its constraints. They resist using help menus and the manuals. I believe it is important for them to see the power of this type of program for future reference.

The overall quality of student formal reports has improved due the use of word processing programs. We have a writing program at the College and a junior laboratory course emphasizing research report writing. Most students will not use the full power of word processing unless you demand it. The prefer to write in equations, drawings, reference numbers etc. even when they know that they will have a number of drafts. Suggestions to use the word processing program to do this early falls on deaf ears in most cases. This was brought home painfully for students and instructors alike when the students were writing their senior theses.

In conclusion, computers have brought improvements to the quality of instruction of undergraduate chemists and their work. Our expectations in the computer area have as in other areas fallen short. This is the nature of education, teaching and learning. '

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Using Student Centered Learning Strategies in the Chemistry Classroom

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If we consider that learning is enhanced when students are engaged in the processing of information, then our challenge as teachers is to find creative ways to design dynamic learning environments that involve students in doing and thinking about chemistry. Over the past few years, I have developed a teaching strategy, which I call LecturePLUS that converts the traditional lecture into a student-centered format. The LecturePLUS environment integrates mini-lectures, formative assessments, and activity worksheets for team learning in the classroom.

Background
Most of us who teach chemistry grew up learning chemistry from the lecture method. For many years, I never doubted that it was the way to teach chemistry. Today the lecture system is the preferred teaching style used by 89% of science professors. Indeed, lecture is a comfortable format for many instructors and a non-threatening one for students. It is low cost, easy to control, and an excellent method for organizing course content. However, many of us are becoming more aware that during lecture students are not actively engaged with the topic, they don't seem to listen for very long, and their retention of concepts is minimal. Studies show that students are not attentive 40% of the time they are in class and that although attention is high for the first 15 minutes, it declines rapidly until the final 10 minutes of class. About 10 years ago, I began to hear about student-centered teaching strategies, but I saw little of it at the college level. Now that is beginning to change. Don Paulson , Chemistry, California State University, reports that the use of active-learning strategies from 1994-1998 provided an average retention rate of 75% for one year of organic chemistry compared to 38% when he used the lecture method. In addition, he reports that students who learned with the intense active-learning approach in lecture did significantly better in both retention and GPA in the laboratory class.

Student Centered Strategies
In a student-centered classroom, students are encouraged to participate actively in learning the material as it is presented rather than being passive and perhaps taking notes quietly. Students are involved throughout the class time in activities that help them construct their understanding of the material that is presented. The instructor no longer delivers a vast amount of information, but uses a variety of hands-on activities to promote learning.

As I learned more about student-centered learning environments, I began to alter the way I taught my chemistry classes. I have now developed a group of learning strategies that I call LecturePLUS to promote **P**articipation, **L**earning, **U**nderstanding, and **S**uccess. My LecturePLUS system includes mini-lectures using PowerPoint presentations, in-class collaborative learning, peer presentations, ongoing assessment techniques, and "ChemWorks", which are group homework projects.

Mini-Lectures

When I learned in a workshop that student attention span in lecture wanes after about 15 minutes, I began to repackage my lecture material. Eventually I had a series of PowerPoint ® slides or CheModules that I utilize as mini-lectures. Many of these are on my web site at http://www.karentimberlake.com or http://www.lectureplus.com. In the classroom, I use a simple media cart with the presentation system on the top level along with my laptop. A VCR on the middle level allows me to show videos full screen through the presentation projector.

In class, the students work out of a syllabus in which I include the Power Point notes. I don't include the solution slides in the notes, but show them after students have given their answers. The same modules are available on my web site for review and do include the solutions. Here are some slides from the CheModule on ionic compounds and their formulas.

Ionic Compounds

Metals lose electrons and nonmetal gain electrons
Ionic bonds are attractions between + ions and - ions

electron transfer
metal ⟶ nonmetal ⟶ ion$^+$ ion$^-$

Electrons lost = Electrons gain

Formulas of Ionic Compounds

Formulas of ionic compounds are determined from the charges on the ions
atoms ions

Na· + ·F: ⟶ Na$^+$:F:$^-$ ⟶ NaF
sodium fluorine sodium fluoride formula
Charge balance: 1+ 1- = 0

Writing a Formula

Write the formula for the ionic compound that will form between Ba^{2+} and Cl^-.
Solution:
1. **Balance charge with + and – ions**
2. **Write the positive ion of metal first, and the negative ion**

Ba^{2+} Cl^-
Cl^-

3. **Write the number of ions needed as subscripts $BaCl_2$**

Learning Check IC1

Write the correct formula for the compounds containing the following ions:

A. Na^+, S^{2-}
1) NaS 2) Na_2S 3) NaS_2
B. Al^{3+}, Cl^-
1) $AlCl_3$ 2) AlCl 3) Al_3Cl
C. Mg^{2+}, N^{3-}
1) MgN 2) Mg_2N_3 3) Mg_3N_2

Solution IC1

Write the correct formula for the compounds containing the following ions:

A. Na^+, S^{2-}
2) Na_2S
B. Al^{3+}, Cl^-
1) $AlCl_3$
C. Mg^{2+}, N^{3-}
3) Mg_3N_2

Naming Binary Ionic Compounds

Contain 2 different elements
Name the metal first, then the nonmetal as *-ide*.
Use name of a metal with a fixed charge Groups 1A, 2A, 3A and Ag, Zn, and Cd
Examples:

NaCl	**sodium chloride**
ZnI	**zinc iodide**
Al_2O_3	**aluminum oxide**

Learning Check IC2

Complete the names of the following binary compounds:

Na_3N	**sodium __________**
KBr	**potassium__________**
Al_2O_3	**aluminum__________**
MgS	**__________**

Solution IC2

Complete the names of the following binary compounds:

Na_3N	**sodium nitride**
KBr	**potassium bromide**
Al_2O_3	**aluminum oxide**
MgS	**magnesium sulfide**

Formative Assessment

In many of our classrooms, we often have a large gap before we test students on the material we discuss in our classes. After the first exam, we are surprised and disappointed by what they students did not learn by this time. It is often too late to make up for the material that was missed. I realized that I wanted to know what students were thinking and learning each day while we were in class. To do this, I integrated learning checks within the PowerPoint slides of my CheModules. In the sample slides, there are learning checks IC1 and IC2. These learning checks are a type of formative assessment techniques, which is a non-graded assessment that occurs throughout the class time.

When a learning check appears in a module, I give students time to work out the answers, individually at first, and then in groups. Many of the learning checks involve short multiple-choice or fill in questions. For the multiple-choice questions, every student has a set of three cards with large numbers 1, 2 and 3 on them. I made these from card stock. When I call for answer cards, everyone raises the card(s) that indicate their answers. The results in class serve as a discussion of the concepts. Students get a quick assessment of their own learning and what they need to work on. The learning checks are a way for students to continually adjust their understanding. The also encourage questions. At the same time, I can determine what is working in my mini-lectures and what needs more attention. The ability to adapt to particular needs has resulted in some of the most productive teaching I have ever done. There are a variety of other types of formative assessments that can be used in a chemistry class to assess what students are thinking and learning each day. Several are described below:

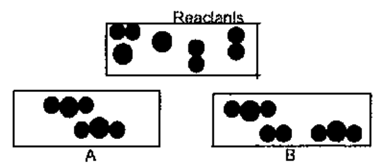
Clarification Pause A quick way to add some active learning to a classroom is to take a lecture break every 15-20 minutes. This means that I stop talking for about 2 minutes while students discuss the ideas with each other, check and clarify their notes, and ask questions. I circulate about the room and help them review the ideas. This is a quick way to add student-centered learning that does not require prepared worksheets or other materials.

Shared Paragraph During class or at the end of class, students are given a few minutes to write a short paragraph in their own words that explains that major ideas discusses that day. They share their paragraphs with other students, and give feedback to each other. They may turn the paragraphs in as they leave class. I return them the next day and discuss any topics that were not clear. I obtain instant feedback in their thinking and students learn to summarize information.

Fish Bowl At the beginning of class, each students writes a question pertaining to class content on a 3" x 5" card and places the card in a container. I draw out some cards and read the questions to the class. Students are expected to provide answers. The discussion reviews topics that were unclear and gives students who would not ask a question in front of their peers a chance to present a question to the instructor. Students learn to assess and articulate what they don't know. And I obtain feedback on the level of difficulty of various topics I present.

The One-Minute Paper **Students are asked to write a short paper or paragraph for one minute. This might be about a section in the chapter or about a concept we just worked on. They are turned in and I quickly look them over. Students learn to clarify the ideas in the reading or lecture material. The paper provides feedback to the instructor on student's ability to understand the concepts in the text. Here is an example of a one-minute paper:**

Carbon and oxygen react according to the following equation: $C + O_2 \rightarrow CO_2$



Select the container (A or B) that represents the molecules after C and O_2 react. Write a one-minute paper to explain your choice.

When I collected the papers, I discovered that although students could do a mechanical calculation of a limiting reactant problem, they did not understand the concept. This result prompted more discussion and analogies concerning limiting reactant concepts.

Results

"B is the correct answer because it contains an equal number of atoms in the products and reactants as well as forming a new compound with an excess of oxygen." (120/180 students)

"A is correct. No oxygen atoms are left over, because the equation states the product is CO_2 and <u>not</u> $CO_2 + O_2$. There is extra oxygen reactant floating around which is not stated in the given equation." (60/180 students)

The benefit of using formative assessments is that instructors and students have an ongoing evaluation of what students understand and what needs more attention. The instructor adapts to the needs of the class by adding another example, challenging thinking, or moving on to the next topic.

Worksheets for Group Work in Class
Within each set of PowerPoint® notes in the syllabus, I integrate worksheets for collaborative learning during class. Students work in study teams applying the concepts immediately and problem-solving together. Learning is enhanced when students become engaged in the processing of information.
Here is an example of one page of a team worksheet done by groups of students in class.

Naming and Writing Ionic Formulas Worksheet 4.3

1. Determine the formula and name of the ionic compound containing the following ions:

Ions	Formula	Name
Na^+ and O^{2-}		
Al^{3+} and S^{2-}		
Ba^{2+} and Cl^-		
K^+ and P^{3-}		

2. Why is Na^+ named sodium ion, while Fe^{2+} must be named as an iron (II) ion?

3. Complete with formulas and names:

	Cl^-	S^{2-}	N^{3-}
Li^+			
Mg^{2+}			
Fe^{3+}			

4. How do you determine the charge of the positive ion in CuO and Cu_2O?

As students work together in the classroom, they think and use the language of chemistry. They use peer instruction to fill in gaps in math and chemistry for each other by providing immediate feedback and correction to each other's ideas. I've found that peer instruction helps students begin to formulate questions about what they don't understand and begin to model successful problem solving for their peers. A former student comments, "The best part of working in groups is that students who are too shy to ask the professor for help can ask a member in the group". The importance of establishing a learning community that supports al the students in the class cannot be overrated. Another student said, "The group methods helped me to understand the material for the first time. It made chemistry enjoyable." One may argue that learning chemistry may not always be so enjoyable, but if too much of it is not, the student will often leave the class.

Peer Presentations
When we are ready to review several chapters for an exam, I hand out a review worksheet or assign a different questions from the text to each study team in the classroom. I have done this with classes up to 200 students. Students manage to find a way to work together regardless of the shape of the classroom or lecture hall. They discuss the problem and write up a solution on a transparency. After 15 minutes, one or two students describe their solution to the class using an overhead projector. I am always impressed with the ability of students to articulate their work and to teach a class. I interject a thought or clarification as needed, but most of the time it is a student who asks a question or makes a suggestion. As long as students are given the time to prepare their solution, the peer presentation is a positive experience that strengthens the self-confidence of many students.

Group Homework Projects "ChemWorks"
In the process of changing to a more student-centered classroom, I found that I said less but taught more. For example, I no longer work problem after problem in class as students snooze. Now students work out problems together using group problem solving homework worksheets I call "ChemWorks". They must get together outside of class with their study teams and work on these homework sets. They have different ways to do this. Some do all the work together. Others assign problems to work on their own and then get together to go over the work . Others email back and forth on their computers. Because I don't cover all the material in class, they must learn from their textbooks

and other resources. At the beginning of each exam (I give 5), one ChemWorks paper is turned in for each study team and each member receives the same grade. An example is shown below:

CHEMWORKS 2
Names and Signatures of Study Team

____
____
____
____

1. Write the formulas or names of the following ions.

________ S^{2-} magnesium ion _______
__________ SO_3^{2-} carbonate ion _______

2. Give the correct formula for the following covalent compounds:

nitrogen trichloride___________iodine ___________
silicon tetrabromide__________carbon dioxide_______

Give the correct name for the following covalent compounds.

PCl_3 __________ O_2 ____________________

4. Draw the electron dot formula of silicon tetrabromide.

5. Complete the following for **ionic** compounds:

	IONS		**CORRECT FORMULA**
	positive	negative	
aluminum bromide	____	_____	_________
iron(III) oxide	_______	_______	_________
calcium phosphate	_____	_______	_________
lead(IV) chloride	_______	_______	_______

6. Write a correct name for the following compounds:

NaI __________ $Ca(NO_3)_2$ ____________
$BaCl_2$ _________ Fe_2O_3 _______________

SHOW WORK AND CORRECT SETUPS ON ALL PROBLEMS.

7. Betahistine, $C_8H_{12}N_2$, is a vasodilator used in the treatment of hypertension by acting directly on the vascular smooth muscle to cause relaxation.
   a. What is the molar mass of betahistine?
   b. How many grams of betahistine are in 0.255 moles of betahistine?

Small-group learning has the benefit of engaging students, sharing teaching and learning, connecting more learning styles, developing higher-order thinking skills, helping students to reflect and increasing success and retention. By working in groups, students learn to take more responsibility for their own learning, which is a process that is important in today's Internet world. A student comments," As each student brings knowledge or insight to the group, the pieces begin to fit together like a puzzle so that basic learn concepts can be applied to a wide variety of situation. You take a more active and responsible role in your learning."

Tips for Adding Student-Centered Learning in the Classroom

If an instructor wants to move toward a student-centered classroom, I have some tips on getting started. Begin using active strategies the first day and start small. Students will know that your course will be different from the traditional lecture format. Clarify procedures and provide a non-threatening environment. Discuss the appropriate behavior for students when they work in groups. Experiment with various activity to find those that are most comfortable and workable within ones own teaching style. Adapt the various activities to fit your class. Be prepared to find out what students do to learn.

There will be mixed reactions from students but I have seen students start a semester thinking this was a ridiculous way to teach and end the semester begging me to teach their next class. Since I started using more interactive techniques, I have become keenly aware that students do not learn the same ways; in fact, they have vastly different ways of processing information and learning how to think.

Conclusions

Student collaboration and peer instruction using non-graded classroom assessments and team worksheets in a student-centered classroom provides continuous feedback to both students and instructor throughout the class time. Students interact with each other as well as the instructor, which means they are processing ideas and learning. They are using new vocabulary in a non-intimidating setting and participating in problem solving as they work and explain concepts to other students. For me, the move to more student-centered teaching has been a most exciting way to put learning back into teaching while providing students with the tools for lifelong learning and success. Now I say less and enjoy teaching more!

Acknowledgments

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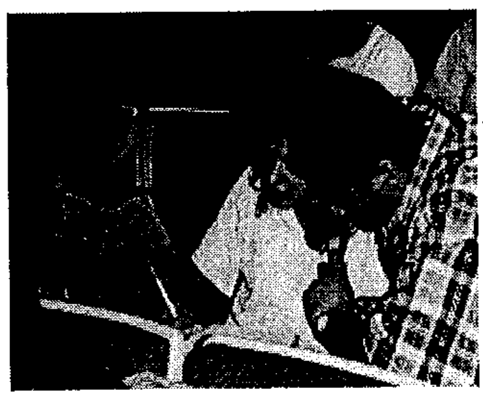

Students are working together on a problem in a lecture setting.