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Science as Inquiry

Second Edition

ACTIVE LEARNING, PROJECT-BASED, WEB-ASSISTED, AND
ACTIVE ASSESSMENT STRATEGIES TO ENHANCE STUDENT LEARNING

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GOOD YEAR BOOKS

v 1.1

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CONTENTS

Science As Inquiry, 2nd Edition weaves together ideas about science teaching and inquiry that were developed over many years of work with practicing science teachers in the context of seminars conducted around the U.S.A, in school district staff development seminars, and courses that I taught at Georgia State University.

Science As Inquiry provides the practical tools, based on theory and research, that science teachers use in their classrooms to involve their students in inquiry learning, including hands-on investigations, project-based activities, Internet-based learning experiences, and science activities in which students are guided to construct meaning and develop ideas about science and how it relates to them and their community.

Inquiry science teaching by its very nature is a humanistic quest. It puts at the center of learning not only the students, but also how science relates to their lived experiences, and issues and concepts that connect to their lives. Doing science in the classroom that is inquiry-based relies on teachers and administrators who are willing to confront the current trend that advocates a standards-based and high stakes testing paradigm. The dominant reason for teaching science is embedded in an "economic" argument that is rooted in the nation's perception of how it compares to other nations in science, technology, and engineering. This led to the development of new science curricula, but it also led to the wide scale use of student achievement scores in measuring learning. Student achievement, as measured on "bubble tests," has become the method to measure effectiveness of school systems, schools, and teachers, not to mention the students.

Although the organizations that have developed the science standards (National Research Council) advocate science teaching as an active process, and suggest that students should be involved in scientific inquiry, there is a disconnect between the standards approach and the implementation of an inquiry-based approach to science teaching. We need to pull back on the drive to create a single set of standards and complementary set of assessments, and move instead toward a system of education that is rooted locally, driven by professional teachers who view learning as more personalized, and conducted in accord with democratic principles, constructivist and inquiry learning, and cultural principles that relate the curriculum to the nature and needs of the students.

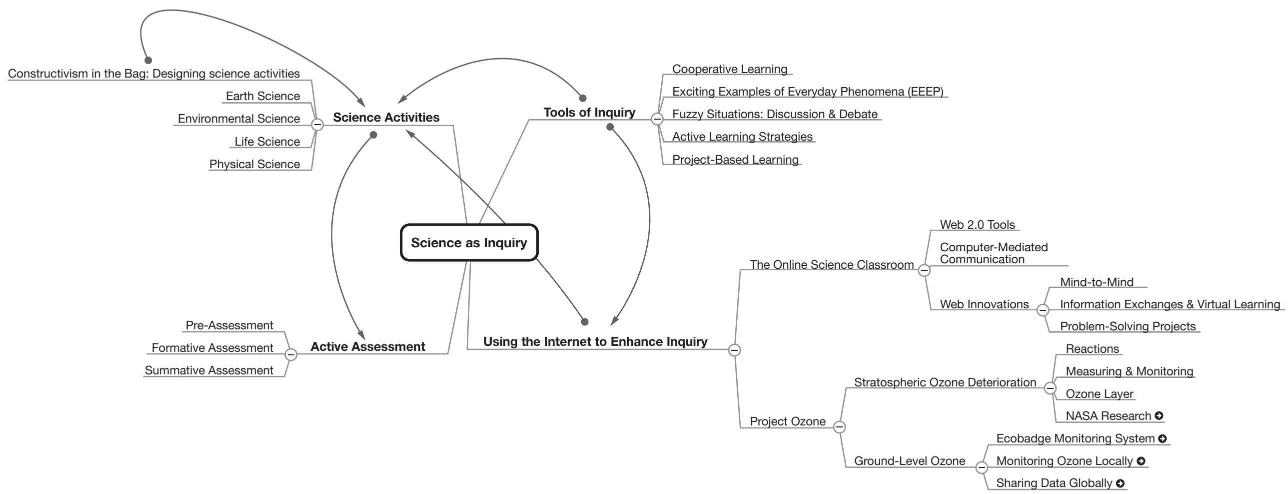
Science education researchers have reported that inquiry-based instructional practices are more likely to increase conceptual understanding than are strategies that rely on more passive techniques, and in the current environment emphasizing a standardized-assessment approach, teachers will tend to rely on more traditional and passive teaching techniques.[1] Inquiry-based teaching is often characterized as actively engaging students in hands-on and minds-on learning experiences. Inquiry-based teaching also is seen as giving students more responsibility for learning. Given that the evidence is somewhat supportive of inquiry-based science, our current scheme of national science standards emphasizing a broad array of concepts to be tested would tend to undermine an inquiry approach.

Teachers who advocate and implement an inquiry philosophy of learning do so because they want to inspire and encourage a love of learning among their students. They see the purpose of schooling as inspiring students, by engaging them in creative and innovative activities and projects. Here is how Kareen Borders[2], a science teacher, frames this view:

> *"My students are not passive learners of science, they ARE scientists. They embrace the idea that they are empowered to own their learning. In addition to creating a*

[1] *Minner, Daphne D.; Levy, Abigail Jurist; and Century, Jeane; "Inquiry-Based Science Instruction—What Is It and Does It Matter?"* Journal of Research in Science Teaching, *Vol. 47, NO. 4, PP. 474-496 (2010)*
[2] *Presidential Awards for Excellence in Mathematics and Science, 2011, from Lakebay, Washington*

Figure I.1.
The Organization of Science As Inquiry into Four Parts and 12 Chapters



love of learning within my students, I am intentional about equipping students with wonder, teamwork strategies, and problem-solving skills for jobs that may not exist yet."

Science As Inquiry embraces 21st century teaching in which inquiry becomes the center and heart of learning. *Science As Inquiry* provides a pathway to make your current approach to teaching more inquiry-oriented, and to embrace the digital world that is ubiquitous to our students and the world they inhabit.

Here are some things to look for as you make use of *Science As Inquiry*.

Organization of *Science As Inquiry*

Science As Inquiry is organized into four parts, including the Tools of Inquiry, Using the Internet to Enhance Science Inquiry, Active Assessment for Active Learning, and Constructivism in the Bag activities. Figure I.1 depicts the organization of *Science As Inquiry* and identifies the chapters comprising each part of the book.

Part I. Tools of Inquiry:

There are number of tools that teachers who embrace inquiry use in their classrooms. In this first part of the book, you will be introduced to collaborative or cooperative learning, which is fundamental to promoting a classroom ecology that supports student inquiry. As a teacher, knowing how to work with students in groups is essential. I have provided details on seven approaches to working with students in groups, based on a series of seminars and research on cooperative learning that I have done with practicing science teachers, grades 6 – 12. Additional tools of inquiry include EEEPs, Fuzzy Situations, active learning strategies, and project-based learning.

Part II. Using the Internet to Enhance Science Inquiry:

We live and work in a digitally transformed world, and science teachers have invented powerful ways of using the Internet to promote inquiry learning. This part of *Science As Inquiry* explores innovations and pedagogies that have emerged from the integration of Web 2.0 and science curriculum. Practical examples of projects and activities are described, showing how the more social and a communicative nature of the Internet results in students sharing, publishing, creating and exploring real science issues locally and globally. I have also included Project Ozone, presented in Chapter 7, an environmental science inquiry in which students design research studies, in collaboration not only with students in their own classes, but with students globally.

Part III. Active Assessment for Active Science:
In this section of the book, you will find an active approach to science assessment that focuses on integrating three aspects of an assessment system: diagnostic ways of assessing students' prior knowledge, formative assessments that help students learn and progress in science, and summative tools that provide feedback to students and teachers about learning.

Part IV. Constructivism in the Bag:
The title is a play on words based on an activity I did with thousands of science teachers in which they were given a plastic baggie of science teaching materials (such as a collection of rocks, a magnifier, a metric ruler, a streak plate) and then were asked, as members of a team, to develop an activity based on a constructivist model of teaching. In this part of the book you will find 31 activities and projects, some of them Internet-based that you can use and implement in your science curriculum.

Themes of *Science As Inquiry*

Tools of Inquiry: The tools of inquiry showcase five tools that are shown in Figure I.2, including Collaborative Learning, EEEPs, Fuzzy Situations, Active Learning Strategies, and Project-Based Learning. You will find specific ways to implement cooperative learning in your class, and for each cooperative learning model, you will find a science activity which you can use both to teach your students the method and to also hone your own cooperative/collaborative teaching skills. EEEPs are Exciting Examples of Everyday Phenomena. An EEEP is a tool in which you present an a demonstration-like event (some call these discrepant events) to the whole class, but students explore the EEEP in collaborative groups. You will find Earth, life, and physical science EEEPs to use with your students. Fuzzy Situations are science- related social issues in story form that engage students in research, discussion and debate of important issues. You can conduct these sessions in class, or use the Internet for students to participate in online discussions of important science- related social issues. Six Active Learning Strategies are presented that will offer ways to enhance student motivation and attitudes in science. The final tool of inquiry is the use of

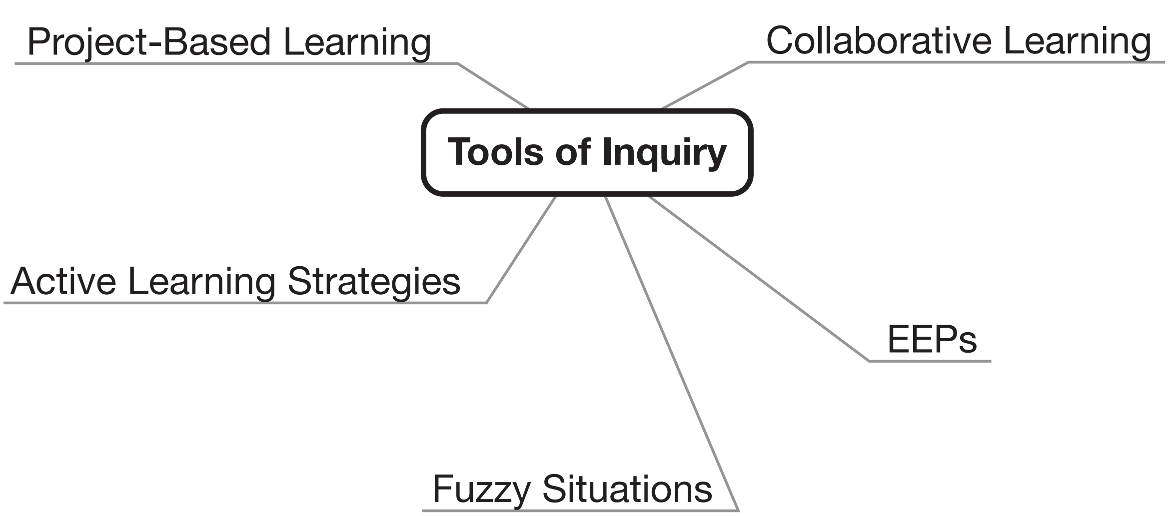
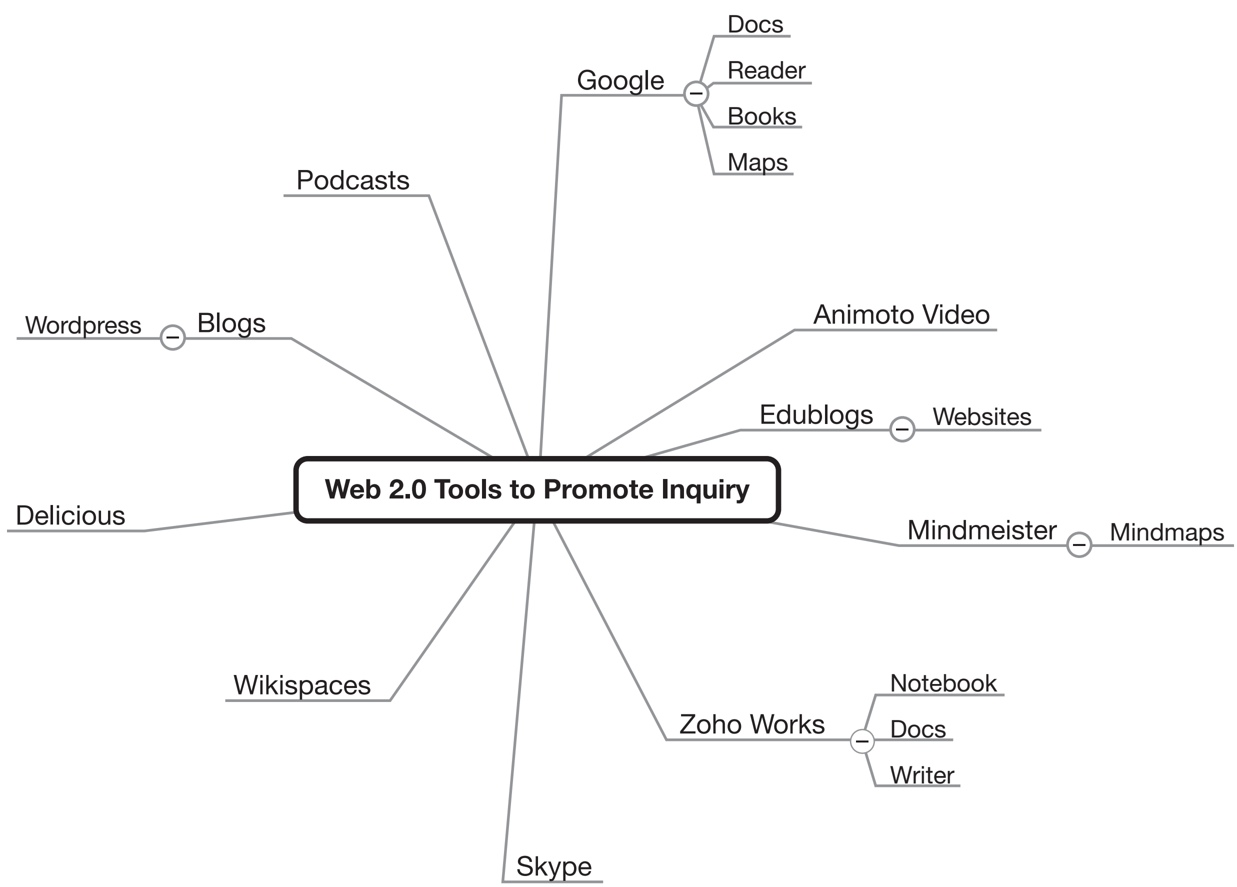


Figure I.2.
The Tools of Inquiry as Teaching Strategies that Promote Inquiry Learning in the Science Classroom

Figure I.3.
Web 2.0 Tools that promote inquiry and that are explore in Part II of the book.



Project-Based Learning activities as a fundamental part of the science curriculum. A cooperative learning model is presented that you can use to implement projects in your class. You will find examples of projects drawn from Earth science, environmental science, life science, and physical science.

Active Learning. This theme is connected to the way students learn science. There is no doubt that students come to science classes from varied backgrounds and with different skills and abilities. Science teaching that engages students in activities that draw on multiple abilities and learning styles will tend to reach a greater number of students than teaching that does not. Active learning, as the concept is used in *Science As Inquiry,* finds students involved in small cooperative groups whose tasks are interesting and problem-oriented. Teachers organize and facilitate group activities by making use of a variety of strategies—for example, cooperative learning groups, hands-on inquiry activities, and collaborative Internet-based studies. Underlying the active learning theme is the idea that learning is best promoted in communities of learners, and that new ideas are linked to previous knowledge and constructed by the learner. Active learning is a metaphor for a humanistic and constructivist model of teaching.

The Internet as a Path to Inquiry. The Internet as a theme of *Science As Inquiry* is viewed as an essential feature of inquiry science teaching. The Internet or Web has become more interactive and social, and consequently students can create, share, publish, and work together in collaborative groups within their own classroom, but also with students in other schools around the world. You will find the world of Web 2.0 presented here with examples of tools of the Internet that you can use with your students to enhance their ability to do inquiry. Figure I.3 is a chart showing the variety of Web 2.0 tools we can use in our classes to help promote inquiry science. The tools that are presented under this theme are exemplified with a variety of activities, as well three project-based science projects, Project Ozone, Project Green Classroom, and Project River Watch.

Assessing Active Learning. Assessment is an important theme in *Science As Inquiry*, and you will find a three-stage model of assessment with practical examples. Diagnostic (or pre-instruction) assessment is designed to assess students' prior knowledge by means of several active assessments. During instruction, formative assessment strategies become the tool that we use to help students learn, and to provide feedback to students. These assessments are embedded in instruction, and include a wide range of activities. After instruction, the goal is to evaluate students' progress and provide feedback about the effectiveness of the methods used by science teachers. Portfolios, interviews with students, written assessments, and performance tasks are explored.

Constructivist Activities. This theme explores the nature of instructional design that fosters inquiry science teaching. In *Science As Inquiry*, a four-stage constructivist design is used to present 31 activities representing Earth science, environmental science, life science, and physical science. Each activity was developed using a cyclic constructivist model of teaching. The elements of the cycle include: Invitation, Exploration, Explanation, and Taking Action.

The *Science As Inquiry* Website To make a seamless connection between the ideas in *Science As Inquiry*, I have designed a website that makes accessible activities, projects and links that are

Figure I.4.
Constructivist Learning Cycle in actiity design

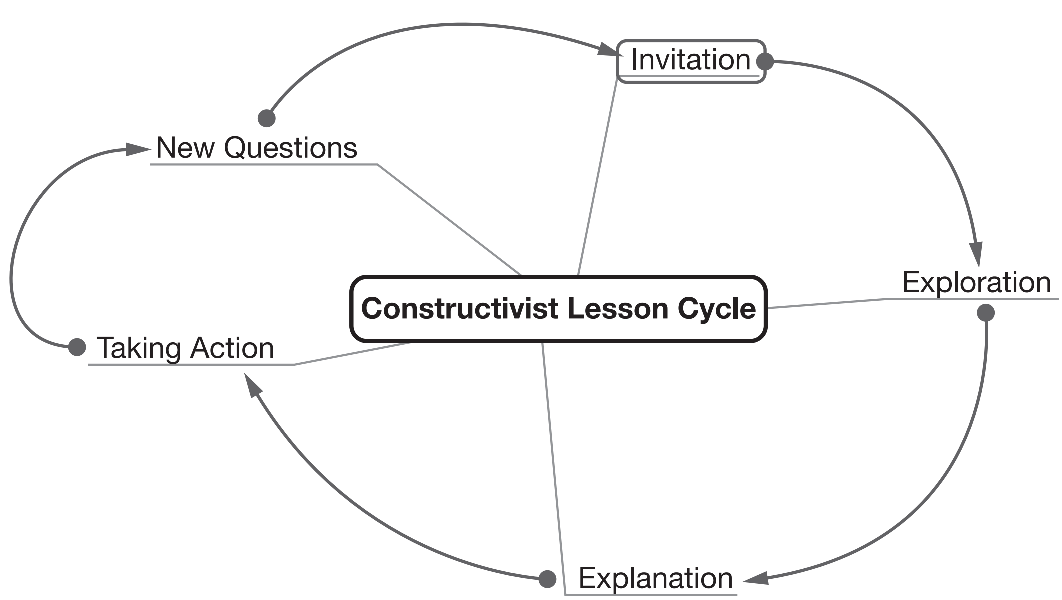
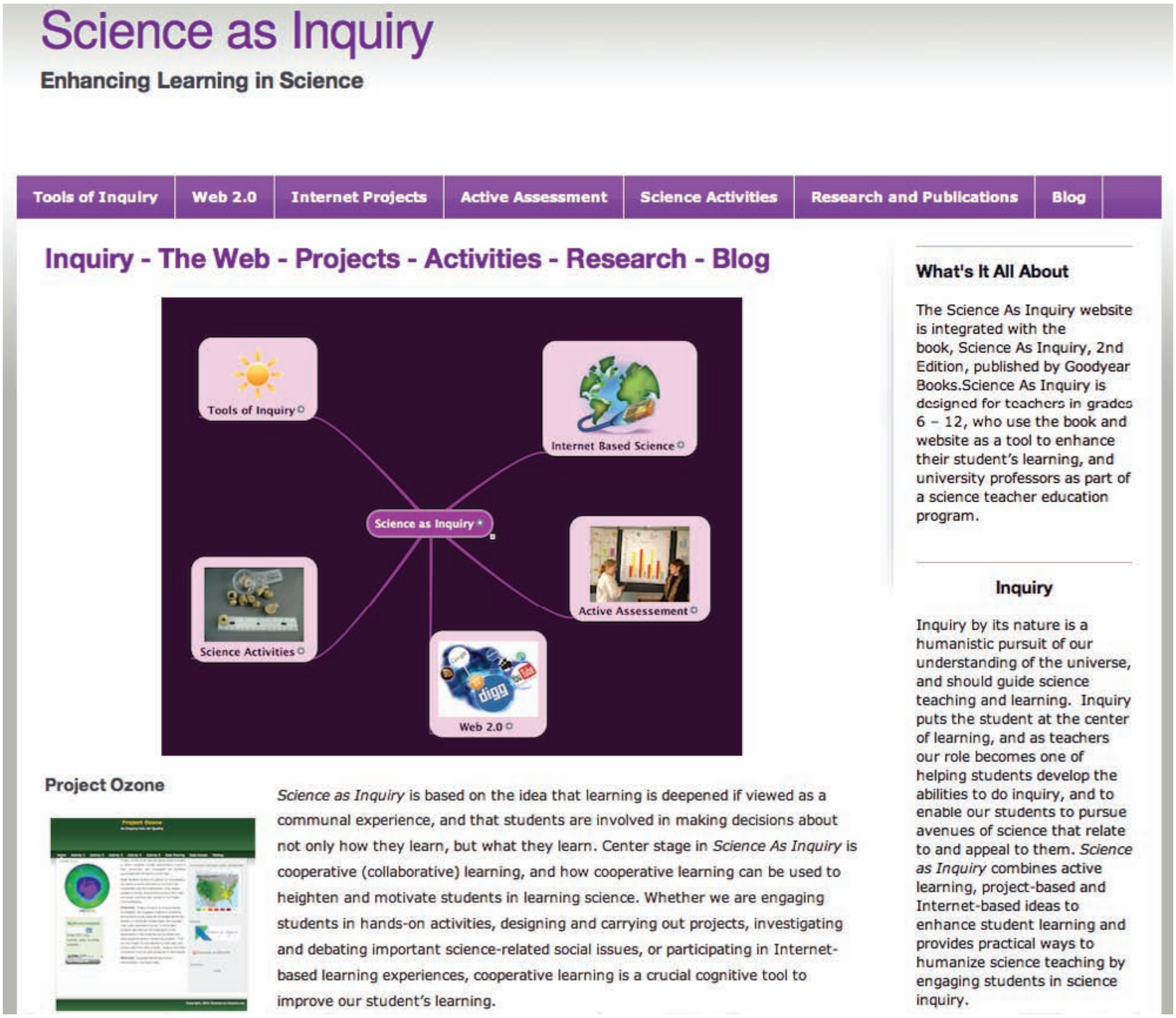


Figure I.5.
Screen shot of the *Science As Inquiry* Website:
http://www.science-as- inquiry.org



discussed and presented in *Science As Inquiry*. You will find science activities, links to teh Tools of Inquiry projects that you can do with your students using the Internet, and links to key research and publications. The website has a link to the *Science As Inquiry* blog enabling you to connect with other teachers using the book.

PART I THE TOOLS OF INQUIRY

Figure 1.1
Cooperative learning is fundamental to learning and brings students together to work on important problems. Learning this way mirrors some of humanity's best efforts at solving real problems.

This chapter will introduce you to several cooperative learning strategies designed to enhance the way students work together in small groups. Science education research has shown that cooperative learning, when used effectively, can lead to greater cognitive gain, better (more positive) attitudes toward science, and a higher motivation to learn science.

Key Concepts

Two concepts are fundamental to implementing cooperative learning strategies: positive interdependence and individual responsibility. The roles of each can best be understood by considering the examples in Figure 1.2. Engendering positive interdependence is the most important thing that we as teachers can do to help students work in small groups. Interdependence can be achieved in science activities by having students collaborate on an activity that requires a single product, by dividing the labor, by assigning roles, or by rewarding all of the students in a group.

Individual responsibility is just as important as positive interdependence. In the activities that we plan, we can encourage individual responsibility by focusing on individual outcomes, by giving feedback on each student's progress, by having students work alone at first and then share their work with the group, or by using experts.

Figure 1.2
Two Key Cooperative Learning Concepts

Positive Interdependence	Individual Responsibility
• We sink or swim together.	• I must learn this material.
• None of us is as smart as all of us.	• I cannot "hitchhike."
• I win when you win.	• My teammates depend on me.
• The whole is greater than the sum of the parts.	

The Strategies

The strategies presented in this chapter will show that cooperative learning is much more than putting students in groups and telling them to work together. Discussed here are seven cooperative learning strategies that have been used successfully in teaching seminar. Each is a stand-alone strategy, which means you can use any strategy in this chapter in any order that you wish.

Collaborative Inquiry Strategy

This approach combines the principles of cooperative learning—individual responsibility and positive interdependence—with science inquiry. On the one hand, each student in the group has a specific role; on the other hand, all students in the group are involved in science inquiry.

Students engaged in collaborative inquiry play one of the four roles shown in Figure 1.3. In science inquiry, students explore problems in

Figure 1.3
Cooperative Inquiry Roles

Communicator	Tracker	Checker	Materials Manager
• Helps resolve problems • Can leave team to communicate • Sends and downloads Internet messages	• Helps track progress • Records data/information for the team • Collaborates with communicator on Internet activity	• Helps team understand the activity • Facilitates talk about the activity • Is not the leader; is a facilitator	• Picks up/returns materials • Facilitates cleanup • Checks to make sure equipment is in working order

SIDEBAR 1.1

Collaborative Inquiry[2]

- Students explore problems in natural world.
- Students "do" science.
- Knowledge about natural world is "constructed" through talk, activity, and interaction.
- Talk is focused through small-group activity.

the natural world. Students "do" science. In Collaborative Science Inquiry, students construct knowledge about the natural world through small-group talk, hands-on activity, and discussion. Sidebar 1.1 lists the key characteristics of "collaborative (science) inquiry."

Thus, in the Collaborative Inquiry approach to cooperative learning, students are not only individually responsible for a part of the activity, they are also interdependent on each other because they have different tasks, all of which play a part in solving a science problem. As you get started with Collaborative Inquiry, it is helpful to provide students with a "role card" describing their collaborative responsibilities. To do this, make each group of students a copy of Figure 1.4, which describes the various roles in Collaborative Inquiry. Have students cut out the cards and distribute them so that each student receives the card describing his or her role. You might also want to make a poster identifying the four roles. By hanging it prominently in your classroom, you can quickly and effectively review the roles with your students.

LESSON PLAN: THE FOOTPRINT INQUIRY

Goals: To give students practice using the Collaborative Inquiry approach to cooperative learning; to generate alternative hypotheses to explain dinosaur footprints found in rocks dated to be 100 million years old; to encourage all group members to participate

Materials: Footprint Recording Sheet (Figure 1.5), Footprint puzzle(s) (Figures 1.6 and 1.7), photographs of dinosaurs

Web Site: http://dsc.discovery.com/dinoaurs/ *Dinosaur Central*

Procedure: Organize your class into teams of three or four students each. Have students number off within each group, and then assign each of the numbers one of the four Collaborative Inquiry roles. (If you decide to work with groups of three, have one of the

[2] After Rosebery, A., Warren, B., and Conant, F. Appropriate Scientific Discourse: Findings from Language Minority Classrooms. Working paper 1–92, Cambridge, MA: TERC.

Cooperative Inquiry Roles

Communicator

- Helps Resolve Problems
- Can Leave Team to Communicate
- Sends and Downloads Internet Messages

Communicator

- Helps Resolve Problems
- Can Leave Team to Communicate
- Sends and Downloads Internet Messages

Material Manager

- Picks Up/Returns Materials
- Facilitates Cleanup
- Checks to Make Sure Equipment Is in Working Order

Material Manager

- Picks Up/Returns Materials
- Facilitates Cleanup
- Checks to Make Sure Equipment Is in Working Order

Checker

- Helps Team Understand the Activity
- Facilitates Talk About the Activity
- Is not the Leader, Is a Faciliatator

Checker

- Helps Team Understand the Activity
- Facilitates Talk About the Activity
- Is not the Leader, Is a Faciliatator

Tracker

- Helps Track Progress
- Records Data/Information for the Team
- Collaborates with Communicator on Internet Activity

Tracker

- Helps Track Progress
- Records Data/Information for the Team
- Collaborates with Communicator on Internet Activity

students be the Communicator as well as the Materials Manager.) Give each team a copy of the Footprint Data Sheet and follow these steps:

1. Investigate the set of footprints with your teammates. Make a list of as many hypotheses to explain the pattern of the footprints as there are members of your team. Make sure that everyone contributes ideas and that you listen to each other's ideas.

2. Explain the task to the students. Tell them their job is to investigate, as a team, a set of footprints (show them Figure 1.6) found in rocks in central Connecticut. The rocks were dated to be about 100 million years old (which means they were deposited during the Cretaceous Period in the Mesozoic Era). Tell students they are to make a list of as many hypotheses as there are people in the group to explain the pattern of the footprints. Tell them to be sure that everyone participates. Give the students about five to eight minutes to generate their hypotheses.

3. At the end of this period, tell the students that you have some additional data from the footprint site—that is, scientists have sent you additional prints. Present Figure 1.7, using a bit of dramatic flair. Now have the students look over their hypotheses and, in light of the "new data," have them revise, discard, or accept their hypotheses. Have each team select one hypothesis to share with the class.

4. Select one student from each group to write the group's hypothesis on a chart or white posterboard. Divide the chart or board into four, so that each group has a space in which to write. Discuss the results, and ask students to defend their ideas with observations they made while working as a group.

5. Announce that the most likely explanation is that these are dinosaur prints, but that no one really knows for certain. Thus all the students' hypotheses can be considered plausible.

6. Going Further. Have your students investigate dinosaurs further. Here are two sites to visit:

http://lawrencehallofscience.org/bigdinos/dino.html
Big Dinos Return

http://paleo.cc/paluxy/ovrdino.htm
Overview of Dinosaur Tracking

SIDEBAR 1.2

Possible Hypotheses

- Two animals (birds) approached a water hole; one flew off, the other walked away.
- Two animals walked toward something; one spotted the other and tried to run; a fight ensued; one walked away.
- Two animals independently approached an area at different times.
- Two animals approached an area (mother, daughter); the daughter rode away on the mother's back.

Footprint Inquiry
Practicing Collaborative Inquiry

Objectives
1. Explore and investigate a problem from the natural world.
2. Generate alternative hypotheses to explain data in the form of footprints found in rocks that are 100 million years old.
3. Practice using Collaborative Inquiry roles.
4. Encourage everyone in the group to communicate ideas.

Materials
1. One set of footprints per team
2. One data recording sheet per team

Collaborative Inquiry Roles

Role	Team Member
Communicator	________________
Materials Manager	________________
Tracker	________________
Checker	________________
Coach	________________

Footprint Data Sheet

Tracker's Name: ______________________________ Date: ____________________

List of Hypotheses

Modified Hypothesis