This suite of class and laboratory experiences provides you the opportunity to explore analytical chemistry in an environment that emphasizes teamwork and to develop skills, both technical and interpersonal, that will help you obtain employment in the professional world, wherever your path may lead. It asks you to become an active participant in your education as well as in the education of those around you. The structure encourages you to tap into your creativity, bring out the creativity in others, and to be a leader in your own life and the life of the team. Role-playing grounds the organization and practice in this learning environment.

The chances are good to excellent that you have heard of role-playing, but probably not in the context of a chemistry course. A well-established team activity, role-playing has been used for management training, training in small group dynamics, chemical rehabilitation, and training educators, among many others. Role-playing comprises a unique way to work in the chemical sciences. It stresses interdependence, as the core part of mature independence, and division of responsibilities, rather than division of labor. The partners approach exemplifies working in a division of labor environment. In these prior experiences, you divided up the work, and were both, or neither, actually held responsible for what happened. Role-playing is not partners, since responsibilities are divided. Each team member assumes responsibility for a key piece of the solution; however, the whole solution cannot materialize without all pieces becoming integrated as a unit through the guidance of appropriate leadership. On the other hand, role-players may do labor that is not in their list of responsibilities. We do, after all, help each other out in all manners of ways. But, no matter who actually does the work, or parts of the work, only one person, the Manager, will be responsible for the team’s results.

Ultimately team members find that the best leadership comes from consensus building, trust, encouraging creativity, and open discussion of the problem and responsibilities. Motivation for finding or working toward the solution comes from the task itself. People must buy into solving the problem or show enlightened self-interest. The former is more essential than the latter; however, when your peers show interest remarkable things happen. Creativity and ownership evolve from the freedom within the mission and develop with scientific skill, learning, and communication. Achieving these conditions arise from an invitation to all participating parties to come as you are and be yourself – to be the leader of your life. When this occurs the learning environment fills with fervor and excitement.

Freedom within a mission defines the objectives and responsibilities within a specific charge to the team; however, it does not give a detailed solution to the problem. The objectives, responsibilities, and resources available create a boundary around the task; they do not explicitly indicate how to arrive at a solution. Think of freedom within a mission as a jigsaw puzzle. The
puzzle pieces have different shapes and have some splashes of color. The objectives, responsibilities, and resources define the border pieces and how the pieces are colored. The team is free to begin putting the puzzle together with any piece or pieces they so choose. Once put together, the team employs their creative insights to fill the remaining colorless spaces with whatever picture yields the working solution. Leadership keeps all the pieces together and implements a plan for achieving the solution. Hopefully the method used to go about putting the puzzle together and then painting it reflects concepts from the course itself. In analytical chemistry I equate the puzzle pieces with the chemistry and analytical method, and the subsequent painting to the interpretation and communication of the results.

As a bridge role-playing allows you to explore management roles, specialist roles, leadership, creativity, and small group communication dynamics, including how to reach a consensus without alienation. Role-playing allows exploration of workplace situations without placing you in the high risk positions that accompany these roles in the professional world. You cannot be laid off or fired from the analytical class or lab!

Formally role-playing is the activity of acting out or mimicking. The mimicked role is a perspective or a personality that is defined to demonstrate some behavior pattern. The role is acted out, usually in a small group of less than 6 people, by adopting an exaggerated stereotypical aspect of the behavior pattern. The stereotyping and the exaggeration accent key functions of the role for teaching purposes.

**Why is all this important?**

Employers, regardless of mission, desire people who can: further the growth of the organization, clearly articulate and effectively communicate their view and ideas, contribute creative solutions to problems, and achieve personal goals. Helen Free, former President of the American Chemical Society and Bayer Corporation employee, states, "We who are technically oriented don't always communicate well with others. Besides chemistry you will need to develop skills in communications, economics, writing, speaking, management/leadership, and how to work with people among others. It is critical to know yourself - what you are best at and worst at." Challenge yourself to develop these insights and skills. A survey of 70 chemical companies revealed the most important traits employers look for in a candidate. Note that the technical skills are not listed; many places will assume you have developed those!

**Most Important Characteristics**

- Communication Skills
- Computer Skills

**Most Important Traits**

- Self Motivation
- Problem Solving Skills
- Team Player

The benefit of role-playing is obvious once it has been done, yet subtly deceptive beforehand. Role-playing allows you to explore the more dramatic aspects of living a role without the penalties of accountable responsibility. After all, you cannot be fired from the class. If you role-play seriously, the experience can be quite intense. It readies you for group interactions in future occupational situations, and it allows a lot more work to be done on increasingly complex, interesting problems.

The class (255) and the laboratory (256) share the same role-playing teams, called a Company. In each environment the teams sit together and assume the professional roles and responsibilities of an analytical chemist: Manager, Chemist, Software, and Hardware. These four roles and related responsibilities are shown below.
**ROLE**

MANAGER… is responsible for the organization, planning and outcomes of team activities. Manager receives all rewards or penalties. *Manager gets the grade; everyone else gets the same grade as Manager, no matter what they have actually done.*

CHEMIST… is responsible for chemical related materials and information.

HARDWARE… is responsible for instrumentation and related information.

SOFTWARE… is responsible for computers and computer programs and related information.

**CLASSROOM**

Team assignments (DAITEM, team projects, posters etc.)

serves as the principle point of interaction with the course instructor

**LABORATORY**

Experiments and progress reports

serves as the principle point of interaction with Upper Management and with Staff

chemical reference information

operation of computational tools such as TI-89 calculators

operation of computers and computer software

CHEMIST… is responsible for chemical related materials and information.

SDS information

preparation & delivery of reagents, standards, and solutions needed to make the team’s plan work at the expected level of quality

operation of any instrumentation needed to make the team’s plan combine with Chemist's information and preparations to make the outcome reside at the expected level of quality

operation of computers and software that make Hardware's instrument or equipment operation combine with Chemist's information and preparations in such a way that Manager can determine what has happened in the experience and report at the expected level of quality

Our sessions will focus on the teams, with a high degree of decision making and interaction on your part. This approach to inquiry strives to expand the conventional scientific educational experience into an interdependent, people-oriented, small group, learning environment. We will learn new chemistry, analytical methods, instrumentation, and computer software while simultaneously encouraging risk-taking and developing management and leadership skills.

The physical arrangements in the classroom and laboratory have been deliberately designed with role-playing in mind. In RNS 410 the companies sit around the crest of each wave with manager and software occupying the center two seats, each flanked by chemist and hardware, respectively. There is space for four companies in RNS 446; the open area between the laboratory benches is designated as a company work area. A company workplace accommodates a maximum of four people, with part of the work area associated with each role. Each company is equipped with its own instrumentation, placed on benches bordering the work area. This allows each company, as well as the people in it, to operate face to face and interdependently.

Each company is equipped with a laptop computer for Manager to use to prepare reports and diagnose results. Hardware and Software use one interfaced, stand-alone, carted computer. In addition to computational resources each company is assigned a meter of hood space, a set of reagents, a sink with deionized water, and glassware for Chemist to use, along with its own small parts collection. The company instrumentation consists of one electronic analytical balance, one serially interfaced pH electrode/DMM, one electronic top loading balance, and one pH electrode (DMM).
balance, one serially interfaced multichannel spectrophotometer, and one isocratic liquid chromatograph. The diagram above shows a typical layout of these resources, with rough locations for the company computer and other instrumentation. Hardware, in consultation with Manager, will determine the daily location of needed devices.

Where is “The Professor” in All of This?

Your professor is Upper Management, the person responsible for the quality of your educational experience. As an educator s/he creates and fosters an environment that allows you to learn under the role-playing construct. During the lab period Upper Management plays the role of consultant. Your professor will consult for you, but not necessarily for free. If you need technical information or advice, then Upper Management will help you get it, and that is free. But, if you want Upper Management to make a decision for you, then they work by contract, and the fee is one apple (or piece of fruit) per request. Upper Management has decision-making experience; consequently, it is a good bargain.

What will Upper Management do during the lab? First, the roles are not self-teaching, and there are techniques to be learned. Upper Management instructs and trouble-shoots to help facilitate this learning. The decision-making responsibilities lie with each company’s Manager. Upper Management establishes the companies, works with the stockroom, holds managerial meetings at the start of each lab period to explain the organization, and writes and rewrites the experiments. The most important thing Upper Management does is evaluate the company through its Manager.

Good results do produce good performance grades; however, the prevailing principle is that good results stem first from leadership and good management.

What does Upper Management value as leadership and good management? Here are some suggestions.

1.) Enabling leadership
   Enablement occupies the most highly valued style of management. This means doing things that make it possible for others in the company to do their work effectively, as opposed to doing it for them. Manager assures that only one person retains responsibility, and accountability, for one role and its outcomes, no matter how labor is locally divided. This style of management is well described in the company reference books located near Manager’s lab desk. Reading these texts is strongly recommended. They are, in order of relevance:

   Empowerment Takes More Than A Minute,

   Empowering Leadership: A Brief Introduction,


   Empowerment Takes More Than A Minute is an excellent, quick-read resource that will help Manager understand how to view empowerment from a big picture perspective. It discusses effective management and provides a plan for implementation based upon the sharing of information (communication!). It stresses the importance of accountability.

   Empowering Leadership clearly explains the management philosophy of enabling a person to do better work. Roberts and Thorshaim use the word empowerment instead of enablement, but the intent is what Upper Management values. The authors clearly show it is often counterproductive to do work for someone else; it can lead to alienation so strong that it becomes
bad management.

Teamwork and empowering leadership are attributes of productive organizations. In his book, *The Five Dysfunctions of a Team*, Patrick Lencioni uses a creative fable to reveal hard truths about business, especially group behavior. The fable deftly describes the way new leadership worked to return functionality to a team that had previously failed. The latter half of the book is dedicated to describing ways for team leaders to recognize and avoid the five dysfunctions: absence of trust; fear of conflict; lack of commitment; avoidance of accountability; and inattention to results. Every role player would do well to look out for these components, and read the provided summary.

In his book *Managing on the Edge*, Pascale shows by case study and example the disastrous results when managers in big industries attempted the kind of control that is the opposite of enablement. He clearly suggests ways to handle the apparent disorder that results when enablement operates. He also deals with apparent paradoxes, and shows how successful enablement operates in Japanese management. He makes very explicit the ways in which others have been able to divide responsibility, to celebrate uniqueness and diversity, while at the same time enabling workers to link together in a non-competitive manner. He calls this the “fit/split” style of managing; Manager can do this here.

All of these goals will require Manager to do quality work in setting up communication between the other roles while the work is ongoing. This is not simple, and in fact becomes the second of Manager's main strategies.

2.) Communication

How can management style be evaluated? One answer lies in the ability of team members to communicate to each other what they are doing, and what is happening because of what they are doing. Simply put, if people are enabled, they will feel willing, even compelled, to talk to each other about what they are doing, and why they are doing it. Enablement enhances openness and good communication.

For example, consider Upper Management approaching your Chemist and asking her why Software was reading the sports page instead of working on a good graphing routine for results that were expected as soon as he finished the present set of dilutions. If Chemist answered, “Don't ask me, I'm Chemist, not Software.” then Upper Management easily could conclude that Manager had instituted a style that led to privatization, as opposed to enablement and open communication. If bad results occurred, Upper Management would look critically at the style Manager used, as well as the specific details of the lab steps. In that sense, style could contribute to, if not actually set, the resulting grade.

What tools are available to help Manager establish this communication? The lab contains a number of networked computational resources. As spreadsheets are designed, as reports are written and modified, as graphs are prepared, and as data are taken from the lab instruments, Manager can bring the other role-players to the computer, and they can all caucus under the lead of Software on the local event. It is very powerful! Outside the lab, video links, texts, shared editable documents on your own devices (tablets, computers, mobile phones, etc.) will enable remote collaboration in addition to face-to-face meetings called by the team leaders.

3.) Overspecialization & Creativity

We all have identifiable specializations, and some styles of management reward high degrees of specialization. Unfortunately specialization can produce isolation, instead of just high skill, when it is over-applied or applied for too long a time. In addition specialization can thwart ‘out of the box’ thinking by all members of the team. If specialties are developed with the idea of solving a problem that only exists for a limited time, and if Manager rewards innovation and creativity with as much fervor as s/he rewards detailed skills, then specialization can be acquired with the idea that it will be shared with others in the group.

Management that avoids overspecialization is one that sets up modes and rewards for frequent coming together to exchange viewpoints and ideas on how each person's role is contributing to the problem solving plan. It studiously avoids diminishing the uniqueness of each role-player and what they bring in their role to the problem.
solving effort.

This kind of management is at the heart of the discussion in M. Scott Peck's book, *The Different Drum* (Simon and Schuster, 1987). Peck points out that the specialization that will accompany each role is best combined on a very regular basis with other specializations so that each person can have the opportunity to modify their approach according to their impact on the others and the net effectiveness they are presently having on progress to a solution. This is a practical way of defining the broader terms of community and interdependence.

4.) Record Keeping

Knowing how to instruct other team members in what records to keep while the work progresses poses a continuous challenge for Manager. There is the question of how, and how much, to record and in what device.

Software can be an asset by setting up a spreadsheet whose function is to hold both narrative remarks about the on-going work, as well as columns of data, labels, and calculations. Spreadsheet programs, like EXCEL, do very well here, since narrative may be entered in its word processor mode, and handling columns of data and formulas are its strength. For the equivalent of legal protection, time and date stamped printouts of the spreadsheet can be dumped during the lab.

5.) Attendance

The company groups are small. The work is not excessive, but the fact that responsibility is divided means that if one role-player is absent, his or her role will suffer and the company will suffer accordingly. Everyone is a key player, and leads in her role. This is not true when labor is divided, and responsibility is diffuse.

Past practice suggests a good way to handle absences, which must be limited to *circumstances beyond the person's control*, is for Manager to assume the additional responsibilities of the absentee role-player. Thus, if Chemist is absent, Manager must both manage and handle all of the responsibilities of having the right solutions in the right place at the right time.

If a role-player drops the course, then Upper Management will work with the remaining members of the company to decide how they will finish the semester. Companies of three have worked successfully in the past, although it makes more work for Manager. Companies of two will not work, and must be disbanded, with the role-players moved into other companies. All Managers should work to encourage all members of their company to stay involved and not drop.

6.) Written Records and Reports

Professional analytical chemists prepare progress reports, research summaries, and proposals in writing; consequently, Manager is responsible for the team’s written electronic submissions, from the progress reports and data in the management interview to the DAITEM, team project, posters and other assignments conducted as part of Chem 255 and 256. Upper Management expects time/date stamps on everything submitted as well as critical data and commentary available such that someone could repeat your company’s approach with the information you supply.

*What Are Some Specific Responsibilities for the Role-Players in the lab?*

Each experiment will have a description of the objectives of the experiment. This will help establish the specific responsibilities. In general, however, there are responsibilities for all of the experiments that fall to the various roles more or less as follows:

Manager

Manager handles the organization of an experiment, explaining and interpreting the written objectives of the experiment. Manager addresses and resolves any conflicts between personnel. Manager decides when parts of the experiment should be done, and how to balance potentially competitive demands on the company resources from becoming impediments to experiment execution. A good manager will ensure the work is done on time, guarantee personnel have read the experiment and know how to implement their roles, understand the roles, and assure that each role is implemented at the level of quality required.
Manager writes the necessary progress reports, maintains electronic lab summaries, reviews the data and submits what is needed to explain the experiment results during the Management Interview. Manager reports directly either to Staff or to Upper Management, and assures Upper Management that each person in the company is fully aware of what is going on in each other's role-playing. Manager may do this in any way desired, ranging from pre-experiment staff meetings to post-experiment debriefing. But, if Software doesn't know the kind of chemistry that Chemist is doing, while Chemist is doing it, then that is a management problem, leading to a lower grade for the entire company! Additionally, in consultation with Upper Management and the company Chemist, Manager is the person who establishes safe laboratory practices within the company.

Chemist

Chemist has the specific responsibility of making, dispensing, and using the solutions and preparations for each experiment. Typically Upper Management provides the stock, but the preparation of sub-standards, aliquots, dilutions, and final solutions for measurement all falls to Chemist. Along with the responsibility for the correct preparation, Chemist is responsible for communicating chemical safety issues and determining the appropriate waste disposal methods.

If, for example, results come in too high because there was an error in the standardization of a base solution due to a weighing error in preparing the primary standard acid, then Chemist must assume local company accountability for that, and Manager must assume responsibility for allowing it to reverberate though the experiment to the final result.

The responsibilities of these two roles are thus close, and in fact are interrelated. The two roles are interdependent. Communication is critically important!

Hardware

Hardware has specific responsibilities associated with making the company instruments run properly. For example, Hardware would read the instruction manual for the instrument and learn from that manual how to operate it in the context of the experiment. In setting up the scan rate for a spectrophotometer, Hardware would have to know if any of the chemicals being measured were unstable with time, perhaps due to air oxidation. Such would influence his/her selection of how to run the instrument for this one experiment, but the same instrument might best be run differently in another experiment.

Hardware connects parts of instruments together, solders cables and connectors, and arranges physical components on the bench. Hardware assembles the circuits needed for the local pH meter, test connections, locates spare parts and, with help from Staff or Upper Management, does limited repairs. Hardware needs to know what Chemist has made, just as Chemist needs to know what the instrument behavior will be as Hardware will use it. These roles are interdependent, and it is up to Manager to make sure that Chemist and Hardware are speaking to each other in time to influence the decisions that each will be making during the lab period. Upper Management will be circulating around the lab looking for this kind of speaking collegially.

Software

Software holds the means for communication, and it is communication between people in the company that makes the whole thing work. While it is Manager who has to electronically write the experiment results, Software makes such writing possible by being on top of the company’s software and helps Manager use it! Software needs to know what Chemist is doing because it is Software who helps Hardware run all of the computer-based instruments.

Software handles the spreadsheets and file management on the company computers and the college networked servers. The spreadsheets are the repository for the data that Chemist solicits from Hardware, and that Manager has to assume are correctly calculated, and so forth. If there are any keys to the kingdom here, it is Software who uses them to unlock the
communication puzzle. And, it most certainly is communication that makes the experiment actually work.

*How is All This Organized?*

Take a look at an excerpt from the lab schedule below and note the column marked **Role**. These responsibilities are clearly marked in the first set of experiments. This is the place for you to practice role-playing in the technical context. These experiments will be the ones you use to learn the roles. Then, in the last set of projects, you put all of your experience to work and do a fully accountable job of role-playing. Notice the roles are rotated! No one person is **Manager** all of the time! In this way, each person gets a chance to play each role, and to understand how that role becomes interdependent with the others when the lab is over for the semester. Roles rotate the same in class and in the lab!

<table>
<thead>
<tr>
<th>Date</th>
<th>Responsibilities</th>
<th>Role</th>
<th>Person</th>
</tr>
</thead>
<tbody>
<tr>
<td>Week1</td>
<td><strong>Lab 1 - Basic Skills</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Teaches all about Laboratory Safety and organization</td>
<td>Manager</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>Teaches all about <strong>MSDS</strong> forms, solution preparation, and disposal</td>
<td>Chemist</td>
<td>B</td>
</tr>
<tr>
<td></td>
<td>Teaches all how to use LabVIEW to acquire data and do file transfers.</td>
<td>Software</td>
<td>C</td>
</tr>
<tr>
<td></td>
<td>Teaches all how to make a cable to connect between balance and computers.</td>
<td>Hardware</td>
<td>D</td>
</tr>
<tr>
<td>Week2</td>
<td><strong>Lab 2 - Glassware</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Select Certification Procedures - Verifying the certifications</td>
<td>Manager</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>Cleans, Handles, and Uses Volumetric Glassware</td>
<td>Chemist</td>
<td>B</td>
</tr>
<tr>
<td></td>
<td>Spreadsheet Setup and Inter-Company Data Telemetry</td>
<td>Software</td>
<td>C</td>
</tr>
<tr>
<td></td>
<td>Electronic Balance Computer Connection and Operation</td>
<td>Hardware</td>
<td>D</td>
</tr>
<tr>
<td>Week3</td>
<td><strong>Lab 3 - Acid1</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Organizes the Weak Acid and Standardization Titrations</td>
<td>Manager</td>
<td>D</td>
</tr>
<tr>
<td></td>
<td>Prepares and Standardizes the Strong Base Titrant and Weak Acid Titrate</td>
<td>Chemist</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>Operates the all LabVIEW Virtual Instruments and does F-Test Statistics</td>
<td>Software</td>
<td>B</td>
</tr>
<tr>
<td></td>
<td>Calibrates pH Electrode and Setup of the Semi-Automated Titration Device.</td>
<td>Hardware</td>
<td>C</td>
</tr>
<tr>
<td>Week4</td>
<td><strong>Lab 4 - Acid2</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Design and Interpretation of the Graphical Procedure</td>
<td>Manager</td>
<td>D</td>
</tr>
<tr>
<td></td>
<td>Prepares Weak Acid Solutions</td>
<td>Chemist</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>Spreadsheet Setup and Inter-Company Data Telemetry</td>
<td>Software</td>
<td>B</td>
</tr>
<tr>
<td></td>
<td>Operates the Semi-Automated Titration Device.</td>
<td>Hardware</td>
<td>C</td>
</tr>
</tbody>
</table>

*What About Grading?*

Team-based assignments in Chem 255 will yield personal points as will questions on Chem 255 exams which arise directly from the laboratory. The role-playing laboratory is graded P/N; however, **Upper Management** and **Manager** will meet in the **Management Interview** to assign letter grades to the experiments. At the end of the semester, **Upper Management** will translate the letter grades into P/N equivalents. Unless performance is noticeably poor, it will take a job performance grade of C or better to pass an experiment, and at least sixty percent of the experiments must be passed and all experiments fully attempted in order to pass the lab. This bar is set so that you are encouraged to think out of the box, to be creative, to take risks, and to reflect on your learning.

The grades assigned in the first set of experiments are developmental grades, and your **Management Interviews** are directed a lot more toward improvement and getting ready than they are toward evaluation. These beginning interview sessions are designed to signal how well the company is progressing toward the last set of experiments. The tough grades are assigned in the last set of experiments. In the role-playing model, **Manager** gets all of the tangibles associated with the experiment: the **Management Interview**, the evaluations, the suggestions for improvements, the requests for permission to use the results in future classes, and, last, the letter grade for the work done. **Manager** then conveys these tangibles to others in the company in the debriefing session. With
So then, why teach and learn this way?

There are a multitude of reasons for using a variety of teaching and learning methods in one's education. A general rationale comes from the way in which each one of us learns. We all learn via different paths and bring unique experiences with us. Role-playing is one way to reach out to different learning paths under the structure of having similar reasons for doing it this way. Those reasons incorporate: developing an understanding of the subject matter; obtaining a taste of workplace experience without the sometimes ruthless consequences (i.e., you may get a poor grade rather than being fired!); learning to communicate effectively as a scientist and concerned citizen; learning what it takes to become a creative problem solver; appreciating how teams can best approach problems; experiencing time management challenges; facing accountability; fostering interest within science; and learning a bit about yourself along the way.

Role-playing aids the educator’s development as well. It helps to invigorate the teaching; it constantly asks you to find new ways to get people involved and encourages you to discover new applications of dry conceptual knowledge. It gives educators an added outlet to encourage self-discovery rather than the dispensing of knowledge and decisions from the front of the room. "Ask your manager. If you want me to make the decision for you then I will have to bill you for it." Ultimately, science and society are about people; we and our predecessors form the roots. Without people, what would science be? For that matter what would anything be? Until we recognize the contributions of people working together, we limit only ourselves in whatever we do. Role-playing is a dynamic activity performed by a community of learners and mirrors much a society. It doesn’t last long, just the length of the course, but that gives value to the time the role-players spend together. How often do we find ourselves saying, "I wish I could have had more time to _____ or more time to explore _____ or spent one more day with _____." Community. Science is an integrated adventure that people do together - learning, living, and even liking!

Role-playing Resources:

Resources on Creativity & Innovation:

Acknowledgements:
The initial discussion of role-playing and its framework was created by my former college, John P. Walters. These ideas form the basis of the work which I have augmented with additional commentary and development. I am indebted to John for his guidance and patience.