	12	21.82%	xxxxxxxxxx
agree	20	36.36%	xxxxxxxxxxxxxxxxxx
neither	14	25.45%	xxxxxxxxxxxx
disagree	6	10.91%	xxxxx
strongly disagree	2	3.64%	x
Missing Data	1	1.82%	

8. Group work contributed significantly to this course.

Mean = 3.91

strongly agree	20	36.36%	xxxxxxxxxxxxxxxxxx
agree	21	38.18%	xxxxxxxxxxxxxxxxxxx
neither	3	5.45%	xx
disagree	5	9.09%	xxxx
strongly disagree	4	7.27%	xxx
Missing Data	2	3.64%	x

9. I learned how to find information on chemicals.

Mean = 3.87

strongly agree	15	27.27%	xxxxxxxxxxxxx
agree	24	43.64%	xxxxxxxxxxxxxxxxxxxxx
neither	10	18.18%	xxxxxxxxx
disagree	3	5.45%	xx
strongly disagree	2	3.64%	x
Missing Data	1	1.82%	

10. I learned how to safely work in a chemistry laboratory.

Mean = 3.94

strongly agree	19	34.55%	xxxxxxxxxxxxxxxxx
agree	18	32.73%	xxxxxxxxxxxxxxxx
neither	12	21.82%	xxxxxxxxxx
disagree	5	9.09%	xxxx
strongly disagree	0	0.00%	
Missing Data	1	1.82%	

11. The oral presentations are an important part of this course.

Mean = 2.96

strongly agree	4	7.27%	xxx
agree	17	30.91%	xxxxxxxxxxxxxxx
neither	13	23.64%	xxxxxxxxxxx
disagree	13	23.64%	xxxxxxxxxxx
strongly disagree	7	12.73%	xxxxxx
Missing Data	1	1.82%	

12. Resource materials were easily found.

Mean = 2.76

strongly agree	1	1.82%	
agree	17	30.91%	xxxxxxxxxxxxxxx
neither	12	21.82%	xxxxxxxxxx
disagree	16	29.09%	xxxxxxxxxxxxxx
strongly disagree	8	14.55%	xxxxxxx
Missing Data	1	1.82%	

13. If I take CHEM 1108, I would prefer this project format instead of a different experiment each week and quizzes every other week.

Mean = 3.39

strongly agree	21	38.18%	xxxxxxxxxxxxxxxxxxx
agree	10	18.18%	xxxxxxxxx
neither	6	10.91%	xxxxx
disagree	3	5.45%	xx
strongly disagree	14	25.45%	xxxxxxxxxxxx
Missing Data	1	1.82%	

14. The skills I learned in this lab, (research, oral presentation) will benefit me later.

Mean = 3.22

strongly agree	8	14.55%	xxxxxxx
agree	22	40.00%	xxxxxxxxxxxxxxxxxxxx
neither	6	10.91%	xxxxx
disagree	10	18.18%	xxxxxxxxx
strongly disagree	8	14.55%	xxxxxxx
Missing Data	1	1.82%	

15. My background was sufficient to enable me to keep pace with the work load.

Mean =	2.98		
strongly agree	5	9.09%	xxxx
agree	15	27.27%	xxxxxxxxxxxxx
neither	14	25.45%	xxxxxxxxxxxx
disagree	12	21.82%	xxxxxxxxxx
strongly disagree	7	12.73%	xxxxxx
Missing Data	2	3.64%	x

16. Overall, I enjoyed this course.

Mean =	3.11		
strongly agree	6	10.91%	xxxxx
agree	23	41.82%	xxxxxxxxxxxxxxxxxxxx
neither	7	12.73%	xxxxxx
disagree	7	12.73%	xxxxxx
strongly disagree	11	20.00%	xxxxxxxxxx
Missing Data	1	1.82%	

17. The project I liked most was

emir's sand	25	45.45%	xxxxxxxxxxxxxxxxxxxxxx
phosphates in cola	9	16.36%	xxxxxxxx
industrial chemicals	20	36.36%	xxxxxxxxxxxxxxxxxx

18. The project I liked least was

emir's sand	3	5.45%	xx
phosphates in cola	36	65.45%	xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
industrial chemicals	14	25.45%	xxxxxxxxxxxx