To the Student

You are now beginning one of the first chemistry courses you will take in college. One of the richest learning experiences you can have will be your work in the chemistry laboratory. Because in the real world teams of individuals accomplish much of the work, you will work on a team during your laboratory session. Sometimes you will work alone but consult directly with a partner; sometimes you will need to have a partner to complete the tasks that you will design.

You and your classmates will design the experiments that you will conduct in the laboratory. The best way for you to learn is to take charge of how you do it. Your focus will be on student-centered techniques and talking with your peers (student to student) rather than with your instructor. You will find this process to be more interesting as well as more instructive to you. By designing your own experiments, you will learn and remember more about what you have done. Your instructor will provide you with plenty of guidance. Instructors who foster this environment can clearly observe the great potential students have for interacting with one another and understanding what they are doing.

Ideally, your instructor guides or coaches the laboratory session. Instead of directly providing you with information when you ask a question, your instructor will ask guiding questions and will redirect you to interact with your group mates. Initially, you may find it frustrating when your instructor does not directly answer your question(s). But, you will soon learn that there are members of your own group who actually *can* answer these questions. You may also discover that you yourself know the answer if you invest the time and effort needed to think through the problem. Your instructor will provide you with support to answer your questions—you will not be abandoned. You will realize that you are relying more on yourself and your peers and less on your instructor.

An SWH classroom is a classroom employing active learning strategies to promote collaboration. You are responsible to one another to complete all necessary tasks, record your data and observations appropriately on the chalkboard for all to share, and attempt to formulate claims based on the evidence collected. The ensuing discussions help you and your classmates to connect your experimental work with related chemistry, constructing your own understanding of the concept(s) under consideration.

What strategies need to be used and when? At the outset, a pre-laboratory discussion among you, your classmates, and your instructor will alert you and your classmates of any special safety or procedural concerns. You and your classmates will

- Assign your own groups;
- Decide what data to gather;
- Prepare the classroom data grid to be completed by the different collaborating groups;
- Determine among yourselves which group(s) would be responsible for individual tasks.

If you are not moving in the direction your instructor thinks will be most effective for you, you will be guided there.

Your instructor will be constantly circulating around the room from group to group asking you questions to determine what you are discovering and learning. The more your questions are redirected back to you to answer, the more you will be encouraged to think about and process what you are learning. Students who receive overt answers from their instructors usually do not interact as much with one another nor are they as motivated as students who talk with one another. By having your instructor answer your questions directly, you will become too dependent on that avenue for answers which means you will think less for yourselves.

Comparing a traditional laboratory session to a student-centered laboratory session.

	Traditional lab	**Student-centered lab**
Pre-lab	The instructor gives step-by-step directions, asks for questions related to "cookbook" procedure.	a. Students write beginning questions (BQs) on chalkboard. b. Together the class discusses which BQs to investigate. c. Students talk about how to divide the tasks among groups, and what data needs to be collected. d. Students prepare class data table on chalkboard.
Students perform experimental work	Students follow procedure outlined in lab manual or outlined by instructor. Students stay at their own experimental workstations and talk mainly with their partner (unless they ask the instructor a question).	a. Students perform lab work necessary to answer their own questions. b. Students talk with other group members and other lab groups about what they are finding.
Data collection	Lab partners check with one another to be certain that both have all data, then leave.	a. Each group enters data in class data table on the chalkboard. b. Groups who have finished "their" part walk around the classroom to check with other groups to determine whether any other group needs help in completing their task(s) or calculations.
Discussion	Student may ask a question of partner and/or instructor, then leaves the classroom.	a. As soon as more than half of the data has been entered in the table, students begin to look for trends to answer their BQs. If data does not agree with an apparent trend, they may repeat their work. b. When all data is on the board, students critically evaluate the information. c. Students work together to negotiate meaning, construct a concept, answer BQs. d. Students write and discuss an appropriate claim and provide supporting evidence.

SWH Format—Detailed Explanation for the Student

Beginning Questions. A pre-laboratory discussion helps to define beginning questions to investigate experimentally. After reading the laboratory material, write a question or two that can be answered *by doing the experiment*. What will you investigate? Often the questions are in the form of a quantitative relationship. Sometimes the questions are qualitative in nature. Acceptable examples are: How does the length of the non-polar region relate to the equilibrium constant? How does the reaction demonstrate equilibrium? How does the amount of compound dissolved in water affect ΔH_{rxn}? Unacceptable examples are: What is the limiting reagent? What color is my product? "Why" questions cannot be answered by doing the lab experiment and are considered nonproductive. For example: Why are there buffers? Why do we use a burette? Questions regarding procedure are not useful. (An example would be: How do I set up a vacuum filtration apparatus?) Most of the time, students will need to share data in order to answer a question that has a relationship. For example: How does the amount of the limiting reagent affect the percent yield? Even though a question may seem obvious, it is important to ask that question, make a claim about it, and then back up the claim with evidence in order to construct a concept.

Safety. How will you stay safe? After reading the laboratory, you should list the major safety concerns for the experiment you are about to do. This is separate from the web-based safety assignments. Additions can be made to your safety section during the pre-lab lecture. For example, some safety considerations include: use gloves when appropriate, use the fume hood when producing a toxic gas, and dispose of your waste products appropriately.

Tests/ Procedure. What will you do? After reading the lab, list the steps that you will take to perform the laboratory experiment. If you are required to propose your own procedures, what strategy will you take to explore your beginning question(s)? Remember, the entire class will work on this project. How will you divide the labor?

You may have multiple sections. You may reference the lab manual, but keep in mind that a list of the major procedural steps may be useful on the lab practical, the laboratory "exam" that you will take in this course. What would you want to include if someone were going to use *only* your procedure to do the lab?

Data/Observations, Graphs, Balanced Equations, and Calculations. What will you see? During the lab, list all data, complete observations, notes, calculations, equations, chemical information etc. in your lab notebook. Do not use another notebook or scratch sheets of paper. You can use your laboratory notebook during the lab practical exams.

Claims. What can you claim? This is to be a one- or two-sentence statement about the results of your laboratory work. It should answer your beginning question(s). For example: If the concentration of reagent A doubles, so does the rate of the reaction. An inappropriate claim would be: My product weighed 2.3 grams.

Evidence. How do you know you can make your claim? Why are you making your claim? This is a written explanation that supports your claims. How do you know that the rate of the reaction increases as the concentration increases? Include time vs. concentration data. Explain the meaning behind the data and calculations. Graphs, balanced equations, and calculations need to be interpreted and explained in order to count as evidence. Simply referring to them is not enough. Appropriate balanced chemical equations and necessary mathematical calculations can be used to support your claims, but the emphasis is on the interpretation and explanation of these results.

Reading/Reflection. How do your ideas compare with others' ideas? Discuss your initial question. Looking back before and during the experiment, have your ideas changed and if so, how? Do you have a new question? How do your results compare to other groups or the textbook or literature value? What connections did you make between the lab and lecture?

Student Guidelines for the Science Writing Heuristic and Inquiry Laboratories

Because inquiry-based laboratories are student-centered, you will be responsible for how you design your experiments and how you collect and analyze your data. Your instructor will serve as a guide or coach to help you to be successful. We have provided a suggested outline of what your responsibilities are during the process of the SWH.

1. Prior to arrival in lab
    a. Prepare beginning question(s), BQs;
    b. Outline procedural strategy;
    c. List safety concerns.
2. Upon arrival in lab
    a. Write BQs on chalkboard while students are storing coats, book bags, etc.;
    b. Discuss BQs with partner or group mates;
    c. Discuss BQs with class to decide which one(s) to study as a group.
3. After deciding on BQ(s), discuss what strategies would be appropriate to answer the BQs,
    a. Divide class into groups (usually four people who can than subdivide into teams of two) to experimentally study all aspects of BQ(s). All team members are expected to be working on some kind of laboratory procedure. No one should just watch!

       Each team member will need to understand how to conduct all parts of the laboratory. Eventually, when working the same kind of experimental procedures for the laboratory practical examination, each team member will be responsible to know what to do for each experiment.

   b. Be certain to provide for appropriate replication of procedures to create a large pool of "good" data.
   c. On the chalkboard, draft appropriate data collection tables, including dependent and independent variables to be investigated.
   d. Identify by initials which student groups or pairs are responsible for different runs. In this way, anyone can talk with the persons who collected any piece(s) of data.

4. After data has been collected, analyze it to try to interpret it.
   a. Look for trends, patterns, and anomalies.
   b. If there are anomalies, decide who will repeat the experiment to replace that data. How do you decide which part(s) too repeat?
   c. It is often useful to graph results and interpret your graph.
5. Enter your data in the class database that can be found on the laboratory computer. This will contribute to the overall course-wide data pool.
6. While waiting for all students to complete work and enter data, propose your claim(s), and cite supporting evidence.
7. Discuss results as class to create an understanding of the concept(s) for the lab. Your instructor will help to guide your discussion.
8. After lab,
   a. Consult the course-wide database that you can find on WebCT to determine whether the data collected by you and your classmates agrees with the data collected by classmates in other laboratory sections.

b. Consult at least three appropriate resources to explain, confirm, or dispute what you have learned in the laboratory. This could be your text, another reference text, the Internet, your instructor, your class notes, etc.
c. Answer any "Post laboratory discussion questions" that have been posed by your instructor or proposed in your laboratory manual.