ChemConnections

A Guide To Teaching With Modules

Joanne L. Stewart

Valorie L. Wilkerson

Hope College

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CONTENTS

Introduction

A Guide to Teaching with Modules is meant as a companion to the individual instructor's manuals, written to support the ChemConnections Modules. This "super" instructor's manual introduces instructors to the active learning and discovery-based approach used in the modules, and provides concrete suggestions on how to implement these approaches in the classroom.

The Guide is divided into four sections. The first section, ***Why Modules?***, describes why the ChemConnections modules were developed and how they may be used to replace or supplement a more traditional introductory chemistry class.

The second section, ***What is a Module?***, explains how each module focuses on a central question and how ***Sessions***, ***Explorations***, and ***Culminating Activities*** are used to guide students to answer that question.

The heart of the Guide is the third section, ***How to Implement Student Learning***. By using many examples from the modules, the active learning approach is made accessible for beginning instructors, and the experienced instructor finds new teaching ideas and learns more about modules.

In the final section, ***What to Expect as an Instructor***, assessment information from early tests of the modular approach is used to help instructors prepare to teach with modules and to anticipate student concerns.

ChemConnections modules create a dynamic, student-centered learning environment for chemistry students. This Guide provides concise suggestions on how to get started and concrete examples of how active learning is used in the modules. ChemConnections materials are flexible and adaptable, and instructors are encouraged to adapt and adopt the modules to fit their own student learning goals, interests, and resources.

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Chapter 1: Why Modules?

History

In 1995 The National Science Foundation (NSF) launched the Systematic Changes in Undergraduate Chemistry Curriculum Initiative with the aim of improving undergraduate chemistry education. This new program followed in the footsteps of similar initiatives in mathematics and engineering, and was in direct response to calls for curriculum reform in chemistry over many years (Gillespie and Humphreys, 1980; Bodner and Herron, 1980; ACS Educational Policies, 1989; A Nation at Risk, 1983; Carter and Brickhouse, 1989). In the original program announcement, NSF sought changes in the chemistry curriculum that would encourage the integration of the chemistry with related disciplines, enhance learning and appreciation of science, and affect all levels of undergraduate instruction. The NSF encouraged institutions to combine their efforts and expertise (NSF, 1999).

A total of five large projects were funded by the Systematic Chemistry Initiative. Each project involves a different consortium of academic institutions, with broad representation from two-year colleges, four-year liberal arts colleges, and comprehensive and research universities. While the five chemistry initiatives represent a variety of perspectives, they share the goal of improving the undergraduate educational experience by using new pedagogical strategies such as group work, hands-on learning, real-world problem solving, and technology enhanced learning as techniques for increasing student engagement in their own learning processes. The ChemConnections modules are a product of the combined efforts of two of these consortia, ChemLinks Coalition and ModularChem Consortium.[1] These two groups worked together to produce chemistry modules focused on real-world questions and using student-centered, active learning pedagogy.

Creating the Modules

The ChemConnections modules' focus on active learning is based on a deep understanding of how students learn most effectively. Cooperative learning, writing across the curriculum, and guided discovery-based learning have all been shown to increase higher-level thinking and problem solving as well as retention of material. The goal of the modules is to provide resources to instructors that will allow them to transform their classrooms into active, student-centered learning environments. Many faculty are interested in this student-centered pedagogical approach, but have found that developing activities that fit together well, tell a coherent story, and cover the appropriate chemistry content is very time-intensive. ChemConnections modules cover a broad

[1] The members of ChemLinks are Beloit College, Carleton College, College of Wooster, Colby Community College, Colorado Community College, Eastern Idaho Technical College, Edmonds Community College, Grinnell College, Hope College, Kalamazoo College, Knox College, Lawrence University, Malacester College, Montana Tech of the University of Montana, Pierce College, Rhodes College, Spelman College, Spokane Community College, St.Olaf College, University of Chicago, Washington University–St.Louis. The members of ModularChem are University of California–Berkeley, University of California–San Diego, California State University–Hayward, California State University–Los Angeles, Clark Atlanta University, Mills College, Morehouse College, Cañada College, Contra Costa College, Diablo Valley College, Laney College, Merritt College, Mesa College, Miramar College, Ohlone Community College, Vista College.

range of chemical topics and provide active learning activities that guide students through the scientific process.

The current paradigm for teaching recognizes that knowledge is constructed, discovered, and extended by students as they interact with their environment. The instructor is important in the learning process as she creates conditions which support and encourage students to construct meaning. For example, classroom research dating back as far as 1929 shows the benefits of cooperative learning over competitive or individualistic learning. Cooperative learning helps students achieve in the areas of long-term retention of material, intrinsic motivation, higher-level reasoning, academic and social support for all students, social development, and self-esteem. (Johnson, Johnson, & Smith, 1994)

It has also been shown that students learn best when they can build on past experience, relate what they are learning to things that are relevant to them, have direct "hands-on" experience, construct their own knowledge in collaboration with other students and faculty, and communicate their results effectively (Anthony et al., 1998). The modules, therefore, are based on a question from the student's surroundings such as: ***What should we do about global warming?***, and ***How can we purify our water?***

Finally, the integration of laboratory work into the context of problem solving is an important goal of the modules. The inquiry-based laboratory activities are designed to allow students to ***discover*** at least some of the chemical principles underlying the experiments. There are also opportunities for students to design experiments and communicate their results.

Module instructors have responded enthusiastically to the transformation of their classrooms into places of rich, active learning. In fact, many have said that they would never "go back" to a more traditionally structured classroom. Teaching with modules creates a lively, dynamic environment where learning, thinking, and doing science are of primary importance.

Chapter 2: What Is A Module?

Each ***Module*** centers on an interesting question that provides a context for understanding and applying specific chemistry concepts. The module question, and its accompanying story line, provide a contextual framework and springboard for guided inquiry and exploration. A Module consists of a series of ***Sessions*** of varying length. Each Session focuses on a smaller, more specific question, and it is through answering the Session questions that students gain the understanding necessary to answer the Module question. All Sessions contain ***Explorations***, which include in-class and out-of-class exercises and laboratory activities. The final Session of the Module is a ***Culminating Activity***, often project-based, for assessment of student learning of chemistry concepts and scientific thinking skills.

The questions, problems, and activities presented in the Modules are intended for use in the classroom and laboratory as substitutes to standard lectures and experiments. Students are encouraged to use a textbook in addition to the Modules as a resource. Module authors and instructors continue to discuss the best way to use the textbook. Usually instructors have the students read the relevant parts of the textbook as they work through the module. It is a good idea to put the textbook reading assignments in the Module syllabus. Some instructors have students work problems from the text in order to provide extra “practice” on some of the concepts.

Modules are divided into Sessions. Each Session is numbered roughly in the order of use. Each Exploration carries the Session number followed by a letter. For example, the first Exploration of the sixth Session is called Exploration 6A. An Exploration usually takes up part or all of a typical (1 hour) class period, though some Explorations can be longer or shorter. As with Session questions, Exploration questions form a coherent intellectual package for inquiry, and thus vary in length depending on context and content.

First Session: A Starting Point and “Buy In”

The first session of a module often begins with an exercise that allows students to assess their current understanding of the module topic. It may include a reading or video that demonstrates why the topic is important. It may include an exercise where students brainstorm in groups about what they will need to learn in order to be able answer the module question. In some modules, the first session contains significant chemistry content and skills building exercises. In others, it serves to introduce and set the context for the culminating activity.

The opening session may be structured as a guided discussion. The module may contain a reading and some questions based on the reading for students to complete before class. When students have completed the reading questions, they meet in class and break up into small groups to discuss their answers. Some examples of Session 1 activities are provided.

Examples of First Sessions

Build A Better CD Player: How Can You Get Blue Light From A Solid?
Session 1: How Can You Make a Solid Give Off Light?

Students read articles from the popular literature about the development of blue LED’s. They are given a set of discussion questions with the readings that help them understand why this is an important topic. They brainstorm either individually or in groups on applications of blue LED’s and blue diode lasers and on things they will need to learn to be able to answer the module question “***How can you get blue light from a solid***?”

Why Does The Ozone Hole Form In The Antarctic Spring?
Session 1: What Does the Public Know about Ozone?

Students are asked to write about one aspect of the ozone hole with which they are already familiar. Groups then gather to formulate questions about ozone they would like answered. Finally students are introduced to media claims about ozone. They are asked to continue thinking about these claims throughout the module so they can be prepared to respond to them in a formal report for the culminating activity.

Computer Chip Thermochemistry: How Can We Create an Integrated Circuit From Sand?
Session 1: How can we create an integrated circuit from sand?

The instructor guides students through a demonstration that shows the major components of a circuit and their functions. Students then look at integrated circuits either with a magnifying glass or on the CD-ROM that comes with the module and compare them to the circuits they looked at in the demonstration. Finally, students look at internet resources or simulations on their CD-ROM to learn what chemical reactions are used to build integrated circuits.

Earth, Wind and Fire: What Is Needed To Make an Effective Air-Bag System?
Session 1: What is needed to make an effective air-bag system?

Students watch a video showing what happens to dummies in car crashes and are asked to brainstorm requirements for an effective air-bag system. Students then develop a plan to study how air-bags are inflated by using resources from the virtual company Air-Bags 'R' Us provided on the CD-ROM.

Middle Sessions: The Inquiry

The middle sessions are the heart of the module. They contain student exercises, laboratories, and computer activities that enable students to understand the chemistry and develop the skills they need in order to answer the module question. The activities and laboratories are called ***Explorations.*** The structure of the middle sessions and the Explorations are where a lot of the flexibility is built into the module. Instructors may choose which Explorations fit their goals and resources.

Explorations

The goal of an Exploration is either to learn something that is needed to answer a Session question or to go beyond a Session question and consider ideas that are related to the Session. Students may be given readings and discussion questions that they work on individually and in small groups. A worksheet involving chemical calculations may be completed in small groups. Students may design and carry out a laboratory experiment, such as measuring how much carbon dioxide they exhale in a year. They may examine real atmospheric data from the Internet and work in pairs to answer a set of questions about the data. An Exploration is not of any one fixed length. It may be completed in-class or it may include an out-of-class component such as reading, writing, homework problems, or computer exercises. Instructors do not need to include all of the Explorations in a Session. The module's instructor's manual will indicate which Explorations are most critical for answering the Session question and which ones are less critical.

The title of an Exploration contains a question to be answered by the Exploration and a phrase indicating what chemistry content will be covered. The Exploration begins with a Creating the Context section, which is usually brief text that introduces and frames the Exploration question and connects it to the module story line. The Preparing for Inquiry section includes the background reading, activities, and/or questions that help students prepare on their own for the main activities in the Exploration. This may be pre-lab questions or pre-class homework or reading.

The Building Ideas section is the centerpiece for the guided inquiry that develops the core ideas in the Exploration. It can be done in many different ways and usually uses active and/or cooperative learning. Students concisely answer the Exploration question at the end of this section.

Most Explorations contain more practice problems or questions using the chemistry ideas and thinking skills that were developed in the Exploration. These problems may be used as either additional in-class work, as out-of-class homework, or as test questions.

At the end of each middle session is a section called ***Making the Link***. This section allows students to reflect on the chemistry they have learned in the context of the module question, and may ask students to examine the chemistry in other contexts. ***Making the Link*** contains the following parts.

Looking Back: What Have You Learned?

This is a list of chemistry concepts and thinking skills that were covered in the session.

Checking Your Progress

This includes text and/or activities that integrate the idea, connect to the Session Question and story line, assess progress on the culminating activity, and look ahead.

Thinking Further

This section may contain additional problems that could be used for homework or tests, or there may be additional readings supplied that the module authors found particularly interesting. Some modules have sections that allow students to apply their new knowledge and skills in a different context.

An Example of a Middle Session

As an example of a middle Session, we will examine Session 4 in Fats, ***How is Fat a Concentrated Energy Source?*** The Explorations are:

Exploration 4A	How do we get energy from what we eat?
Exploration 4B	How is energy stored in chemical bonds?
Making The Link	How is fat a concentrated energy source?

Session 4 begins with a reading on a solo trek to the North Pole that describes caloric intake and some text that gives background information and spells out the goals for the Session. In Exploration 4A, students carry out a simple calorimetry experiment on the combustion of nuts, cheese puffs, or other snack foods. There are discussion questions that ask students to think critically about the experiment (sources of error, precision, and accuracy). Exploration 4B has several parts. First, students complete a worksheet by computing enthalpy of reaction from bond energies. Then they convert their answers to Calories/gram and classify glucose, octane, stearic acid, and ethanol into fuel types. Finally, students are asked to use conversion techniques to answer questions about the calories in food. In the Making the Link section, students are asked to interpret data about rates of obesity in America. Students are also asked to determine which of a list of reactions is a good source of chemical energy and to determine if eating fats actually burns calories and thus makes us skinnier.

Final Session: Culminating Activity

The culminating activity allows the students to pull together what they have learned to answer the module question. There are usually several options for the culminating activity described in the individual instructor's manuals: students may write an essay, design a product, teach the topic to someone outside of the class, or participate in a debate or town meeting.

The culminating activity is the capstone for the module. The students are expected to bring together all of the chemistry they have learned and the skills they have developed in order to answer the module question. In each case, students are asked to think critically about their answer or their solution and defend it with sound scientific arguments. Often they are also asked to consider broader aspects of the question, such as social or economic factors.

The modules are designed to provide instructors with significant flexibility on the structure of the project. Instructors are encouraged to think creatively and to define a project that best fits their students and their resources. Some modules explicitly provide several options for the culminating activity. Some examples of Culminating Activities are described.

Examples of Culminating Activities

What Should We Do About Global Warming?

Students may write a paper individually, carry out a mock United Nations meeting, or hold a poster session where they address the question "What Should We Do About Global Warming?" Students are told to consider the trends in average global temperature, the role of human activity, the magnitude and nature of potential effects of global warming, and society's options in responding. They are told to consider the political, economic, and social ramifications of their answer, as well as the scientific data.

Computer Chip Thermochemistry: How Can We Create an Integrated Circuit from Sand?

There are two options provided where students answer the question "How do we use thermodynamics in the production of integrated circuits?" The first is a jig-saw discussion, where students first become experts on one step (plating, etching, etc.) then the experts come together in a group to plan out the best sequence of steps for making an integrated circuit. In the other option, students actually design and make a complex pattern on an aluminum substrate. This takes more time, but it is more hands-on than the discussion.

Why Does The Ozone Hole Form In The Antarctic Spring?

There are two options for the culminating activity. The first option asks students to use scientific data and reasoning to write a persuasive response to incorrect media claims. The second option challenges students to teach peers who are not in the class about ozone. This project encourages students to have a complete grasp of the information and articulate the information in a way that is understandable.

Chapter 3: How to Promote Student Learning

Active Learning and the Interactive Classroom

Students construct knowledge by thinking and giving explanations about what they are learning. Active learning involves building activities into the class that allow students to examine, analyze, evaluate, and apply course-related concepts. The information in this section is intended to help instructors get started with teaching modules. The references that are provided throughout give more in-depth background information and examples of this approach to student learning.

For any of the activities described here, the instructor should keep in mind some general "good practices." Each activity should have a beginning, a middle, and an end. To begin, the instructor may set the stage perhaps telling the students what material is to be covered during the class period or doing a demonstration. The students then continue with the activity planned for the day. At the end of class, the instructor facilitates a closure activity. This closure activity should review the goals accomplished during the class. This structure of setting the stage, doing the activity, and coming to closure should be applied to every class period.

The instructor should also vary the types of activities that are used. Learning effectiveness is lost if the students are doing only worksheets or only small group discussions.

Getting Started: Pair Learning

There are many ways that students can be asked to interact with each other, and having students work in pairs is a simple way to get started. Working with one other student does not require complex organizational schemes, and it allows students to both express their ideas and make sense of the ideas of their partner.

Think-pair-share

Think-pair-share is one of the easiest ways to get students actively involved in learning. The instructor asks students to "turn to their neighbor" to explain a demonstration, summarize key points of a lecture, complete a ConcepTest (for more information on ConcepTests see http://www.chem.wisc.edu/~concept or http://www.wcer.wisc.edu/nise/cl1/flag/cat/catframe.asp), or compare answers to a problem. These paired learning times are most effective when students are asked to take one minute to think individually about the problem at hand and write down answers or ideas. Students are then asked to take 2-3 minutes to discuss with a partner the answers or ideas. Finally, the pair reports to the whole class or to a small group (Millis & Cottell, 1998), (Kagan, 1992).

Think-pair-share can be used to complete and discuss the ConcepTest questions in the module: ***Build A Better CD Player: How Can You Get Blue Light From A Solid?*** In Exploration 2A, questions are asked about the electrical conductance of certain elements and the periodic trends of metals. Students are asked to vote individually on answers to the questions. If there is little class consensus, students are asked to turn to a partner and explain their reasoning, and then a second vote on the answers is taken.

Think-pair-share can be used along with the demonstration in Exploration 2A of the module: ***Earth, Fire, and Air What is Needed to Make an Effective Air-Bag System?*** The instructor shows a series of demonstrations that illustrate gas behavior. Students are asked to make a list of macroscopic properties, identify these properties as physical or chemical, and to come up with alternative ways to illustrate the properties. Students can answer these questions as they watch the demonstrations. They can share their answers with a partner, and then the class can form a list on the board of the chemical properties and ways of illustrating them.

Predict-observe-explain

Pairs can be used in combination with ***predict-observe-explain*** activities. A student can work with a partner to make predictions about a demonstration, and then the pair can discuss their observations after the demonstration is completed. An example of a demonstration that uses the predict-observe-explain sequence is found in the module ***Water Treatment: How Can We Purify Our Water?*** Exploration 1B includes a demonstration where students are asked to look at samples of water. They predict what substances are expected to be in the water such as suspended dirt, human or animal byproducts, oil or gasoline, algae or other contaminants. Then they look at water samples and confirm or add to their list of substances. Working with a partner, they explain why they would expect these substances to be present in the water.

In a laboratory setting partners can work together throughout the entire predict-observe-explain process in order to confirm each other's findings. An example of a laboratory activity that can use pairs and predict-observe-explain is found in the module: ***Computer Chip Thermochemistry: How Can We Create an Integrated Circuit From Sand?*** Exploration 4B contains a laboratory exercise that encourages students to formulate a general rule about what factors affect heat transfer and what factors affect temperature change. After making some initial observations about the change of temperature when salt is added to water, students are asked to predict two conditions for which heat transfer will be the same and two conditions for which temperature change will be the same. Students are then asked to test these predictions and explain how well their observations match their predictions. The students are also asked to explain why measuring temperature change is not sufficient information for determining enthalpy change. They are meant to discover that enthalpy relies on other factors, such as molar ratios of reactants. Working together on this activity allows students to check reasoning skills and understanding of the procedure with a partner.

Peer writing and editing

Peer writing and editing is an excellent approach for formal reports or writing assignments. One student explains to her partner what she is going to write. The partner listens, asks questions, and prepares an outline of the paper based on what was described. The roles are then reversed. Each student does the necessary research alone. Then partners meet to write the first paragraph of each composition together. The students complete their compositions on their own and proofread each other's compositions, making corrections and suggested revisions. After revisions are made, students proofread each other's papers again before the papers are turned in. (Johnson, Johnson, & Smith, 1994)

Peer editing can be used in Exploration 4C of the module: ***Would You Like Fries With That? The Fuss About Fat in Our Diet.*** This Exploration asks students to write a response to the question: "Do fats make you fat?" Peer editors could explain to each other the basic outline and arguments they will use in their response. They can each do further research and review of materials already presented in the module. The pairs would then have a second meeting to help each other write an introductory paragraph. After each student has his response written, the peer editor pair would meet a third time for correcting and revising. A final proof reading would be done before the response was turned in to the instructor.

Getting Students Up Front or At the Microphone in Class

Public speaking skills are important for all students, but students often feel very uncomfortable when asked to speak in class. The structures of the activities in the ChemConnections modules help to alleviate this anxiety. In general, students first share their ideas with a partner or in a small group. The small group environment feels much safer to students, and everyone gets a chance to participate as opposed to whole class discussion, where only a small number of students participate. The small group specifies a "reporter" at the beginning of the activity, so that students know in advance who will be called on. Because students are reporting out for their whole group, they have much more confidence about what they are saying. The reporter position is rotated so all students will have a chance to speak at some time.

Each group can be given an overhead transparency and pen to record their group responses. These transparencies aid in presenting material to the whole class by adding a visual presentation to the oral response. This approach takes less class time than writing on the chalkboard, because groups are making the product as they work in their group.

If there is insufficient time for all groups to report out, as in larger classes, the instructor should devise a way to call on groups randomly. Pulling seat numbers out of a hat or handing out playing cards and drawing a card from a deck are two possible approaches.

In larger classes and in rooms with poor acoustics, it can be difficult for everyone to hear what is being reported. In this situation, using a portable microphone can have an amazing effect. In large, anonymous lecture halls it is quite gratifying to watch students "find their voices."

There are several opportunities to get students in front of the class throughout the modules. The most obvious of these examples is in the module: ***Would You Like Fries With That? The Fuss About Fat in Our Diet.*** The culminating activity is a debate over the topic: ***Resolved: The FDA approval of olestra should be revoked***. For this final project, students present orally the pros and cons of this resolution. This encourages the students to express the results of research. This also requires the expression of critical thinking as students respond to opposing arguments.

The culminating activity for the module: ***Earth, Fire, and Air What Is Needed to Make an Effective Air-Bag System?*** also includes a presentation. In option C of this culminating activity, students make a poster explaining a new application of the air-bag technology they have been working with. These students present the poster in the same way as a professional poster would be presented at a conference. The students must defend their research and work to peers and instructors as they answer questions about their poster.

There are many other opportunities to get students up front. Any time that students are to share data with the class there is an opportunity to have them speak to the class. In the module: ***Computer Chip Thermochemistry How Can We Create an Integrated Circuit From Sand?*** Exploration 4D contains a laboratory exercise focusing on the enthalpy change of reactions. To answer the questions, students must compare data from the entire class. While there are a number of ways students can report their data, such as posting to a discussion board on the web or making photocopies and handing them out in class, a good option would be to ask students to present their results in front of the class. Students can also have a chance to be in front of class while sharing predictions about demonstrations or sharing answers to worksheet questions.

Cooperative Learning

Many of the activities, discussions, and laboratory activities in the ChemConnections modules involve pedagogical approaches that use the basics of cooperative learning. Cooperative learning is based on the belief that learning is an active and constructive process, and that students benefit from organizing their ideas and giving explanations, as well as listening to alternate or conflicting ideas. Cooperative learning incorporates respect for students of all backgrounds, and it stresses that all students can be successful academically.

Research shows that students benefit from cooperative learning in three major areas. These areas are academic achievement, positive relationships between students, and psychological health including self-esteem (Johnson, Johnson, & Smith, 1994).

Positive Group Interdependence and Individual Accountability

Research has shown that in order for cooperative learning to be effective, certain components must be promoted and structured into the learning activity. The two most important components are ***positive group interdependence*** and ***individual accountability***. In order to help students work successfully in groups, the instructor should also find ways to enable students to develop interpersonal and ***small group skills*** and allow time for ***group processing*** or reflection.

With ***positive interdependence***, students feel that they truly need and depend on one another to complete the task at hand. The students feel they are linked together and are concerned with one another's success. All of the students must see that by helping the other members of the group achieve goals, they help themselves.

Individual accountability means that students are ultimately held responsible for their own learning and for their contributions to the group process. This equality encourages a socially stable and emotionally safe working environment. To mandate this independent accountability, instructors must build some individual participation and objectives into the activity (Johnson, Johnson, & Holubec, 1994).

An example of an exercise that promotes positive interdependence and independent accountability can be found in the module: ***Would You Like Fries With That? The Fuss About Fat in Our Diet.*** The culminating activity is first described in Session 1. It is a debate which asks students to prepare and present two opposing sides to the topic: ***Resolve: FDA approval of olestra should be revoked***. Two parts of the assignment are meant to be done in a group and two independently. Every student must turn in a debate brief which provides the factual support for the debate presentation. This is followed by the debate presentation, where each group presents one argument for or against the resolution. The group then takes a quiz, where students work together to answer questions about the chemical properties of fat and olestra. As a final component, the students write individual essays in the form of an editorial focusing on the student's view about what choices should be made concerning olestra. The students depend on each other to complete the debate presentation and the quiz, a show of positive interdependence. They must each be responsible for the outcomes of the group work, which they demonstrate in their debate brief and editorial. This is a show of individual accountability.

Another type of activity that builds in positive interdependence and individual accountability is a ***jigsaw***. This type of activity is explained in more detail later, but an example is provided here to illustrate the components of cooperative learning. Session 6 in ***Water Treatment: How Can We Purify Our Water?*** asks students to develop a procedure to remove contaminants from a water supply. “Expert” groups meet first, with each expert group examining the chemistry of a different target ion: fluoride, iron, calcium, and magnesium. Then the students are shuffled into new groups, or “base” groups, that consist of one or more students from each of the expert groups. The base groups must complete the exercise by combining their expertise to generate a comprehensive clean-up plan for all the ions. There is positive interdependence because students must rely on each other in order to be able to understand the chemistry of ***all*** the ions. There is individual accountability because each student in the base group is responsible for being the "expert" on the chemistry of one of the ions.

Developing Small Group Skills

In order for cooperative groups to work well, it is important for group members to develop the skills necessary for working together successfully. It is problematic for instructors to assume that "This is college so I don't have to worry about student behavior." Students still need assistance in learning how to be good group citizens. They need to be aware of the importance of being good listeners and efficient team members.

One way to teach students about appropriate group behavior is through assigning roles. Roles may be rotated for different activities and can be dropped all together if you choose as the semester proceeds. Possible group job assignments include:

- **Task leader:** a task leader starts the group discussion and keeps the discussion moving toward the group objectives.
- **Time-keeper:** a student who makes sure that small tasks are not taking too long and reminds other group members of the time remaining.
- **Recorder:** a student who keeps minutes of the group meeting or produces a written version of the outcomes of the group discussion.
- **Reader:** a student who verbalizes any written information given to the group.
- **Materials manager:** a student who makes sure each group member has any materials necessary, and that the group receives any materials from the instructor.
- **Praiser:** a student who gives positive feedback to group members sharing good ideas. This student should exclaim periodically, "That's a great idea!"
- **Participation encourager:** a student who makes sure all group members are actively participating in the discussions.

By naming and describing the skills and behaviors used by each of these positions, validity is given to students expressing these behaviors. Also, this helps to eliminate unhelpful or anti-social behaviors. Students can increase positive interpersonal and group skills as they focus on them while working in cooperative groups (Millis & Cottell, 1998), (Kagan, 1992).

Group Processing and Reflection

To increase the effectiveness of continued group work, student assessment of group process is helpful. This assessment increases the effectiveness of students in subsequent group work by allowing them to recognize the actions that contribute to collaborative efforts and help reach group goals. This assessment may be as simple as asking students to discuss in their small groups what parts of an assignment the group members felt they did well and what parts they thought they could improve (Johnson, Johnson, & Holubec, 1994).

In larger group projects, students can be asked to rate their own contribution to the project, as well as those of other group members. Students are remarkably honest and accurate in their assessments.

The following form could be used to get the students to think about the group process.

EVALUATION

WITH THE MEMBERS OF YOUR GROUP, discuss and answer the following three questions.

1. List two new things you learned during the discussion.

2. List two things your group did well together.

3. List one thing your group could improve.

BY YOURSELF, check the response you most agree with.

OVERALL REACTIONS:

	lots	some	none
I learned	___	___	___
I participated	___	___	___
I enjoyed	___	___	___

GENERAL DYNAMICS:

	Yes	?	No
Completed agenda satisfactorily	___	___	___
Everyone participated	___	___	___
Leadership functions were distributed	___	___	___

ROLES: Check your own and circle those your observed in others.

Positive Roles		Negative Roles
Initiating	Gave/asked examples	Sidetrack to own area
Asked for information	Timekeeping	Interrupted others
Gave information	Encouraging	Monopolized discussion
Asked for reactions	Tension release	Put-down
Gave reactions	Useful pause	Irrelevant stories, etc.
Restated point	Summarized discussion	Apologizing
Asked for summary		Withdrawal
		Failure to listen

Grading

Instructors and students often have questions and concerns about how to grade cooperative efforts. Instructors should realize that groups that work together can be much like teams in the workforce and like these teams can be evaluated on the outcomes of the group. This means that all members of a team can earn the same grade. This does not mean that every grade should be given to the team as a whole. Many of the exercises in the modules are meant to be done individually and should be graded likewise.

Students may be apprehensive about grading if they have had previous bad experiences with group work, where positive interdependence and individual accountability were not built into the activity. If an explicit method of telling students how grades will be awarded is used, these difficulties can easily be overcome. When students are confident about how they will be graded, they will work toward achieving a high standard.

In exercises that stress positive group interdependence, the students are given the same grade as all of the other students in the group, so each student's work can raise or lower the grade of the entire group. This increases the likelihood that students will encourage each other to achieve a high standard in order to keep a high group grade. In the module, ***Water Treatment: How Can We Purify Our Water?***, Session 6 is a laboratory experiment where students work in groups to develop a water treatment plan. In the laboratory each student of the group works on optimizing one aspect of the treatment. At the end of the experiment they are asked to answer questions that require input from each member of the group. These answers are turned in by the group, and the entire group receives one grade on this part of the assignment.

Some instructors choose to increase individual accountability by grading individuals on related assignments while other instructors grade on the visible group participation. In the debate project in the module, ***Would You Like Fries With That? The Fuss about Fat in Our Diet***, described in the Positive Group Interdependence and Individual Accountability section, each student is responsible for turning in an individual debate brief. In addition, he is required to write an individual essay as part of his individual grade. This grading reinforces the responsibility of the student and increases the student's independent accountability.

One problem that has been encountered with teaching modules is known as the "paper tsunami." If students are actively participating in each class, they could turn something in at the end of each class period. Processing this much paper, even if it is not all carefully graded, quickly becomes untenable. Instructors need to decide ahead of time what assignments will be turned in.

Forming Groups

Groups are the core of cooperative learning. Group members depend on each other to reach objectives and improve their interpersonal skills. The group is the framework that allows easy transition into teaching and learning techniques such as think-pair-share, jigsaw, laboratory work, and group discussions.

Group Size

Many questions arise as to how many students should be in a group. There are many factors that affect the optimal size of the groups. One factor is the level of interpersonal skills used effectively by the students. A small group, 2-3 students, has few interpersonal interactions and is better for students who are beginning to build their skills. Large groups, those of 7-8 students, have many interactions and therefore do not work well until the students have built their skill to this level. Another factor is the time available; the less time available the smaller the group should be. A final factor is the number of material sets available. Laboratory equipment, for example, may limit the number of groups in the class.

Groups of four seem to be optimal for work that needs a variety of personal resources without overburdening students who have trouble with interpersonal skills. Groups of four are easy to structure when all four students sit around a table, or when a pair of students turns around to another pair in a lecture hall. Smaller groups work well for short in-class exercises that take a minimal level of interpersonal skills. Three students sitting in a row can work together as long as there is not a feeling of two against one. Pairs work well in any situation, and two pairs can work together to expand into groups of four (Millis & Cottell, 1998).

Assigning Students to Groups

The compositions of groups can be determined in any number of ways. A random assignment is most common for short-term groups. These can be assigned by counting off or by handing out cards that indicate what group the student is in. In a chemistry class, it is fun to give students cards with either an element's name, symbol, atomic number, or atomic mass. The students are then told to find their groups, with no explanation as to what the symbols or numbers on their cards mean. One group should end up with all of the characteristics of one element. This is a good icebreaker exercise in two ways. Students must cooperate to solve the "puzzle," and they must deal with the ambiguity of working with "data" and being asked to discover the algorithm.

For long term projects, students are usually assigned to groups by the instructor. Students benefit from working in groups that are heterogeneous with respect to student's backgrounds, abilities, experiences, and interests. Students in these situations gain insight into different ideas, explanations, problem solving techniques, and they engage in more frequent elaborate thinking in discussing material. These activities increase depth of understanding, quality of reasoning, and accuracy of long-term retention (Johnson, Johnson, and Smith, 1994).

When assigning groups based on the skills and abilities of the students, instructors should strive to ensure that minority students are not isolated and that best friends or worst enemies are not placed in the same group. An ability-based assignment could be formed by listing the class in the order of past performance in the class or related classes, then grouping the highest, lowest, and middle 2 students into one group, then repeating the process until all students are assigned. This type of assignment would help produce supportive groups for ***academically*** "at-risk" students. To create support groups for ***socially*** "at-risk" students, instructors can ask students to request three other students with whom they wish to work. This is normally accompanied by a promise to put students with at least one person from their list. Students who do not appear on very many lists should be placed with students who are particularly friendly and supportive (Kagan, 1992).

When students from different backgrounds with different personalities are forced to work together there may be some difficulties. Groups may become dysfunctional. In order to decrease this possibility, students should be told how often and for what duration the groups will be in place. This may put things in perspective and encourage students to work through their difficulties. If students voice sincere concerns about the ability of their group to work together effectively, an instructor may choose to intervene and help the group discuss the problem and possible solutions. The end of a module provides a natural break for rearranging student groups.

Duration of Group Work

The length of time that groups stay together depends on the activity at hand. The group should stay together to finish a project. If the group's goal is to discuss observations of a demonstration, they will only meet for a few minutes. If the purpose is to present a culminating activity, they should work together throughout an entire module.

Groups can be big or small, long term or short term, formal or informal, randomly chosen or instructor assigned. Group assignments influence the effectiveness of group work and therefore the effectiveness of class work as you proceed through a module.

Jigsaw

Jigsaw group work allows students to become experts in a subtopic and share this information with a small group. It is an effective learning technique because each student expert brings a piece of the "puzzle" back to their group, and the group must put all of the pieces together to achieve the learning objective (Vacca & Vacca, 1998).

Jigsaw discussions and laboratory exercises are built into several of the modules explicitly--if you like this learning strategy, many of the Explorations are adaptable to this approach. Students meet with an expert group in order to read materials, research further sources, discuss uncertainties, and prepare presentation strategies. Students reassemble into base groups composed of one student from each expert group. Each expert presents to the base group until all subtopics have been covered in each base group. All students are held responsible for the information presented on each subtopic.

A good example of jigsaw work can be found in the module: ***Why Does The Ozone Hole Form In The Antarctic Spring?*** Exploration 8A asks students to become experts on one of the three readings provided on the polar vortex, the inactive and active forms of chlorine, and surface reactions on clouds. After reading one article, students gather with a group who has read the same article. This expert group discusses the main ideas, answers the questions on the worksheet pertaining to the article they read, and develops ways to present these ideas to peers. Students then move to base groups of three students, one from each expert group. The base groups complete a group worksheet and combine their expertise to answer the question, "Why is Antarctic ozone chemistry unique?"

Activities that can be broken into three or more subtopics are good candidates for jigsaw work, even though they may not be specifically organized that way in the module. A demonstration that could be adapted as a jigsaw can be found in ***Computer Chip Thermochemistry: How Can We Create an Integrated Circuit from Sand?*** Exploration 3A includes a demonstration where students are asked to observe evidence of an enthalpy change in the making of a "hot pack" ($CuSO_4$ dissolved in water), the combining of $KClO_3$ and sugar, and the making of a "cold pack" (NH_4NO_3 dissolved in water). Students could be divided into expert groups to make observations on one of the reactions. These students could then get into groups with one member from each of the other expert groups and discuss similarities and differences in the three reactions.

Worksheets

Many of the Explorations in ChemConnections modules contain worksheets or work-sheet-type questions. In a traditional setting these questions would probably have been assigned as homework problems. In the modules, we encourage worksheets to be used to aid discussions and to guide group work. Well-designed worksheets have clear questions and directions. They should begin with easy questions and progress to more difficult ones, culminating in an open-ended question for groups that work at a faster pace. That way, the faster groups will remain engaged while waiting for the slower groups to finish. Another option is to assign students the questions to do on their own outside of class, and then have them share answers with a group or as part of a class discussion.

In the module: ***What Should We Do About Global Warming?,*** Session 4, Gathering and Working with Information, there are questions about the changes in concentrations of greenhouse gases over time. This set of questions has the directions " Answer the following questions. Be prepared to share your results with the rest of the class." These directions suggest a class or group discussion. This discussion can be structured by having the students complete the questions outside of class, then meet with their group to check answers. Once the group has come to a consensus, they can report their findings by having one student from each group write the answers on the chalkboard or announce the answers to the entire class.

In the module: ***Water Treatment: How Can We Purify Our Water?,*** Exploration 3C, Developing Ideas, the students are asked questions about polarity, solubility, and intermolecular forces. The worksheet questions are specifically designed to be used in groups of three or four. The students can work together on the questions checking to make sure group members understand each classification. By teaching each other how to make this type of decision, the students will better understand how to do the classifications. Time can be set aside during class to work in groups on this worksheet, or groups can be asked to meet outside of class time.

Group Discussions

Discussions can be structured in a number of ways. To make the discussions work well, it is important that the instructions and objectives are explained well. These instructions should include individual goals to be accomplished before the group meets, group goals, time limits for group work, ordered discussion questions, and a description of how the results of the small group discussion will be shared with the entire class. In the ChemConnections modules, small groups are used to tackle questions resulting from demonstrations, to brainstorm, and to view videos to catch all of the important points.

By working in a small group to make observations or answer questions about a demonstration, students benefit from hearing the viewpoint of their colleagues. They can tackle questions in a more organized manner, producing quicker answers, or explore ideas more in depth, producing ideas that are more creative.

An example of using a group discussion to analyze a demonstration can be found in the module: Earth***, Fire, and Air: What Is Needed To Make an Effective Air-Bag System?*** Exploration 1D begins with a demonstration of two ways to inflate an air-bag: releasing gas from a storage container or generating gas by a chemical reaction. The instructor asks students to write down the similarities and differences that they observe. Then students get into groups to compare their lists and answer questions about the similarities and differences of the two methods. The students are asked to discuss situations where one inflation process would be better than the other. These ideas are recorded for the groups to save and use later in the module.

Brainstorming allows students to access what they already know about a certain subject or topic and lets them push this knowledge into a second arena of questions that they want answered. It also allows students to consider their misconceptions and to begin constructing an alternative explanation that is more consistent with good science. Brainstorming is often used in the business workplace to find possible solutions to problems and can be used in a similar fashion when teaching ChemConnection modules. To generate a brainstorm list, a problem is posed to a group. The recorder writes all the ideas that are offered, not making judgements about the quality of an idea. This generates a list of possible answers or solutions to problems that can be further explored to determine the best solutions.

An example of group brainstorming can be found in the module ***Build a Better CD Player; How Can You Get Blue Light From A Solid?*** In Session 1 Storyline, students are asked to read articles about the current research in getting blue light from solids. The students are then asked to work together to brainstorm a list of possible applications of blue light and the problems and benefits of these ideas. One member from each group can report this list by putting it on the board. This class list can be used to begin an instructor led discussion about the importance of this technology and why the students will be learning about it.

Videos are usually information rich and move at a quick pace. Viewing a video one time is usually not adequate to catch and understand all of the important points. In order to save time, instead of watching the video four times, four people can watch the video once, watching for specific ideas as assigned by the instructor. These four people can then share the information they learned. This is similar to the jigsaw exercises as described earlier.

An information rich video is used in the module: ***What Should We do about Global Warming?*** A Sierra Club video is used in Session1 to expose students to one side of the global warming debate. The video is entitled "The Climate Report." Each student in a group is asked to look for data in one of the following four areas: 1) the increase in temperature due to the increase in CO_2 levels, 2) the rise in sea levels, 3) the redistribution of disease breakout, and 4) the responses that humans should have to the threat of global warming. When students have viewed the video, group members share the information collected from the video. They compare what they learned from the video with information from articles with different points of view.

Outside the Classroom

At some institutions, students can be expected to meet with their groups out of class. However, even at small colleges, it is not uncommon for a group of 3-4 students to find it impossible to find one hour in the week when they are all free. The creation of the electronic discussion board has provided an outstanding solution to this problem. With a discussion board, students do not need to all be available at the same time (asynchronous communication). They may access the discussion board via the World Wide Web, so they do not have to be in a specific location to participate. Private or locked discussion areas can be created so that a group may work privately without other students "looking over their shoulders."

Instructors should check with their computer center to find out if their institution has adopted a specific discussion package. A free discussion board that has been used by some institutions using ChemConnections modules is called ***Discus***. Information about ***Discus*** can be found at http://www.chem.hope.edu/discus/.

Writing to Learn

Writing is a powerful way to get students to reflect on their own understanding. It helps them pull together what they are learning and shape it into a meaningful picture. Writing also helps instructors assess student progress.

Students realize the importance of writing skills, but, according to early evaluation results, they do not feel that their writing improves during a modular chemistry course. If a goal of the instructor is to improve student writing, then the instructor must structure activities into the class that focus on this goal. Many instructors at module test sites report that they do not feel prepared to teach writing skills. Some ideas to begin with are requiring students to turn in rough drafts, developing strategies for peer review of drafts, or allowing for rewrites on final drafts. Explanations of these ideas and additional possibilities can be found in John Bean's book titled Engaging Ideas (1996). This book is a good resource for instructors who wish to improve their students' writing skills.

Writing to Assess Prior Knowledge

For instructors, a short writing assignment at the beginning of a class, lesson, or topic can ensure the upcoming lesson(s) will effectively reach the students. An assessment of prior knowledge can focus students' attention on the most important material to be studied, providing a preview of what is to come and a review of what they already know about the topic (Angelo & Cross, 1993).

These writing assignments can be in the form of questionnaires with short answer or multiple choice questions. Many of the ChemConnections Modules have developing ideas sections that ask students to assess their prior knowledge before gathering data. This type of assessment question can be found in the module: ***Water Treatment: How Can We Purify Our Water?*** In Exploration 2A, students are asked to devise an analytical plan to determine how to separate candies, how to determine if athletes are using performance-enhancing drugs, or how to separate soil of different sized particles. The students later discuss and determine the steps required in forming an analytical technique. The answers to these questions help the instructor understand the level of reasoning skills the students have. The exercise helps students practice the skills they already have.

Minute Papers

Short half sheet responses or ***minute papers*** can be used to assess strong points and muddy points after a lesson. Students are asked to write the main themes of the lecture, the things they do not understand, or a brief answer to a question about the lecture. This technique is quick and easy, taking only the last two or three minutes of class. A manageable amount of timely and useful feedback is provided to the instructor. When students are asked to write down main points and areas that are unclear to them, they are forced to reflect on the lesson and their understanding of it (Angelo & Cross, 1993).

In the ChemConnections modules, there are structured writing activities that are called 5-Minute Writing Questions. These have the same goals as a minute paper, but ask for more information and feedback. A 5-Minute Writing Questions exercise can be found in the module: ***How Can You Get Blue Light From A Solid?*** After a lesson on conductivity and structures (Session 3), questions are asked about the conductivity of the allotropes of tin and about what chemistry was learned in the session.

The module lessons can also be followed with less structured questions such as: " What were the main points of today's activity?" and "What questions do you still have about the topic we just finished?" These can be applied to any of the module Sessions.

There are some things to keep in mind when using minute papers. Instructors wishing to respond to points that were unclear to students find that it takes more time than expected. Explanations of a previous lesson often lead to further questions on that lesson. When instructors do not have time to explain every unclear point, they should let students know that a few points that were unclear to a number of students will be covered.

Culminating Activities

The culminating activities provide an opportunity for synthesis of all the material that was covered in a module. These assignments are used by the instructor to evaluate the student's ability to integrate the concepts in the module. The types of activities range from written responses to media claims, to class debates, to formal reports or poster presentations.

In the module: ***Why Does the Ozone Hole Form In the Antarctic Spring?***, the students respond to the following three media claims in the culminating activity: 1) CFC's are the dominant players in the Antarctic ozone depletion, 2) the ozone hole has been around for a long time and was first noted in 1956 by a British study, and 3) all the important Antarctic ozone destruction chemistry occurs in the gas phase and in the sunlight. Students are given a checklist of important aspects of the argument and supporting evidence they should include while writing to refute the media claims. They are asked to turn in a number of rough drafts so that the instructor can help guide revisions.

In the module: ***Computer Chip Thermochemistry: How Can We Create an Integrated Circuit From Sand?***, Project 9B is a two part laboratory exercise where students first make predictions about a series of plating and etching reactions. They then use their experiment outcomes to develop and justify a sequence of chemical reactions that will mimic the production of a transistor and to test their proposed sequence on an aluminum substrate. Each student is then asked to write a formal report that includes an introduction to the chosen process, an analysis of the steps of the sequence, and a defense in support of the process used, along with their product.

In the module: ***Water Treatment: How Can We Purify Our Water?***, students are asked to present a poster in Session 9, Project 1. In this poster, the students describe the scheme they used to measure and remove the contaminant in a sample they treated in an earlier laboratory session. In addition to writing about the experiments and results, students have a chance to use their other language art skills as they graphically represent data in tables and describe their results to peers and instructors.

Laboratory Exercises

Many chemistry courses are accompanied by a separate laboratory course. In ChemConnections modules, the laboratory exercises are integral to the module and to the success of student learning. These exercises promote learning by incorporating kinesthetic and visual learning activities, as well as sense-making activities, into the learning environment. ChemConnections laboratory activities are designed to promote critical thinking skills. Students use prior knowledge as they predict possible outcomes of an experiment. They increase their observation skills as they are asked to record their observations. Students are encouraged to incorporate the new information so that they can use it in a variety of situations. The exercises can be separated into two main categories, ***guided or structured inquiry exercises***, sometimes called "guided discovery labs", and ***open-ended inquiry exercises***.

Guided Inquiry

In guided inquiry, students begin by observing something interesting or generating some data. With some help from guiding questions, they must then "discover" the chemical principles behind their observations. In these guided inquiries, the instructor often has a very specific outcome in mind.

An excellent example of a guided inquiry exercise can be found in the module: ***Earth, Fire, and Air: What Is Needed to Make an Effective Air-Bag System?*** Exploration 4B guides students to "discover" Avogadro's hypothesis. This laboratory exercise poses a question about the weight of equal volumes of different types of gases. Students use a 1 gallon milk jug as a weighing container, which is then filled with gas from a compressed gas tank. The experiment is repeated with different gases to find the mass of equal volumes of different gases. They explain the relationship between masses of different gases in the same volume. Using their data and the ideal gas law, they determine how many atoms and how many molecules are in each sample. This data analysis allows students to formulate the relation of volume to number of particles, as is Avogadro's hypothesis.

Open-ended Inquiries

In open-ended inquiries, the process of doing science is stressed. Students may begin by proposing a question they would like to investigate, designing experiments, collecting data, analyzing the data, and defending their results. In these open-ended inquiries, the instructor does not necessarily have a specific outcome in mind, but rather sets up a situation where students can be creative while learning science, and develop their skills at experimental design and data analysis.

A good example of an open-ended inquiry exercise can be found in the module: ***Why Does The Ozone Hole Form In The Antarctic Spring?*** Exploration 4B encourages students to work in groups to design experiments that will help them find out how well some materials protect against UV radiation. The students, not the instructor, formulate the specific questions they are trying to answer. They are given a list of materials and asked to design an experiment to answer the question, "Which materials block us from UV light?" In the laboratory, the students perform their experiments to collect data. After analyzing the data, the students meet with the instructor to explain and defend their results.

It should be noted that many students really thrive and are excited by these open-ended activities, but that a few students are vaguely terrified by not having a set of instructions. For the success of an open-ended activity, it is important to have the students work in groups and to spell out carefully how students will be evaluated.

Using the Computer

ChemConnections modules provide students the opportunity to use computers to graph data, model kinetic and molecular situations, and gain more information using the World Wide Web. Students learn most effectively from computer exercises when they are guided into looking for specific information. This can be done by having them answer questions assigned before they begin working or by holding discussions as they work. Instructors must be very conscious of the fact that very little learning occurs if students are just told to "go and look" at something on the CD-ROM or on a web site.

Graphing

Several modules provide opportunities for students to examine and interpret real data. Students may be asked to graph the data using the appropriate spreadsheet or graphing package that is available locally. One such data set can be found on the CD-ROM in the section accompanying the module: ***What Should We Do About Global Warming?*** The instructor may choose to use the graphs that are provided or may provide students with a link to a web site with the data and ask students to graph it themselves. The data shows the long-term trends in the levels of atmospheric CO_2, CH_4, and N_2O. These graphs are meant to be used along with Session 4, which focuses on the interpretation of data in the form of graphs. Students are guided through the interpretation by being asked questions about rates of change and changes in rates of change. They are finally asked to make predictions about future levels of these atmospheric gases. Students get to experience real data, which is often noisy and shows fluctuations.

Modeling

Computers can use simple models to show how reactions take place as we see in the module: ***Why Does the Ozone Hole Form in the Antarctic Spring?*** The computer animated models of how ozone is formed and depleted can give students a mental picture of how the reaction takes place and the importance of stoichiometry in the reaction. The exercise is guided by periodic class discussions to ensure the entire class is able to follow the instructions and that they are staying on-task. Instructors can check student learning in this exercise by having them complete simple stoichiometry problems.

Computers can also mimic real life as students enter a virtual office in the module: ***Earth, Fire, and Air: What Is Needed To Make an Effective Air-Bag System?*** This virtual office, found on the Module Web Tools CD, comes with a virtual boss and work assignments that can be completed on-line. Many of the resources that students need for problem solving are found within the virtual office library or laboratory. Within this virtual office, students are asked to view video clips of air-bags being inflated, to use the virtual laboratory to determine how much sodium azide is needed to inflate an air-bag to a desired volume, and to research hazards in potential materials to be used. After these items have been found in the virtual office, students report to a virtual boss who gives immediate feedback on the outcomes of the student's work.

World Wide Web

The World Wide Web has a treasure chest of information available to anyone who knows how to find it. In the ChemConnections modules, there are activities that can introduce students to the scientific resources available. A good example of this is the guided web activity found in the module: ***Why Does the Ozone Hole Form In the Antarctic Spring?*** The activity introduces students to the wide range of resources available on the web about issues related to Antarctic ozone hole. Students have hot links to specific resources from NASA, Dobson ozone measurements, and TOMS satellite measurements of column ozone. As the students browse through these resources, they are asked questions that encourage them to make complete observations before drawing conclusions.

Discussion Boards

Electronic discussion boards are now available at many institutions. These can be used as an arena for class members to give opinions about class discussions or laboratories. Students and faculty can share information about valuable resources with the entire class. Results and data from laboratories can be shared on these discussion boards. Individual chat rooms or locked discussion areas can be set aside for small groups to work in before reporting to the instructor or entire class. Instructors should contact the computer center at their institution to find out what discussion board resources are available.

Chapter 4: What to Expect as an Instructor

Getting Ready

The lead time necessary for teaching a ChemConnections module is greater than that needed for a new course taught in a more traditional manner. Lead time is needed for:

- getting other instructors, support staff, and teaching assistants on-board,
- adapting the module for your institution and writing a module syllabus,
- obtaining materials for new laboratory activities, and
- preparing campus computing facilities to support new computer exercises.

It should be noted, however, that much of this work is needed in order to get the module up and running for the first time; the time required for subsequent preparations is greatly reduced.

Getting Staff On-Board

Evaluation interviews at ChemConnections adapter sites have found that laboratory instructors and teaching assistants who do not support this student-centered, active learning approach can undermine its effectiveness and contribute to negative attitudes among students. The most effective way to ensure successful implementation of the modules is to bring all members of the teaching team on board at an early stage in planning, and to bring as many of them as is practical to a ChemConnections workshop. Ideally, the workshop should be attended by all of the faculty who will be teaching modules and by key support staff, such as laboratory instructors or head teaching assistants. At larger institutions, it will not be possible to have every instructor and teaching assistant attend a workshop, so in-house preparation will be necessary. For more information about workshops see the ModularChem Consortium homepage at: http://mc2.cchem.berkeley.edu.

There will be more information forthcoming about teaching assistant training by the year 2000. It is not surprising that the attitudes of instructors and teaching assistants influence the attitudes of the students taking the course. Most teaching assistants have limited general teaching experience and lack the skills and knowledge required to teach interactively or to help students "discover" chemical concepts. They therefore fall back on the methods by which they themselves were taught. They may feel undermined when the very methods by which they have succeeded are implicitly defined as in need of improvement. If it is possible, undergraduate teaching assistants who have taken modular courses should be used in order to increase acceptance of the methods of modular teaching and learning. Helping teaching assistants develop the skills needed to teach interactively by modeling and practicing them in pre-course teaching assistant workshops is beneficial. Working collegially with the teaching assistants is also essential. They should be included in weekly planning meetings and all trouble-shooting sessions; their feedback should be listened to and acted upon, and their ideas and concerns treated respectfully. Interviews with teaching assistants have found that such respect is important to them and to ensuring that they support the approach.

The same is true for laboratory instructors and staff who service the modular laboratories. The new approach has to be marketed and modeled to co-workers. Issues should be addressed collectively – both by pre-planning and as they arise. Where co-workers announce at an early stage that they have serious reservations about the introduction of modules, it may be better to request an alternative assignment for them. The evaluators have found that opposition sustained throughout the semester or term seriously jeopardizes the effectiveness of the modular course among students who are taught by a contrary-minded instructor or teaching assistant.

Adapting the Module

Each institution is implementing modular learning into a unique set of circumstances. Therefore, each instructor must adapt modules to the setting in which he will be teaching. This includes deciding how much time is to be spent on the module, and whether laboratory exercises will be done in a separate course or as an in-class demonstration or hands-on activity.

Adapting a module also depends on the instructor's goals for the course. A good way for instructors to articulate goals for student learning is to use an instrument like the Teaching Goals Inventory, found in Angelo and Cross' Classroom Assessment Techniques (1996). When an instructor has articulated these goals, she can compare them to the "What Have You Learned" section located under Looking Back at the end of each Exploration. The Instructor then chooses what Explorations to do based on how well the Exploration matches with the teaching goals.

Modules have been implemented successfully in a variety of institutions. The two major logistical variables are class size and class schedule. At smaller institutions, where the instructor is responsible for both the “lecture” and laboratory components of the course, students may move relatively easily between in-class and in-lab activities. In fact, the distinction between lecture and lab is quickly blurred. At Beloit College, for example, the introductory course is now scheduled for three two-hour blocks per week, with no distinction between the lecture portion and the laboratory portion of the class. In this type of setting, almost all activities may be hands-on, with little need for demonstrations or lengthy lectures.

At slightly larger institutions, where laboratory time and lecture are scheduled separately and class size may be around 100 students, the lecture and laboratory instructors must work together to coordinate the module schedule. Because the class size is still relatively small, small group discussions and, to a limited extent, whole class discussions still work. Students may carry out some of the activities right in the lecture hall, depending on the materials that are required. If the materials are too hazardous, the instructor may do the activity as a demonstration or schedule it for the students to do in the laboratory. Because many of the activities require sharing of data and small group or whole class discussion, laboratory instructors must be prepared to take an active role in guiding the laboratory period.

At larger institutions with classes much larger than 100 students, techniques must be developed to facilitate small group work in a large lecture hall. One approach is to have students sit with their laboratory section in the lecture hall and to have the laboratory teaching assistants present to help. In this setting, the class period may begin with a demonstration or computer animation, with students being asked to ***predict-observe-explain*** with a partner or a small group. Again, laboratory instructors or teaching assistants must be well prepared for the modular laboratory exercises.

The individual module instructor’s manual will contain suggestions for different ways to adapt the module for different settings. When preparing to teach a module for the first time, the process of making decisions about which Explorations will be included and how the activities will carried out is probably the most difficult and time-consuming part of the planning process.

Gathering Materials

With new hands-on activities, instructors should give themselves adequate time to gather materials for demonstrations, in-class explorations, and laboratory exercises. The individual instructor's manuals have lists of materials needed for each of the exercises. Undoubtedly, instructors will want to adapt laboratory exercises to their local circumstances. Some of the module developers and testers have had great success hiring undergraduate students to test the exercises and computer examples the summer before the modules were to be implemented.

Computer Needs

Some of the modules have a large computer component. Students may be asked to complete exercises or view video clips from a companion CD-ROM, or they may be asked to find information on the World Wide Web, possibly using the links on the Wiley web page (www.wiley.com) to get to the same information on the CD-ROM. The implementation of these computer exercises must be dealt with in a local fashion, because each campus computing system has its own idiosyncrasies. Many faculty implementing the modules report that it was important to contact the managers of the school-wide computer system in order to make sure that students could easily access the information they needed. This must be done with appropriate lead time. For World Wide Web exercises that use external web sites, some instructors prefer to move information to a local server, so they can assure student access to it without having to rely on other servers. Again, it is important to have someone such as an undergraduate student test all computer exercises ahead of time.

The instructor should also decide in advance how to deal with difficulties that arise with students' personal computers. Support staff on campus may be of technical assistance and additional help may be found on the CD-ROM under the link "A more detailed page of frequently asked questions" or through Wiley's technical support at www.wiley.com/techsupport.

Finally, instructors must pay careful attention to ensuring that students are instructed on ***how to learn*** from multimedia materials. Feedback from research in general and from adapter sites indicates that simply telling students to go look at something on a CD-ROM or web site does not lead to much student learning. The use of multimedia materials must be carefully guided with well thought out questions as described in the section in this manual titled How To Implement Student Learning, Using the Computer.

The Culture of the Last Minute

Feedback from module testers has been a reminder that we live in a culture of "the last minute." Preparing a lecture or a student assignment the night before or the morning it is to be delivered is not unusual. Taking this approach when teaching modules may be highly problematic. Moving away from a fully lecture-oriented approach does not mean less work for the instructor. Instead of spending time developing a finely-crafted lecture, the instructor must implement a finely-crafted student exercise that will lead to student engagement and learning. The ChemConnection modules contain such exercises, and it is the instructor's job to ensure that the students receive clear instructions about how to complete the exercise and about what they are expected to learn.

Jumping In

Modules help to restructure the classroom environment. Along with this change, instructors need to adapt to a way of teaching that helps students become comfortable with these changes. Interview data from ChemConnections adapter sites has raised some student and instructor concerns.

Student Concerns

Using Resources In New Ways

In moving away from a traditional textbook, the overall picture is sometimes lost to many students. Early assessments of ChemConnections modules report that some students have difficulty seeing how the Explorations tie together. Students describe this problem as a lack of fit between elements of the class. Students grope for connections between class activities, laboratory activities, reading assignments, computer work, and, above all, graded assignments. The evaluators have found problems of incoherence in both modular and traditional classes. However, in traditional classes the students tend to use the order of chapters in their text as a framework where none other is offered. This feedback continues to emphasize the need for instructors to provide a modular syllabus for students which includes daily assignments, laboratory activities, and due dates.

Some modular class students have reported problems using their text book as only a resource, instead of marching through the text in a linear fashion. They may assume that the text represents the only way in which the topics it contains can be related to each other. The multiple source nature of the modules can help the students learn a more sophisticated way of approaching source and reference materials. However, the modular teacher must make a special effort to place the elements of the whole course into a conceptual and activity framework that allows the student to structure knowledge coherently. Instructors, therefore, need to remind students daily of the story line and of the overarching question that is driving the individual inquiries in class and in the laboratory. These frequent verbal reminders are called sign-posts. Each class period and each Session must have closure, especially when the class is working in small groups. It is important that the students come back to a focal point and confirm that what they are doing in their groups is on track.

In summary, students need sign-posts to remind them:

- where the class finished in the prior meeting,
- where the class is headed in the current meeting,
- how the ideas discussed in the current class connect with prior work in class and in the laboratory, and with other areas of chemistry or other disciplines, and
- what the objectives of the forthcoming assignments are and when they are due.

The latter is especially important because students will otherwise assume they should prepare for tests in ways that have previously produced good grades. They need to understand what is required of them and how it differs from previous experience.

Students report greater learning gains from their tests and assignments when faculty or teaching assistants take time to go over completed tests, explaining areas of common difficulty.

Setting Expectations

What the instructor says to the students about this “new” approach will strongly influence student attitudes. Remember, the course is really only “new” to the instructor. Many students are doing more active, small group work in high school, and they move relatively comfortably into using this aspect of the modules. Moreover, the students in first semester college courses do not know what to expect of college chemistry. Telling students that “we’re going to do something really different” will serve to heighten anxieties and make the students feel like guinea pigs.

Students quickly pick up the models of teaching and learning that dominate in any college or university department. Where these methods reinforce the patterns that students have already learned–for example, focusing on the grade rather than what is learned–it is harder to get them to reconsider their learning methods. For this reason, it is better, whenever possible, to introduce a new type of pedagogy to entering freshman classes. It is harder to "sell" any form of active learning to students whose expectations have been set. It has been found, however, that even established student expectations can be changed over the course of a two-semester course, and can be changed when groups of colleagues in a department agree to adopt an active learning or modular approach for all of their entry-level courses. In both cases, new learning traditions become perceived by students as a normal and productive way to learn. Embedding single modules into an otherwise traditional class, unless done as a capstone activity, can be more difficult than switching to a completely modular course, as the shift in methods has to be explained and the transitions may feel awkward.

Preparing for Future Challenges

Some students express concerns about whether they are getting “enough chemistry” from the modules. Using sign-posts to periodically review what chemical concepts have been covered can help. These students can be reassured that the modular approach and the follow-the-textbook approach lead to comparable scores on the standardized American Chemical Society general chemistry exam and to better performance on conceptual tests by students in modular courses. The evaluators have found that many premed students often express anxiety about the preparation offered by modules for the MCAT examinations, without having any direct knowledge of the nature of the recent reformatting of MCAT examination questions. These students need to know that the MCAT examination contains many problems that ask students to apply their knowledge, just as they do in Module Explorations. For example, in the physical sciences section of the MCAT, students are given a reading passage and asked to answer a series of questions that apply their science knowledge to the reading. Recent MCAT study guides contain readings and questions about water quality (***Water Treatment***), the relationship between light and energy (***Global Warming, Blue Light*** and others), and fluorescent lamps (***Blue Light***). (MCAT Practice Test II, III, 1993, 1995) Helping students realize that they are indeed becoming prepared for future academic challenges is important for engaging them in the modular approach.

Setting the Pace

As with many traditionally taught chemistry classes, students are concerned with the pace and volume of class work. In a traditional introductory course, the reasoning behind covering a multitude of topics is that students need a base of information to use in subsequent classes. However, students have difficulty seeing connections between the topics and rarely get the chance to reflect on and integrate what they are learning. Modules help students learn how to solve problems and work with information, thus helping them to deal with new information when it is introduced to them in an introductory or upper level course.

Many of the concerns voiced by students can be alleviated by instructor explanations of why this is an effective way to learn and reassurances about the quality of their preparation for future classes and examinations, regular sign-posting, teaching assistant training, and the use of all-modular offerings early in the chemistry sequence. Many student concerns decrease or disappear over time as students adjust to the new teaching and learning style. The Assessment of Student Learning Gains instrument (Appendix A) shows that students report more gains and higher approval of modular learning after a year of a modular class than students taking one semester of a modular class.

Instructor Concerns

Some instructors fear that turning class time over to students for small group discussions may cause the instructor to "lose control" of the class. By giving students the power to express themselves in small groups, the quiet order of a lecture hall is certainly lost. However, this does not mean that the teacher has lost control. Establishing a quiet sign or setting a specified time to turn attention to the front of the class may be helpful in maintaining order. Group work seems messy and non-linear to instructors who are used to presenting traditional linear outlined lectures. Instructors should remember that student learning is usually nonlinear. Students enter the classroom with different prior knowledge and experiences, and their path to the "finish line" usually involves a number of starts, stops, and sidetracks (Herron, 1996).

Students learn in different ways, some by listening to an instructor, some by seeing a demonstration, and others by manipulating the world around them. However, research shows that successful students engage in activities that allow them to reflect on their own understanding and practice giving explanations about what they are learning. Group work can offer a positive learning experience to students with a variety of preferred learning styles. Although it is important to realize that students often thrive in a nonlinear learning environment, some students do not know how to handle the ambiguity inherent in open-ended activities. Many students feel that the chemistry in a textbook is absolute truth and fail to think about it as a model for representing the world or as a source of questions. Again, reassurance from the instructor that becoming good problem solvers is hard work and some initial discomfort might be expected eases student concerns.

Grading

When preparing to teach a module, instructors must decide which activities will be turned in and graded, and who will do the grading. If student graders or teaching assistants are asked to do a considerable amount of grading, it is important that these graders know what the goals of the assignment are and how grading should reflect these goals. With the multitude of in-class exercises, worksheets, and observations that students make, it is easy for instructors to find themselves in a "paper tsunami" if they ask for all work to be turned in. If no work is turned in, students lose the sense of accountability and instructors have no way to track student performance. Instructors must find a balance of how much work is to be turned in.

Instructors must also make sure that their methods of assessing student learning are consistent with their goals for the course. For example, if having students work together cooperatively is important, then the instructor should not grade on a curve, because a curve pits students against one another. If the mastery of basic chemistry content is desired, then tests and other grading tools should assess basic content. However, if students are expected to develop higher order thinking skills, then it is not adequate to assess only their knowledge of basic chemistry content. Many of the exercises within the modules are designed to assess higher order thinking skills. If the instructor grades the result of such an Exploration, then it may not be necessary to test these thinking skills again on an exam. For example, the students' ability to design an experiment is tested in the module: ***Why Does the Ozone Hole Form In the Antarctic Spring?*** In Exploration 4B students are asked to work in groups to design an experiment that will answer a question about how well sunscreen and different types of glass will protect against solar UV radiation. Evaluation of the students' proposals and analysis serves as a measure of students' planning and reasoning skills.

Next Time

Looking back at the first run of a modular class, instructors should realize that the implementation of every new class has its glitches. Instructors should not expect perfection the first time through. Instructors should look at what worked and what did not in order to improve the class the next time it is taught. Valuable feedback leading to adjustments can be gathered from other instructors, support staff, teaching assistants, and the students themselves. The students give very useful feedback on what strategies helped them learn and what strategies were ineffective. An example of a useful evaluation tool that gathers student feedback, ***Assessment of Student Learning Gains***, is now available as an on-line instrument. A sample format is included in Appendix A. This assessment and additional valuable evaluation tools, including faculty and teaching assistant interviews, can be found at http://newtraditions.chem.wisc.edu/Flag/nt-flag.htm and http://www.wcer.wisc.edu/cl1/flag/flaghome.asp.

Some Final Thoughts

The process that module authors followed in developing the ChemConnections modules is much like the process new ChemConnections instructors must follow when adapting and teaching with modules. The primary question in the first year of the reform project was “What’s a module?” And the initial answer was “I don’t know, let’s write some and see.” New adapters of ChemConnections materials must also grapple with the question “What’s a module?” Hopefully, this guide provides some answers and insight, but it is not a substitute for the intense learning that occurs the first time that an instructor teaches a module.

ChemConnections modules are not intended to be simply another product from another curriculum reform project. Just as ChemConnections modules focus on the content ***and*** process of science, teaching with modules brings the instructor into the ***process of curriculum change***. With each new modular course, the reform process is nurtured and sustained, and a growing group of chemistry students is reached.

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Appendix A: Assessment of Student Learning Gains

For use as a supplement to, or replacement of, institutional student classroom evaluations.

The format of this instrument is intended to elicit students' estimates of how much they gained from the class, and to relate their gains to particular aspects of the class pedagogy. It aims to take the focus off the teacher, per se, and avoids critiques of pedagogy that are not directly related to student estimations of what they gained.

Faculty should add specific elements of this class for which they seek feedback, but, in each case, should frame each question so that it asks students what they felt that they gained—whether in understanding, skills, attitudes, approach to learning or to the discipline. I have marked (*) the places in the format where you might want to ask about specific items. You may also want to delete line items that do not apply, or in order to shorten the instrument overall. You could also use some/all of the questions for feedback at mid-term.

The instrument can be found on the ChemLinks, MC2, and FLAG web-sites, so you can import it and make your own editorial adjustments:
Chemlinks=http://Chemlinks.beloit.edu. MC2=http://mc2.cchem.berkeley.edu.
Field-tested Learning Assessment Guide=http://newtraditions.chem.wisc.edu
The FLAG web-site gives details of other users whom you may wish to contact.

This instrument was written as part of a wider attempt to meet the need for improved classroom assessment tools. Its particular focus (on what students **gained** from the class) arises from a strong finding from our student interviews on ten campuses. We found that asking students what they "liked" or "valued" about their classes, or how they evaluated their teachers was far less productive than asking them what they had specifically gained. It is our hypothesis that students can meaningfully answer questions about their own gains, whereas what they "like," and how they judge faculty in their role as teachers is much less reliable. This proposition is supported by faculty interview data in which faculty express mistrust of the numeric data (if not the written comments) provided by many institutional classroom evaluations.

If you choose to use some/all of this format to supplement or replace your usual student evaluation instrument, we would like to know how well it works. Does it give you the kinds of feedback on student learning that you want? We would like as much field-testing and feedback as possible so that we can improve the instrument. We recently added the last question (5B) at the request of existing users. The instrument only works if it's useful to you.

Elaine Seymour
University of Colorado
Bureau of Sociological Research
Seymour@spot.colorado.edu
(303) 492-0084

Joshua Gutwill
Department of Chemistry
University of California, Berkeley,
gutwill@socrates.berkeley.edu
(510) 643-5610

ASSESSMENT OF STUDENT LEARNING GAINS

Instructions to students: Check one box for each question on each scale:

NA=Not Applicable, 1= lowest rating,…, 5=highest rating.

You may add a comment for any item on the last sheet. Number your comments by the same numbers as the items in the questionnaire.

Q1. HOW MUCH did each of the following aspects of the class HELP YOUR LEARNING?

		NA	Was of no help	Helped a little	Helped	Helped a good deal	Helped a great deal
A.	**The class's focus on answering real world questions**	**NA**	**1**	**2**	**3**	**4**	**5**
B.	**How the class activities, labs, reading, and assignments fitted together**	**NA**	**1**	**2**	**3**	**4**	**5**
C.	**The pace at which we worked**	**NA**	**1**	**2**	**3**	**4**	**5**

D.	**The class and lab activities:**	**NA**					
1.	class presentations (incl.lectures)	**NA**	**1**	**2**	**3**	**4**	**5**
2.	discussions in class	**NA**	**1**	**2**	**3**	**4**	**5**
3.	group work in class	**NA**	**1**	**2**	**3**	**4**	**5**
4.	hands-on class activities	**NA**	**1**	**2**	**3**	**4**	**5**
5.	understanding why we were doing each activity/lab	**NA**	**1**	**2**	**3**	**4**	**5**
6.	written lab instructions	**NA**	**1**	**2**	**3**	**4**	**5**
7.	lab organization	**NA**	**1**	**2**	**3**	**4**	**5**
8.	Teamwork in labs	**NA**	**1**	**2**	**3**	**4**	**5**
9.	lab reports	**NA**	**1**	**2**	**3**	**4**	**5**
***10.**	specific class activities (list)	**NA**	**1**	**2**	**3**	**4**	**5**
***11.**	specific labs/activities (list)	**NA**	**1**	**2**	**3**	**4**	**5**
***12.**	Specific lab assignments (list)	**NA**	**1**	**2**	**3**	**4**	**5**

E.	**Tests, graded activities and assignments:**	**NA**					
1.	opportunities for in-class review	**NA**	**1**	**2**	**3**	**4**	**5**
2.	the number and spacing of tests/assignments	**NA**	**1**	**2**	**3**	**4**	**5**
3.	the fairness of test content	**NA**	**1**	**2**	**3**	**4**	**5**
4.	the mental stretch required of us	**NA**	**1**	**2**	**3**	**4**	**5**
5.	the grading system used	**NA**	**1**	**2**	**3**	**4**	**5**
6.	the feedback we got	**NA**	**1**	**2**	**3**	**4**	**5**

(Please continue on to Q1 F. on the next page)

Q1. (continued) HOW MUCH did each of the following aspects of the class HELP YOUR LEARNING?

		NA	Was of no help	Helped a little	Helped	Helped a good deal	Helped a great deal
F.	**Resources:**	**NA**					
1.	the module student manual(s)	**NA**	**1**	**2**	**3**	**4**	**5**
2.	the text	**NA**	**1**	**2**	**3**	**4**	**5**
3.	other reading materials	**NA**	**1**	**2**	**3**	**4**	**5**
4.	the use made of the Web in this class	**NA**	**1**	**2**	**3**	**4**	**5**
*** 5.**	other technical resources (TEACHER: WRITE IN)	**NA**	**1**	**2**	**3**	**4**	**5**

G.	**The information we were given about:**	**NA**	**Was of no help**	**Helped a little**	**Helped**	**Helped a good deal**	**Helped a great deal**
1.	class activities for each week	**NA**	**1**	**2**	**3**	**4**	**5**
2.	how parts of the classwork, labs, reading, or assignments related to each other	**NA**	**1**	**2**	**3**	**4**	**5**
***3.**	specific class assignments (TEACHER: WRITE IN)	**NA**	**1**	**2**	**3**	**4**	**5**
4.	the grading system for the class	**NA**	**1**	**2**	**3**	**4**	**5**

H.	**Individual support as a learner:**	**NA**	**Was of no help**	**Helped a little**	**Helped**	**Helped a good deal**	**Helped a great deal**
1.	the quality of contact with the teacher	**NA**	**1**	**2**	**3**	**4**	**5**
2.	the quality of contact with TAs (as relevant)	**NA**	**1**	**2**	**3**	**4**	**5**
3.	working with peers outside of class	**NA**	**1**	**2**	**3**	**4**	**5**

K.	**The way that this class was taught overall**	**NA**	**Was of no help**	**Helped a little**	**Helped**	**Helped a good deal**	**Helped a great deal**
		NA	**1**	**2**	**3**	**4**	**5**

(Please continue on to Q2. on the next page.)

Q2. As a result of your work in this class, how well do you think that you now UNDERSTAND each of the following?

*List concepts or other important material that you most want the student to understand

		NA	Not at all	Just a little	Somewhat	A lot	A great deal
1.	(TEACHER: WRITE IN)	**NA**	**1**	**2**	**3**	**4**	**5**
2.		**NA**	**1**	**2**	**3**	**4**	**5**
3.		**NA**	**1**	**2**	**3**	**4**	**5**
Etc.		**NA**	**1**	**2**	**3**	**4**	**5**

Q3. How much has this class ADDED TO YOUR SKILLS in each of the following?

		NA	Nothing	Just a little	Somewhat	A lot	A great deal
1.	solving problems	**NA**	**1**	**2**	**3**	**4**	**5**
2.	writing papers	**NA**	**1**	**2**	**3**	**4**	**5**
3.	designing lab experiments	**NA**	**1**	**2**	**3**	**4**	**5**
4.	finding trends in data	**NA**	**1**	**2**	**3**	**4**	**5**
5.	critically reviewing articles	**NA**	**1**	**2**	**3**	**4**	**5**
6.	working effectively with others	**NA**	**1**	**2**	**3**	**4**	**5**
7.	giving oral presentations	**NA**	**1**	**2**	**3**	**4**	**5**
*****	(Teachers: add any others)	**NA**	**1**	**2**	**3**	**4**	**5**

Q4. To what extent did you MAKE GAINS in any of the following as a result of what you did in this class?

		NA	Not at all	Just a little	Somewhat	A lot	A great deal
1.	understanding the main concepts	**NA**	**1**	**2**	**3**	**4**	**5**
2.	understanding the relationship between concepts	**NA**	**1**	**2**	**3**	**4**	**5**
3.	understanding how ideas in this class relate to those in other chemistry, science, or math classes	**NA**	**1**	**2**	**3**	**4**	**5**
4.	understanding the relevance of chemistry to real world issues	**NA**	**1**	**2**	**3**	**4**	**5**
5.	understanding the nature of chemistry	**NA**	**1**	**2**	**3**	**4**	**5**
6.	appreciating the methods of chemistry	**NA**	**1**	**2**	**3**	**4**	**5**
7.	ability to think through a problem or argument	**NA**	**1**	**2**	**3**	**4**	**5**

(Please continue on to Q4. 8. On the next page)

Q4. (continued) To what extent did you MAKE GAINS in any of the following as a result of what you did in this class?

		NA	Not at all	Just a little	Somewhat	A lot	A great deal
8.	confidence in your ability to do chemistry	**NA**	**1**	**2**	**3**	**4**	**5**
9.	feeling comfortable with complex ideas	**NA**	**1**	**2**	**3**	**4**	**5**
10.	enthusiasm for chemistry	**NA**	**1**	**2**	**3**	**4**	**5**
*	(Teachers: add any others)	**NA**	**1**	**2**	**3**	**4**	**5**

Q5A. How much of what you learned in this class (i.e., knowledge, skills, and other gains) do you think you will REMEMBER, and CARRY WITH YOU into other classes or other aspects of your life?

		NA	Nothing	Just a little	A moder-ate amount	A lot	A great deal
1.	understanding the main concepts	**NA**	**1**	**2**	**3**	**4**	**5**
*	(Teachers: add any others)	**NA**	**1**	**2**	**3**	**4**	**5**

Q5B. How well did your (modular) learning experiences in (WRITE IN course name and number) prepare you for the work you have recently done in (WRITE IN course name and number)?**

		NA	Nothing	Just a little	A moder-ate amount	A lot	A great deal
1.	understanding the main concepts	**NA**	**1**	**2**	**3**	**4**	**5**
*	(Teachers: add any others)	**NA**	**1**	**2**	**3**	**4**	**5**

**Note to faculty: If the prior class in a sequence of classes contained one or more modules (or other special features) insert “modular” (or other appropriate term). If not, leave out.

Note to Students: ADD YOUR OWN COMMENTS below. If they are tied to a particular question, use the same number/letter as the question to which they apply.

Appendix B: How Can You Learn From Our Modular Approach?

This guidebook includes inquiry-based activities for the classroom, for the laboratory, for the computer laboratory, and for homework. What do we mean by inquiry-based activities? Instead of giving you the answers and requiring you to memorize facts, we give you questions that will lead you toward a deeper understanding of chemistry concepts and approaches used by scientists in solving problems. The curriculum requires active participation from you, not only in the laboratories but also in the classroom. You will be recording observations from demonstrations, doing experiments, solving problems, discussing results, and constructing models to explain your observations and analyses.

Organization of the Module

The module begins with a question that provides a context for understanding and exploring chemistry concepts.

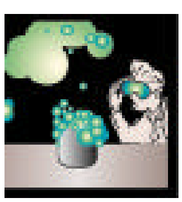
Sessions. The module is divided into sessions, each beginning with a Session Question. Each session focuses on one aspect of the Module Question and will raise the issues you need to consider to respond to the Module Question.

Explorations. The Session Question will be examined in classroom, laboratory, and computer Explorations. Each Exploration begins with a question that considers the Session Question in more depth and in different ways. ***Your instructor will choose which Explorations to use*** depending on her or his goals and the needs of your class.

The first Exploration in each session is called the Story-Line. It guides you to a first response to the Session Question. Responding to the Session Questions will help you respond to the Module Question, and thus, the first Exploration connects intimately with the "story" or context. Further Explorations in a given session guide you to think about the Session Question in more depth.

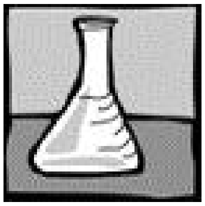
Each Exploration is divided into four sections:

1. **Creating the context**. This section states the goal of the Exploration and frames the Exploration Question. The text discusses why the question is important, reminds you of information discussed previously, gives background information, and describes what you can do to find out more. **Bold** type is used for key chemistry concepts.
2. **Building a model**. In order to respond to the Session and Exploration Questions, you will need to improve upon your current understanding, or **model**, of specific chemistry concepts. This central section describes how to gather the new information and generate the new ideas that you will need. Activities of the following types are used for this guided inquiry, as indicated by the icons shown here.



a. ***Demonstrations*** will be performed by your instructor, shown on a video, or simulated on a computer. You'll need to understand the purpose of the experiment, make detailed observations, and attempt to explain these observations.

b. ***Small group discussion and class discussion*** will help you formulate responses to questions, gather data from other groups, and give you different perspectives.



c. In a ***laboratory exploration***, you will design and carry out experiments to respond to a specific question. These experiments will require you to use chemistry principles and thinking skills related to your work in the classroom.

d. ***Computer assignments*** will ask you to use the computer to gather information, design experiments, and even run them.

3. **Applying your model**. The questions in this section provide you with additional opportunities to use the model, or understanding, that you have developed or refined. Your instructor will choose which of these questions to use for interactive discussion, small group work, or homework.

4. **Making the link**. In this section, you will reflect on what you needed to know to respond to the Exploration Question and how your response has helped you provide a more complete response to the Session Question.

Looking Back. Each Session ends with a section called Looking Back. The Looking Back provides you with a list of the chemistry concepts you have learned, indicated by **bold** type, and a list of problem-solving skills that are appropriate to put on a resume. In addition, we work out an example in another context to show you how the concepts you have learned can be applied elsewhere.

Culminating Project. As the Module ends, you will be asked to do a project that will integrate everything you have learned.

General approach

Learning in a Context. You may wonder about the necessity of a context for learning chemistry. You may feel that you could just learn the concepts and not bother learning all the contextual information. Research in cognitive science has shown, however, that we retain knowledge better when appropriate background material is available. As an example, try the following experiment. Read the following paragraph once, close the book, and write down as much as you remember.

> The procedure is not difficult. First, bring 1 liter of water to a state where it has undergone partially a phase transition in which the vapor pressure of the steam that is formed is equal to the pressure of the atmosphere. Then add 1.0 of the mixture of chemicals known as camilla thea. The important ingredient in this mixture is 3,7-dihydro-1,3,7-trimethy-1H-purine-2,6-dione. Allow the mixture to stir for 5 minutes. Finally, filter the undissolved solids and collect the liquid.

If you are unfamiliar with the technical language, you may not be able to recall much of these instructions. However, if you are told that the passage is about making tea, suddenly you can figure out much of the new vocabulary and enhance your retention of the instructions. The context has helped you use background knowledge to comprehend the passage. We have built a context surrounding the chemistry concepts and the problem-solving skills that we hope you will learn in this module. We hope that this context will help you make links to your background knowledge and to experiences from your everyday life. We believe that making these connections will aid your comprehension and enhance your retention.

Transforming knowledge. As part of this module, you will also be encouraged to find solutions to problems that cannot be solved by simply ”telling” knowledge. At this stage in your academic careers, you need to make the transition from simply “telling” facts you have memorized to ” transforming” your knowledge to solve new problems. This is what scientists and professionals such as doctors do. As an example, consider the type of problem that a medical doctor must solve.

> A patient who is quite ill is examined by Dr. Rosario. After examining the patient the doctor realizes that he has never encountered this set of symptoms before, or at least he doesn't remember having encountered them. Imagine Dr. Rosario giving one of the following responses to the patient:
>
> 1. “Sorry, I can't help you. I can't find the answer in my textbook.”
> 2. “Sorry, I can't help you. There is something wrong with your blood chemistry but I can't remember what I learned in first-year chemistry.”
> 3. “Sorry, I can't help you. I wasn't told about symptoms like yours in medical school.”

Clearly, doctors or scientists cannot be familiar with every case or remember all the information they learned in their training. But if they have learned how to approach complex problems, they will be equipped to deal with cases for which they were trained and more importantly able to deal with new issues. Therefore, they must know how to approach complex problems.

In this module, we hope to give you experience with approaches used by scientists to solve problems, especially those for which an answer is not immediately obvious and for which multiple solutions are possible. You will find that real-life problem solving is an iterative process. When you do not know how to solve a problem, you start by exploring your best model. If this model does not lead you toward a solution, you may have to back-track, rethink your ideas, and try something else. This process of generating and then refining your model allows you to define the problem more clearly. Eventually, you may reach an acceptable solution. As you generate and refine ideas about the issues and concepts in this module, your thinking will become more sophisticated, and your understanding will deepen.

Enjoy!

Angelica M. Stacy
Jennifer G. Loeser
Marco Molinaro

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