Inquiry into CHEMISTRY
TEACHER'S RESOURCE

INTRODUCTION AND IMPLEMENTATION

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Introducing *Inquiry into Chemistry* Program

Inquiry into Chemistry is a complete chemistry education program designed for the Alberta 20/30 Chemistry curriculum in effect as of September 2007.

Teachers and students in Alberta classrooms, consultants, and educational writers have written, reviewed, and field tested this material to ensure that it is accurate, comprehensive, enticing, and classroom-friendly. The material found in the student textbook, this Teacher's Resource, and the support materials will ensure that you can meet all Alberta Chemistry 20/30 curriculum expectations.

Alberta Education's vision for the provincial science program is that "all students, regardless of gender or cultural background, should have the opportunity to develop scientific literacy." This scientific literacy is to be built on four foundations:

- knowledge and understanding of concepts in various scientific disciplines and the ability to apply this understanding
- an understanding of the nature of science and technology, the relationship between the two, and of their social and environmental contexts
- skills for solving problems, communicating scientific ideas and results, working collaboratively, and making informed decisions
- attitudes that support responsible use of scientific and technological knowledge for the benefit of all

The text and activities in *Inquiry into Chemistry* have been written with this vision and these foundations in mind. The basic concepts are clearly explained in both words and illustrations. Science at work in the real world of technology is shown in activities, Connections features, Career features, and in-margin features that will inspire further investigation. The lab activities provide ample opportunities for students to practice the necessary skills. The issues raised in the textbook features will spark thoughtful debate on science-related issues.

The technology examples and social and environmental contexts used throughout the student textbook reflect the lives of all Albertans, whether male or female; Aboriginal, newcomer, or long-term resident. They also reflect modern economic realities and social contexts familiar to students.

Scientific literacy is an evolving combination of the science-related attitudes, skills, and knowledge. With *Inquiry into Chemistry* students will be able to develop their inquiry, problem-solving, and decision-making abilities; become life-long learners; and maintain a sense of wonder about the world around them. Diverse learning experiences that provide opportunities to explore, analyze, evaluate, synthesize, appreciate, and understand the interrelationships among science, technology, society, and the environment will enable students to develop scientific literacy through their senior high school science studies.

OVERVIEW OF A UNIT IN THIS TEACHER'S RESOURCE

This Teacher's Resource is packed with science background notes, teaching strategies, and answers to questions posed in captions, in-margin features, Investigations, and Thought Labs, Q questions, Connections features, Career features, Practice Problems, and Section, Chapter, and Unit review questions. (Activities and answers have been indexed for ease of use, at the back of this Teacher's Resource.) There are also special tips for addressing the diverse needs of students, which have been included where applicable. Course materials and apparatus lists have been compiled by unit, and curriculum correlations are done by chapter. Material that is directly related to the student text appears in the order it appears in the student text.

At the beginning of each Unit, you will find:

- a detailed Table of Contents
- an introductory teaching essay that briefly outlines the general outcomes, the contents, where the material fits in the curriculum, a curriculum-related chart of the chapter concepts, and a chart of activities and target skills. This essay also includes a discussion of the conceptual challenges in the material, with suggestions for overcoming them, and tips for using the Unit Preparation and Unit Opener features
- a detailed Course Materials list for the unit

At the beginning of each Chapter, you will find:

- a detailed Curriculum Correlation
- a summary of the Chapter Concepts
- a summary of Common Misconceptions that students may have, with suggested teaching strategies for dealing with them
- a list of Helpful Resources, including Books and Journal articles, Web Sites, and a complete list of

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blackline masters (BLMs) that have been prepared to support the chapter
- Teaching Strategies for using the chapter opener
- full notes on the Launch Lab related to the chapter opener

At the beginning of each Section, you will find:
- a list of the Section Outcomes as noted in the student text
- a list of the Key Terms as noted in the student text
- "Chemistry Background"—a bulleted list of key scientific points relevant to the section
- Teaching Strategies for the section, including a more targeted list of non-activity-related BLMs for that section
- suggestions for supporting the diverse needs of students

Also in each Section, you will find:
- Answers to all Q questions (questions testing student comprehension)
- Answers to all Practice Problems (full solutions are posted at **www.albertachemistry.ca**, Online Learning Centre, Instructor Edition)
- Notes and answers to Web Links, FYI, and Try This in-margin features and questions found in captions
- Detailed notes for all activities, including student text reference, purpose, related curriculum outcomes, advance preparation suggestions, materials list, a suggested time allocation, helpful tips on any and all aspects of the activity (including supporting BLMs), suggestions for supporting diverse needs of ESL or gifted students, safety precautions, answers to all questions, and suggested assessment options
- Teaching Strategies for the chapter's Connection feature where it appears, including answers to all questions posed
- Answers to all Section Review questions

At the end of each Chapter, you will find:
- Answers to all Chapter Review questions

At the end of each Unit, you will find:
- Teaching strategies for the Career Focus feature and answers to the "Go Further…" questions posed
- Answers to all Unit Review questions

Additional Teacher Support Materials

In addition to this Teacher's Resource, the **CD-ROM** accompanying this resource includes an electronic version of this Teacher's Resource with hot-linked activity and answer indexes. The CD-ROM also includes **hundreds of supporting blackline masters** (BLMs) in both pdf and Word formats for easy printing or customization. The BLMs that support the course material include sample problems and concept quizzes, as well as key illustrations from the text with all labels and notes for use as an overhead, a handout, or an answer key. In addition, the same art is supplied as a BLM without labels for use as student practice or a quiz. There are BLMs for every activity—Launch Labs, Investigations, and Thought Labs—in the student text, with an answer key version included. These BLMs have been saved with both number and name for quick reference and access.

The Online Learning Centre at **www.albertachemistry.ca** was developed for *Inquiry into Chemistry*. The site is the home of internet-based support for both students and teachers.

The link to the Student Edition delivers students to the Unit Prequizzes (computer-based, multiple-choice tests of students' readiness), web links supporting the in-margin features (Web Links, FYI, and Try This) and activities throughout the student text. Links include animations, Virtual Lab Exercises, and the Essential Study Partner.

The link to the Instructor Edition will take you to a password-protected site that includes the student text links but also has additional sites to support the teaching of the material, plus all the BLMs—overheads, activities, chapter tests, and answer keys—found on the CD-ROM. You will also find a link to an electronic version of this Teacher's Resource.

To register to use the Instructor Edition, go to **www.albertachemstry.ca**, and click on "Visit our up-to-date enhanced site providing value-added resources." Choose the Online Learning Centre, Instructor Edition. Follow the instructions for a first-time user. For registration purposes, your username is alberta2 and your password is teach_chem.

Extra features found only at the Online Learning Centre include:
- consolidated course materials lists for Units 1 to 4, and Units 5 to 8
- full solutions to all Practice Problems
- computer slide show presentations for each chapter
- selected textbook art in electronic form
- a test version of a hot-linked curriculum correlation for Unit 7 that will display course content and support materials for each learning outcome

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- a direct link to the revised curriculum document, as published by Alberta Education
- a direct link to *Safety in the Science Classroom* from Alberta Education
- a direct link Alberta Education's Online Reference Centre, available through the LearnAlberta.ca web site (**www.learnalberta.ca**). This is a suite of reference databases and online encyclopedias that are available at no cost to Alberta teachers, students (and their parents). Specific databases may change over time, but access to resources such as maps, newspapers, magazines, scholarly journals, and book reviews will be maintained. This site contains links to some of the key chemistry journals cited in this Teacher's Resource.

OPPORTUNITIES FOR STUDENT ASSESSMENT

The student text and teacher support materials for *Inquiry into Chemistry* provide numerous opportunities both for students to informally evaluate their progress and for teachers to collect data with respect to student performance in a wide variety of formats in order to find out what students know and what they can do.

Informal assessment for students begins with the **Unit PreQuiz** feature, to be found at **www.albertachemistry.ca**, Online Learning Centre, Student Edition. Students can take the Unit PreQuiz prior to beginning the course material to assess their grasp of the background skills and knowledge required to master the unit. The Unit Preparation feature in the student textbook can be used before taking the quiz or as a review of knowledge gaps after the student has used the computer-based test. This combination of features has been created to assess the students' readiness and ensure that students are prepared for the material to come.

Throughout the sections in the student text, boxed **Q questions** are posted so students can test their comprehension of the material they have just read. Q questions are basic knowledge questions designed to reinforce the material and give students an opportunity to review new information and put it into their own words. Answers to all Q questions are in the Teacher's Resource, in the order of appearance in the student text.

In addition to Q questions, **blackline masters** (BLMs) have been prepared for key illustrations in *Inquiry into Chemistry*, including sample problems. These have often been prepared in two versions: fully labelled for use as an overhead or an answer key and in a handout version with the opportunity for students to add labels, assign labels, and/or write text explanations of the processes shown. These BLMs can be used as either reinforcement or as tools to assess learning.

Throughout the chapters, **Practice Problems** have been included to enable students to practice problem-solving skills shown in the Sample Problems in the chapter. In addition, Appendix B at the back of the student textbook includes **over 200 Supplemental Practice Problems**, representing all chapters in the student textbook.

Blackline masters have also been prepared for all Launch Labs, Thought Labs, and Investigations. These **activity BLMs** can be collected after completion to assess the results of the students' work. The activities in *Inquiry into Chemistry* are performance tasks designed to develop skills in the four categories of initiating and planning, performing and recording, analyzing and interpreting, and communication and teamwork. Suggested results and sample answers to the questions posed in the activities can be found in this Teacher's Resource. In addition, an "Answer Key" version each of the activities has been provided for easy reference or use as a student handout. There are **10 Assessment Checklists** (provided in Appendix A as hard copy or on the CD-ROM or the web site at **www.albertachemistry.ca**, Online Learning Centre, Instructor Edition in Word format for easy customization). They are:

1: Designing an Experiment
2: Laboratory Report
3: Performance Task Self-Assessment
4: Performance Task Group Assessment
5: Learning Skills
6: Using Math in Science
7: Independent Research Skills
8: Oral Presentation Checklist
9: Developing Models
10: Research Project Evaluation

Every chapter also includes a Connections feature, exploring contemporary issues relating to the chapter information in a look at basic science, science and technology issues, or science in a social and environmental context. The **Connections feature questions** ask students to do surveys, investigate issues, do research, and form opinions. These are opportunities for students to apply the knowledge and skills they have

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gained to solve real-life problems and analyze real-life situations. Suggested answers to these questions are also provided in this Teacher's Resource as a guideline for ongoing assessment of students' work.

In addition, each unit contains a **Career Focus feature, with "Go Further…"** questions. Beginning with an interview with a Canadian who is applying the science in their work and a brief overview of related careers, the questions encourage students to apply the science to other aspects of the subject through research of their own.

More formal assessment of learning opportunities begins with **Section Review questions** at the end of every section, testing students on a basic understanding of the material in the preceding pages. Section Review questions quiz students on their understanding of terms, functions, and processes. **ICT** opportunities are included to give students a chance to use word processing, spreadsheet, or graphics software.

Chapter Review questions are grouped under the headings Understanding Concepts, Applying Concepts, Solving Problems and Making Connections.

- "Understanding Concepts" questions require a basic comprehension of the material and are most closely tied to Knowledge Outcomes. Students are asked to describe, define, compare, contrast, list, name, or explain.
- "Applying Concepts" questions ask students to interpret data, infer the meaning of new terms, hypothesize, and solve simple problems.
- "Solving Problems" questions ask students to make calculations, manipulate and convert units, write scientific notation, and solve problems all while using correct significant digits.
- "Making Connections" questions ask students to apply their knowledge practically, and many use real-world data or situations to put the information students have learned into a real-life context.

The same categories of questions are used in the **Unit Review questions**, which combine the knowledge across chapters and ask students to apply it.

The answers to all of the review questions appear in this Teacher's Resource, in textbook order. For quick reference, see the Answer Index at the back of this Teacher's Resource or use the hot-linked index on the CD-ROM that accompanies this Teacher's Resource.

Sample **Chapter Tests** have been prepared as blackline masters in Word format for easy customization and are accompanied by answer keys. These can be found on the CD-ROM that accompanies this Teacher's Resource or at **www.albertachemistry.ca**, Online Learning Centre, Instructor Edition, BLMs. The Chapter Test question formats are multiple choice, numeric response, or written response and are compatible with standard answer sheets.

The *Inquiry into Chemistry* **Computerized Assessment Bank (CAB)** contains over 2,000 questions based on the material presented in the student text. The CAB presents a range of question types, including multiple choice, short answer, critical thinking, application, practice problems, and Diploma Exam style, that target critical skills such as processing and interpreting data, recognizing patterns, hypothesizing and predicting, and designing experiments.

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LABORATORY SAFETY: THE SCHOOL'S ROLE

Safety awareness begins with the school board and each school principal. Laboratory safety is supervised by the department head (when one is designated within a school) and is taught (and modelled) by the individual teachers. The Alberta Ministry of Education has published *Safety in the Science Classroom*, a comprehensive presentation of safety guidelines for the province's science classrooms. This document can be downloaded from the Alberta Education web site or via a link at **www.albertachemistry.ca**, Instructor Edition, Teacher Web Links.

Principals should be familiar with the guidelines for laboratory safety and provide continual supervision to ensure compliance with guidelines. Principals need to be supportive of teachers requesting assistance in implementing safety procedures.

Each teacher has the ultimate responsibility for enforcing safety standards in the laboratory and for setting a proper example by observing basic rules such as wearing goggles and protective clothing when in the laboratory and by not working alone. Planning and practice are essential to laboratory safety. Planning should include how to prevent accidents, and practice should include what to do in an emergency.

The activities and investigations in *Inquiry into Chemistry* are designed to minimize dangers in the laboratory. Nevertheless, there are no guarantees against accidents. Careful planning and preparation, as well as awareness of hazards, will help keep accidents to a minimum. Much of the available information on planning safe procedures can be summarized by the phrase "Be prepared!" Know the rules and what common violations occur. Know your students and their degrees of respect for rules and understanding of the possible consequences of risk-taking behaviour. Know where emergency equipment is stored and how to use it. Practise good laboratory housekeeping and management. Know and observe regulations and guidelines.

In the Science Classroom/Laboratory

Below are some basic guidelines to consider as you plan your course.

1. Chemicals:
   (a) All chemicals and specimens should be kept in a vented and secure storage room. Chemical storage rooms should not be accessible to unauthorized persons.
   (b) Keep an accurate inventory of chemicals. Update it annually.
   (c) Keep a binder with current (no more than 3 years old) Materials Safety Data Sheets (MSDS) for every chemical
   (d) Store only those chemicals and specimens that you plan to use.
   (e) Ensure chemical containers are properly labelled. Apply purchase date and the name of the school, special precautions, and expiration date. When a solution is made up from a chemical or chemicals, this container must also be appropriately labelled with the name of the chemical, concentration, and WHMIS labels.
   (f) Separate chemicals by reaction type (acids, bases, oxidizers) and/or WHMIS hazard class. Do not store them above eye level. Acids and bases must be stored at ground level or in an appropriate vented storage cabinet; flammables should also be in a separate vented storage cabinet.
   (g) Shelving should be firmly attached to walls and have anti-roll lips.
   (h) Discard outdated or unnecessary chemicals according to appropriate disposal methods.
2. Equipment:
   (a) It is best if equipment is kept in a secure storage room. The storage room should not be accessible to unauthorized persons.
   (b) Label and organize equipment so that it is easily accessible.
   (c) Protect equipment, especially electronic equipment and microscopes, from dust, humidity, and extreme temperatures.
   (d) Keep equipment in good repair. Do not use it if it is damaged or dirty.
   (e) Hot plates are the preferred heat source. Be sure the room has an adequate number of electrical outlets. If laboratory burners are used, a central shut-off valve for the gas supply should be accessible to you, the teacher. Never use open flames when flammable solvent is in the same room.
3. The Classroom/Laboratory Itself
   (a) Check to ensure that safety equipment is accessible and working properly. Ideally, safety equipment should include fire extinguishers, first aid kits, eyewash stations, lab aprons, safety goggles, fumehood, and a chemical spill kit.
   (b) Check that there is adequate workspace for stu-

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dents to do investigations.
(c) Confirm that room ventilation and fumehoods meet safety standards.
(d) Post safety and evacuation guidelines.
(e) Provide containers for disposing of chemicals, waste products, and biological specimens. Disposal methods must meet local guidelines.

First Day of Class/Labs with Students

Every class is a mix of individuals with different levels of curiosity, respect for rules and authority, and tolerance for risk. In addition, those in this age group do not always have a well-developed ability to anticipate the consequences of their actions.

1. Discuss the feature *Safety in Your Chemistry Laboratory* on pages xii-xv of *Inquiry into Chemistry*. To ensure students are familiar with WHMIS symbols, direct them to page xv of *Inquiry into Chemistry*.
2. You may want to create a safety contract for students to sign that outlines the safety rules they need to follow and documents their understanding of the rules. The following list contains points that you may wish to include in your safety contract.
   (a) no chemicals or apparatus can be removed from the laboratory
   (b) no unauthorized experiments can be performed in the laboratory
   (c) students should work in a calm, methodical way; there is to be no horseplay in the lab
   (d) students should wear appropriate personal safety protection equipment (e.g., goggles, gloves, aprons) at all times. Long hair must be tied back.
   (e) students should not eat, drink, or chew gum while in the laboratory
   (f) chemicals should never be tasted in the laboratory
   (g) students should use suction devices for pipettes. Pipetting by mouth of any sort, chemical or biological, is strictly forbidden.
   (h) students should inform the teacher if they wear contact lenses. Have the student and parent(s) sign a contact lens safety contract, if available.
   (i) students should inform the teacher of any health conditions, Medic Alert cautions, or any allergies, sensitivities, or other possible health-related considerations
   (j) accidents and spills should be reported to the teacher at once
   (k) extra chemicals should be disposed of as directed, not flushed down the drain or returned to stock bottles
   (l) students should use the proper technique for smelling gases
3. Review safe use of all equipment, chemicals, and biological specimens.
4. Review the use and location of safety equipment, and practice evacuation procedures.
5. Discuss safe disposal of materials and laboratory cleanup policy.
6. Discuss proper attitude for working in the laboratory, including appropriate behaviour when working with animals and plants.
7. Review the above points with students often during the school year.

Before Each Lab

1. Perform each activity yourself before assigning it to students in order to determine where students may have trouble or where safety concerns may arise.
2. Arrange the lab in such a way that equipment and supplies are clearly labelled and easily accessible. Avoid confusion in the area where solutions and reagents are dispensed. Ensure that disposal containers are clearly labelled and easily accessible.
3. Have only equipment and supplies needed to complete the assigned activity available. This practice helps eliminate the problem of students doing unauthorized experiments.
4. Review the procedure with students. Emphasize cautions within the procedure. If students have designed their own procedure, ensure each procedure includes the appropriate safety precautions.

During Each Lab

1. Make sure the laboratory is clean and free of clutter.
2. Ensure that safety equipment is available and that students are wearing gloves, aprons, or goggles as instructed.
3. Never allow students to work alone.
4. Shield systems under pressure or vacuum. If you are doing a demonstration, you must shield both yourself and your students. Use extreme caution if you use a pressure cooker for sterilization purposes. Turn off the heat source and allow pressure to return to normal before opening the cover.
5. Students should not point the open end of a heated test tube toward anyone.

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6. Remove broken, chipped, or cracked glassware from use immediately.
7. Be sure all glassware that is to be heated is of a heat-treated type that will not shatter.
8. Remind students that heated glassware looks the same as glassware that is cool enough to be handled safely.
9. Clean up spills immediately. Follow proper cleaning protocol as indicated on the MSDS.
10. Prohibit food as well as all eating and drinking in the lab.

After the Lab

1. Be sure that the laboratory is clean, including all work surfaces and equipment.
2. Be sure that all laboratory equipment has been turned off, cleaned, and returned to storage properly.
3. Be certain that students have disposed of broken glassware and chemicals properly. Ensure that only allowable chemicals or specimens are disposed of down the drain or in the garbage.
4. Ensure that students wash their hands when laboratory work is completed.

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CO-OPERATIVE LEARNING IN YOUR CLASSROOM

Scientific work involves collaboration, and learning science is a social activity. At this point in their education, students will have had some experience with group work and co-operative learning and will likely have some thoughts on the value (or perceived lack of value) of the experience. They will almost certainly have some thoughts about the difficulties in making co-operative learning successful. Whether they are preparing to go on in their studies or into the workforce, students should understand that working in teams is standard practice, and the possibility of success in the future will depend on their ability to work well with others. Mastering co-operative learning skills will not only enhance their scientific studies—these are skills that will be useful throughout their lives.

Basic Elements of Co-operative Learning

Language and *communication* are important in developing and consolidating ideas. Co-operative learning groups should encourage communication on a variety of levels. Students need to learn how to listen, respond, agree, disagree, clarify, encourage, and evaluate objectively. These skills help teams work together productively.

Beyond communication skills, students must learn to divide up tasks and accept an *equally shared responsibility* for helping the group achieve a *common goal*. Ideally, students should be given one evaluation or reward applicable to all members of the group. Accepting that their success rests with the group, rather than themselves can be a major challenge for some students. The reward strategy can be modified for specific group or individual problems (such as those described in the Troubleshooting section below) in order to encourage those resistant to pooling their resources and talents. You may wish to develop a secondary or parallel reward strategy that holds students individually accountable for material worked on in co-operative groups.

Strategies for Developing Communication Skills

- **Paraphrase First:** When groups begin working together, ask that each time a group member has contributed an idea, another group member correctly restate the idea before another idea can be contributed. Mastering this basic listening technique should help student groups work together more successfully.
- **Make Analogies:** Ask students to brainstorm ways a concept is like something in everyday life in order to enhance the group's understanding. For example, students may compare performing an experiment to producing a play. Or they may liken the work to other sequential processes such as production of a newspaper, baking a cake, or taking a vacation. If appropriate for the concept, give each group a large sheet of paper to use to create a labelled diagram of its analogy. The diagram should illustrate the everyday process with vocabulary labels from the scientific process. This strategy works well to help students, individually or in groups, understand a difficult scientific concept.
- **Use Talking Chips:** To ensure that group members develop the habit of contributing, and also to ensure that one group member does not dominate discussions, give each group member five small pieces of blank paper. Each time a member speaks, he or she must give up a piece of paper. When a group member is out of paper, he or she cannot speak again until everyone else has used all their pieces of paper. (To continue the discussion, the pieces may be reissued when all have been handed in.)

Strategies for Forming Groups

Groups should contain two to five students. Heterogeneous groups that represent a mixture of abilities, genders, and ethnicity expose students to peers with ideas different from their own and help them learn to work with a variety of people. To that end, it may be useful to break up pairs or groups of close friends to encourage fresh associations and discourage the exclusion of less popular students. (A possible exception to this group format may be for the material in Unit 6: Reproduction and Development when, depending on the cultural or religious beliefs prevailing in the class, it may be better to have groups that are more culturally or gender homogeneous.)

At first, co-operative learning groups should work together for only a day or two or for short assignments. Once students gain more experience, groups are ready for longer assignments.

Basic Co-operative Learning Strategies for Developing Group Skills

- **Study Buddies:** Have students work in groups of two to question each other about the material being studied. Award bonus points to the team for scores

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above a certain percentage. (Having a short time limit on this question period will help to keep students on task.) A variation on the question strategy is to give students a specific topic of study, and have them rally back and forth, each supplying a piece of information related to the topic.

- **Checkmates:** Have group members compare homework answers or class handout answers. Students should discuss answers and come to agreement on the best ones. To ensure that all group members participate in this discussion, students could draw numbers from a hat to establish which question each group member will respond to. Feedback or additional information can be added by the rest of the group after a response is read out. Collect one paper per group. Do not tell the class in advance which paper you are planning to collect.
- **Turn to Your Neighbour:** After a teacher-led discussion of a topic, an explanation of directions, or notification of an assignment, ask students to turn to their neighbour and summarize the key points of what was said in a paraphrasing exercise.
- **Write a Note:** Have all members of the team write a note that begins, "What I understand about this section is… I am still having trouble with…" Ask students to trade notes with someone who is not having the same trouble and reply to the note. They should write the note as if they were writing a real note to a friend.
- **Brainstorming:** Use this strategy to generate a large number of ideas for discussion of a question. Ask students to make a group list. They should not evaluate the ideas until the list is complete. Encourage them to build on each other's ideas, go on sidetracks, and gather the silliest and weirdest ideas they can think up. Stress that all ideas are acceptable on a brainstorming list. Evaluation begins when students have no more ideas or the time is up.
- **Chalkboard Share:** Ask one member from each group to put their best idea or answer on the chalkboard. This strategy allows the groups still at work to consider the ideas on the board as well as their own and perhaps come to an even higher level of thinking.
- **Jigsaw:** On a reading assignment of one or two pages that is not structured sequentially for understanding, divide up the reading among the members of a group of three or four. Each person reads his or her part of the assignment and then explains it to the other group members. Other group members should be quizzed by the teacher to make sure that they understand the material. Do not divide up whole chapters or units until students have considerable experience in co-operative learning. This strategy can become an advanced co-operative learning task with larger blocks of material.
- **Coaching Lab Teams:** Students will be doing group work for investigations and thought labs throughout the course. Coach students on how to divide up work, perhaps by creating roles with mini-job descriptions for set up, observing, measuring, recording data, etc. Assist the planning of a rotation through various lab roles or a discussion on whether group members would prefer to take and keep roles based on an area of strength. As groups prepare for an investigation, have each group member paraphrase part of the procedure so that the activity is clear and the entire group is aware of the necessary steps before they begin.

Advanced Co-operative Learning Strategies

- **Snowballing:** A pair of students answers worksheet questions or compares lab report conclusions or other written work. Two pairs come together to review and compare answers. Two groups of four come together and compare. One person from the group of eight writes answers or conclusions on the board.
- **Roundtable:** One group member has a pencil and paper. He or she reads a question out loud. Group members consult and refer to the textbook in order to agree on the answer. The group member who has the pencil and paper writes the answer. The answer sheet is passed to the next group member. Repeat the process until all questions are answered. One person in each group should check the answers using a key provided by the teacher. Alternatively, each student can have a worksheet and answers can be written down by all members of the group once discussion has concluded. Collect only one worksheet per group. This strategy is especially useful for section, chapter, or unit review questions.
- **Group Interdependence:** For each group, prepare a set of four to five "clue cards" for one concept, including a distractor clue. For example, you could make a set of clues for adaptations, another for variations, and another for natural selection. The sets

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are traded from one group to another as they figure them out. Instruct students: (a) not to allow anyone to see their clue; (b) to verbally communicate their clues to their group; (c) to decide which clues are distractors; and (d) to decide what concept the clues represent.

- **Group Visits:** Three students from each group take their completed work and visit another group. One student in each group remains and presents his or her group's work to the visitors. The visitors compare their work and note any differences. Students return to their original groups. A different group member then remains while the other three visit different groups. Visits continue until every student has visited three times and explained once. This strategy is useful for checking work.

Troubleshooting[1]

If there is initial resistance to co-operative learning or team activities in the class, you may wish to provide an opportunity to air the objections, provided this can be done in a neutral way. Ask students for examples (without naming names) of difficulties they have encountered. Brainstorm ideas for overcoming these difficulties.

You may wish to use this exercise to develop a mutually agreed upon group contract at the beginning of the process. This contract should stress respect for each other and the group work process and could include some of the following points:

- Punctuality
  - students will be on time for class/group meetings
  - students will meet due dates for tasks assigned by the group
- Preparedness
  - students will bring necessary equipment: ruler, calculator, graph paper, portable data storage device, notebook, etc.
  - students will have completed tasks as assigned at the last group meeting in preparation for the next steps (e.g., assembling research, obtaining materials or equipment)
- Group Contribution
  - students will participate in discussions in a constructive way
  - students will refer to previous discussions and contributions of others
  - students will focus on ways to achieve the group's common goal
  - students will acknowledge and accept assigned roles (e.g., timekeeper, materials manager, recorder, co-ordinator)
  - students will respect and acknowledge the contributions of other members of the group
- Active Listening
  - students will be attentive in discussions
  - students will listen when others in the group are talking
  - students will ask questions to clarify and confirm
- Politeness & Tolerance
  - students will be calm, congenial, and objective when disagreements arise within the group

If a group contract is not used at the outset or if difficulties arise, use the suggestions below, perhaps beginning with peer feedback or a revised group contract, to help students develop strategies for dealing with the challenges of making group work a success.

- **Peer Feedback:** Distribute Assessment Checklist 3: Performance Task Self-Assessment. Students could evaluate themselves and then share their self-assessment with the rest of the group, or they could evaluate another person's performance within the group, using the same checklist. Encourage students to comment on what is good before saying anything negative. Students who are listening to assessments from others should be encouraged to paraphrase comments so there is agreement as to what has been said.
- **Revised Group Contract:** Ask each group to make a list of specific behaviours that can be changed to improve their group. "We need to work together better" is not specific. Examples of specific behaviours include "Everyone should come to class on time" or "No one should be busy texting while we're working." Beside each item, have students write how the change will benefit the group's work. You may need to chair the discussion among the group members as they collaborate to share out the responsibilities.
- If a Group Consistently Refuses to Work with a Particular Student: If students insist on the right to effectively "vote someone off the island," use self-assessment, peer review, and the group contract techniques to assess the issues. Depending on the outcome of the assessment, you may feel it's appropriate to give the outcast student a role with leadership responsibility.

1 Adapted from *Cooperative Learning in the Science Classroom.* Glencoe McGraw-Hill, New York, NY.

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Be careful when grouping or re-grouping. Be sure one student in the group has some positive feelings about the outcast group member. Each day, ask the group to start by saying one positive comment to each person in the group. Use strategies for conflict resolution and structure the activities so the student is needed by the group for them to be successful. Strategies such as jigsaw may be included. Ask the group to practise skills such as honouring individual differences and showing appreciation and empathy.

Common Co-operative Learning Challenges

- **Group Members Do Not Share Equally in the Work:** Divide up materials so that each group member has information others need. Give the group only one worksheet. Assign each group member an essential role. Make sure students are using the "Talking Chips" technique. If one group member consistently does not participate despite efforts by others to include him or her, take this into consideration when assigning the group mark so other group members are not penalized.
- **Students Do Not Effectively Use Co-operative Skills:** Allow ample time for groups to evaluate their work using Assessment Checklist 3: Performance Task Self-Assessment and Assessment Checklist 4: Performance Task Group Assessment. Encourage individuals or groups to commit to improving specific skills by forming a group contract. Recognize and reward improvement.
- **A Student Is a High Achiever:** Reward the student for developing co-operative skills. This may be an enormous challenge for this type of student. Evaluate his or her potential to work with a partner with lower science abilities or a language challenge. (Remember that the brightest students don't always make the best tutors; do not automatically assign this role.) Assign challenging roles that the student does not usually take. (This student may do observations of the co-operative efforts of the entire class.) Occasionally group the high achievers together to work on an especially fast-paced, challenging project. If necessary, reassure the student (and parents, possibly) that research shows that mastery and retention of academic material by high-ability students is found to be higher in co-operative than in competitive or individualistic learning situations. Also stress the importance of co-operative learning skills for success in future endeavours.
- **A Student Resists Working in a Group:** In the rare case of determined opposition to working in a group (which may be related to self-perceptions of being a high achiever), you may decide to allow a student to work individually. The larger workload involved may lead the student to reconsider. Alternatively, suggest that the student commit to a group for a limited time, perhaps three weeks. Monitor the group closely during this time, encouraging other group members to take advantage of the skills this student brings to the group.
- **A Student's Ability Is Considerably Lower Than That of Other Group Members:** Take the weaker student's abilities into consideration when assigning tasks. Provide appropriate reference materials for him or her to use. You may want to adapt tests and quizzes or the scoring method you use, or automatically add points to the student's individual grade when using it to figure the group mark.
- **A Student Is Absent:** Have the group suggest appropriate make-up work. Approve the assignment. Consider combining groups if two or more students are absent from a group. Another option is to have floaters who are academically successful and skilled in using co-operative strategies fill in empty places.
- **A Student Is Chronically Absent:** Assign the student as an extra member to a group with a core that is usually present, or have the student fill in for absent students when he or she does come to class. Offer a permanent assignment when attendance improves.

Behaviour Issues

- **The Noise Level Rises Too High:** Develop a signal that means "quiet." You may simply raise your hand, with students following your example as soon as they see you raise your hand. It may be a quick flick of the light switch. Have students practise the co-operative skill of working as a group to establish their own technique for keeping noise down early in the year (or again and again) if noise is a problem, particularly if they are working in the library or computer lab. Educate your colleagues and principal about the difference between "noise" and "beehive of activity" in co-operative learning. Remind students that excessive noise could result in loss of access to some resources such as the library or computer lab.
- **A Student Is Extremely Shy:** Use team-building, trust-building, and active listening activities that create an atmosphere of acceptance and respect for

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each other. Make complimenting, encouraging participation, and appreciating individual differences the co-operative skills that groups must practise. Assign shy students to a smaller group. Ask the group to take on task roles and assign the shy student the role of reader, recorder, or spokesperson. If you use the "Talking Chips" technique, you may wish to assign this student a smaller number of chips until they have gained some confidence.

- **A Student Behaves Inappropriately:** Whenever possible, allow the group to deal with the problem. By intervening you give up your most powerful tool: peer influence. You also risk sending the message that the students are not capable of solving their own problems. When necessary, offer assistance in the form of a specially designed group analysis questionnaire or checklist.
- **Students Use "Put-downs," Ridicule, and Demeaning Remarks:** If you observe negative behaviour, intercede, and discuss with the group how people usually like others to treat them. Refer to the group contract or have the students start a list of respectful ways to interact. Have the students write ways in which they would try to develop these behaviours and foster them in others. You may wish to post the list and have the class contribute to it over time.
- **A Student Actively Attempts to Sabotage Group Work or Products:** Reinforce daily any behaviour that is near the co-operative goal. Assign a co-operative skill tied to the disruptive behaviour, such as asking clarifying questions and paraphrasing discussion points for a group member who is distracted or fails to participate regularly; or performing scheduling and organization tasks for a student who has difficulty with punctuality and preparedness. This will give the student a chance to redeem him/herself and will offer the teacher a chance to evaluate improvement.

Use the group contract to reinforce the need for co-operation. Role-play the problem with the other students in the class and have a class discussion about how to solve the problem.

If these strategies are not effective, a group meeting with other group members making impact statements about the student's behaviour—where each group member explains how the problem student's behaviour is negatively affecting the group—could help. As a last resort, ask the disruptive student to work alone until he or she is willing to practise co-operative skills.

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SUPPORTING THE DIVERSE NEEDS OF STUDENTS

Each student brings his or her own unique set of abilities, perceptions, and learning needs into the classroom. Making the classroom environment as receptive to these differences as possible is always a challenge, and the mix is different for every class.

Individual learning styles are the first variable to assess when meeting a new class. Learning styles are not a reflection of a student's ability level, and most students will be able to learn in a variety of ways, although they will have a preferred style. While the combination of text material and activities means a reliance on linguistic and kinesthetic styles, *Inquiry into Chemistry* includes both photographs and art on every page to assist visual-spatial learners. In addition, there are opportunities for group and individual work. You will be able to accommodate other styles by allowing students to use them when they create reports for some of the labs or projects.

Some Major Learning Styles

	Characteristics
Auditory-Musical	Students learn by listening to the spoken word and to tones and rhythm.
Interpersonal	Students learn by interacting with others.
Intrapersonal	Students learn by working alone.
Kinesthetic	Students learn from touch, movement, and manipulating objects.
Linguistic	Students learn by using and understanding words.
Logical-Mathematical	Students learn by using numbers and reasoning.
Visual-Spatial	Students learn by responding to images and illustrations.

Strategies for Supporting the Diverse Needs of Students

Beyond differing learning styles, students may bring other learning challenges to the classroom. Look for the icon "Supporting Diverse Student Needs" throughout this Teacher's Resource for tips, which generally include strategies for ESL and gifted students. In addition, see the tips for delivering challenging concepts that appear in the initial teaching notes for each unit. The chart below is a summary of basic teaching tips.

	Tips for Instruction
Students Who Speak English as a Second Language Recent immigrants may speak English as a second language or not at all. In addition, the customs and behaviour of people in the majority culture may be confusing or create some conflicts for some of these students. Cultural values may inhibit some ESL students from full participation in class activities.	■ Remember that a student's ability to speak English does not reflect his or her academic ability. ■ Just as you would connect with Aboriginal elders in order to get a better understanding of any Aboriginal students, talk to knowledgeable colleagues or representatives of the student's community or family to get an understanding of how the student's cultural needs will affect your science classroom. ■ Try to incorporate the student's cultural experience into your instruction. ■ Include information about different cultures in your curriculum. Avoid cultural stereotypes. ■ Encourage students to share their cultures in the classroom.

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	Tips for Instruction
Students Who Have Behaviour Disorders Students with behaviour disorders deviate from certain standards or expectations of behaviour. These students may also be gifted or learning disabled.	■ Provide a clearly structured environment with regard to scheduling, rules, room arrangement, and safety. ■ Clearly outline objectives and how you will help these students attain these objectives. ■ Seek input from these students about their strengths, weaknesses, and goals. ■ Reinforce appropriate behaviour, and model it for students. ■ Do not expect immediate success. Work for long-term improvement. ■ Balance individual needs with the needs of the class.
Students Who Are Gifted Although no formal definition exists, these students can be described as having above-average ability, task commitment, and creativity. Gifted students rank in the top 5 percent of their class. They usually finish work more quickly than other students, and are capable of divergent thinking. They can also become bored and disruptive or struggle to respect less gifted students.	■ Make arrangements for students to finish selected subjects early and work on independent projects. ■ Encourage students to express themselves in art forms such as drawing, creative writing, or acting. ■ Ask "what if" questions to develop high-level thinking skills. Establish an environment that is safe for risk taking and creative thinking. ■ Emphasize concepts, theories, ideas, relationships, and generalizations. ■ Do not assume that these students will make good tutors for others, however encourage the interaction if the student expresses an interest.
Students Who Have Learning Disabilities All learning disabled students have an academic problem in one or more areas, such as academic learning, language, perception, social-emotional adjustment, memory, or attention.	■ Provide support and structure with clearly specified rules, assignments, and duties. ■ Establish learning situations that lead to success. ■ Use games and drills to help maintain student interest and give them frequent practice of necessary skills. ■ Allow students to record answers on tape and allow extra time to complete tests and assignments. ■ Provide outlines or tape lecture material. ■ Pair students with peer helpers and provide class time for pair interaction. ■ Be prepared to work with family members or outside tutors to assist academic achievement.
Students Who Are Physically Challenged Students who are physically challenged fall into two main categories—those with orthopedic impairments and those with other health impairments. Students who have the use of one or more limbs severely restricted will likely be using orthopedic supports such as wheelchairs, crutches, or braces. Students with other health problems may require the use of respirators or other medical equipment.	■ Openly discuss with the student any uncertainties you have about when to offer aid. ■ Ensure that you and at least one other student know how to deal with any orthopedic devices that may be complicated. ■ Ask parents or therapists and the student what special devices or procedures are needed, and if any special safety precautions need to be taken. ■ Ensure that the entire class knows how to recognize and deal with an emergency, even if this simply means knowing who to call. ■ Allow physically disabled students to do everything their peers do, including participating in field trips, special events, and projects to the extent that it is possible and beneficial for that student. ■ Help non-disabled students and adults understand physically disabled students.
Students Who Are Visually Impaired Students who are visually impaired have partial or total loss of sight. Individuals with visual impairments are not significantly different from their sighted peers in ability range or personality. However, blindness may affect cognitive, motor, and social development, especially if early intervention is lacking.	■ As with all students, help the student become independent. Some assignments may need to be modified. ■ Assist classmates in learning how to serve as guides. ■ Limit unnecessary noise in the classroom. ■ Encourage these students to use their sense of touch. Provide tactile models whenever possible. ■ Describe people and events as they occur in the classroom. ■ Provide taped lectures and reading assignments. ■ Team the student with a sighted peer for laboratory work.

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	Tips for Instruction
Students Who Are Hearing Impaired Students who are hearing impaired have partial or total loss of hearing. Individuals with hearing impairments are not significantly different from their hearing peers in ability range or personality. However, the chronic condition of deafness may affect cognitive, motor, and social development if early intervention is lacking. Speech development may also be affected.	■ Seat students where they can see your lip movement easily, and avoid visual distractions. ■ Avoid standing with your back to the window or a light source. ■ Use an overhead projector so you can maintain eye contact while writing. ■ Seat students where they can see speakers. ■ Write all assignments on the chalkboard, or hand out written instructions. ■ If the student has an interpreter, allow both student and interpreter to select the most favourable seating arrangements.