DOCUMENT RESUME

ED 429 807 SE 062 036

AUTHOR	Bainer, Deb; Barron, Pat; Cantrell, Diane
TITLE	SWEEP: Sciencing with Watersheds, Environmental Education and Partnerships. Instructor's Guide to Implementation and Summer Institute Participant Notebook.
INSTITUTION	Ohio State Univ. Mansfield Campus.; Science and Mathematics Network of Central Ohio.; Ohio State Dept. of Natural Resources, Columbus.
SPONS AGENCY	Office of Educational Research and Improvement (ED), Washington, DC.; Eisenhower Program for Mathematics and Science Education (ED), Washington, DC.
PUB DATE	1998-00-00
NOTE	332p.
AVAILABLE FROM	Partnership Office, c/o Dr. Deborah Bainer, The Ohio State University at Mansfield, 1680 University Drive, Mansfield, OH 44906.
PUB TYPE	Guides - Classroom - Learner (051) -- Guides - Classroom - Teacher (052)
EDRS PRICE	MF01/PC14 Plus Postage.
DESCRIPTORS	Conservation Education; Elementary Education; *Elementary School Science; Elementary School Teachers; *Environmental Education; *Faculty Development; Hands on Science; Inquiry; Inservice Teacher Education; Institutes (Training Programs); Integrated Curriculum; *Partnerships in Education; Science Instruction; Thematic Approach; Water Resources
IDENTIFIERS	Ohio; *Watersheds

ABSTRACT

Sciencing with Watersheds, Environmental Education, and Partnerships (SWEEP) is a professional development program designed to help elementary teachers improve the way they teach science using partnerships among teachers and resource professionals. SWEEP follows a thematic approach using watersheds as the core concept of an integrated elementary curriculum. The program involves a four-day intensive summer institute for teams of one to four teachers representing one school building. During the institute, teachers team with resource professionals or volunteers from agencies and businesses who possess science content expertise and a desire to work collaboratively with teachers to strengthen science instruction. Together teachers and resource professionals engage in activities in content areas such as partnering, instructional methods from exposition to inquiry, watersheds and theme issues, thematic planning, child development, process skills, materials management, questioning strategies, and assessment. Each partnership is maintained throughout the school year. The instructor's implementation guide provides logistical information about operating the SWEEP program, detailed teaching notes, and an in-depth discussion on establishing and supporting effective partnership teams. A matrix outlining basic aspects related to how SWEEP was originally implemented in Ohio in the Cuyahoga River watershed and the lower Scioto River watershed and guidelines to consider when modifying or adapting it to other settings are also included. The notebook is used to provide professional development for those teachers and resource professionals who attend the summer workshop and is designed to be used with the implementation guide for program instructors. The notebook is divided into tabbed sections that correspond to the nine content areas listed in the table of contents of the Instructor's Guide. Each session presents an essential skill to make hands-on, minds-on science work for classroom teachers and resource partners. (PVD)

Sciencing with Watersheds, Environmental Education and Partnerships

Instructor's Guide to Implementation

Co-sponsored by
The Ohio State University at Mansfield
Ohio Department of Natural Resources,
Division of Soil & Water Conservation
Science & Mathematics Network of Central Ohio

Funded in part by
The U.S. Department of Education, OERI
Dwight D. Eisenhower Mathematics and Science Education Program

Steering Committee

Elaine Andrews,
University of Wisconsin-Madison,
Cooperative Extension

Linda Erickson-Eastwood,
Minnesota Department of
Natural Resources-Fisheries

Thomas Gadsden,
Eisenhower National Clearinghouse

Joe Heimlich,
Ohio State University Extension
and ERIC

Kevin Hennis,
Environmental Education Council of Ohio

Diana Hunn,
Science Education Council of Ohio,
University of Dayton

Ruth Jacquot,
Murray State University

Marylin Lisowski,
Eastern Illinois University

Paul Loeffelman,
American Electric Power

Martha Monroe,
National Consortium for Environmental
Education and Training (NCEET)

William Stapp,
Global Rivers Environmental Education
Network (GREEN)

David Todt,
Shawnee State University

Joe Wright,
Indiana Department of Education

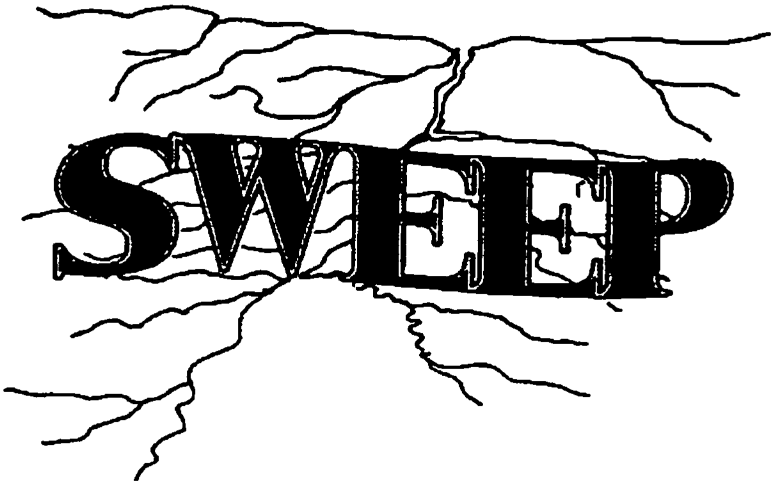
Deb Yandala,
Cuyahoga Valley Environmental
Education Center

Special Thanks to:

Alma Steveline, Project Assistant
Chris Halon, Research Assistant
The Ohio State University-Mansfield

Cathy Behrends, Assistant Director
Joy Brady, Program Assistant
Paula Rose, Program Assistant
Science and Mathematics Network of Central Ohio

Tina Ray, Office Assistant
ODNR Division of Soil & Water Conservation



Sciencing with Watersheds, Environmental Education and Partnerships

Instructor's Guide to Implementation

Project Co-Directors and Authors

Deb Bainer, Associate Professor
The Ohio State University, Mansfield
1680 University Drive
Mansfield OH 44906
(419) 755-4287
bainer.1@osu.edu

Pat Barron, Executive Director
Science & Mathematics Network of Central Ohio
807 Kinnear Road
Columbus OH 43212
(614) 485-9800
pbarron@enc.org

Diane Cantrell, Deputy Chief
ODNR Division of Soil & Water Conservation
1939 Fountain Sq. Ct., E-2
Columbus OH 43224
(614) 265-6788
diane.cantrell@dnr.state.oh.us

Additional copies are available from:

Partnership Office
c/o Dr. Deborah Bainer
The Ohio State University at Mansfield
1680 University Drive
Mansfield OH 44906
(419) 755-4287

This *SWEEP Instructor's Guide to Implementation* was funded in part by a grant from the Eisenhower Federal Activities Program, Office of Educational Research and Improvement (OERI), U.S. Department of Education.

Table of Contents

Welcome to SWEEP!

Introduction to SWEEP

Sciencing with Watersheds, Environmental Education, and Partnerships (SWEEP) is a professional development program to challenge elementary school teachers to improve the way they teach science. SWEEP is not a watershed education program for students; it is not a new curriculum. It is a model for the professional development of teachers and resource professionals who work with teachers in classrooms. The key elements of the program are found in its name: SWEEP.

- The program is aimed at enhancing **science** instruction in elementary (K-6) classrooms, although the concepts and methods can be applied at any grade level as well as to nonformal education settings.
- The program involves a thematic approach, using **watersheds** as the core concept of an integrated elementary curriculum.
- The program emphasizes **environmental education**, extending the classroom to the outdoors and studying the interconnected topics and issues which students in a particular watershed experience every day.
- The program accomplishes all of this by establishing **partnerships** among teachers and resource professionals or volunteers from agencies and businesses who possess science content expertise and a desire to work collaboratively with teachers to strengthen science instruction.

Program Description: Elementary teachers cite lack of content knowledge and confidence as primary reasons for teaching science inadequately. SWEEP provides professional development to address these two concerns by pairing classroom teachers with science professionals in long-term partnerships, and by providing training in the pedagogy necessary to make inquiry-based science instruction effective.

The program presents a four-day intensive summer institute for teams of one to four teachers representing one school building. During the institute, they team with a resource professional and together learn about partnering, instructional methods, thematic planning, child development, process skills, materials management, questioning strategies, and assessment. For each topic, they expand their understanding of the theory, see the theory modeled in practice, and enhance their own skills in implementation. Participation in inquiry-based activities and debriefings also focus on building and sustaining relationships within a partnership. Each partnership reconceptualizes its grade-level curriculum around an integrated watershed theme and develops an action plan to implement that curriculum during the next academic year.

Throughout the year, teachers and resource professionals collaboratively teach the integrated environmental science curriculum. Classrooms throughout the watershed communicate and share projects and data, thus enhancing science instruction and reinforcing the interconnectedness throughout the watershed. Follow-up meetings during the autumn and spring provide sharing, reflection, and evaluation times. Site visits and communication with project staff provide on-going support and networking opportunities.

During a two-day workshop the following summer, partnership teams share and reflect on their action plans, plan for the next year, and strategize ways to extend the program within their building or district.

Program Impact: Research and evaluation of the SWEEP program suggest that teachers, students, and resource professionals benefit from the program. Teachers show more confidence with science content and provide more skilled instruction. They describe their science teaching as less traditional and textbook-based and more hands-on, integrated, and collaborative. They are more aware of and use more science education resources, and evaluate student learning with a wider range of assessment strategies.

Students involved with the SWEEP program are reportedly more enthusiastic and hold more positive attitudes toward science and school. Improved behavior, enhanced leadership and social skills, and reduced gender stereotypes associated with science careers are also noted. Parents report that students involved with SWEEP ask more science-related questions and extend science activities into the home. Parent involvement in school activities related to SWEEP increases.

Resource professionals show enhanced job-related skills and competencies as a result of participating in school-based partnership teams. They state that they have greater knoweldge of and ability to work within their agency; provide more leadership, flexibility, and collaborative problem-solving to the agency; are more sensitive and empathic as they interact with co-workers; communicate more clearly and comfortably with a range of audiences; and use listening skills to better understand and meet the needs of clients.

Implementing SWEEP

SWEEP was originally implemented in the Cuyahoga River watershed in northern Ohio and the lower Scioto River watershed in southern Ohio. Now it is time to move on…to SWEEP the nation, so to speak. To help you replicate the SWEEP program in your school, district, or region, two resource guides are available. While you will need to adapt the program to your specific setting and goals, these resources contain guidelines and information you need to initiate and sustain the program.

Participant's Notebook: This 268-page notebook is used to provide professional development for teachers and resource professionals who attend the summer institute. It contains the basic concepts, activities, and selected readings to acquaint participants with the four components of SWEEP: hands-on science, watersheds as an integrating theme, environmental education, and partnering. The first tabbed section of the notebook gives an overview of the program and describes how we begin the institute. The other nine tabbed sections reflect institute content sessions. The partnering theme is presented early in the institute in a session that describes and models the unique reform-based partnering relationship which is the heart of the SWEEP program. Teaching inquiry science is the focus of eight sessions: Exposition to Inquiry, Watersheds and Issues, Thematic Approach, Child Development, Process Skills, Management, Questioning, and Assessment. Each presents an essential skill to make hands-on, minds-on science "work" for classroom teachers and resource partners.

Instructor's Guide to Implementation: This manual contains the same ten sections as the *Participant's Notebook* but provides greater detail to assist you in leading a SWEEP institute. Page references in this guide link the explanations to similar pages and activities found in the *Participant's Notebook.* Because the activities included in the *Participant's Notebook* are not duplicated in this guide, you will need both the notebook and the guide to fully reflect the SWEEP Institute. The guide provides an in-depth discussion of reform-based partnering, characteristics of effective partnerships, how to weave the partnership theme throughout the institute, and a description of the "action plan" which participants develop to restructure their science curricula during the following academic year.

Further, it provides detailed teaching notes to enable you to replicate the institute or to restructure the science curriculum in your classroom, building, or district. Each of the pedagogy sections has a similar structure:

- a **rationale** explains how the topic links to SWEEP and inquiry science;
- the **background** presents learning theory and concepts related to the topic to develop participants' foundational understandings;
- the **activity(s)** include details on how to conduct, debrief, and manage activities found in the *Participant's Notebook*;
- the **closure** debriefs the theory behind the activity and reinforces essential concepts; and
- the **related readings** and references suggest further reading and resources.

Implementation Options: We recognize that, like any program, SWEEP will need to be modified to be an effective professional development program in your situation. To that end, we have examined the basic elements of SWEEP to differentiate between characteristics which may vary based on the context or setting to which the program is adapted, and core characteristics which must remain intact if SWEEP is to be replicated.

The following matrix outlines basic aspects related to how SWEEP was originally implemented in Ohio and suggests guidelines to consider when modifying or adapting it to other settings. This is offered as a tool to help you evaluate if SWEEP meets your programmatic goals and is appropriate for your situation. Further, it should help you determine how to build flexibility into the format for implementing SWEEP.

Replication Matrix for SWEEP Program

Topic	Ohio Model	Guidelines for Adaptation
Implementation Team		
Composition	1 Education Professor 1 Natural Resources/Watershed Representative 1 Partnering Expert	2-3 people with expertise and experience in education, natural resources/ watershed, partnering
Responsibilities	Develop and implement program Recruit partnership teams Teach institute Provide year-long support	Modify Ohio program to meet local needs Recruit teams Teach institute Provide follow-up
Program Overview		
Goal	To improve elementary science education	Same
Core elements of SWEEP	Professional development through partnerships between teachers and resource professionals How to teach inquiry-based, hands-on science "Watershed" as integrating theme	Same
Audience	Elementary (K-6) teachers and resource professionals	Teachers (elementary, middle or high school) and resource professionals
Institute	4- or 5-day summer institute	Minimum of 2-day workshop
Institute product	Yearlong action plan	Same
Follow-up	2 half-day meetings, written communications, phone calls, site visits, evaluation instruments	1 half-day meeting, letters

Topic	Ohio Model	Guidelines for Adaptation
Duration of program	2 or more years plus sustained partnerships	1 or more years plus sustained partnerships
Partnerships		
Task	Collaboratively plan, implement and assess a yearlong action plan	Same
Composition of team	2-3 teachers plus 1 resource professional	1-3 teachers and 1 resource professional
Number of times in classroom	Monthly doing active learning	Approximately monthly doing active learning
Duration of partnerships	2 years minimum, hopefully on-going	1 year minimum, hopefully on-going
Content of Institute		
Main topics	Overview: Setting the stage for inquiry science	Same
	Partnering	Same
	Planning time	Same
	Thematic approach	Same
	Process skills	Same
	Networking within watersheds	Same (if 2 or more schools)
	Institute evaluation	Same

Topic	Ohio Model	Guidelines for Adaptation
	Child development	Integrated throughout
	Management	Integrated throughout
	Questioning	Integrated throughout
	Several times for sharing	At least one time for sharing
	Exposition to Inquiry	Optional
	Watersheds and Issues	Optional
	Assessment	Optional
	Field experiences	Optional
Number of hands-on activities	15+	Minimum of 3-4

Related Readings and Resources

For more information about SWEEP, sample action plans, and evaluation and research on the program's impact, contact us via email at: sweep@osu.edu.

Visit our website at: http://www.mansfield.ohio-state.edu/mans/sweep/index.html

Please note that this website address is **incorrect** in the participant's notebook. The above address is correct.

Overview

Rationale

This is where the institute begins. This "Overview" session introduces the participants to each other, to inquiry science, and to the logistics of the institute. This section in the *Participant's Notebook* contains organizational information needed throughout the institute and for teams as they continue to network throughout the year. So, we revisit it frequently. We view the following as essential parts of the "Overview" section in the notebook (Note: Because this information is situation specific, only an agenda is included in the *Participant's Notebook.*):

- institute **agenda** (pp.1-4) listing the daily schedule;
- **activity list** indexing activities used throughout the institute by title, page in the notebook, and source;
- project **staff directory** listing institute personnel including name, position, and all contact information;
- **participant list by watershed** providing contact information for participating schools within both watersheds represented at the institute, including names, grade levels, and contact information for each team member;
- **alphabetical participant list** presenting contact information for all participants;
- **state map** showing all counties and rivers within the two watershed regions, and locating participants' schools within those watersheds; and
- **action plan** outlining the yearlong curriculum plan to be completed by each team (located in the "Partnering" section of the *Participant's Notebook*).

When appropriate, the following may also be included:

- **course syllabus** providing university-related information if participants are receiving course credit;
- book and equipment **order forms** with instructions if monies are available to provide these for participants; and
- **reference list** showing curricular materials, trade books, or other resources used during the institute or available for participants to browse or use.

Beginning the Institute

We actively involve participants with each other and with activities from the very beginning of the institute. As participants arrive, register, and receive their notebooks, we have them make a nametag using construction paper. We display directions on an overhead in the meeting room and provide supplies on each team's assigned table. Names must be printed large enough so that they can be read from across the room. The nametag should show three characteristics of the individual so that they can serve as conversation starters as participants become acquainted. For example, a nametag might display a plant, a rabbit, and a book to indicate the participant's interests in gardening, a pet rabbit, and mystery novels. We request that participants wear nametags to all sessions. Laminating nametags ensures that they will last throughout the week.

Activity: Knots (p. 5)

Procedure: After a brief welcome, participants engage in an activity such as Knots to get them interacting. This mixer introduces what the institute is all about: active participation and joining together with others to solve problems. The activity works well with participants divided into groups of up to 10.

Debriefing: The discussion questions contained in the activity provide a nice transition to talking about the institute and partnering. Staff introductions follow, with each person giving a brief biography to establish the context of who the leaders are and what their role is in SWEEP. Participants briefly introduce themselves to the group as well.

Activity: Clearer than Mud (pp. 7-8)

Background and Procedure: Next, we set the stage for hands-on science by engaging participants in an inquiry activity. This activity enables participants to experience inquiry-based teaching and learning and to glimpse the "watershed" theme. More important, it calls attention to models of how children learn called **learning cycles.**

Research on how children learn has strongly influenced current science education reform efforts. Many teachers believe that students should be able to understand and learn from well-organized verbal explanations of concepts. Others think that simply engaging learners in hands-on activities leads to learning. A basic premise of the learning cycle articulated by Renner and Marek (1988), however, is that for learning to occur, the teacher must intervene before, during, and after the learning episode. The learning cycle of teacher/student interaction has four phases.

1. The teacher first must **engage** the students in the big idea, concept, or problem involved with the lesson by posing an interesting problem, allowing creative drawing or writing, or focusing on a current news story. Accessing prior knowledge to find out what students already know is vital.
2. Second, students investigate and **explore,** through some common experience or activity, to establish a common experience base and to begin to communicate and clarify ideas and explanations. Activities like the ones included in the SWEEP institute engage students in this exploration phase.
3. Next, students **develop** explanations or solutions based on prior knowledge and exploration experiences. Teachers encourage students to organize and clarify their explanations using a variety of resources and communication methods (e.g., charts, posters, tables, photos, transparencies, logs, journals).
4. Students **extend and apply** their understanding of concepts and skills to different, real-world situations. Teachers help students connect their understandings to their social context, discover ways to take action, or build working models to show the relationship among concepts.

A review of the literature would produce a number of different versions of the learning cycle, with anywhere from three to seven phases. Each, however, uses the core ideas of first exploring, then conceptualizing, and finally applying (reapplying or extending) the "new" understandings. For elementary grades, we use Wassermann and Ivany's version (1988) which has three cycles that young learners can easily understand: play, debrief, and replay.

"Clearer than Mud" is an inquiry activity that we use to illustrate the learning cycle. We begin by presenting partnership teams with a jar of dirty water and their first challenge: clean up the water. By applying trial and error, drawing from previous knowledge (this is where some resource professionals have an opportunity to shine!), and branching off from related experiences, teams work for 15 minutes to produce a baby food jar of their cleanest water. While this is hard work, it illustrates the "play" part of the learning cycle.

For the "debrief" phase, team representatives stand in the front of the room, forming a continuum of water samples ranging from the dirtiest to cleanest water. They discuss what procedures they used.

If time permits, the "replay" phase can be undertaken. In any case, we ask teams to suggest how they would modify their procedure to get better results.

Debrief: In addition to the discussion questions provided in the activity, we ask questions like the following.

1. What prior knowledge and experiences did you have that influenced your procedure?
2. What effect did materials from the supply table have on the dirty water (e.g., alum causes dirt to form clumps and precipitate out)?
3. How did this activity engage you in the learning cycle? How did you feel during each phase?

Management: This time-consuming activity is hastened along by having all supplies well organized and a flow pattern for picking up materials. Be sure to cover trays with a thick layer of newspaper. The materials manager uses the tray to pick up additional supplies and the "play" begins. An abundance of extra supplies is available for the materials manager to fetch if the team needs them. If pressed for time, you can begin by having a full range of supplies on each tray rather than having teams decide what they want to use.

Cleanup for this activity can be a nightmare. We facilitate cleanup by having managers return all materials on the tray; dump the dirty water into a large pail; dump wet sand, gravel, and non-reusable supplies directly into a sturdy trash can; sort the containers into piles for washing; and wipe off and stack their tray. Volunteer help is always welcome.

Related Activities: Two similar but more structured activities are "Water Purification" in *Consider the Earth: Environmental Activities for Grades 4-8* (by J. M. Gates, 1989, Teacher Ideas Press), and "Mini Water Treatment Simulation" in the Project AIMS book, *Water, Precious Water* (1988 by AIMS Education Foundation, Fresno, CA).

Closure

These activities set the stage for an active and interactive institute focused on teaching and learning inquiry science. As we dismiss participants to lunch, their assignment is to interview their partners to begin building strong relationships within their partnership team, which is the topic of the afternoon sessions.

Related Readings and References

Barman, C. R. (Winter 1996-97). Revising the learning cycle. *CESI Science*, pp. 8-9.
Presents a learning cycle model including four phases: assessment, dialog, presentation, and application.

Burton, V. & Campbell, M. (October 1997). The seven "E" teaching model. *Science Scope,* pp. 32-34.
Defines seven steps to engage students in inquiry-based learning: expectation, enticement, engagement, explanation, exploration, extension, and evidence.

Renner, J. W. & Marek, E. A. (1988). *The learning cycle in elementary school.* Portsmouth, NH: Heinemann Educational Books, Inc.
Discusses the engage, explore, develop, extend and apply learning cycle in depth.

Wassermann, S., & Ivany, J.W.G. (1988). Teachers, children, and science: Theoretical perspectives. In *Teaching elementary science: Who's afraid of spiders?* (pp. 1-36). New York: Harper & Row.
Describes the learning cycle for young children doing science.

Developing SWEEP Partnerships

Rationale

Partnerships between schools and agencies have been advocated as a vehicle for improving science education for over a decade. Collaboration among educators at all levels, state and local policymakers, business and industry, parents, and the community at large is viewed as essential to bringing about significant change in education. As a result, partnerships have been springing up around the country at an astonishing rate. In 1989, the Department of Education estimated that over 140,000 partnerships between schools and businesses existed nationwide (Rigden, 1991).

Good partnerships can help to improve the quantity and quality of science instruction. Businesses and agencies provide needed resources and role models. Schools provide agency partners with ways to fulfill their social goals and responsibilities in the community, to influence the skills and knowledge of potential employees, and to enhance job-related skills for their workforce (Bainer, Barron, & Cantrell, 1995; Hall, Castrale, & Zimmerman, 1993).

The SWEEP program recognizes the potential impact of partnerships on students, teachers, and resource professionals. Establishing effective partnerships that will lead to better science teaching and learning is a core focus of the SWEEP program. Unfortunately, "partnership" has become a buzzword with a variety of meanings. In order to truly understand and replicate the SWEEP program, you must first understand the qualities of the effective partnerships that the program seeks to establish.

Background

It is essential that, during the four-day summer institute, partnership teams are established and their direction and relationships firmly developed if they are to impact science instruction throughout the following academic year. Beginning early in the institute, we introduce partnership teams to the concept of collaborative partnering and provide them with instruction and materials to guide them in developing their partnership focus.

Types of Partnerships: Reform-based, collaborative partnering which is the focus of SWEEP is different from other partnership models. In collaborative partnerships, elementary classroom teachers and resource professionals work as equals to blend the teacher's curricula with the resource professional's expertise in those areas. The result is that students participate in hands-on, real-world activities which are tied directly to what they are learning. The experiences help build bridges between the concepts and "real life." Partners work together with teachers in the classroom at least once a month over the entire school year, which enriches the experience for students and helps break down stereotypes as the students and the professionals get to know each other as individuals. This reform-based partnership model has been informed by Rigden's conceptualization of school-business partnerships (*Participant Notebook*, p. 9).

How do reform-based partnerships differ from other partnership models? The continuum of different levels of partnering (see below) shows how teachers and businesses or agencies have worked together in partnerships in recent years.

Partnering Continuum

- **None:** This was the status quo for many years. Teachers and business people did not think about working together nor see any benefits to this type of interaction.
- **Getting Together:** After a key education report, *A Nation at Risk,* was released in 1980, the U.S. Chamber of Commerce formed the Adopt-A-School program. Adopt-A-School relationships today are very diverse. Some are very rich, with both the school and business or agency highly involved with each other and with the students. Others are characterized by more limited involvement and interaction. For example, the business donates money or equipment to the school and the students send thank you notes or pictures back to the business. This type of relationship is not counterproductive. While it certainly gets schools and businesses acquainted, we believe that more can be gained with a deeper partnering relationship.
- **Great Projects:** In some relationships, schools and businesses or agencies find that they want to work together more closely, so they decide to plan and carry out a short-term project or collaborative activity. These projects frequently involve interaction between resource professionals and students, but they do not extend over the school year and may not be tied to the curriculum. Holding an Invention Convention or organizing a school-wide field trip to a state park are examples of these projects.
- **Reform-Based/Collaborative Partnering:** This type of partnering goes beyond short-term projects. It involves a long-term commitment and close interaction among the members of the partnership team and with the students. On the very edge of the continuum, ideal Reform-Based Partnering is very difficult to attain. We use this continuum, however, to help participants label the types of partnerships they have heard about or experienced, and to remind them that partnership teams are dynamic; there is almost always a next step in the evolution of their partnership.

Forming Partnership Teams: Partnership teams can be formed in two primary ways: by the leaders of the institute or by someone interested in being a member of a partnership team. We use the first approach in our SWEEP program. First, we recruit the teachers for each team by sending a letter of invitation with an information packet and application form to selected schools. Based upon the applications, we select the teams of teachers. At the same time, we send letters of invitation with an information packet and confirmation form to resource people we know or who are recommended to us. We recruit enough resource professionals to have at least one per team of teachers. In pairing the partner with the teachers, we consider the resource professional's grade-level preference and travel time to the school.

Interested teachers or resource professionals can also initiate a partnership team on their own. For example, teachers may want to approach a parent whose job is related to environmental issues or contact business, government agencies, colleges or other community resources that are near their school to find an environmental scientist or natural resource professional who is willing to partner with them. In a similar way, resource professionals who want to form a partnership can start by asking a teacher they already know to partner with them (e.g., their own child's teacher, a neighbor, someone from church). If these resources are not available, they can contact schools near their place of work, the local science curriculum supervisor or the state science teachers association.

There is no cookie-cutter formula for how teams should be configured. It could be one teacher and one resource professional, or two to four teachers with one or two resource professionals. However, we have found that if the resource professional will be working with two or more teachers, then the teachers should either be from the same grade level or team teaching in order to make things easier for the partner (i.e., not spread the resource person too thin).

Characteristics of Reform-Based Partnering: To help participants better understand the reform-based partnership model used in SWEEP, we have identified a list of characteristics of reform-based partnerships (p. 10). This list has been developed and refined, based on the experiences of successful partnerships we have worked with over the years. Hopefully, these characteristics will help participants begin to develop a vision of what they want their partnership to become.

- **Jointly-Developed Goals:** This characteristic is key to the future effectiveness of the partnership. When teachers and resource professionals have carefully thought through their overarching goals, they understand why they should make time for the partnership. Jointly developed goals help participants understand how the partnership can benefit everyone: teachers, resource professionals, and students. Establishing clear goals also helps teachers and partners justify and promote the partnership to others (e.g., parents, colleagues, administrators, school board, manager, CEO).
- **Collaborative Planning and Implementation:** This is one of the most important features of reform-based partnerships. It is probably the best example of what sets reform-based partnering apart from other types of school-business/agency relationships. Teachers and partners are committed to planning together and then, together, implementing those plans in the classroom. For many teams, most of the "big picture" planning for the entire school year can be accomplished at the institute. This leaves only the specifics of a particular school visit to be planned at a time closer to the activity. Once the plan is in place, what actually occurs in the classroom is different than the traditional "outside speaker" format. The partner leads or

co-leads the activity with the teacher. Both are actively involved by interacting with the students, answering questions, and encouraging students to question and investigate. Because the resource professionals have contact with the teachers and students throughout the school year, they become aware of the content, vocabulary, and level of learning of the students in the classroom.

- **Activities are Hands-On, Appropriate to Age, and Linked to Curriculum:** Recent research about how children learn confirms that lessons that actively engage students are most effective in bringing about learning. When teachers and resource professionals collaboratively plan these hands-on activities, it helps to ensure that they are at the correct developmental level for the learners. In addition, a key to a reform-based partnership is that the topics addressed by the partnership are part of the regular curriculum. The school day is filled with many topics to cover. If partnering activities are linked to the established course of study, the probability that the partnership will succeed is enhanced. Effective partnerships are an integral part of the curriculum, not just another "add on" or optional program.
- **Classroom-Based Relationship:** Effective partnerships involve the entire class in partnering activities, rather than providing it as an enrichment or pull-out program.
- **Multi-Level, Long-Term Support from School and Business:** Strong support from peers and administrators or managers is key to the success of reform-based partnerships. Various audiences such as boards of education, CEOs, principals, supervisors, and professional associations need to provide conceptual and, in some cases, tangible support for the partnership teams.
- **Changes Embedded in the System:** Reform-based partnerships should bring about lasting changes in the teachers, resource professionals, schools, and businesses or agencies that are involved – changes that radically alter previously-held ideas or ways of doing things. For example, at one partnership school, the resource professional confided that he was very apprehensive before visiting the school the first time. The teachers agreed that they were also apprehensive. After all, they had been alone in their classrooms for a long time and everything was going well. The partner's and teachers' common concerns soon dissolved as they got to know each other better and started working together in the classroom. The partner soon became acquainted with the secretary and understood that a key moment had come when he could just "help himself" to materials in the school supply closet. From a classroom perspective, the students were amazed that he could be a scientist <u>and</u> be married, so they had him bring his wife in to class to meet them. Being invited to the end of the year party and being included in the school staff picture cemented his feeling of acceptance. The teachers were equally engaged. They said, "We may have been apprehensive, but now that our partner has become part of our classroom, we can see how much we can gain from having someone from outside the school here. We would never want to teach without someone from the community in our classroom again."

This is an example of a true change in the perspectives of teachers and partners, and in the climate of a school. This exemplifies our goal in reform-based partnering.

- **Innovative and Pioneering Spirit:** The partnering experience is viewed as an opportunity to try new roles and instructional strategies. A sense of risk-taking and adventure prevails.
- **Actions and Activities Reflect National and State Goals:** This characteristic assures that the partnership is in line with the larger agenda and critical issues in science education. Basing activities on recognized goals also helps the teacher and partners justify the extra time required to make a partnership successful.
- **Authentic Assessment:** The impact and effectiveness of the partnership is measured by applying authentic assessment strategies to students knowledge, skills, and attitudes. While it is perhaps the most difficult component to accomplish, assessment could also be one of the most important. Student learning through partnership activities is often process-oriented and non-traditional. It is difficult, perhaps impossible, to assess inquiry learning through paper and pencil tests. In the same way, the impact and effectiveness of the partnership itself can best be evaluated through a multifaceted approach, using several strategies to indicate the level of effectiveness. (Note: this topic is addressed in more detail in the "Assessment" section, pp. 235-268.)

Descriptions of what partner teams actually do in the classroom more clearly defines what we mean by reform-based partnering. For examples of team activities, see the *Participant Notebook* (p. 11), or review partnership action plan summaries on the SWEEP website.

Model Partnerships: As we previously indicated, true reform-based partnering is often difficult to achieve because it requires roles which are radically different from the traditional roles which teachers and resource professionals are comfortable with. Realizing that experience is the best teacher, we expose participants to "real" partnership teams from previous institutes whenever possible. We accomplish this modeling and interaction in three formats.

1. **Team Presentation:** Whenever possible, we invite an exemplary team from past institutes to talk about their partnership and the activities they undertook during the school year. We also ask them to talk about challenges that arose and how they dealt with them. New SWEEP participants are especially interested in practical challenges related to partnering, such as finding time to meet and handling changes in the schedule. Teachers and resource professionals often share their personal feelings during this session which reinforces the notion that effective partnerships are built on a deep, collaborative relationship, and that the partners have fun. Teams often bring a display with pictures and examples of student work to enhance their presentation. Following the team presentation, we draw parallels between the

partnership activities and the characteristics of reform-based partnering, choosing a few of the characteristics best exemplified. If no model partner teams are available, participants may read and discuss the article from the notebook which describes several of these partnerships, "Science is Everybody's Business" (pp. 29-30). We also encourage the teams to review other articles in the notebook (pp. 12-28 and 31-34) for examples and ideas.

2. **Poster Session:** During the Partner Poster Session, veteran partner teams set up displays that describe their partnership activities including pictures, timelines, student work, videotapes, and other documentation of their yearlong activities. It worked well for us to display posters and artifacts on tables around the parameter of a room or down a hallway; somewhere where participants have ample space to roam among exhibits, to stop and talk, and to investigate activities closely.
3. **Round Tables:** New partnership teams find it very beneficial to speak openly and frankly with veteran teams. In a large room, we seat each veteran team at a different table. The new teams split up and each member goes to a table with a different veteran partnership. We encourage participants to generate their own questions to ask veteran teams. Potential questions include the following:
    - When did you plan?
    - How did you decide what activities to do?
    - What was your biggest obstacle? How did you overcome it?
    - Could your students really understand the concept of watershed?
    - How did you arrange activities with multiple grade levels or classrooms and only one resource professional?
    - What was the best thing you did? How did it impact your students?

An afternoon snack helps to establish a friendly, conversational atmosphere during the round table session. Allocate a brief time after the round table discussions for new team members to regroup and share the various ideas and issues they heard. We also encourage them to continue processing the information and suggestions over dinner.

Benefits of Reform-Based Partnering: Various studies conducted by the SWEEP collaborators identify the impact of partnerships on students, teachers, and the resource professionals involved. Because reform-based partnerships require so much time and effort, it is important to recognize the potential benefits.

A long range study being conducted explores the impact of partnerships on **student** achievement, interest and confidence in science and math, high school course choices, and higher education and career choices. The initial data indicates that students from classrooms participating in partnerships are more confident and comfortable with math and science. A trend emerging from the data suggests that multiple years of exposure to a partnership is especially effective.

Teachers show more confidence with science content and instruction as a result of participating in SWEEP. They describe their science teaching as less traditional and textbook-based and more hands-on, integrated, and collaborative. They are more aware of and use more science education resources, and evaluate student learning with a wider range of assessment strategies. In short, they are practicing what is considered "good science."

Resource professionals show enhanced job-related skills and competencies as a result of participating in school-based partnership teams. They state that they have greater knowledge of and ability to work within their agency; provide more leadership, flexibility, and collaborative problem-solving to the agency; are more sensitive and empathic as they interact with co-workers; communicate more clearly and comfortably with a range of audiences; and use listening skills to better understand and meet the needs of clients.

Greater detail on these and other studies measuring the impact of SWEEP can be accessed through the SWEEP website.

Partnering Activities

While most of the sessions at the summer institute focus on the pedagogy of inquiry science, the emphasis on opening day is on understanding and building partnerships. Following are partnering-related activities listed in the agenda (pp. 1-4), along with elaboration on how we frame, explain, and facilitate each activity. We use two or three staff facilitators for an institute of approximately 20 partner teams, since the strongest partnerships are developed when there is ample opportunity for personal interactions among the teams and staff.

Building the partnering relationship and developing the action plan are two priorities woven throughout the institute. Each partnering session has a specific objective with a topic to discuss or a task to complete. These build toward a collaboratively developed plan of partnering activities for the school year. Interspersing planning time throughout the institute enables teams to experience the hands-on activities, to observe teaching strategies, and to immediately consider incorporating them into their action plans.

Activity: Partner Interviews

Procedure: We begin to build relationships among partners during their first meal together (i.e., lunch) by asking them to interview each other. Most teachers and partners do not know each other before coming to the institute. Further, they often do not know much about each other's jobs. The interview provides a structured mechanism to assure that discussion occurs about these topics. Interview questions might include the following:

1. Describe a typical day in your workplace or classroom.
2. What person or event has influenced your life the most?
3. In your opinion, what are the most significant issues facing education and the environment?

Debriefing: At the end of lunch, participants briefly introduce their partner to the group seated at their table. If we do large group introductions, we ask volunteers to share. We stress to the large group the importance of relationships to effective partnerships, and challenge them to build those relationships throughout the institute.

Activity: Job Alike Groups

Procedure: In this activity, the group is divided. Educators assemble in one room, and all resource professionals in another room. The purpose of the session is to have each group independently explore what they perceive may be the positive aspects and potential problems related to partnering. While one staff member facilitates the discussion, another records all responses on flip chart paper legible to a large group. Both groups answer the same set of questions, which include the following:

1. What do you think are some positive benefits that can come from partnering?
2. What do you think will be some challenges about partnering for you?
3. What would you like the other group to know about your work life, your "culture"?

When both groups are finished, the entire group reassembles. One person from each job alike group talks about how they answered the questions in a "reporting-out" format. Generally, there is quite a bit of overlap in the answers between the two groups.

Debriefing: In a debrief by the lead facilitator, the group is asked to identify similarities and differences between the two lists. Participants are generally surprised to see that the members of the other group share their anxieties about partnering, have similar challenges in the workplace, and hold similar concerns related to educating children about the environment. Because we deal openly with issues such as having difficulty in contacting each other, finding time to plan, and changing schedules at the last minute, the teams have a common ground to more openly and comfortably discuss challenges. How they will design their work to minimize the impact of those challenges is an essential part of their planning during the institute.

Building the Action Plan

Early on the second day of the institute, we provide detailed information to the teams about the action plan. Throughout the institute, each partnership team collaborates on a plan to refocus their science curriculum around the watershed theme for the next school year, drawing upon the expertise of the resource professional. The action plan is submitted in draft form at the end of the institute, and in final form approximately two months later.

Content: The action plan (pp. 39-40) provides questions to guide their planning. We discuss the questions and the rationale behind them with participants to reduce their anxiety.

1. What are the specific goals or objectives of your partnership?

   Here teams refine and record the goals for their partnership which they develop during the planning session on the first day. We stress that the goals should be specific and measurable whenever possible. Taking time to develop mutual goals is essential to effective partnering throughout the year.

2. What significant changes in the teaching/learning environment do you hope to achieve through your partnership?

   This section is designed to ensure that the partners reflect on what makes their partnership reform-based. We want them to identify lasting changes that they want to make as a result of the partnership.

3. Diagram your web here or attach it to the plan.

   This section is a place to present the curriculum web that they develop during the "Thematic Approach" session (pp. 123-148). The web uses watersheds as its core and contains concepts and brainstormed ideas for many activities that the team will attempt to complete during the year.

4. Outline the activities you plan to carry out (a tentative timeline for this would be helpful).

   This is the most extensive and detailed section of the action plan. Teams actually describe the detailed plans for each classroom session that they will conduct. Teams are encouraged to include the activities for the entire year if possible, but at least a half-year of detailed plans should be included. These are intermediate level plans; they are not detailed, specific lesson plans. By asking for an assessment strategy, we challenge the partners to develop ways to measure if their partnership meets its goals. While this is often difficult, partners are encouraged to start small, if necessary, but at least to begin to reflect on their effectiveness.

5. How will you introduce the partnership to the class, parents, staff, etc.?

   This question creates a conversation among the teachers and partners about how to begin the partnership. We feel that if the students, other staff, and parents get to know the partners and understand the partnership, they will be more supportive and involved. This sense of shared ownership will also help the partner team follow through with the partnership.

6. With two or more teachers and only one partner, how will you structure your activities so the students from each class get to know the partner, but the time required is not prohibitive?

   This section ensures that teams reflect on how to best share the partner's time. The desire is to provide a quality experience for the students without overextending the resource partner. We remind teams that resource partners generally spend one day per month in the classroom, so their time must be well coordinated and used productively.

7. Which unit(s) or topic(s) from the curriculum will be addressed?
   This question compels the partners to link their activities to specific curriculum topics and objectives in the district science course of study. It ensures that the action plan is another way of teaching the course of study, not another "add on" program.

8. In what ways does the school hope to benefit, and what will it be contributing?
   This question and question 9 focus on the understanding that both the school and the business or agency give and gain as a result of the partnership. It will be easier for both groups to justify their partnership if they can articulate both the contributions they make and benefits they will receive to their supervisors.

9. In what ways do the partners hope to benefit and what will they be contributing?
   See question 8.

10. How do you plan to create parental awareness of and involvement in the partnership?
    This section encourages the partners to develop a plan for getting parents involved with the partnership. Existing partnerships have found that strong parent support adds greatly to the impact and effectiveness of the partnership.

11. Is there anything else that would be helpful to record here?

Planning: Throughout the institute are interspersed times for teams to pull away from the large group to focus on their partnership and action plan. While they are expected to plan on their own, partnership teams report that it is critical that, during the institute, they have ample time to complete the bulk of their planning for the year. Each planning session has a task to accomplish. We encourage teams to find a comfortable place to work, but a place where we can find them as we circulate to answer questions or provide feedback on the emerging action plans. Following is the sequence of planning times we provide throughout the institute.

- Session 1 – Goals Identification: In this first planning time (Day One, all evening), we ask the teams to think about the over-arching goals for their partnership. It is critical at this point to urge them not to jump directly into the selection of activities or actions, but instead to clearly define what they are trying to accomplish through their partnership. The common understanding and agreement about these goals will help both the resource partners and educators justify to their administrators and managers the time and other support that may be needed for the partnership. We encourage teams to begin the discussion of goals by using the "Needs/Resources Sheet" (pp. 35-37). The sample in the *Participant's Notebook* shows how to use the sheet to analyze the common areas around which the partnership can be formed. We encourage the teams to have three or four goals. Preferably, at least one of those goals address student learning. As teams work on their goals, one of the facilitators moves from team to team, mostly listening, but interjecting questions or comments when appropriate.

- Session 2 – General Plans: In this session (Day Two, all evening), teams continue the work begun during the goal-setting process by thinking about what activities they might do to accomplish their goals. At this stage, they are asked not to specifically decide on final activities, but instead to think broadly, almost in a brainstorming fashion, about all the different activities that they might do. We encourage them to draw ideas from the watershed curriculum web they completed earlier in the day and from the numerous resource guides and activity books we have on display.
- Session 3 – Team Conferences: During this planning time (Day Three, late morning), teams expand their ideas for collaborative activities to do in classrooms, and complete the various sections of the action plan. Also during this time, the project facilitators conduct individual conferences with all the teams. We question the teams about observations made as we circulated during other planning times, about their action plans, and the role of the partner. Common questions used during the conference are:
    1. Share a brief overview of your plans.
    2. Specifically, where do the activities fit into the curriculum?
    3. What changes do you hope to see in students, especially changes in student knowledge?
    4. How will you structure your activities to use and not abuse the partner if there are multiple grade levels in the partnership?
    5. How can we assist you as you complete the final draft of your action plan?
- Session 4 –Progress Reports: On Day Three, teams share their progress with other teams in their watershed group. This holds them accountable for making progress on their action plans and enables them to gain feedback and new ideas from other teams. Each team reports on their goals and some of the activity ideas they have at this point. As facilitators, we determine if the goals are general yet measurable and that at least one goal addresses student-learning. When teams discuss their activities, the facilitator reinforces the whole-class activities that involve the resource professional in a substantive, collaborative way.
- Session 5 – Final Planning: Teams solidify and finalize their action plan drafts during two final planning sessions (Day Three, all evening; Day Four, late morning). They select their activities for the year and complete all sections of the action plan.
- Session 6 – Whole Group Sharing: On the afternoon of Day Four, all teams very briefly share the highlights of their action plans. Where possible, facilitators reiterate and reinforce an aspect of their plan that is particularly strong, unique, or reinforces a characteristic of reform-based partnering.

Before teams leave the institute, they submit a draft action plan. This plan can be handwritten and some questions may still be unanswered, depending on how far the team has progressed. Within two weeks, we review each draft action plan and make specific comments concerning strengths and areas that need to be addressed. Comments are returned to the team leader and used to refine the draft for their final action plan.

Final action plans are due approximately two months after the institute. This gives the partnership enough time to specifically plan their year, and provides us with enough time to review the plans and return comments before the school year begins. We require that action plans be typed and well organized.

Follow-up: Periodic follow-up helps to sustain the partnerships through communication, sharing, and moral support. We use three different strategies. First, every 4-6 weeks we send a mailing. These might include directions for an up-coming event, a new activity, or a special resource. It always gives a pat on the back and words of encouragement. Twice a year, in autumn and spring, we hold a mini-conference (ours are watershed based). We find that the teams want to get together to share what they have done and to gain new ideas from the other watershed teams. From our perspective, these meetings encourage teams to fulfill their action plans, proved time for reflection and planning, and give us an opportunity to gather data for evaluation of the program. Finally, we hold a two-day summer follow-up session for both watersheds in conjunction with a summer institute. This serves many of the same functions as the mini-conference plus it provides an opportunity for teams to develop action plans for the next year and to serve as a role model for the new teams attending the summer institute (i.e., team presentations, poster session, round tables). In addition, the SWEEP staff, including two local watershed coordinators, is available year round to meet the needs of teams and individuals. This on-going support to the partnership teams reinforces their efforts and encourages their continuation.

Challenges Partnerships May Experience

Partnership teams generally leave the summer institute tired, but enthused and motivated. Most teams work closely to improve the science program in the school. However, some partner teams experience challenges as their relationship unfolds. By maintaining contact with the teams throughout the school year, we try to be aware of emerging problems and to intervene when necessary. Following are some of the most common challenges that we see teams experience and our best suggestions on how they may be successfully addressed.

Change in Participants: When a member leaves a team temporarily due to pregnancy, illness, or job change, it is typical for the team to suspend partner activities for a period of time. This seems to work better than trying to maintain the partnership under less than desirable circumstances. The key is to agree on a time when the team will reconvene, who will be responsible for initiating communication, and what strategy will be employed to reactivate the partnership.

If a member must leave permanently, often that person will mentor a new colleague who will eventually take the place of the departing member. It is helpful for the reconfigured team to attend a portion of the institute again to establish a common ground of information. Many times, the other team members lead the new member through the institute content using their *Partnership Notebook.* We have found that the key here is to allow the new team member to assist in redesigning the partnering activities to reflect his or her area of expertise and interest.

Sometimes, partnerships grow to include more teachers in the school. In this instance, partners may refocus their efforts to include more cross-grade level activities that enable the new teachers to be included. The partners may also recruit colleagues to work with the new teachers. It is critical for the original partner team to retain their relationship and to avoid asking the resource professional to work with an ever-increasing number of classrooms without developing a plan for bringing more resource professionals into the team. Again, it may be appropriate for new team members to attend portions or all of an institute to develop a common base of knowledge.

Communication Among Members: One of the most critical factors to the long-term success and health of the partnership is communication among the team members. While communication links are forged during the institute, continuing that flow, especially during the busy school year, is not easy. Difficulties often arise in two areas:

1. Partner team members are not getting together, either in the classroom, or to plan for classroom activities. We encourage members to apprise their team leader immediately if communication has lapsed. The team leader can then help the team develop a strategy for reaching each other, which may include pre-arranging a time to call one another, talking at home at night, faxing, and/or e-mailing. If the problem persists and/or becomes chronic, then it is appropriate for us to meet with the team members to discuss the situation and to help the team identify a communication strategy that all partners can agree upon.
2. Unresolved issues related to the partnership trouble one or more partner team members. We encourage team members to consult an outside third party, which is often a SWEEP staff person, to help identify and communicate the issues in a non-threatening way. It is important that all team members hear the problem and develop a collaborative solution. If a SWEEP facilitator is not available to play this role, the building principal, or a business supervisor, who is knowledgeable about the partnership, could fill it.

Lack of Multi-Level Support: In some instances, a new supervisor or principal who is not knowledgeable about partnering can pose a challenge to the continued success of the partner team. There are several ways to build support for the partner team.

1. Sit down and meet as a team with the new supervisor. Having both sides of the partnership represented demonstrates in a powerful way the collaborative nature of the team's work and underscores that both sides are committed to engaging and involving the new supervisor in the team's activities and goals. We encourage partnerships to share our findings on the benefits of partnering for students, teachers, and resource professionals with a reluctant supervisor.
2. Invite the new supervisor to see the partnership "in action" in the classroom.
3. Provide the new supervisor with specific ways they can support the partnership, such as: provide release time or materials as needed; communicate to their superiors about the partnership and its value to the school and business or agency; communicate about the partnership to parents

or community; and/or participate in key partnership activities (e.g., major field trip).

If support is not forthcoming, the team may need to temporarily modify partnership activities and give the supervisor time to observe, appreciate, and support the partnership's work.

Closure

SWEEP is a professional development program designed to improve elementary science instruction through partnerships that focus on a watershed theme. These partnerships are reform-based with an emphasis on collaborative planning, teaching, and assessment; links to the curriculum, classroom, and real world; and systemic support and change. This section provides useful information and helpful tips on how to establish, develop and sustain these partnerships.

Related Readings and Resources

Bainer, D. L. (Winter 1997). A comparison of four models of group efforts and their implications for establishing educational partnerships. *Journal of Research on Rural Education*, pp. 143-152.
Provides a complete review of literature on how groups work together and what contributes to their effectiveness.

Bainer, D. L., Barron, P., & Cantrell, D. (Winter 1996-1997). Enhancing science instruction in rural elementary schools through partnering. *Rural Educator,* pp. 12-16.
Describes the environmental science/partnership program that SWEEP is based on and the research on the impact of the program.

Hall, R. F., Castrale, E. G., & Zimmerman, S. (1993). *Business-education partnerships: Developing a collaborative relationship with business and community.* Macomb, IL: Western Illinois University.
Reports research on the effect of partnerships.

Rigden, D. W. (1991). *Business/school partnerships: A path to effective restructuring.* New York: Council for Aid to Education.
Describes partnering efforts as they are conceived at the national level.

Exposition to Inquiry: A Continuum of Teaching Methods

Rationale

SWEEP emphasizes an inquiry approach to teaching; yet, we devote a whole session to discussing and demonstrating the full range of teaching methods from exposition to inquiry. Why? First, it clarifies what these terms mean and places them in context by showing their relationship to one another and to other methods. This deepens the understanding of inquiry as well as other strategies. For example, we often hear educators say, "I always use a variety of methods when I teach. Sure I lecture, but we also watch videos, listen to guest speakers, and read novels that bring the topic to life." While this example shows variety, each strategy is simply another form of exposition.

Second, we demonstrate how the same concepts can be taught effectively using each of the different methods. More importantly, we stress that because students learn differently, based on learning styles and multiple intelligences, teachers need to use the full range of methods in order to meet their learning needs. Since SWEEP is described as an inquiry approach, participants are often surprised when we support the use of exposition in science or environmental education. The issue is not that exposition should not be used but that inquiry needs to be used more often and more effectively than it is generally used. We are looking for a balance of approaches that best meets the needs of all learners.

Finally, we explain that the reason we emphasize inquiry in SWEEP is because the other methods are more routinely used in schools and, therefore, both educators and resource professionals feel more comfortable with them. Our goal is to make the inquiry approach feel just as comfortable and to increase its use.

Background

The variety of different teaching methods can be described based upon their position on a continuum from exposition to inquiry. **Exposition** refers to an approach where information is delivered to the learner in its final form. **Inquiry** refers to an approach where the learner generates the form of the information.

Exposition ⟵⟶ **Inquiry**

• Teacher-centered --teacher active --learner passive	• Learner-centered --teacher facilitates --learner active
• Content emphasis	• Process emphasis

In general, exposition is considered teacher-centered with an emphasis on content delivery while inquiry is considered learner-centered with the emphasis on the process of learning. In a typical learning situation, this suggests that for exposition the teacher is actively involved (e.g., lecturing, reading aloud, showing a video) and the learner is passively taking in the information (e.g., listening, reading an overhead, watching a video). In contrast, learners engaged in inquiry are actively involved (e.g., conducting investigations, processing information and data) while the teacher helps to facilitate the process of learning.

Eight major methods illustrate the progression from exposition to inquiry: exposition, exposition with interaction, discussion, Socratic method, ordinary demonstration, guided demonstration, guided discovery, and open inquiry. Each has different uses and benefits as well as problems and concerns (pp. 41-45).

A more extensive list of specific teaching strategies, loosely arranged from exposition to inquiry, is provided in the *Participant's Notebook* (p. 61). It illustrates a wide range of approaches that expands upon the continuum and can be used to meet the needs of different learners (e.g., whether they are visual, auditory, kinesthetic or symbolic).

We use the following series of "activities" to demonstrate how concepts related to "watershed" can be taught using the different teaching methods along the continuum. Since educators are more familiar with the exposition side, we spend very little time on these. We use them more to set a context for the inquiry side than to demonstrate effective ways to lecture or lead discussions. We spend much more time on guided discovery and inquiry because they model the strategies we emphasize in SWEEP.

Activity 1: Exposition – Lecture on the Concept of Watershed

Procedure: We begin with a lecture, the classic example of exposition. Many of our participants are not familiar with vocabulary and concepts related to watersheds. This gives us our first opportunity to introduce key terms and the integrating theme for SWEEP. We model effective lecturing by using two important strategies: analogies (i.e., using cupped hands and a divided sink to represent a watershed) and visual aids (e.g., overhead transparencies of watersheds with key terms illustrated).

Debrief: To debrief this activity, we check for understanding by asking several questions.

1. What is a watershed?
2. What is another term for a watershed?
3. How do activities in the upper areas of a watershed effect the lower drainage basin?

Activity 2: Exposition with Interaction – Lecture and Discussion on the Water Cycle and Land Use

Procedure: This approach extends the previous activity. Each participant receives a color copy of the poster entitled, "Groundwater and Land Use in the Water Cycle" (available from Bureau of Water Resources Management, Wisconsin Department of

Natural Resources, Box 7921, Madison, WI 53707). We ask a series of questions. Modeling effective questioning strategies (see "Questioning," pp. 207-227), we probe, build upon participants' responses, and deliver additional content information.

Debriefing: To debrief this part, we ask each member of the partnership team to state in his or her own words one important idea or concept they learned about watersheds.

Activity 3: Discussion – Issues in Your Watershed

Procedure: We introduce this session by explaining the difference between "ping pong" and "basketball" style discussion. The former involves the leader (or facilitator) saying something first, then a participant responding and then back to the leader. This back-and-forth keeps the interaction under the control of the leader. The latter involves the leader saying something and then the discussion bounces around among the participants with little or no involvement by the leader. Basketball style discussions tend to involve more participants and generate a wider range of ideas and perspectives.

In addition to encouraging the basketball approach, we work in partnership teams, again, to promote the greatest interaction. Within the partnership teams, individuals volunteer to be the recorder, reporter, and facilitator. Each team discusses two questions as they relate to their own watershed:

1. What is the most important environmental issue in your watershed? Why?
2. What can you do as individuals to help protect your watershed?

This is the first time in the institute that the teams focus on their watershed. It starts them thinking about how they will adapt ideas from the workshop to their local environment and begins to lay the foundation for their integrated web (pp. 123-134).

Debriefing: Debriefing occurs on two levels. First, each team shares its main discussion points for each of these questions. Then, based upon the sharing from all teams, we summarize similarities and differences related to their watershed issues and how they can help to protect their watershed.

Activity 4: Socratic Method

The Socratic Method – where carefully crafted questions and probing elicit desired content from learners – is a very effective strategy. However, it is neither widely nor effectively used. Since people have little experience with this strategy and it would take too much time to properly teach how to use it, we do not include it in the institute. We encourage people to pursue this approach on their own because the method is highly compatible with inquiry.

Activity 5: Ordinary Demonstration

The ordinary demonstration is basically a lecture that accompanies a demonstration (e.g., doing an experiment, working a model, operating equipment). Since we model the lecture, we do not use this technique, preferring to focus on the "discovery demonstration" that promotes more interaction and higher level thinking.

Activity 6: Discovery Demonstration – Ground Water Flow Model

Procedure: The ground water flow model provides an excellent tool for making very abstract, "invisible to the eye" concepts and processes more concrete and visual. The model is available for purchase from science catalogs and some universities. It may be available to borrow from local soil and water conservation districts, county extensions offices, state agencies (e.g., environmental protection, natural resources), or local universities. Sometimes these organizations will send a resource person with the model to conduct the demonstration for the class.

The emphasis of this session is twofold. First, it is another opportunity to present content information about watersheds, this time as it relates to ground water. Second, it illustrates how an ordinary demonstration can become more inquiry-based. Through a sequence of demonstration steps and the use of questions, participants predict what will happen, observe processes, define terms, classify their observations, infer why something happens, and interpret results.

Debriefing: Through the debriefing we discuss how this demonstration was "discovery" rather than "ordinary." Examples are given which illustrate how participants were involved in constructing meaning (i.e., discovery demonstration) rather than receiving information (i.e., ordinary demonstration).

Management: The discovery demonstration provides a wonderful opportunity to talk about some of the challenges of doing a demonstration in front of groups of 20 – 30 students. We provide the following tips for using the model:

- Practice, Practice and Practice – Anytime you do a demonstration, it is important to try it out first, to be sure you know that it will work the way it is supposed to and to identify potential problems. This is especially true for the ground water model. Be sure to read the manual thoroughly and practice each step. Remember one of Murphy's laws for science: If you tell your students something will always happen, it won't and if you tell them it never happens, it will.
- Take precautions – Have lots of paper towels available and protect surface areas with plastic.
- Be sure everything is visible – Elevate the model as high as is practical (e.g., place it on a sturdy box on the table). Stand behind or to the side of the model so that you do not block the learners' view. Use food coloring in the water you inject into the model to make it visible as it moves through the model. Have the learners sit in a tiered or layered arrangement like bleachers close to the model so that everyone can see (e.g., the first row sits on the floor, the second sits on chairs, and the third sits on desk or table tops).

Related Activity: If you cannot find a ground water flow model or want a hands-on approach, you can make your own model from a jar or tumbler using the directions in "Ground-Water Model" in *Always a River* (by U.S. Environmental Protection Agency, Office of Research and Development, Cincinnati, OH, Publication # AWBERC-91-09).

Activity 7: Guided Discovery – Incredible Journey (pp. 51-55)

Procedure: We use "Incredible Journey" to further and more concretely develop the concept of the water cycle and its role in the watershed. By following the directions in the activity as written, we model a guided discovery approach. After participants take eight turns, writing down each station in order (including staying at a station), they sit down. When everyone is done, we debrief.

Debrief: Based upon their beginning station, we ask for one volunteer from each of the nine stations to come up to the overhead projector. Each person is asked to trace the path that he or she took through the water cycle on to an overhead transparency that has the names of the stations written in a circle. Using a different colored pen, each person traces his or her pathway by drawing from name to name and using an "x" to indicate when they had to "stay." While they are taking turns tracing their route, the rest of the group is discussing what they experienced (e.g., how many different stations they went to; did they ever return to their first station; where the most people were; the least).

After all nine station volunteers have traced their path, we turn on the overhead projector to observe what happened. We compare this water "web" to the traditionally portrayed water "cycle" and discuss which is a better model of what happens in nature.

Management: The most important aspect of conducting this simulation is giving very clear directions. If the directions are understood, all goes well. So we give them in both oral and written form plus we role-play what to do. Depending on the age and gender of learners, you may or may not ask them to link arms or hold hands as they move from station to station. Because a long line tends to form at the "cloud" station, we assign one person to help facilitate the flow of activities at that station, often using more than one die.

Through the years, we have heard of many adaptations and extensions of this activity. Here are two favorites:

- Place a tall, thin, clear container at each station (e.g., graduated cylinder). Give each participant 8 marbles or other tokens. Instead of writing down each station, they drop a marble into the container at each station they visit. When everyone is done, you can line up the containers to see an instant bar graph.
- Make the dice out of small, wooden baby blocks covered with mailing labels with the stations printed on them. Assign one "helper" to each station. Give each helper a page of labels with the name of the station on it. When someone arrives at the station or rolls "stay," the helper pulls off a label and places it on the person's record sheet. This eliminates the need for students to carry pencils with them. It's fun afterwards to discuss how the busy "cloud helpers" felt compared to the "soil helpers".

Activity 8: Open Inquiry – What Can You Learn About a Watershed? (pp. 57-60)

Procedure: Finally, we progress to the far right side of the continuum – open inquiry. We designed this activity to be as open ended as possible within the constraints of the workshop setting and timeframe. We recognize that this approach is uncomfortable for some so we use the KWL chart to provide a little structure and direction without being directive. A KWL chart asks participants to list what they already know about the watershed, what they want to find out, and what they learned (p. 59).

As described in the activity, we begin by looking at topographic maps and using a patchwork quilt analogy for watersheds. Then we complete the KWL chart as a large group, writing down what they know about the watershed immediately surrounding the building and what else they would like to know. Working with their partnership team, they decide what they specifically want to investigate. Using the list of available equipment, they design and conduct their investigation. When finished, they complete "what we learned" on their KWL chart.

Debrief: Keeping with the spirit of open inquiry, the debriefing focuses more on the process rather than content of what they learned. The discussion questions in the activity (p. 58) serve as a springboard for this session.

Management: Access to equipment is key to this activity. First, we try to anticipate everything that teams might request and then some (our list has grown over time). Second, we have duplicate equipment stations located around the building so teams do not have to walk very far to get the materials they need. Providing access to water is always a challenge. We locate all the outside faucets and check that they work as well as bring many hoses, buckets, and jugs.

Related Activities: We developed this activity from "Rainy-Day Hike," a more guided discovery activity from the *Project WET Curriculum and Activity Guide* (by the Watercourse/Montana State University and Council for Environmental Education, 1995) and from "What Can You Learn About a Leaf?", an inquiry-based activity in *Integrating Environmental Education and Science* (by D. Cantrell and P. Barron, 1994, OEEF, Ohio Environmental Protection Agency, Columbus, OH).

Closure

The intent of modeling "activities" along this continuum is to bring the full range of teaching methods to life and develop a deeper understanding of each, especially inquiry, through comparison and contrast. Some of the questions we ask include:

1. What did this series of "activities" demonstrate?
2. How did your role change from activity to activity?
3. When did you feel the most comfortable as a learner? Why?
4. Why is it important to teach using the whole continuum of teaching methods?
5. Why would inquiry be an effective approach to use in studying a watershed?

In closing, we showcase the articles in the *Participant's Notebook* and emphasize the key points of each. For example, "Inquiry/Discovery Revisited" (pp. 63-64), helps to define inquiry and then discusses different patterns of inquiry (i.e., a continuum within inquiry) that shows different roles for the teacher and students. "Shifting from Activitymania to Inquiry" (pp. 65-69) compares and contrasts the traditional activity approach to an inquiry approach and describes how to make the transition to inquiry by simply modifying existing curricula rather than discarding everything. "Inquiring Minds Want to Know" (pp. 75-77) stresses the need to help students develop a "good" inquiry question as a foundation for inquiry. Finally, "Student-Designed River Study" (pp. 71-74) models the kind of integrated, inquiry-based watershed investigation that the SWEEP partnership teams might develop.

Related Readings and References

Ross, M.E. (May 1997). Scientists at play. *Science and Children*, pp. 35-38.
Describes what conditions support and encourage young children to pursue inquiry.

Sutman, F. X. (January 1995). Define your terms. *Science and Children*, pp.33-34.
Defines terms related to the continuum of exposition to inquiry and identifies benefits of inquiry/discovery instruction.

Watersheds and Issues

Rationale

The "W" in SWEEP stands for "watersheds," the integrating theme for the program. In selecting this topic, two criteria were used. First, we needed a broad-based theme that would address the curricular requirements of any grade (K-6) and provide multiple avenues for inquiry. Second, we needed a topic that would draw upon the expertise of a wide variety of resource professionals.

Watershed meets both of these criteria, providing a rich context for the partnership activities. Since a watershed is the land area where all precipitation drains to a common outlet, anything within that area becomes a potential focus for investigation – geology, climate, ecosystems, water quantity and quality, plants and animals, other natural resources, local issues, land use, watershed protection, and socio-cultural dimensions, to name a few. Teams can choose one or more focus areas depending on the expertise of the resource professional and the courses of study of the teachers. They must, however, always relate these focus areas back to the theme of watershed. Consequently, each partnership team's yearlong action plan has watersheds as the central theme, but is unique and highly relevant to their specific needs.

Background

The four different sub-sections of this part of the *Participant's Notebook* correspond to different time blocks on the agenda. They are clustered together in this section so that all watershed-related materials are easily accessed in one location. The following shows how each sub-section is used:

- "What is a Watershed" (pp. 79-94) provides background information not only for this section but also for the "Exposition to Inquiry" session on the first day and "Thematic Approach" session (pp.123-147) on the second day.
- "How to Delineate a Watershed" (pp. 95-99) and "Investigating a Watershed" (pp.101-114) are both used during the field experience on the second day.
- "Investigating Issues in a Watershed" (pp. 115-119) provides information on why and how to investigate issues in the local watershed. It is used to introduce "Community Investigation" (pp. 121-122) as well as to provide a strategy for conducting this investigation on the third day.

As indicated above, the content information in "What is a Watershed" is integrated throughout several sessions of the institute. We point out this section to the participants and encourage them to read the material on their own and to use it as a reference source later on.

Activity: How to Delineate a Watershed (pp. 95-99)

Procedure: On the second day, we immerse participants in the local watershed by taking them on a field trip to one of the tributaries of Deer Creek, the drainage outlet for the watershed we are studying. Since our group is so large (50+ participants), we divide them into two groups, dividing each partnership team in half.

We begin the field experience with several mapping activities. First, we do an exercise that demonstrates how contour lines work (p. 97), making this abstract concept more concrete for young learners. Second, we build on the contour lines by using a topographic map to introduce participants to the local area. Working in small groups, they read the maps and discuss different features of topographic maps. Next, we ask participants to find our location on the map. Using the strategy described on pages 98-99, each group outlines the watershed that we are investigating.

Debrief: We conclude this session with several questions:

1. What can you tell about this watershed based upon this map?
2. What kinds of problems did you experience while trying to delineate the watershed?
3. How would you adapt this activity to your grade level?

Management: Many participants are frustrated by this activity, partly because they are not familiar with topographic maps and partly because of the difficulty of finding the outer boundaries of the watershed. It is helpful to have participants work in small groups so they may help each other and to have several facilitators available to assist the groups as needed. We provide information on where to purchase topographical maps in Ohio and how to receive free classroom sets of out-of-date maps (i.e., contact ODNR Division of Geological Survey, 4383 Fountain Square Drive, B-2, Columbus, OH 43224-1362).

Activity: Investigating a Watershed – A Lesson Plan for Measuring Some Aspects of Water Quality (pp. 101-114)

Procedure: Following these introductory mapping activities, we proceed with the field investigation by conducting the activity, "A Lesson Plan for Measuring Some Aspects of Water Quality." This inquiry-based activity was developed by the U.S. Forest Service and used the methodology from SAPA (*Science: A Process Approach*), a federally funded science education initiative from the 1960s, as its foundation.

Working in the same two groups, we basically do the same series of activities with a slight variation. One group follows the procedures as outlined in the notebook with an emphasis on the science process skills. The second does the core activities (e.g., collect critters, chemical testing) plus other activities emphasizing art and language arts extensions, especially for younger learners (i.e., poetry and drawing). Each group receives the same basic experience, just with a different emphasis.

Debrief: During the activity, we debrief after each task. This allows the content information to unfold as the inquiry tasks are completed. Following the entire water investigation, we combine the two groups together again and debrief the session in two ways. First we ask the "Summary Questions" that are at the end of the activity (p. 112). Second, we ask the teams how they might modify or adapt these activities for use in their partnership activities.

Management: Providing enough equipment is always a challenge. While each of the two groups conduct the same water investigations, we arrange the order of the rest of the activities so that both groups do not need the equipment at the same time. In addition, we set up different stations and have smaller groups within each large group rotate through them (e.g., seining, chemical testing, and velocity). A facilitator is available at each station to assist as needed.

Because this session is conducted outdoors, we model strategies that attend to both creature comfort and outdoor teaching. In general, we follow the suggestions for teaching outdoors that are outlined on pages 203-204 in the "Management" section of the *Participant's Notebook*. In addition we:

- Are always prepared for rain (e.g., slip clipboards with worksheets into gallon-size plastic bags so participants can write without their paper becoming wet; provide large garbage bags to wear as emergency ponchos);
- Have extra sunscreen and bug spray for anyone who forgets theirs;
- Provide cold drinks and snacks;
- Provide some extra boots for those who forget wading shoes but want to get into the stream; and
- Hold discussion sessions where participants can be out of the sun and not looking into the sun.

Activity: Investigating Issues in the Watershed – Community Investigation (pp. 115-122)

It helps to have some philosophical and theoretical context to introduce the activity, "Community Investigation," before actually conducting it. We use the following as background information for a pre-activity lecture that provides some of this context. Part of the information below is summarized for the participants in their notebook (pp. 117-119).

Background Information: A major goal of SWEEP is to have learners investigate environmental issues of concern in their local watershed. If you analyze different definitions and discourses on environmental education, you will find that investigating issues and taking informed, responsible action are common elements. Views on when and how this should happen vary among practitioners, however.

To begin these discussions it is important to differentiate between "environmental problems" and "environmental issues." **Environmental problems** are related to people, the environment, and the interaction between the two. **Environmental issues** are *environmental problems* about which two or more parties cannot agree. For example, a flood spilling onto an undeveloped flood plain is usually not considered an environmental problem. If the flood plain is developed, it can become a problem for those people affected if the floodwaters damage property or take human life. It can become an environmental issue if parties disagree about whether future development on the flood plain should be stopped.

There are several concerns about involving learners in the investigation of local environmental issues and action taking. While young people rank the environment among their top concerns, they tend to be misinformed, often by popular culture and sometimes by well-intentioned educators, about the facts surrounding environmental issues. Assuring that learners are working with the most accurate and current information is critical to any study of a local environmental issue.

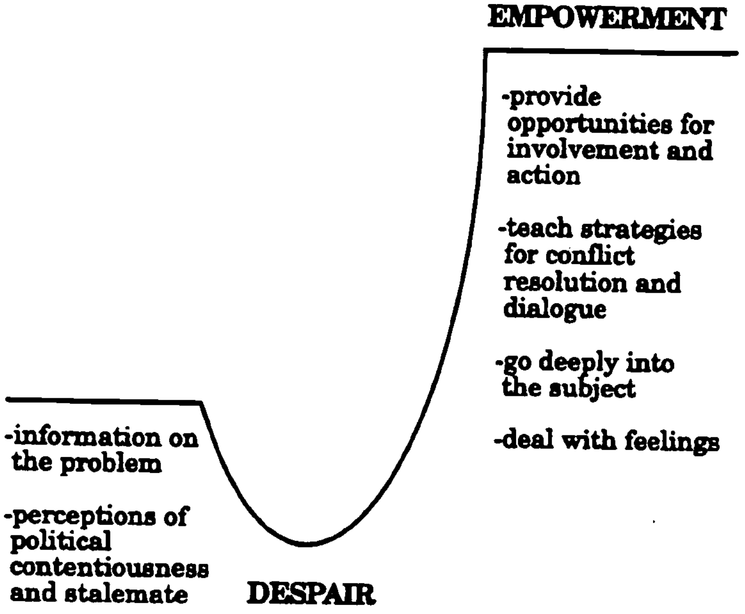
Second, it is equally important to examine the issue from diverse perspectives. Learners' limited understanding of the different sides of the issue can further compound their lack of information or misinformation. Realizing that different sides view the issue differently and can present conflicting facts and scientific data demonstrates an understanding of the complexity of many environmental issues.

Third, concerns have been raised about the age-appropriateness of involving young children in investigating issues. For example, educators and others are sometimes heard saying that we must "save the earth," with the inference that "we" includes young learners. In the big picture, however, the issue is not one of saving the earth, which has been around for 4.5 billion years and will continue to evolve, but of saving Homo sapiens and other life forms on the planet. Mike Weilbacher (1994) stresses that all learners should understand the permanence of the earth over time and how the earth works in terms of cycles, adaptation, communities, and interrelationships. He believes that this foundation is critical before learners tackle environmental issues. The concluding paragraphs of Weilbacher's article summarizes his philosophy:

> First, a time to watch ants, to grow peas, to feed winter birds, to wander through goldenrod fields, to stare at a resplendent Monarch emerging from its chrysalis.
>
> Then a time for repairing ozone holes, cooling the climate, buying a section of the Amazon rain forest, adopting a whale, and voting that ecologically lazy Senator out of office.
>
> Teach with time and perspective. A first-grader cannot, and should not, think she must save an entire planet. It is an unbearable burden that so young a child just cannot carry. Can she improve the planet? Of course. Save it? No. Our job is not to save the Earth, but rather to save ourselves, and the millions of species that inhabit this time with us. (Weilbacher, p. 3)

The above concerns are mentioned not to suggest that students should not investigate issues and take action but to emphasize that activities that focus on issues need to be built on a firm foundation of knowledge, skills and positive attitudes. Part of the SWEEP program involves learners in investigating local issues. It also encourages learners to take responsible action based upon informed decisions. How this occurs and at what age needs to be determined by the partnership team within the context of the school and community.

The critical point is that these investigations should not take place in a "doom and gloom" or the "sky is falling" atmosphere. Sheldon Berman (1990) describes a "Despair-Empowerment Curve" (see below) that emphasizes the need to not just examine the issue by gathering all the information and looking at the different perspectives because this can just lead to despair. Learners need to feel that they can do something or be empowered to act. The partnership activities should also build skills such as those indicated on the empowerment side of the curve. This enables learners not to feel despair but rather a sense of deeper understanding and perhaps a desire to act – to become involved.



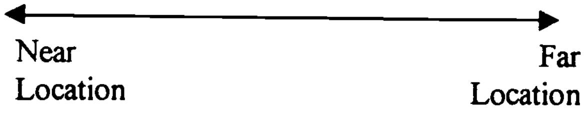
Despair-Empowerment Curve

McBee (1996) supports the idea that young learners need to develop the kinds of skills suggested on the empowerment side of the curve – skills he sees as tied to citizenship. He explains:

> If the promise of public schools as a citizenship training ground is to be realized, then students – from the very earliest ages – must acquire and practice the following:
>
> 1. Skills in interpersonal communication;
> 2. Tolerance for diverse perspectives;
> 3. The critical and constructive thinking processes needed to analyze actions and practices in the context of democratic ideals; and

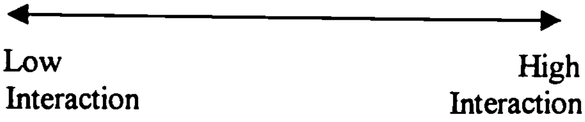
4. The ability to engage in civil public discourse in the face of legitimately diverse claims and interests. (McBee, p. 38)

If young learners are to become involved in investigating local issues in the watershed, they need these types of skills. Exactly what form their investigation takes will vary greatly from partnership to partnership. The evaluation of one environmental education program (Cantrell, 1990) identified three criteria, explained in the form of three continua, that describe variations in involvement. The first continuum indicates how near or how far away from the classroom the activity occurs in **location**. The classroom on the one end represents "near." As the continuum progresses, it moves from in the classroom, to outside the classroom, to the whole school, to outside the school, to home, to the neighborhood, to the community on the other end which represents "far."

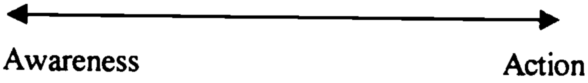


For example, writing a class letter to the local newspaper would be located on the "near" end of the continuum but visiting the local newspaper to interview the editor would be located toward the "far" end.

The second continuum describes the amount of **interaction** learners have with people in the community. This ranges from "low" interaction such as reading about the mayor or writing to the commissioner, to "high" interaction such as circulating petitions or testifying at a hearing.



The third continuum ranges from **awareness** to **action**, with the right side representing passive involvement and the left side active involvement.



Students on the "awareness" end may discuss issues but not go beyond that to read information, write to a government agency for materials, or poll the community on its attitudes toward an issue.

Together these three continua provide criteria for describing the extent to which learners in this project were involved in the community as they investigated local environmental issues. As a second part of the evaluation, specific activities conducted by teachers were categorized and placed along a composite continuum ranging from "low involvement" to "high involvement." Figure 1 (p.119) summarizes this analysis. "X" represents the number of teachers in this study who used this approach; each teacher may have used the approach more than once (e.g., one teacher could have taken four field trips).

This study provides one way of looking at learner involvement in investigating issues in the community. As participants plan their SWEEP activities, they need to consider the three continua (location, interaction and awareness to action) and to decide to what extent their students should be immersed in the watershed and actively involved in analyzing and seeking solutions to local issues.

Procedure: After the lecture, we explain that each team is going to conduct an investigation of some aspect of Deer Creek State Park (i.e., lodge and park area) and explain how this aspect connects to the watershed. We explain the process they will use by modeling the steps we would take to investigate the topic "cultivated plants." Using an overhead projector and a transparency of a *3-Stage Data Collecting Chart*, we brainstorm "what we want to find out about the use of cultivated plants at the park." After generating 8-10 ideas, we give an example for each of "how to collect data" and "how to record it" (see example, p. 121). Then we explain that as a team we would select 1-3 items from Column 1 and design a data collection instrument and recording device.

At this point, we assign each partnership team one of the topics listed in the activity (e.g., housekeeping, grounds keeping). Each team has 2 ½ hours to conduct their investigation and prepare a 3-minute report using the guidelines in the activity.

Debriefing: After each team gives its presentation, there is time for 1-3 questions. After all the groups present, we ask the questions listed in the activity under discussion (pp. 122). Finally, we ask them how this activity could be adapted to their watershed using the school, local neighborhood, and/or community.

Management: Before the institute begins, we work with the Park's conference coordinator to identify the names of each Deer Creek staff person who has the major responsibility for each of the watershed investigation topics (e.g., head of housekeeping, manager of golf course). These people are asked to be available during the two-hour time block for the investigation. We post a list of these people.

For the presentation, we emphasize the 3-minute time period and hold up a series of warning cards to be sure everyone has the same amount of time (e.g., 1 minute, 15 seconds, stop). The emphasis in the presentation is more on the process they used during their investigation, with only a sampling of what they found out.

Closure

The theme of watershed is integrated throughout the SWEEP program through content information, hands-on activities, field experience, and a community investigation. These represent just a sampling of the multitude of possibilities that the partnership teams can consider as they develop their yearlong action plans.

Related Readings and References

Berman, S. (November 1990). Educating for social responsibility. *Educational Leadership*, pp. 75-80.
Describes why it is important to teach social responsibility and identifies appropriate approaches to use.

Cantrell, D. C. (1990). *Final evaluation report for the Southern Highlands Environmental Project.* Newark, OH: The Ohio State University.
Evaluates a yearlong program, Southern Highlands Environmental Project, that promoted student investigations of local environmental issues.

McBee, R. H. (June 1996). Can controversial topics be taught in the early grades? The answer is yes! *Social Education*, pp. 38-41.
Describes why teaching controversial issues is appropriate in lower grade levels and draws upon law-related education to suggest some strategies to use.

Weilbacher, M. (Winter 1994). The single most important thing to know about the earth. *EE News: Environmental Education in Wisconsin*, pp. 1-3.
Addresses the issue of what is age appropriate to teach young learners and why.

Thematic Approach

Rationale

Every aspect of SWEEP emphasizes an integrated, or interdisciplinary, approach. This is evident from the name.

> **S**ciencing encompasses all sciences. Since the focus of SWEEP is on environmental science, the life sciences (e.g., ecology, biology, botany, zoology) and earth science (e.g., geology, meteorology) come quickly to mind. But chemistry and physics are also integrated, especially during the water-related and issues investigations.
>
> **W**atershed is the integrating theme. As discussed in the section on watersheds, this topic provides a rich context for integrated studies. For example, one of our teachers shared, "I was amazed to see that I could fit all of my sixth grade objectives into this watershed theme." Since every aspect of a drainage area is interrelated, it is difficult to investigate one aspect without exploring its connections to others.
>
> **E**nvironmental **E**ducation is defined as an interdisciplinary process. While many perceive it as science, it integrates all disciplines (e.g., ecology, economics, sociology, humanities, political science, aesthetics). Environmental issues are typically very complex, requiring a multifaceted problem-solving approach.
>
> **P**artnerships are formed by bringing together education professionals and natural resource/environmental science professionals. This blending of expertise contributes strongly to the integrated, thematic approach of SWEEP.

This rich, integrated context lends itself well to developing yearlong action plans based upon a thematic approach. In this session, we focus on how to do thematic planning.

Background

Webbing is one process that is helpful in developing long-term thematic units or action plans. It uses brainstorming to generate a schematic representation of an idea. For SWEEP, this is the watershed theme. Webbing not only identifies key concepts and skills related to the idea, but also shows relationships among the concepts. It also reveals misconceptions which learners may hold.

Pages 123-129 in the *Participant's Notebook* outline and illustrate a step-by-step process for developing a **web**, which is the product of webbing. After the selection of a theme or topic, ideas are brainstormed, categorized, labeled, and organized. Once this is fleshed out, interdisciplinary instructional objectives are identified and linked to each topic. Finally, specific teaching strategies, learning experiences, and resources are selected to achieve the objectives. In this way, the web provides the conceptual framework for developing the partnership's action plan, making instructional decisions, and assessing student learning (see the example of "Winter Wonders" on pp. 125-129 for a detailed explanation of these steps).

When adapting SWEEP for replication, a different theme could be used (e.g., "w" could have stood for wildlife or weather). You may want to create a new name or acronym with another letter representing your big idea (e.g., "f" for forests, "h" for habitats). Several criteria should be considered when selecting the content focus for your program. The theme should be:

- Based upon the courses of study and instructional objectives for the appropriate grade level(s);
- Based upon the interests and natural curiosity of the learners;
- Broad-based enough to generate a diversity of ideas, variety of resources, and multiple learning opportunities; and
- Narrow enough for learners to see interconnections.

Activity: Making a Watershed Web (pp. 131-134)

Procedure: The directions in the *Participant's Notebook* fully outline the procedure we use to conduct this activity. By the end of the session, we have a watershed web, synthesizing all of the ideas of all of the teams, sprawling as one huge display on the floor of the room.

Debriefing: After participants complete the group web, we distribute the one we developed in planning for the SWEEP institute. We ask the group the following questions:

1. Looking at these two webs, what can you say about watersheds?
2. How does our group web compare with the one developed for SWEEP?
3. How can a web be used as a tool for teaching and learning?
4. How does the web lend itself to interdisciplinary teaching?

Management: Most of the management issues are already addressed through the procedures. In step 5, where groups come up one at a time to place their new ideas into the web, we start out by following this procedure. Eventually enough groups have placed their ideas in the web and the rest of the groups are so eager to contribute that teams start to work simultaneously. This keeps the process moving without creating total chaos.

In order to make the group web available to all teams as they develop their individual webs, we hang it on the wall. Needless to say, this is not easy, but it makes an impressive visual display when done. Using clear packaging tape, we connect one category name and all its sub-topics together in one long line (i.e., one spoke of the wheel). Using a tall ladder, we hang this on the wall with the category name near the ceiling. Each "spoke" is hung in the same way, like an inverted bar graph rather than a round web like it was on the floor.

Closure

The visual display created by the web quickly illustrates the richness of watersheds as an integrating theme, the interrelationships among the disciplines, and the potential for connections to the curriculum. As additional examples, the *Participant's Notebook* contains a matrix of a K-12 program that uses watershed as the integrating theme (pp. 139-142) and a write-up of a science and social studies "river" unit (pp. 143-147). The article, "Science Is Part of the Big Picture" (pp. 135-137), shows how seemingly isolated educational reforms are linked and emphasizes the role of thematic teaching in helping learners make connections. It supports the conceptual and pedagogical approach modeled by SWEEP.

Related Readings and References

Kotar, M., Guenter, C.E., Metzger, D., & Overholt, J.L. (February 1998). Curriculum integration: A teacher education model. *Science and Children*, pp. 40-43. Describes a course designed to instruct preservice teachers on curriculum development and interdisciplinary education by asking them to design an integrated unit.

Child Development

Rationale

A key to the effectiveness of a partnership's efforts will be to identify and present concepts and activities appropriate for the age group with which it is working. Therefore, it is essential to understand the physical and emotional characteristics of learners, how these vary across age groups, and their implications for teaching and learning.

For adults, who are not experienced teachers, effective communication with learners is not always easy. Adults often ask young children to "line up," for example, and think they are disobedient when they continue to mill around. We need to realize that children have no concept of what a line is, let alone how to form one, until after first grade. One resource person asked a third grade class to begin by writing their names on their papers only to be met by stares and whispers. He was perplexed, but later was told that these children had not learned to write. They could only print, so his directions were confusing and frustrating to them.

Each time we have presented this "Child Development" segment at an institute we get mixed evaluations. Teachers say to eliminate this session or to make it optional because the information is common knowledge for them. Resource professionals, however, find it absolutely essential and think the session should be expanded! We choose to spent time on this topic with all institute participants for two reasons. First, we believe that the information is essential for both resource professionals and teachers. While teachers may feel that they "know" children at the grade level with which they normally work, this session serves as a helpful review of the big picture of child development and of children's abilities to learn science concepts at different levels. For resource people, this information is basic and enables them to select topics and materials appropriate for children. It also helps to reduce their anxiety about working with students, especially young children.

Second, this topic enables us to cast the classroom teachers as experts as they share their knowledge and experience related to child development with their resource partners. We want the partnerships to realize that they are indeed a team — a team of science content experts and child development experts who must combine their expertise in order to be effective. Every team member has something important to contribute.

Background

We use a constructivist approach to draw upon teachers' expertise and generate a list of child development characteristics at different ages and their implications for teaching. Divide the participants into groups of about five made up of at least one primary teacher (K-3), one intermediate teacher (4-6) and one resource professional. Challenge each group to develop a chart, "What do we know about kids?", stating characteristics of the age group and specific implications of those characteristics for teaching and learning. For example, a characteristic of primary children is that they have short attention spans. The implication for teaching is that lessons must be short and should include variety. Half the groups should begin by developing a chart for primary-level learners while the other half begins by charting the characteristics of intermediate learners. Allow groups about ten minutes to develop their first chart, then signal them to work on the second chart. The discussion during this sharing is especially rich. Teachers are challenged to think of direct implications for teaching as they relate amusing stories to illustrate age level characteristics. Resource people openly probe teachers for deeper understanding. Afterward, individual groups report and we compile a master list. Then we refer participants to the notebook list, "A Summary of Normal Development" (pp. 151-155), for further information.

We next focus on how children learn concepts. Jerome Bruner described how people of any age learn concepts. Bruner says that, in order for concepts to be truly learned and understood, they must first be introduced to learners in a ***concrete*** way. That is, the concept must be developed by involving the learner with it through the use of manipulatives, hands-on activities, or other physical involvements. After a learner has a concrete foundational understanding, the concept can be further developed in an ***iconic*** way; that is, through pictures, representations, or demonstrations. Only after the concept has been introduced and developed iconically should it be reinforced through ***abstract*** learning, such as discussion or lecture.

Barriers to learning concepts are discussed in the accompanying article, "Teaching for Conceptual Change: Confronting Children's Experience" (pp. 157-162). These include protective-belt ideas, language, perceptions, developmental level. and critical barriers.

We illustrate how to build children's concepts over time by engaging participants in a sequence of mapping activities, developing the concept of "where." We chose mapping activities because understanding maps is essential to understanding watersheds, mapping skills are interdisciplinary, and many educators are not aware of how and when to teach mapping skills and concepts to students. We present and discuss the following key mapping concepts and indicate at what grade level they should be introduced. In subsequent grades these concepts are developed and reinforced. The following table, "Children's Learning of Mapping Concepts," shows activities in which we engage participants to introduce mapping concepts in a concrete way.

Children's Learning of Mapping Concepts

Concept	Level	Understanding	Activity
Representation	K-1	A globe is a small model or representation of the earth.	Surf 'n Sand Toss
Features	K-1	A map is a small, flat representation of the earth showing its features, much like a photograph.	Me Maps
Symbol	1-2	Colors and pictorial symbols stand for things which are identified in the key or legend.	Me Maps
Scale & Perspective	2-4	Maps are like looking at the earth from a different perspective. They look smaller, but their size is relative or proportional to the real feature.	Fly's Eye View
Topography	4-6	Abstract symbols show distance, elevation, and land features.	The Great Flood

Activity: Surf 'n Sand Toss (pp. 163-171)

Procedure: We start the series of activities on building mapping concepts with this activity because it is useful in teaching "representation" to young children. While the concept that 72% of the earth's surface is covered with water is quite abstract, this activity communicates that concept to young children because they are physically involved and they see their finger landing on water more than on land masses and hear their classmates calling out the same results. Depending on time and the number of participants, we usually form large circles of 12-20 people and limit the number of tosses to 20. Each group must have a recorder to tally the results on the worksheet.

Debriefing: To debrief the activity, we use an overhead transparency of the worksheet to compare results across groups. The following discussion questions help to debrief the activity.

1. Did your group's results reflect the true amount of water found on the globe? Why or why not? How could you get the results to be a more accurate representation of the true ratio between water and land when you do this activity with your learners?
2. Did anyone have problems deciding where their finger landed? How did your group solve the problem? (Sometimes fingers land on a spot which contains both land and water, or on a white spot in Antarctica or the Arctic.)
3. How could you extend this idea to integrate more math? To integrate more social studies concepts? For older learners? (Several extensions of this activity are presented in pp. 166-171 to develop and reinforce the mapping concepts of representation and feature for older learners and to integrate math skills including probability, ratios, fractions, and graphs.)

Management: We also deal with management of students and materials as we debrief each activity. For this activity, elicit from the group suggestions about how to organize students to keep confusion and noise at a minimum. Suggestions might include the following.

1. As you introduce the activity, demonstrate for students how to appropriately toss the inflatable globe (e.g., not too high, not so hard that it knocks anyone's glasses off), how to catch the globe and locate the spot under the index finger of the right hand, and what voice level to use when calling off the result for the recorder. Point out that for young learners, an underinflated globe is easier to catch and hold.
2. Have students count off for groups or assign them to groups in some way. Assign the recorder as well. Designate where in the room each group will form its circle. Especially for younger students, have them point to where they will go when they are dismissed and quickly scan the room to see that everyone knows where to go. Then dismiss the students by group to set up their circles. Have the recorder from each group get a globe, tally sheet, and pencil for their group.

Activity: Me Maps (pp. 173-174)

Procedure: The concept of "features" is effectively presented by engaging participants in making "Me Maps." We do this activity as partnership teams, to emphasize communication and collaboration skills among team members. Each team prepares a map of one of its members, including the outline and some physical and facial features.

Debriefing: We talk about extending the activity to replace actual features with symbols, such as representing the nose with a triangle, and including a key or legend. We also point out that by using grid paper, the activity effectively teaches the concept of "scale." First, make the Me Map on one-inch grid paper. Then, have the students transfer their drawing to graph paper with smaller squares. To conclude, we ask the following questions.

1. What other extensions can you see for this mapping activity?
2. How can this activity serve as a link to other subject areas or topics in your curriculum?

Management: It is important to address management issues with this activity. Suggestions that might arise from the group include the following.

1. Precut the paper for each group. Have students take their crayons or pencils with them when they divide into groups.
2. This activity is best accomplished in the hallway or gymnasium, rather than a regular classroom with limited floor space. Distribute a piece of paper to each group when they have decided where they will meet.
3. Beginning at about third grade, students become very aware of and sometimes insecure about their bodies. Be aware of this with your students. You may want to use same sex groups and to have them map a student wearing pants rather than a dress. With some age groups you may need to specify which features should be represented on the Me Map.
4. Groups will finish at different times with this activity. To prevent misbehavior, the teacher should be ready to suggest extensions (e.g., add clothing or other detail, add a grid) to keep all groups involved throughout the time allotted for the activity.

Related Activity: A good activity for teaching the concept of "scale" is "Fly's Eye View" in *The Book of Where, or How to be Naturally Geographic* (by N. Bell, 1982, published by Little, Brown & Co.).

Activity: The Great Flood (pp. 175-178)

Procedure: The complex concept of topography is greatly simplified if it is introduced with an activity such as "The Great Flood." Young learners find it very challenging to translate a concrete three-dimensional map to an abstract two-dimensional map, particularly when it involves contour lines. We begin the activity by demonstrating the steps, showing the directions on the overhead projector and modeling each one (e.g.

demonstrate placing a 4-cm piece of tape on the side of a clear plastic shoe box and making 1-cm marks on the tape). Then we have each group of participants make their own contour map repeating these modeled procedures.

Debriefing: In debriefing this activity, we ask several questions.

1. In what ways does this activity help learners move from the concrete to the abstract?
2. For what age level do you think this activity is appropriate?
3. What other ideas do you have for extending this activity? (e.g., line up all models and mix up the contour maps to see if learners can match the contour maps to the models)

Management: Model the following management strategies during the activity. Discuss how this helped to make the activity run smoothly, and ask for suggestions of other strategies.

1. Have all materials for each group on trays that are easily distributed. It is important to have an easy method for obtaining and discarding water. For example, if there is no sink in the room, have buckets of water for filling cups and empty buckets for disposal of water.
2. The accuracy of the contour maps depends on the learners' ability to trace the model. The tip about closing one eye and keeping the other eye directly over the pen (step #6) is very helpful. Because this is easier if they use their dominant eye, we use this as an opportunity to teach learners how to determine their dominant eye. Just as people are left-handed or right-handed, they have one eye that is more dominant than the other. To determine dominance, hold a hand at arms-length away from your body. Pointing your index finger directly towards the ceiling, line it up with a distant object (look with both eyes). Without moving your hand or arm, open and close each eye, watching to see what happens with the alignment of your index finger with the object. Your finger should stay aligned with the object when one eye is open and shift to the other side when the other eye is open. The eye where no sift occurs is the dominant eye.

Closure

If we want to be effective teachers, it is essential that we consider the developmental level of our learners as we plan lessons and activities. This is especially true when we teach concepts. It takes time to lead students through the steps (from concrete, through iconic, to abstract) to truly learn concepts. Close this session by discussing the following.

1. How did this sequence of activities model child development theory?
2. Evaluate the value and effectiveness of these activities in teaching concepts.
3. What would you do if, for example, a fourth grade class had not yet mastered lower level mapping concepts?
4. How does teaching mapping concepts relate to trends in science education?

Related Readings and References

Anderson, T. (March/April 1996). What in the world is constructivism? *Learning*, pp. 48-51.

Describes practical ways to refocus your teaching to build better thinkers.

Burton, G. (April 1996). Huge trees, small drawings: Ideas of relative sizes. *Teaching Children Mathematics*, pp. 466-470.

Tells how one teacher links math and science concepts of size and scale through a rainforest unit using Lynn Cherry's book, *The Great Kapok Tree*.

Grosse, B. (December/January 1995/96). Making "sense" of science. *Green Teacher*, pp. 25-28.

Contends that science programs should encourage students to explore in creative ways, thus teaching empathy along with analysis.

Harris, K. R. & Graham, S. (February 1996). Memo to constructivists: Skills count, too. *Educational Leadership*, pp. 26-29.

Argues that a balance of discovery-oriented and skill-development approaches is essential in the classroom, especially for special needs students.

Maxim, G. (November/December 1997). When to answer the question "why?". *Science and Children*, pp. 41-45.

Describes how children investigate and ask questions at different developmental stages.

Watson, B. & Konicek, R. (May 1990). Teaching for conceptual change: Confronting children's experience. *Phi Delta Kappan*, pp. 680-685.

Describes how an inquiry-oriented lesson on heat revealed how skewed students' understandings of the concept were, and one teacher's enlightening struggle to correct misconceptions.

Process Skills and Inquiry

Rationale

A familiar Chinese proverb captures the importance of process skills:

> Give people a fish and they can eat for a day.
> Teach them to fish and they can eat for a lifetime.

We might just as easily say, "Give learners a fact and they can answer the question of the day. Teach them process skills and they can answer questions and solve problems for a lifetime." In other words, they can inquire throughout their lives.

However, educational testing and research show that we have a ways to go in reaching this goal. For example, test scores from the Third International Mathematics and Science Study (TIMSS, 1997) indicate that students are not scoring well on process and higher level thinking questions. John Goodlad's national research (1991) shows that 90% of the teachers use textbooks 95% of the time and that the ratio of teacher talk to student talk is 3:1, with only 1% of the teacher talk requiring students to engage in anything over recall.

For this reason, we include a separate session on process skills and demonstrate their relationship to inquiry.

Background

As previously indicated in the section on "Exposition to Inquiry," SWEEP emphasizes an inquiry approach to teaching and learning. Process skills are the backbone of inquiry. In fact, it is difficult to talk about inquiry without discussing process skills and vice versa. The following list of characteristics of inquiry shows that process skills and critical thinking are embedded within inquiry (Rakow, 1986; Birnie, 1984; Victor, 1974).

1. Inquiry is carefully planned around a series of problem solving investigations that actively involve the learner.
2. Inquiry lessons follow a general pattern:
    - Develop a question,
    - Identify the problem,
    - Gather data through investigation,
    - Analyze and interpret data, and
    - Draw and communicate conclusions.
3. Inquiry is highly process-oriented and involves critical thinking.
4. Teaching and learning are question-centered and answers are not known in advance.
5. The end product may be a discovery, but discovery is only a part of the overall process.
6. Inquiry is learner-centered.

7. Inquiry educators:
    - Model scientific attitudes,
    - Are creative and resourceful,
    - Are flexible,
    - Use effective questioning strategies, and
    - Teach both skills and content.
8. Time is not of prime importance during inquiry lessons.

Inquiry teaching, like Shakespeare's rose, has many other names – discovery, guided discovery, hands-on, activity-based – but they all have process skills as the backbone. Research findings indicate positive benefits to using a hands-on, activity-based approach. For example, one review of research studies (Haury & Rillero, 1992) indicates that using a hands-on, activity-based approach to science:

1. Increases learning and achievement in science content.
2. Improves students' attitudes towards science.
3. Increases skill proficiency in the processes of science.
4. Benefits academically or economically disadvantaged learners most.
5. Helps in language development.
6. Enhances reading readiness and oral communication.
7. Encourages creativity in problem solving and promotes student independence.

This discussion of the characteristics of inquiry and related research findings suggests several specific implications for educational practice. When using an inquiry approach, consider incorporating the following qualities:

1. Involve learners with concrete materials
    - to match how they learn, and
    - to engage them (thinking, feeling, doing).
2. Use open-ended investigations
    - to provide more opportunity for success, and
    - to allow learners to work at their own level.
3. Emphasize process over one correct answer
    - to provide practice with procedures rather than memorization, and
    - to encourage transfer across disciplines.
4. Provide adequate time for tasks
    - to give learners time to process ideas and to think at higher levels, and
    - to recognize that learners need time to engage in thinking if they are going to learn to think.
5. Use teacher-learner interactions that promote inquiry
    - to encourage thinking and independence, and
    - to foster collaboration among learners.

Inquiry teaching and learning that incorporates these qualities can transform a basic hands-on approach to a hands-on, minds-on approach where learners are fully engaged, both physically and mentally. Through the SWEEP activities, we try to model these practices as much as possible. In addition, we devote one whole session to process skills. Because we know that hands-on, activity-based approaches work and that process skills are the backbone to inquiry, focusing on the teaching of process skills makes sense.

What are the process skills? If we were to ask different educators for a list of process skills, we would probably receive a variety of answers. Several different categories of skills are provided on pages 187-188 in the *Participant's Notebook* to demonstrate the wide range of skills that learners use throughout their lives. Those listed under "process skills" are based upon the 1960's curriculum reform program, *Science – A Process Approach* (SAPA). This is a relatively well-accepted list that differentiates between basic skills and integrated or advanced skills:

Basic Process Skills (Grades K-3)
- Observing
- Classifying
- Using space/time relationships
- Using numbers
- Communicating
- Measuring
- Predicting
- Inferring

Integrated Process Skills (Grades 4-6)
- Formulating Hypotheses
- Controlling Variables
- Experimenting
- Defining Operationally
- Formulating Models
- Interpreting data

A definition for each of these is provided on the backs of the process skill cards located in the *Participant's Notebook* (pp. 183-186).

In our discussions of inquiry and process skills, we use a basketball analogy to suggest an effective way to teach process skills. Basketball coaches drill team members on individual skills – dribbling, passing, shooting lay ups. But learning these skills only in isolation will not lead to effective team play. So, the coach also has the players practice how to use these isolated skills in an integrated way during a game. Further, playing games without first developing these skills would be neither successful nor productive.

The relationship between science process skills and inquiry is similar. We need to help learners focus on specific skills – to hone their observation or predicting skills – while they also learn how to use their skills in an integrated way to conduct effective inquiry.

Activity: Process Skill Cards (pp. 183-186)

Procedure: Before the institute, we copy the process skill cards (pp. 183-186) on card stock (i.e., picture on front and definition on back) and laminate the sheets. The cards are cut apart and made into decks. During the session on process skills, each partnership team is given a deck of cards to evenly distribute among its members. Then we ask participants to think back on all the activities they have experienced to this point during the institute. For each card, they list as many examples as possible of when they used that skill during the various SWEEP activities.

Debriefing: In addition to the cards, we display posters of each skill on the wall throughout the institute. To debrief the activity, we focus on each poster and have the teams share their examples of when they have used the skill.

Management: To assure maximum participation and processing of ideas, we give each team a complete deck of skill cards and have them distribute them evenly among the team members. Each person is asked to begin the discussion of the skill card he or she holds and then other members can contribute.

Activity: Litter Alert (pp. 195-197)

Procedure: Picking up litter is a popular activity to involve young learners in taking action on behalf of the environment. While there are many benefits from this activity such as a cleaner environment, safer habitat, and social responsibility, it has limited value as an inquiry activity as it is traditionally done. We use "Litter Alert" to demonstrate how to modify an activity to make it a more powerful inquiry lesson.

At the institute, we provide each team with a bag of litter that could have been collected at a park or recreational area during the week of the institute. Each bag of litter is similar, containing approximately 20 items (e.g., aluminum can, styrene cup, film box, orange peel, cigarette butt, toy, flip-flops, fast food container). Each team is asked to categorize their bag of trash and then label the categories. (Note: We have adapted this activity to fit a workshop style setting and to move from individual team classification to large group sharing, rather than large group to team involvement).

Debrief: First, we debrief by having one member of each team explain the categories they used to classify the litter. Then, we ask the following questions:

1. What were some of the different ways teams classified litter?
2. How could teams classify their trash differently when everyone had the same set of trash?
3. Based just on the trash provided, in what season do you think it was collected? What evidence would you use to justify your answer?
4. What do you predict that you would find if trash were collected in the fall, winter, or spring? In what season do you think you would find the most trash?
5. What different process skills did you use during this activity? (hold up skill cards)

6. How is this approach to litter cleanup different than the traditional approach?

Finally, we review how this activity would be conducted over a yearlong period. For example, a class could adopt an area to cleanup several times during the year (e.g., bike trail, park, school grounds). They can predict what and how much they will collect based on location (e.g., near a snack shop, popular fishing area) and/or season. Each time they collect trash, they can measure it by volume and weight, compare and contrast what they found, graph data, and map areas of high and low concentrations of trash. Learners can summarize their findings and, if appropriate, write letters recommending ways to prevent litter (e.g., ask city maintenance to provide additional trash cans in a particular location).

Management: Providing identical bags of trash can be a challenge, so start early to collect the items. Wash and clean up the trash to avoid odors and germs and to allow for long-term storage if you want to use the activity again. We place cigarette butts in sealed plastic bags and do not use beer cans. If you are going to have learners pick up trash, provide plastic gloves and bags. Also, go over safety procedures (e.g., wear orange vests if near car or bike traffic; have an adult pick up broken glass).

Closure

During this session, we emphasize three main points:

1. inquiry and process skills go hand-in-hand,
2. inquiry will be more effective if learners have the opportunity to develop process skills, both by working on the skills individually and by integrating them into activities, and
3. traditional activities can be transformed into inquiry activities by adding process skills.

The article, "Decookbook It!" (pp. 189-193), reinforces this session by providing three examples of how to transform activities from a "recipe" approach to an inquiry approach where learners ask questions and design experiments.

Related Readings and References

Birnie, H.H, & Ryan, A. (April 1984). Inquiry/discovery revisited. *Science & Children*, pp. 31-32.

Describes characteristics of inquiry and a continuum of patterns of inquiry based upon the roles of the teacher and students.

Butts, D.P., & Hofman, H. (February 1993). Hands-on, brains-on: For children, the words following the activity complete the concept. *Science & Children*, pp. 15-16.

Describes why and how the discussion (minds-on) that follows hands-on activities is important in helping children learn concepts and correct misconceptions.

Goodlad, J. I. (1984). *A place called school: Prospects for the future*. NY: McGraw-Hill.
Presents findings from a comprehensive national study on education.

Haury, D.L., & Rillero, P. (1992). *Hands-on approaches to science teaching.* Columbus, OH: ERIC Clearinghouse for Science, Mathematics, and Environmental Education.
Reviews and synthesizes research related to hands-on, activity-based approaches to science.

Padilla, M.J., & Pyle, E.J. (May 1996). Observing and inferring promotes science learning. *Science & Children*, pp. 22-25.
Differentiates between observation and inference, and describes a game that helps students use these skills in science inquiry.

Raizen, S.A. & Michelsohn, A.M. (1994). *The future of science in elementary schools.* San Francisco, CA: Jossey-Bass.
Describes the status of elementary science teaching and presents a vision for transforming teachers into facilitators of children's active science learning.

Rakow, S.J. (1986). *Teaching science as inquiry*. (Fastback #246). Bloomington, IN: Phi Delta Kappan.
Provides an overview of inquiry with examples, presents and describes 14 process skills used by K-3 versus 4-6 grade students, and explains the learning cycle.

Schwartz, S. L. (March 1996). Hidden messages in teacher talk: Praise and empowerment. *Teaching Children Mathematics*, pp. 396-401.
Discusses the impact of teacher-talk and questioning on how students use process skills during learning activities.

Victor, E. (October 1974). The inquiry approach to teaching & learning: A primer for teachers. *Science and Children*, pp. 23-25.
Describes characteristics of inquiry, advantages for learners, and associated problems.

SWEEP

Managing Materials and Students

Rationale

While many teachers believe that the inquiry approach is the best way for students to learn science, they do not practice it because they are afraid that they will lose control during the activities. Further, many are dissuaded because hands-on learning is usually materials intensive; all those materials must be gathered, purchased, and stored.

We try to minimize these excuses not to use inquiry learning by addressing the management of materials and students in the context of each session during the SWEEP institute. During this session, however, we draw participants' attention to aspects of our management that they may have overlooked.

Background

Management is often a sensitive topic because students, teachers, and administrators have high expectations about organization and student behavior. Often when management is discussed, discipline is really the focus. That is, the emphasis is on what to do with or to students when they misbehave. Research since the 1970s, however, shows that the most effective managers practice preventive management. That is, they anticipate problems and work to prevent them from arising.

With inquiry-based science, anticipating and preventing problems by managing materials and interacting appropriately with students is the key to success and learning. We emphasize this by contrasting the "wrong" and "right" way to lead a materials-intensive activity called "Garbage Bag Watershed."

Activity: Garbage Bag Watershed (p. 205) – "Wrong" way

Procedure: We begin the session by modeling the "wrong" way to manage materials and students. We arrive and start the session a bit late, after participants are already seated and waiting. Materials are laid out on a supply table: boxes of jello, containers of cocoa, spoons to scoop supplies into film canisters to carry to the tables, spray bottles containing water, and other items. We provide all the necessary supplies, but they are difficult to access because boxes are unopened and must be shared, not enough spoons are available, and canisters are so small that filling them is problematic.

We give very general directions. Participants are told to send someone from their group to get one of everything from the supply table. Because we started late, we tell them that whoever finishes the activity first will get to go to lunch first. Before long, pandemonium breaks out at the supply table. People are pushing; supplies are spilt; water fights break out with the spray bottles. Then we call a halt to the whole process.

Debriefing: By this time, most participants realize that we are demonstrating how *not* to manage materials and students. Amidst laughter, we ask them to describe what was going on, how they felt, and what we said and did that set up the disastrous situation.

It is amazing how many confess to practicing many of these poor management techniques themselves! We then proceed to model how to appropriately manage materials and students in this activity.

Activity: Garbage Bag Watershed (p. 205) – "Right" way

Procedure: Each person on the partnership team is given a card with a symbol on it identifying their task during the activity (e.g., a shoe designates the materials manager; one raindrop symbolizes the first rainstorm maker; two raindrops for the second rainstorm maker). Thus everyone in the team has a specific role.

We demonstrate the entire activity, giving specific, detailed directions and prompting participants to watch and listen for their assigned role during the activity. We have organized materials so that only three things are needed from the supply table: newspaper, a towel, and a plastic grocery bag containing all other supplies. We lay the newspaper carefully on the table, pointing out how it extends beyond the edge of the table. We arrange the containers to form hills and mountains, cover them with a towel, and cover the towel with a garbage bag. We point out how the garbage bag covers the towel completely so that it does not get wet. We model drawing in the land uses, making rain, adding nonpoint sources of pollution, and the subsequent rain and observed runoff. (Note: This activity builds nicely on the "Dragonfly Pond" activity on pages 229-234 in the "Questioning" session if participants model their landscape and land use after their Dragonfly Pond map.)

Cleanup is also well organized. When the activity is completed, we model how to carefully pick up all four corners of the garbage bag so that all runoff stays on the plastic bag and is easily disposed of. The other supplies are returned to the plastic grocery bag; the towel and dry newspapers are refolded and returned to the supply table. Wet newspapers are disposed of.

Before releasing teams to begin the activity, we check for understanding of roles by asking the materials manager from each group to raise his/her hand, the first rainmaker, etc. This way we are sure that everyone has a role and understands it.

Debriefing: What a difference organization makes! This complex activity proceeds with ease, and participants enjoy creating rain and observing its impact on their created landscape. The questions at the end of the activity serve to debrief the content; we also focus on debriefing the management.

1. Compare how you felt as a learner in this activity to the way you felt in the previous, poorly managed activity.
2. With respect to managing materials in this activity, what "worked" for you? What additional suggestions can you provide?
3. With respect to managing students in this activity, what "worked" for you? What additional suggestions can you provide?

Management: We point out other important aspects of managing materials and students related to inquiry science. For example, we store all materials for each activity in a cardboard box with a lid. A laminated label on the top and side of each box bears the name of the activity contained therein. Inside the box are all the supplies needed for that activity. We replenish supplies each time the activity is used so that, at all times, it is ready to pull off the shelf and use. If the activity requires perishable supplies, these are listed on the inside of the box lid so that they are easily identified. If multiple boxes are needed to hold all the supplies, each is numbered as "box 1 of 2" and "box 2 of 2," etc. A laminated folder inside the box contains a laminated copy of the activity and any related information or paperwork.

Participants are asked to share their management tips as well.

Related Activity: A similar activity is "Over Hill and Dale" in *WOW!: The Wonders of Wetlands*, published by Environmental Concerns, Inc., P.O. Box P, St. Michaels, Maryland 21663.

Closure

Anticipating trouble spots during inquiry activities and planning carefully to prevent those is a key to effective inquiry science. This relieves the stress of the teacher prior to the activity and allows the teacher to enter the activity more confident and free of management problems. It also provides a safer, more comfortable learning environment for students. These risks and rewards are further discussed in "Managing Hands-on Inquiry" (pp. 199-201).

What about managing outdoor activities? We review the main points of "Teaching Outdoors" (pp. 203-204) about preparing activities and learners for outdoor activities. Participants also are asked to share tips they have used effectively with outdoor instruction.

Related Readings and References

Abruscato, J. (1988). *Teaching children science.* Englewood Cliffs, NJ: Prentice Hall.
Contains a chapter on discovery learning which discusses teaching strategies, textbooks, and classroom organization and management tips.

Carin, R. A., & Sund, R. B. (1989). *Teaching science through discovery.* Columbus, OH: Charles E. Merrill.
Contains a chapter on how to plan, set up, and manage your science classroom.

Cruickshank, D. R., Bainer, D. L., & Metcalf, K. K. (1999). *The act of teaching, 2nd edition.* New York: McGraw Hill.
Chapter 12 discusses effective classroom management with an emphasis on organization that prevents problems from arising in the first place.

Weiner, W. (1997). Taking the headache out of hands-on learning. *Learning*, pp. 94-98.
Provides practical tips on storing materials, creating learning centers, and organizing hands-on materials using common household items.

Questioning Strategies

Rationale

Effective questioning is critical to inquiry teaching and learning. When to ask questions, how to ask them, who asks them, and about what are a few of the key issues related to questioning strategies. Too often when educators are pressed for planning time, they do not think through the key questions they want to ask. This can be problematic because effective questions trigger inquiry, and probing questions sustain it. In addition, handling students' questions is a challenge. Students often comment (or complain) that their teachers never answer their questions but simply ask more questions. These teachers understand that one of the fastest ways to stop inquiry is to answer questions. At the same time, not responding to learners is extremely difficult for many educators. Because developing a questioning strategy poses so many challenges, it is important to take a closer look at how to do this.

Background

One way to think about a questioning strategy is as a formula:

Content of Question	+	Purpose of Question	+	Delivery and Follow-up	=	Your Questioning Strategy

Content of the Question: The content has to do with the subject matter or focus of the question. Too often, this is simply viewed as knowledge or facts, but this only represents one level or aspect of learning. In general, a balanced curriculum or program involves four major components or domains: knowledge, skills, attitudes, and behavior. Questions should be asked by teachers and learners that address all four areas.

Knowledge (Content)	Examples of Questions
Facts and terms	
Concepts	What is a wetland?
Generalizations	What percentage of wetlands have we lost?
Theories	What are the major functions of a wetland?

Skills (Processes)	Examples of Questions
Science processes	
Critical thinking	How can you categorize these wetland plants?
Problem solving	What would happen if we lowered the water?
Decision making	How could you restore this wetland?
Communication	
Research	
Mathematical	
Psychomotor	
Interpersonal relations	

Attitudes (Affective)	Examples of Questions
Feelings	
Beliefs	Why do you think it is important to protect wetlands?
Dispositions	
Opinions	Should all wetlands be protected? Why or why not?
Values	

Behavior (Action)	Examples of Questions
Applying knowledge and skills	How can we reintroduce wetland plants to this area?
Solving a problem	
Acting based upon a decision	

If these four domains of learning truly represent a balanced curriculum, then educators must ask questions and provide experiences that help learners grow in all four areas.

Purpose of the Question: The purpose of a question refers to what a person is trying to accomplish by asking one type of question versus another type of question (i.e., the objective). Following are two different approaches to determining purpose.

1. Bloom's Taxonomy of Educational Objectives – Benjamin Bloom developed a taxonomy of educational objectives for the cognitive domain, which has six levels: knowledge, comprehension, application, analysis, synthesis and evaluation. This taxonomy parallels much of the previously discussed content of a balanced curriculum. We can use Bloom's hierarchy to guide the development of questions at different levels. For example, are you asking learners to recall facts or synthesize information? To apply knowledge or

analyze interrelationships? "Applying Bloom's Taxonomy of Educational Objectives to Question Writing" is a reference tool in the *Participant's Notebook* (pp. 209-212) that provides descriptions and examples to use in writing questions for each level. Consistently using this tool will help to assure that you are writing questions at all levels. This is important because studies continue to show that up to 90% of teacher-asked questions in schools are at the lower levels. These types of questions are ineffective in promoting inquiry.

2. Convergent and Divergent Questions – Another approach focuses on asking a combination of convergent (closed) and divergent (open) questions. **Closed questions** elicit a limited number of responses or "right answers" (e.g., What is another name for a wetland? What type of soil is characteristic of wetlands?). **Open questions** elicit multiple answers (e.g., What are some wetlands that you know of in Ohio or other states? If we were to create a wetland on our school grounds, what should it be like?).

   A common misperception is that closed questions are always lower level and that open questions are always higher level. But this is not necessarily true. For example, "What are some animals that live in a wetland?" is relatively open-ended but lower level. "Which wetland proposal do you like best and why?" is closed-ended in the choice but higher level in its justification.

   By asking a variety of questions that cross all levels and provide opportunities for both open- and closed-ended questions, you provide the greatest opportunity to challenge and stimulate learners. Inquiry is best fostered by this diversity.

<u>Delivery and Follow-up:</u> How you deliver or pose your questions has two elements: the sequence in which you ask the questions and the wait time between the question and answers.

1. In terms of **sequencing**, it is important to pre-plan what questions you will ask and in what order. The order is not as important as is a conscience decision about that order. Is it in some way logical? Does it achieve a specific purpose? For example, questions that model Bloom's taxonomy need not appear in ascending order. A knowledge question can be followed by an evaluation and then application question.

   One pattern that often works is one used by the U.S. Forest Service in its program "Investigating Your Environment" (Pager, 1993). It begins with very **open** questions that elicit many responses and allow learners to feel confident because many answers are acceptable. From these responses, more **focused** questions are posed to narrow the scope of the discussion or investigation. This leads to **interpretive** questions that ask learners to process the information in some way. Finally, **summary** questions tie the discussion together.

Open: What do you think of when I say "wetland'?
Focus: What are some different types of wetlands?
Interpretive: What is the difference between permanent & temporary wetlands?
Summary: What can you tell me about wetlands?

2. **Wait time** refers to the amount of time allowed between the question and the learner response – the opportunity to think about the question and to formulate a response. Because some learners think and reflect more quickly than others do, it is important to wait and allow all learners time to process their answer. Specifically, Wait Time I refers to the time the teacher pauses between asking the question and calling on a learner to respond. Wait Time II refers to the time the teacher pauses between the learner's response and the teacher's follow-up response. Typically teachers only wait 0.5 or 1.2 seconds. Research suggests that waiting 3-5 seconds has tremendous benefit for learners (Rowe, 1987). For example:
    - The length of student responses increases.
    - More inferences are supported by evidence and logical argument.
    - The incidence of speculative thinking increases.
    - The number of questions asked by students increases.
    - Student-student exchanges increase; teacher-centered "show-and-tell" behavior decreases.
    - Failure to respond decreases.
    - Inappropriate behavior decreases.

"Wait Time: Slowing Down May Be a Way of Speeding Up" (pp. 221-227) fully describes the wait time research conducted by Mary Budd Rowe.

Further, questioning can be enhanced by effective **follow-up**. This complements and extends wait time and is used to clarify, synthesize, expand, modify, raise the level of, or evaluate students' responses (Cruickshank, Bainer, & Metcalf, 1999). Exactly how teachers follow-up depends on how students respond. If students respond correctly and confidently, it is appropriate to accept and acknowledge the response without over-praising them. If, however, they fail to respond accurately and/or confidently, one of the follow-up strategies listed below should be used:

1. Providing the correct answer – is used when the student responds carelessly and inaccurately.
2. Probing – means asking additional questions in order to expand or raise the level of the response, to focus attention on a specific aspect of the question, or to remove the student's uncertainty about why an answer was correct.
3. Redirecting –involves asking other students the same question in order to involve more students in the discussion or to challenge or reaffirm the original response. The purpose of redirecting is not to correct the original respondent, but to expand discussion. Otherwise, this strategy may be damaging to the first respondent's self-confidence.
4. Rephrasing – means rewording the question and is only necessary if the original question was poorly phrased.

When educators carefully and deliberating consider the content and purpose of their questions, and then ask the questions in a thoughtful sequence using wait time and follow-up, they have a powerful formula for a successful questioning strategy. This in turn will enhance and enrich their inquiry approach to teaching.

Activity: Dragonfly Pond (pp. 229-234)

Procedure: "Dragonfly Pond" provides another watershed activity, this one looking at diverse land use perspectives. We closely follow the directions as written in the activity. Each partnership team represents a different special interest group (depending on the number of teams, two or more teams may have to represent the same special interest). When the activity is completed, we hang all of the land use plans on the walls in the hall for everyone to see.

Debriefing: Since this session is about questioning, the focus of the debriefing is on questioning. Each partnership team is asked to write a sequence of five to seven questions that they could use to debrief this activity with their students. This assignment enables us to process the content of the activity as well as the theory behind questioning.

Each set of questions should indicated the order in which they would be asked, cover two or more domains of learning (i.e., knowledge, skills, attitudes, behavior), include both lower and higher level questions (i.e., Bloom's taxonomy; divergent and convergent), and suggest probing or follow-up questions if appropriate. When everyone is finished, we ask several groups to share or role-play their sequence. For each, we analyze their strategy (e.g., which questions were higher level, were any directed at attitudes or behavior). We close this session with several questions to the large group:

1. How were these sequences of questions similar or different?
2. What was the most challenging part of this questioning assignment?
3. What changes, if any, would you like to make in your current practice as it relates to questioning?
4. In what ways is effective questioning critical to inquiry teaching and learning?

Management: In preparing the materials for "Dragonfly Pond," we enlarge (11" x 17") the two cut out sheets and use flip chart paper as the base for the pond. To save time, we pre-cut the land use pieces and put them in an envelope with the picture of the pond. Glue sticks, scissors, and markers are available at each table.

Closure

If any of the elements of the formula is missing, the questioning strategy is less effective. It takes constant diligence to consistently ask good questions. Too often we focus only on the role of the educator as the questioner. "The Pyramid Approach to Reading, Writing, and Asking Questions" (pp. 213-218) describes a way to teach students how to use Bloom's taxonomy in independent research. "Relevant Inquiry" (pp. 219-220) lists six key questions that students use to focus their inquiry process and establish relevancy to their daily lives as they participant in different science experiences.

Related Readings and References

Burns, M. (October 1997). Math in action: Probing questions help develop skills. *Instructor*, pp. 100-101.
Provides an example of an adaptable graphing activity and a list of follow-up questions that lead students from lower order to higher order thinking.

Cruickshank, D., Bainer, D. L. & Metcalf, K. K. (1999). *The act of teaching* (2nd edition). New York: McGraw Hill.
Provides details on questioning and other effective teaching skills in chapter 11.

Pager, J. (1993). *Teaching materials for environmental education: Investigating your environment: A process approach.* Portland, OR: U.S. Forest Service.
Presents a series of activities which emphasize process skills, based on SAPA.

Schwartz, S. L. (March 1996). Hidden messages in teacher talk: Praise and empowerment. *Teaching Children Mathematics*, pp. 396-401.
Discusses the impact of teacher-talk and questioning on how students use process skills during learning activities.

Assessment

Rationale

"This was a good activity, but how do I give students a grade for it?" This teacher's concern about assessing what students learn from inquiry lessons is widespread. Because many teachers do not know how to assign grades to hands-on lessons, these activities are often used as filler or enrichment activities rather than as the core of an integrated science program.

In this session of the institute, we discuss some key understandings related to assessment and evaluation. While many pencil-and-paper tests effectively measure the verbal aspects of learning in a science lesson, they do not allow students to demonstrate the practical learning they have acquired. Because we believe in hands-on learning, we must find out what was learned by using practical, hands-on assessment strategies. We have found that most teachers welcome the information and examples presented during this session.

Background

We begin the assessment session with a short activity. Each group of four or fewer receives three cookies: chocolate chip, Oreo, and ginger snap. Participants are asked to assign a letter grade to each cookie, and to write a narrative evaluation of each cookie. Discussion within the groups is rich for five minutes, then we tally and share results. Participants are asked what they notice about the two procedures. Generally, a wide range of grades is assigned to the cookies. The narratives are more similar across groups. Participants discuss how both procedures reflect values held by the team members, which are often dissimilar!

This discussion enables us to point out the difference between two often misunderstood terms. **Assessment** is the process of gathering data or information about students. **Evaluation** is the process of giving that data meaning or valuing it. Consider a student, for example, whose learning on a physics test yields a score of 29. That raw score or assessment is meaningless until it is compared with or valued against scores of other students in the class. The comparison shows that it is the second highest score! This evaluation gives the score meaning.

What influences how we assess student learning? Certainly the objectives of the lesson do. Equally important, the nature of the instruction or activity used to achieve those objectives influences assessment. Further, the strategies we have available to assess students influence how and what we assess. As a result, our assessment is in danger of being useless, of presenting an incomplete picture, or of being mismatched to the true learning that occurred. The article, "Assessment, Practically Speaking" (pp. 235-236) points out these limitations of assessment in elementary science lessons.

Similarly, evaluation is influenced by the values and biases we hold, as well as by our past experiences with evaluation. As a result, evaluation is in danger of being highly subjective. The dangers inherent to the assessment and evaluation processes are especially true with hands-on science, where traditional methods of assessment are simply not a good match to practical objectives.

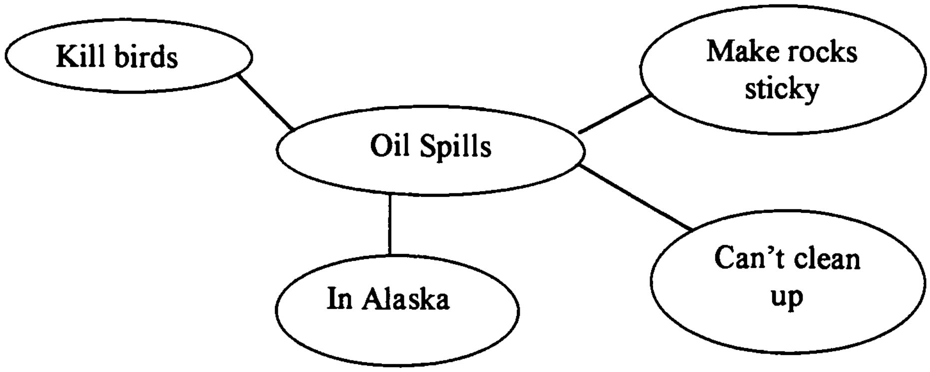
Given the limitations and dangers of assessing student learning, why do we engage in it? We ask the participants to suggest reasons.

- Assessment impacts instruction. For example, it shows which points need to be revisited, what skills students have acquired, and what connections students are making among concepts.
- Assessment motivates students to learn. While some students are highly motivated by grades, most students are encouraged by the feedback about their progress that assessment can provide throughout the process of learning.
- Assessment enables us to give grades. And, after all, this is part of a teacher's job!
- Assessment leads to our own professional development. It provides us with a reading of how effective our instruction has been. It tells us if we made wise instructional decisions, and suggests ways to modify instruction for future lessons.

Without assessment, inquiry science tends to be merely hands-on, rather than hands-on, minds-on. Students engage in activities without being challenged to think about what they are doing and what they are learning. This "activitymania" falls short of the learning goals which can be achieved through inquiry science.

Activity: Oil Spill (pp. 265-268)

Procedure: We use the "oil spill" activity to focus participants' attention on assessing inquiry science. We begin this activity by asking each participant to develop a concept map on a notecard, responding to the question, "What do you know about oil spills?" This helps participants pre-assess their knowledge of oil spills.



We then provide a brief context for the activity by probing the group for their recollection of the impact of oil spills such as the *Exxon Valdez, Torrey Canyon*, and more recent incidents. Because rapid action is the key to reducing the impact of the pollution, determining agents that effectively clean up oil is vital. We then brainstorm a list of techniques used to clean up oil spills.

As presented in the *Participant's Notebook*, this activity is quite prescriptive, that is, a guided discovery lesson. We modify the activity to reinforce participants' use of process skills by providing each partnership team (2-5 participants) with a tray containing a variety of supplies and challenge them to solve the problem, "How can an oil spill be cleaned up?" This inquiry approach requires approximately 20 minutes.

Debriefing: In debriefing this activity, we ask participants to share their findings.

1. What did you try that cleaned up the oil spill? What did not work?
2. How do these materials and methods simulate techniques actually used to clean up a large spill in the ocean?
3. How did you draw from news accounts of oil spill clean ups to solve this problem?
4. What are the advantages and disadvantages of each technique?

Management: Have all materials for each group on trays that are easily distributed. Because participants are working with matches, oil, and potentially dangerous materials, a few words about safety are necessary before doing this activity with students. An environmentally-conscious participant inevitably asks how we will dispose of the oil, a hazardous material. Because the activity requires only a few drops of oil (most of which is soaked up during the activity), little oil remains as waste. Because the environment naturally cleans up spills (e.g., filtered through soil, bacteria called petrophiles break down oil), we mix waste oil with water and dump it in a grassy area outdoors. While cooking oil may be substituted for motor oil, it is difficult to see on water so the impact of the activity is reduced. Adding food coloring to the water helps, but motor oil is still more visible.

Closure

This session focuses on assessment, so we close by talking about how we could assess this oil spill activity. We ask participants, "What do you need to know before you can assess this activity?" Discussion emphasizes that they need to know the objectives for the activity, which are: 1) the learner will use process skills to solve the problem; 2) the learner will identify effective and less effective methods of oil spill clean up; 3) the learner will identify the advantages and disadvantages of each technique, and 4) the learner will work cooperatively in a group. We then brainstorm strategies to assess each objective. From this, the three "rules of thumb" for effective assessment usually emerge. We display these on an overhead:

- assessment should be linked to objectives;
- a variety of assessment strategies should be used; and
- strategies should assess learning at a variety of levels.

The article in the *Participant's Notebook*, "Assessment, Practically Speaking" (pp. 235-236), reinforces the importance of assessing both verbal and practical learning in science lessons and suggests strategies for assessing skills. A variety of instruments specifically developed to assess environmental science knowledge, skills, and attitudes are presented in pp. 237-257. We make several of these into overhead transparencies and ask participants how they could be used in their classrooms. Information on portfolio and rubric assessment (pp. 259-263) provides helpful ideas about how to use these popular approaches.

Concept mapping is one strategy useful in measuring learning in inquiry activities. We close the session by revising the concept maps which participants drew prior to the oil spill activity. They add new things they have learned about oil spills as a result of this session. This provides them with a "picture" of their learning, and a sample tool for assessing learning in inquiry activities.

Related Readings and References

Berenson, S.B. & Carter, G.S. (Spring 1994). Writing open-ended science problems. *Science Educator*, pp. 23-26.
Suggests alternative assessment strategies that can improve student learning of science concepts.

Hein, G. E. (October 1987). The right test for hands-on learning? *Science and Children*, pp. 8-12.
Argues that both science educators and test makers are responsible for the currently bad situation regarding assessment of inquiry learning. Points out promising developments that lead to better assessment.

Jones, M. G. (March 1992). Assessment takes wing. *Science Scope*, pp. 19-20.
Shares how one teacher used multiple strategies to assess student learning following a study of birds.

Kagan, S. (January/February 1996). Avoiding the group-grades trap. *Learning*, pp. 36-38.
Considers the negative consequences of giving group grades and presents positive alternatives.

Raizen. S. A. & Kaser, J. S. (May 1989). Assessing science learning in elementary school: Why, what, and how? *Phi Delta Kappan*, pp. 718-722.
Emphasizes how to strengthen the quality and quantity of science instruction by focusing more clearly on the outcomes we wish to achieve and how we assess them.

Notes:

SWEEP

Sciencing
with
Watersheds, Environmental Education
and
Partnerships

Summer Institute
Participant Notebook

Co-sponsored by
The Ohio State University at Mansfield
Ohio Department of Natural Resources
Science & Mathematics Network of Central Ohio

Funded in part by
The U.S. Department of Education, OERI
Dwight D. Eisenhower Mathematics and Science Education Program

Welcome to SWEEP!

Sciencing with Watersheds, Environmental Education and Partnerships (SWEEP) is a professional development program to challenge elementary school teachers to improve the way they teach science. The key elements of the program are found in its name: SWEEP. The program is aimed at enhancing **science** instruction in elementary (K-6) classrooms, although the concepts and methods can be applied at any grade level as well as to nonformal education settings. The program involves a thematic approach, using **watersheds** as the core concept of an integrated elementary curriculum. Further, the program emphasizes **environmental education**, extending the classroom to the outdoors and studying the interconnected topics and issues which students in a particular watershed experience every day. Finally, the program accomplishes all of this by establishing **partnerships** among teachers and resource professionals or volunteers from agencies and businesses who possess science content expertise and a desire to work collaboratively with teachers to strengthen science instruction.

The SWEEP program begins when teams of teachers and resource professionals attend an intensive summer institute to improve teaching and partnering skills. At the institute, they collaboratively develop goals, build team spirit, and examine their school curricula. They prepare an action plan to restructure their science curriculum around the watershed theme, which they collaboratively implement during the following school year. Throughout their participation in SWEEP, partnership teams are provided with support and resources and encouraged to develop networks within their schools and communities. Classrooms throughout the watershed communicate and share projects and data, thus enhancing science instruction and reinforcing the interconnectedness throughout the watershed.

SWEEP was originally implemented in the Cuyahoga River watershed and the lower Scioto River watershed in Ohio. Now it is time to move on...to SWEEP the nation, so to speak. And that is where this notebook comes in. To expand the program, two resources have been developed. This is the **Participant's Notebook**. It contains the basic concepts, activities, and selected readings which are used during an intensive summer institute. Also available is the **Instructor's Implementation Guide**. This manual provides logistical information about operating the SWEEP program, detailed teaching notes, and an in-depth discussion on establishing and supporting effective partnership teams. We hope that these resources will encourage and enable you to adapt this hands-on, integrated program in elementary classrooms in your area.

For more information about SWEEP, contact us via email at: sweep@osu.edu
Or, visit our website at: www.mansfield.ohio-state.edu/mans/sweep/index.htm
Of course, you may contact the project co-directors as well:

Deb Bainer
The Ohio State University,
Mansfield
1680 University Drive
Mansfield, OH 44906
419/755-4287

Pat Barron
Science & Math Network
of Central Ohio
807 Kinnear Road
Columbus, OH 43212
614/485-9800

Diane Cantrell
Ohio Department of
Natural Resources
1939 Fountain Sq., E2
Columbus, OH 43224
614/265-6788

Additional copies are available from:

Partnership Office
c/o Dr. Deborah Bainer
The Ohio State University at Mansfield
1680 University Drive
Mansfield, OH 44906
(419) 755-4287

This *SWEEP Participant's Notebook* was funded in part by a grant from the Eisenhower Federal Activities Program, Office of Educational Research and Improvement (OERI), U.S. Department of Education. The contents of this publication do not necessarily reflect the views or policies of the U.S. Department of Education.

SCIENCING with WATERSHEDS, ENVIRONMENTAL EDUCATION and PARTNERSHIPS

Agenda

Day 1

9:30 Registration

10:00 Welcome, activity and introductions
    Knots
  Pretest/Assessment
  Setting the stage for inquiry science
    Water Purification
    Mini Water Treatment Simulation

11:45 Lunch and Who's Who

12:45 Introduction to SWEEP

1:00 Job alike groups

1:45 Introduction to partnering

2:30 Partner poster session

3:15 Partnership round tables and break

4:00 Multiple ways to teach: Exposition to inquiry – activities
    Ground Water Model
    Incredible Journey
    What Can you Learn About a Watershed? (adapted)

5:45 Check-in and time on own

6:15 Dinner

7:00 Course overview
  Reflection

7:30 Planning time

Day 2

8:00 Breakfast

8:45 Introduction to Science and Mathematics Network
Introduction to action plan

9:00 Thematic approach using watersheds -- Webbing

10:15 Break

10:45 Child development/Age appropriateness -- Activities
- Surf 'n Sand
- Me Maps
- Fly's Eye View and Scale
- The Great Flood

12:15 Lunch

1:15 Introduction to process skills
- Litter Alert

1:45 Move to cars

2:00 Travel

2:30 Field experience
- Watershed Mapping Activities
- Watershed Activities

5:30 Travel

6:00 Clean-up

6:45 Dinner
- Overview of ordering books
- Reflection
- Planning
- Ordering books

Day 3

8:00 Breakfast

8:45 Introduction to ODNR

9:00 Concurrent sessions and activities
Introduction to jigsaw and travel
- Management – Garbage Bag Watershed
- Quesstioning – Dragon Fly Pond
- Assessment – Oil Spill

10:00 Travel and debrief jigsaw

10:45 Break

11:15 Planning time and team conferences

12:15 Lunch and planning time

1:00 Partner sharing

1:30 Introduction to investigating local issues

2:00 Deer Creek Investingation

4:30 Deer Creek reports

5:00 Optional activities

6:30 Dinner

7:30 Reflection
Overview of equipment orders
Book orders
Planning

9:00 Turn in book orders
And more planning

Day 4

8:00 Breakfast

8:45 Introduction to OSU-Mansfield

9:00 Local watershed issues

9:45 Networking within watersheds

10:15 Book order update

10:30 Break

10:45 Final planning

11:45 Check-out

12:30 Lunch

1:15 Sharing plans

2:00 Post-test/Assessment

2:45 Evaluation

3:00 Closing ceremony

3:45 Adjourn

ICE BREAKER:
KNOTS

Purpose:

This activity is used as an opening mixer and to introduce the concepts of inquiry and scientific process.

Materials:

None

Procedures:

1. Divide into groups of 6-7.
2. Stand in a circle, shoulder to shoulder.
3. Place your hands in the center of the circle and mix your hands around.
4. Grab a hand in each of your hands. **Make sure that you are not holding both hands of the same person or the hand of the person next to you.** Switch hands around if necessary.
5. Now try to "unknot" yourselves without completely letting go of your hands. Step over, under and through your teammates until you form a circle (some of you may be facing in and others out).
6. If time permits – after you have solved your knot, join another successful team to make a bigger knot.

   Tips:
   - If you are having difficulty and are convinced that your knot cannot be untangled, have one person squeeze his/her right hand. The person who receives the squeeze passes it on with his/her other hand. If the squeeze goes all the way around to the first person, the knot is solvable.
   - Sometimes instead of one large circle, you will end up with two interconnected ones.

Discussion:

1. Why would we start the workshop with this activity?
2. What did you have to do to solve the "knot"?
3. How is participating in this activity similar to doing science? Doing inquiry?

Adapted from: Fluegelman, A. (Ed.). (1976). The new games book. Garden City, NY

SWEEP
ACTIVITY

CLEARER THAN MUD

Purpose:

This activity is used to introduce inquiry-based teaching and learning, the learning cycle, and the "watershed" theme. In this simulation, participants have the opportunity to experience and explore the scientific processes and methods that might be used to clean water.

Materials:

The following supplies, centrally located on tables, are available in quantities adequate for all groups:

- Assorted cups
- Liter bottles (no bottom)
- Funnels
- Coffee filters
- Screen
- Sand
- Gravel
- Soil
- Baby food jars
- Paper towels
- Peanut butter jars
- Stockings
- Rubber bands
- Scissors
- Alum
- Other

Each group has a tray with the following:

- Empty baby food jar
- Peanut butter jar (with lid) containing 1 cup water and ¼ cup soil

Procedure:

Phase I – Play

1. From what sources do we get our drinking water? (e.g., treatment plant, well, bottled water, drinking fountain)
2. Whether we get our drinking water from a treatment plant, well, or bottled water, we want our water clean. Each group has a jar of muddy water. Shake it up thoroughly.
3. For this task, you are going to investigate the question: **How can we make this muddy water clean?**
4. In your groups (4 people) decide who is going to be the materials manager, recorder, reporter, and encourager.
5. As a group, look at the list of materials available to you and decide what steps you want to take to clean up your water.
6. Have the materials manager gather the materials you need. Have the recorder keep notes on what you do and the results. At the end of your procedure, you should have at least ¼ of a baby food jar of the cleanest water you could achieve.

Phase II – Debrief

1. Have the reporter from each group bring the jar of "clean water" up front. Line up in a continuum from the dirtiest to the cleanest water.
2. What are some of the things you tried that seemed to work the best? (Have reporters share the procedures).
3. What are some of the procedures that seemed to work best for multiple groups?

Phase III – Replay (if time permits)

1. Based upon what you learned from your first attempt to clean the water and from what others learned, redesign your procedure.
2. Have the materials manager gather the materials you need including another jar of muddy water and a clean baby food jar. Have the recorder keep notes on what you do and the results. At the end of your procedure, you should have at least ¼ of a baby food jar of the cleanest water you could achieve.

Discussion:

Have the reporter from each group bring your jar of "clean water" up front. Line up in a continuum from the dirtiest to the cleanest water.

1. How does this continuum compare to the first one?
2. Why do you think there is a difference?
3. What did you do differently the second time? How did it work?
4. If we were to recommend the "best" way to clean muddy water, what would that be?

Business/School Partnerships: A Path to Effective School Restructuring[*]

The direction a partnership takes, the methods it uses to promote school change, and its success with different strategies are all strongly influenced by local needs and policies. What works well in a medium-sized community may not have the same success within a large urban system. Overall reform principles, however, remain consistent. Below are some general guidelines for companies interested in support of school-based restructuring efforts.

The Role of Partnerships in Supporting School Reform

Business/school partnerships encompass a variety of different relationships, but it is possible to characterize most of them as belonging to one of three primary configurations: adopt-a-school model, project-driven model, and reform model. These are not altogether tidy distinctions. Partnerships change over time, acquiring greater complexity as partners develop a commitment to undertake long-term reforms or shift their priorities to meet the needs and interests of changing players.

> *Coming together*
> *is a beginning;*
> *keeping together*
> *is progress;*
> *and working together*
> *is success.*
> *—Henry Ford*

The Reform-Model Partnership

What it is: Often developing out of relationships established through earlier partnerships, the reform-model partnership focuses on system change: finding ways to change the learning and teaching environment by expanding the responsibilities and roles of students, extending teaching practices and empowering teachers, changing the organizational and management structure within schools and districts, and developing proficiency model assessment tools.
What it can accomplish: Reform-model partnerships seek changes that become embedded in the system and remain in place and supportive of structural reform over the long term.

Five Steps to Developing Reform-Model Partnerships

The steps to develop a reform-model partnership aimed at helping schools and school systems change are different in focus and application from those steps taken to form traditional partnerships. The mission, goals, and strategies of reform-model partnerships are centered on the task of challenging current school practices (teaching, learning, and management) and developing school-based system change. The five steps are as follows:

1. **Agree on Specific Goals.** Partners in a reform-model partnership must identify partnership outcomes that directly relate to restructuring outcomes.
2. **Develop Strategies for Involvement.** In reform-model partnerships, these strategies for involvement must not only be directed at helping the district make the change necessary to achieve restructuring goals but also at incorporating those changes into the structure of school and district.
3. **Identify Costs in Resources and Personnel.** All partners must understand the additional costs in resources and personnel that the restructuring effort will require.
4. **Monitor, Assess, and Evaluate Outcomes.** The partners need to establish a system to monitor, assess, and evaluate how well partnership activities help the school and school system reach restructuring goals.
5. **Manage the Partner Relationship.** The partner relationship must be managed so that it effectively fulfills its responsibility as a catalyst to school restructuring.

Reform-Model Partnerships Address Restructuring Goals by:

- Increasing student learning
- Extending the capacity of teachers
- Creating school systems that encourage innovation
- Developing effective assessment tools.

Reprinted with permission from the Council for Aid to Education.

---

[*] The ideas and information presented are excerpted from the report, *Business/School Partnerships: A Path to Effective School Restructuring*, available from the Council for Aid to Education.

BEST COPY AVAILABLE

Characteristics of Successful Reform-Based Partnerships

1. Innovative and Pioneering

2. Jointly Developed Goals

3. Collaborative Planning & Implementation

4. Classroom-Based Relationship

5. Activities are Hands-on, Appropriate to Age & Linked to Curriculum

6. Reflect National and State Goals

7. Include Assessment Strategy

8. Changes Embedded in the System

9. Multi-level, Long-term Support from School and Business

Showcase Partnerships

TS Trim Industries, Inc. & Canal Winchester Elementary

In this partnership, several teachers from the school are partnered with associates from TS Trim, an automobile components manufacturer. The "crown jewel" of their work together is Simple Machines Day. This school-wide event is the culmination of numerous classroom explorations of simple machines and their uses in the manufacturing plant. During the Day, students conduct experiments using life-size levers, screws, pulleys, etc., built by the associates, and explore real-life examples of machines brought to the school by area businesses. Students demonstrate to the associates their knowledge of how and why simple machines work. They also participate in classroom-based activities in which they build smaller versions of simple machines.

U.S. Geological Survey & Darby Woods Elementary

Not all Network-assisted partnerships involve multiple staff members and professionals; in fact, most of them involve one to two teachers working with one or two professionals. Ralph Haefner, a hydrologist at the U.S. Geological Survey partners with Lily Wagoner and Michele Pall, both 1st grade teachers from Darby Woods Elementary. Their partnership focuses on helping students develop an understanding of earth systems through activities which develop skills in observation, recording cause and effect, drawing conclusions, measurement and classification. In the photo below, children are directing Ralph where to place rocks they have brought from home on a large chart. Students use their knowledge of various geological characteristics to determine where the rocks should be placed. Other activities will focus on determining properties of air; discussing the influence of air quality on our quality of life; and exploring the chemical properties of water.

Battelle & Longfellow Elementary

Two of the partnerships at Longfellow Elementary involve retired scientists from Battelle. In one of the partner teams, Peter Taussig, a former Battelle employee, partners with Charlie Lozano, the school's 5th grade teacher. They have worked together for six years, and focus on helping students hone scientific process skills, such as recognizing experimental variables and determine the impact of these variables on the accuracy of data, results and conclusions. Experiment topics included studying molecules and atoms, and making and testing parachutes.

Franklin County Soil & Water Conservation Division & Fair Avenue Elementary

This partner team focuses on environmental issues for all of the 3rd graders at Fair Avenue Elementary. Linda Pettit, environmental education coordinator for the SWCD, works with teacher Willa Jackson to use environmental topics which help students develop problem solving skills and see that "everything affects everything." Their activities are all tied to the theme of weather, and include making a cloud in a baggie and studying leaves to understand how deciduous and coniferous trees each survive the winter.

Partnership Do's and Don'ts

With seven years of experience in partnerships, Kathy Back, principal, Camelback High School, Phoenix, Ariz., has witnessed the growth and change of the field. She's coordinated partnerships with airlines, hotels, credit unions, automobile stores and travel agencies. But in spite of the change, she's also noted a few constants. Here she outlines key *Partnership Do's and Don'ts* that are applicable to any organization.

Partnership Do's

1) Do identify the need for a partnership. Preferably the solution to the need will be mutually beneficial for the school and the business.

2) Do be open-minded and willing to look at a problem in a variety of ways.

3) Do build accountability into the partnership using a reporting system. The business needs to know what it's getting, and needs to be ensured that what they're giving is valuable and being used.

4) Do plan for positive PR. Promotion is often the key to success. It's nice to involve both the local media as well as the school's communication department.

5) Do incorporate a renewal plan on an annual basis. Don't just assume the partnership will continue the next year. At the end of the partnership's first year, review the program. Decide if you will go forward. And if so, build on your strengths and fix your weaknesses.

6) Do line up dynamic and enthusiastic faculty and personnel.

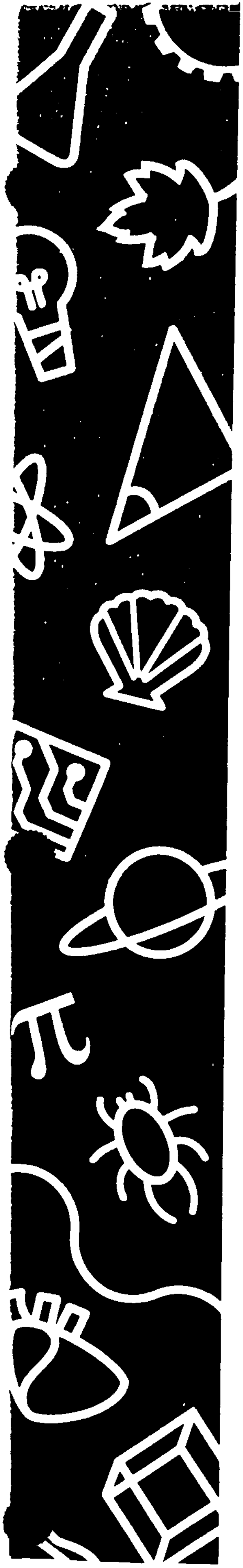
Partnership Don'ts

1) Don't have a fixed agenda when you meet with an executive of a company. Yes, you should have identified your need, but don't lock into exactly how you want that need fulfilled. It may not work if the executive has a different idea. The open-mindedness also helps to solve problems. There's not just one solution.

2) Don't have the mindset that money is the only resource you'll accept. There are many other resources to accept. First off, not all companies are even able to give money. And secondly, if your timing isn't right you're not going to be on the corporate contribution schedule anyway (most companies budget these monies between November and February).

3) Don't create complex projects. You're better off to keep the structure simple until you've established a relationship. Otherwise, you may get bogged down with details, and tire yourself out.

Contact:
Camelback High School,
Kathy Back
(602) 271-2200



Sharing Science:

Linking Students with Scientists and Engineers

A Survival Guide for Teachers

The Task . . .

Students learning science can experience the excitement of discovery and invention. Understanding science prepares them to participate in an increasingly complex and competitive scientific and technological world.

Meeting the challenge of teaching our children in this rapidly changing world is not easy. Teachers have limited time and materials for teaching science and often find themselves teaching without access to the real world experiences that can make science come alive.

One of the best allies any teacher can have is a person who knows and understands science. A scientist or engineer can help students:

- experience the excitement of discovery and invention
- develop an informed approach to the role of science and technology in our world
- observe teachers and scientists working together as partners
- associate science with a real human being
- see the personal rewards of scientific and technical careers
- realize that women and minorities can pursue careers in these fields

Every community is home to a variety of science professionals who are concerned, just as you are, about educating tomorrow's citizens. Across the nation thousands of them have demonstrated their willingness and ability to become involved in our schools. This guide provides suggestions to help you collaborate successfully with scientists and engineers in your classroom and to make the experience a success for you, for your students, and for those who volunteer to share science with you.

Now —
Get ready!
Get set!
Go!

Reprinted with permission from the North Carolina Museum of Life and Science

GET READY!

- **Think creatively about what you want to accomplish.**
  Look for opportunities for your students to get to know a real scientist as an interesting person. Encourage scientists to share the excitement of discovery and enthusiasm for their professions. Cultivate student interests and questions through new experiences, ideas and information.

- **Identify a scientist, engineer, or a science user.**
  Many school systems have formed active partnerships with science centers, science alliances, scientific societies and local universities. Corporations and business groups are interested in volunteering in the classroom. Ask your system or state science coordinator for help in contacting local scientists. It may be easier than you think.

"We had a discussion about AIDS. The teacher & I had talked it over prior to my visit, and I was prepared in case awkward issues arose. I think my communication with the teacher was essential in this case."

—Deborah K. Smith, Ph.D.

- **Make contact well in advance.**
  Remember, it will take time to develop a plan. Your volunteer has a busy schedule, too, so be flexible. Find out when and how each of you prefers to be contacted. Provide backup phone numbers in case a change in plans makes last minute contact necessary.

- **Decide together what to do.**
  Have a conversation with your volunteer about what she can do to help you enrich your science program. Explore with her what experiences, activities, information would be of interest to your students and appropriate to your curriculum. Agree on one or more activities which engage your students.

To ask questions and to find out — science is a part of what it means to be human. Teachers, scientists and engineers have to become partners in efforts to bring science to children. Working together, we can connect children to the ideas and the processes of science, to the applications of science and mathematics which are all around us, and to the promises and challenges of science and technology.

Teachers are vitally important to education and literacy in science because K-12 is the front end of the pipeline toward careers in science, engineering and medicine; it is also the gateway to lifelong learning, enjoyment and appreciation of science. Scientists have much to share and much to learn when they link to teachers and students. It is worth the effort to reach out and bring scientists into your classroom. Some of them used to teach in schools, as I did. Many of them are parents of school age children, as I am.

This guide will help you make the experience of sharing science a meaningful one for you, for them, and most importantly, for your students.

Shirley M. Malcom, Ph.D.
Head, Directorate for Education and Human Resources Programs
American Association for the Advancement of Science

GET SET!

A month or so in advance:

- **Schedule and determine the setting for the a**
  Will the scientist work with your whole class or wit groups? Will the activity be indoors or out? Agre time allotted for the activity. Allow for flexibility!
- **Identify any special equipment or space that is needed.**
  This could include laboratory equipment, A-V materials, flat tables, electrical outlets, water, or scissors. Agree on how materials and equipment will be managed to ensure both safety and efficiency.
- **Give the scientist a profile of your students.**
  Let him know the number, age, learning characteristics, and special needs of your group. Tell the volunteer what your students have been studying and how the proposed activity will fit in.
- **Provide directions to the school and parking information.**
  Tell the scientist where and how she will be greeted.

A few days before the visit:

- **Call the volunteer to confirm your plans.**
- **Prepare a welcome.**
  Select a team of several students to greet the volunteer and help with any equipment which may need to be carried in.
- **Prepare your students.**
  Explain who their guest is and what he will be doing. Review rules of courtesy. Prepare name tags so the scientist can call on students by name. If students will be working in groups, assign them ahead of time.

"I have no children of my own; I have never had a teacher education course; and I have never taught either grade school or high school before in my life. Consequently, I was a bit apprehensive about the whole thing. However, you put me at ease, and your class was a model of attentiveness and good behavior. I found your students to be a joy to teach. If ever you feel like taking a chance with me again, I'd love to come and teach your class a second time."

—Dr. David M. DeMarini,
Research Genetic Toxicologist

"I...discussed basic principles of electricity and magnetism and helped students make simple circuits. Students enjoyed the "hands-on" experience. Based on past experience, I expected iron filings and small compasses to be available. I should have reviewed the list of materials with the teacher ahead of time."

— William M. Yeager, Ph.D.

You're Not in This Alone!

Science education is a national priority. Thousands of scientists are interested in volunteering. *Sharing Science With Children: A Survival Guide for Scientists and Engineers*, a companion to this publication,is in the hands of tens of thousands of scientists. Many national organizations have committed to improving science learning.

The National Science Foundation (NSF) has designated National Science & Technology Week, 1992 as April 26-May 2 and 1993 as April 25-May 1. NSF encourages teachers, scientists, and others to participate through school activities, community projects, and public lectures.

Science centers provide rich experiences in science. They are a resource for science activities and ideas for teaching science. Their national organization, the Association of Science-Technology Centers (ASTC), is promoting partnerships between teachers, museums, and scientists. Contact your local science center to learn what is available in your community.

The American Association for the Advancement of Science (AAAS), a national organization of 130,000 scientists, actively encourages member scientists to work with teachers in schools. Their publication, *Sourcebook for Science, Mathematics & Technology Education*, includes more than 2,000 listings of programs, people, projects, publications, and organizations. It can be ordered by writing: AAAS, 1333 H Street, NW, Washington, DC 20005.

Developed by the North Carolina Museum of Life and Science.
Thomas H. Krakauer, Executive Director
Georgiana M. Searles, Editor and Director of Education

For additional copies of this guide or its companion, *"Sharing Science With Children: A Survival Guide for Scientists and Engineers,"* write:

Georgiana M. Searles
North Carolina Museum of Life and Science
P.O. Box 15190
Durham, North Carolina 27704

The North Carolina Museum of Life and Science gratefully acknowledges funding support from:

National Science Foundation
North Carolina Science and Mathematics Alliance

North Carolina
Museum of Life and Science

Sharing Science:

Linking Students with Scientists and Engineers

A Survival Guide for Teachers

Printed on recycled paper

GO!

On the day of the visit:

- **Be sure students, equipment, and space are ready.**

- **Have your welcome team meet your visitor.**

- **Introduce the visitor to your class.**

- **Remain actively involved during the visit.**
  Show your students that teachers are learners, too. When you are interested, students will follow your example. Be a second pair of adult hands if needed. Lend your quiet expertise in classroom management.

- **Understand what your students are learning.**
  Anticipate and identify questions they may have so that you can prepare to follow up.

After the visit:

- **Extend appreciation.**
  Thank-you notes, drawings, or photographs from students are always appreciated. Scientists especially like to know what students learned and what interested them.

- **Provide feedback about the activity to the scientist.**
  Scientists are learners, too. They will respond to your positive reinforcement as well as constructive criticism.

- **Follow up**
  Discuss with your students what they learned and what else they want to know. Build on their experience with follow up activities. Incorporate interdisciplinary activities in writing, spelling, art, social studies, reading, and math. Complete any experiments left by the visitor and let her know the results.

- **Share your experience with parents and colleagues as well as school administrators.**

- **Plan for more visitors.**
  Make your experiences diverse. Invite people with different backgrounds, women and men, minorities, and people with disabilities.

"Like the children we teach, we learn as a result of our own activity—our own struggle to make sense of what we see.... We are in this classroom together, and this science work will only be exciting if we care about it together. If I say 'Scientists are curious,' but I am not showing curiosity, children will perceive this inconsistency. I need to show, as well as say, how that looks."

—Ellen Doris, Northeast Foundation for Children, "Doing What Scientists Do"

"More than twenty "Thank-You" cards made by these students with their own words of personal appreciation were sent to me. This was certainly unexpected but was definitely a thrill for me to see the creativity of these students, of how they conceived the microbes and me and then expressed it in pictorial illustrations."

—Joseph K. Li, Pharmacologist

How Scientists Can Help You

Scientists, engineers, and people who use science in daily life can:

- Demonstrate scientific concepts and direct applications of science and technology
- Develop experiments and do them with students
- Lead or arrange for field trips or guest speakers
- Stimulate and guide independent research
- Show students practical applications of computers in science
- Serve as a resource person for you or your students
- Help obtain, fix, and maintain equipment
- Serve as tutors, mentors, and role models for individuals or small groups
- Encourage female and minority students to enter science-oriented careers
- Work with parents and families
- Lead after-school science and math clubs
- Assist with science, math, and career festivals

and more—be creative!

"Thank you so much for visiting our class. The kids (and I) learned a lot about Marine Biology and Diving. Last week in Reading Class we were studying "Diagrams" and we had a practice paper with a diagram of "diving gear." I was pleased to see how much of the equipment the kids still recognized! Thank you, especially, for giving the kids a chance to see that scientists can be "real people". I am not sure that is something I realized at their age. P.S. You can see from the kid's letters what an impression your visit made upon them."

—Bonnie Farb, 5th grade teacher

"One thing I try to get across is that you don't have to have a Ph.D. to contribute in science."

—Melissa Mar, Research Biologist

"I discussed the role of fungi in our lives and displayed examples of fruiting bodies and culture plates. The students displayed a great deal of interest and asked both interesting and stimulating questions. The teacher showed an extremely high degree of interest and enthusiasm that seemed to transfer to students. I found the experience to be rewarding beyond my expectations."

—Dr. John E. Mayfield, Mycologist

"I liked when you put the blue and orange compounds together in the liquids. Please say hello to Dr. Hegley, and doctor Pinhas for me. Your friend, Dennis (the person who wants to find out the chemical reaction)."

—5th Grade Student

"I talked about entomology, showed the students a collection of unusual insects, allow the students to handle some live insects, and gave each of them caterpillars and supplies to rear them to adults. The students were interested and excited. Meeting with a scientist enhanced the students' perception that science is a real activity and occupation, and not just a school subject."

—M. Scott Thomson

"I showed the separation of dyes in grape soft drink as a way of illustrating separations and their utility in analyzing for pollutants. Students reacted with enthusiasm and suggested other separations to try. I hope students learned that scientists are real people and that science can be fun."

—Douglas E. Rickert

"A scientist helped a second-grade class make electromagnets from materials no more complex than a battery, a nail, and a length of wire. With fumbling fingers, the students created their apparatus and then proceeded, without foreknowledge, to see what the contraption would do. Thrilled with herself and her creation, one bright-eyed girl cried out, "I made a magnet! I did it! I really made a magnet!" Relating his experience, the scientist grew wistful. "It was that experience," he said, "that reminded me of why I am doing all this. Now I know my efforts are worth something."

—Colorado Alliance for Science

We Are All Scientists!

Children and scientists have much in common. Naturally inquisitive, young children ask endless questions. They may spend half an hour watching a bug crawl on the floor. Children sort money, pictures, toys, shells, pasta shapes, and words. They experiment by pouring water into soil, mixing different colors of paints, or adding blocks to a tower until it falls. They draw conclusions about the way things work. They learn from and share information with others.

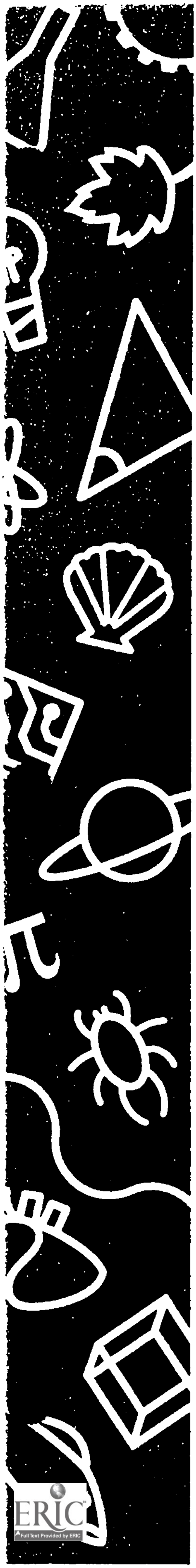
Scientists share with children a natural curiosity about the world. They are trained to use a more systematic and sophisticated approach to inquiry than children do. They have developed the discipline to remain objective, to reserve judgment until they have the facts, and to recognize the limits of their knowledge. Nevertheless, the skills used in doing science are the same — whether you're a student or a scientist!

Science Process Skill	Children	Scientists
observe	look, touch, smell, taste, listen	microscope, x-rays, chromatography, seismograph
experiment	change something and watch what happens	change and control variables
collaborate	partners in classroom	colleagues around world
record	journal, score card	field notes, computer
measure	scale, ruler, stopwatch measuring cup	computer analysis, calibrated apparatus
sort and classify	color, size, shape, weight	taxonomic key, relevant functional groupings
compare	fastest, largest, farthest	change over time, change in differing conditions
analyze	what happens most	statistical analysis
share information	class meeting; at recess, "Guess what I found out?"	scientific meetings, E-mail; over coffee, "Guess what I found out!"

Science in the Classroom

Listed below are suggestions of people who might be able to help you in the classroom. Some are research scientists. Others use science in their everyday work life. Other people who might be helpful are hobbyists and collectors who study weather, plants, animals, astronomy, rocks and minerals, or fossils.

Animals	Zoologist, entomologist, microbiologist, marine biologist, paleontologist, cytologist, physiologist, chemist, ecologist, neurobiologist, geneticist, anatomist, mammalogist, limnologist, pharmacologist	Zookeeper, veterinarian, beekeeper, animal trainer, physician, forest ranger, wildlife manager, farmer, rancher, audiologist, nurse, dietician, X-ray technician, forensic specialist, pharmacist
Plants	Botanist, paleobotanist, agronomist, agricultural chemist, ecologist, geneticist, paleontologist, pathologist, soil scientist	Horticulturist, farmer, forest manager, nutritionist, landscape architect, soil conservation officer, park ranger, agricultural extension agent
Weather	Meteorologist, ecologist, agronomist, geologist, oceanographer, climatologist	TV weather forecaster, airport flight controller, fisherman, boat captain, farmer, pilot, environmentalist, soil and water conservation agent
Physical & Chemical Properties	Chemist, biochemist, pharmacologist, molecular biologist, physicist, ecologist, toxicologist, metallurgist, geologist, forensic criminologist, materials scientist, engineers: chemical, textile, industrial, acoustical, optical, mechanical, civil, nuclear, agricultural, and ceramic	Architect, inventor, mechanic, carpenter, musical instrument maker, musician, photographer, builder, police lab technician, water company technician, cosmetics developer, gemologist, building inspector, potter
Electricity & Magnetism	Physicist, geologist, computer hardware/software designer, engineers: industrial, electrical, thermal, mechanical, and electronic	Electrician, radar technician, amateur radio operator, telephone system maintenance technician, electrical inspector, inventor, radio/TV engineer
Earth & Space Science	Astronomer, geologist, paleontologist, ecologist, physicist, biologist, chemist, vulcanologist, seismologist, oceanographer, soil scientist, engineers: aeronautical, aviation, construction, and civil	Pilot, astronaut, geographer, cartographer, surveyor, geotechnical tester, aerial photographer
Behavioral & Social Science	Animal psychologist, clinical psychologist, psychiatrist, sociologist, anthropologist, historian, archaeologist, geographer, demographer	Marketing professional, business manager, city planner, applied economist, school psychologist, pollster, market research analyst, statistician



SHARING SCIENCE WITH CHILDREN:

A Survival Guide for Scientists and Engineers

The Task . . .

We face a challenge. Our children need to learn about rapidly changing science and technology. Already, many of your colleagues, along with educators, parents, and local, state, and national organizations, have joined together to meet the challenge. They support science education by allocating resources, building community support, and providing tools and materials for teachers.

You can help. One of the best tools any teacher can have is a person who knows and understands science and technology — a person like you. By sharing science in the classroom, you can help students...

- understand the positive and vital role of science, mathematics, and technology in today's world,
- gain an understanding of the work scientists do,
- see scientists as real people,
- lay the foundation for careers in science and technology, and
- grow in their enjoyment of the world around them.

Just a few hours of your time can make a big difference. Teachers are eager to invite you into their classrooms and to help you work with their students. This guide provides suggestions to smooth your transition from lab to classroom.

You and your colleagues working in science and technology fields are doers . . . doers can teach — by example, by working to expand science education in all levels of the educational system, and by sharing with teachers and students in the classroom.

Now —

Get ready!

Get set!

Go!

GET READY!

Survival Tips for Your Classroom Visit

Before you go into the classroom...

- **Decide on your approach.**
  You may select some aspect of the curriculum. An alternative, more personalized, approach is to focus on what you do.

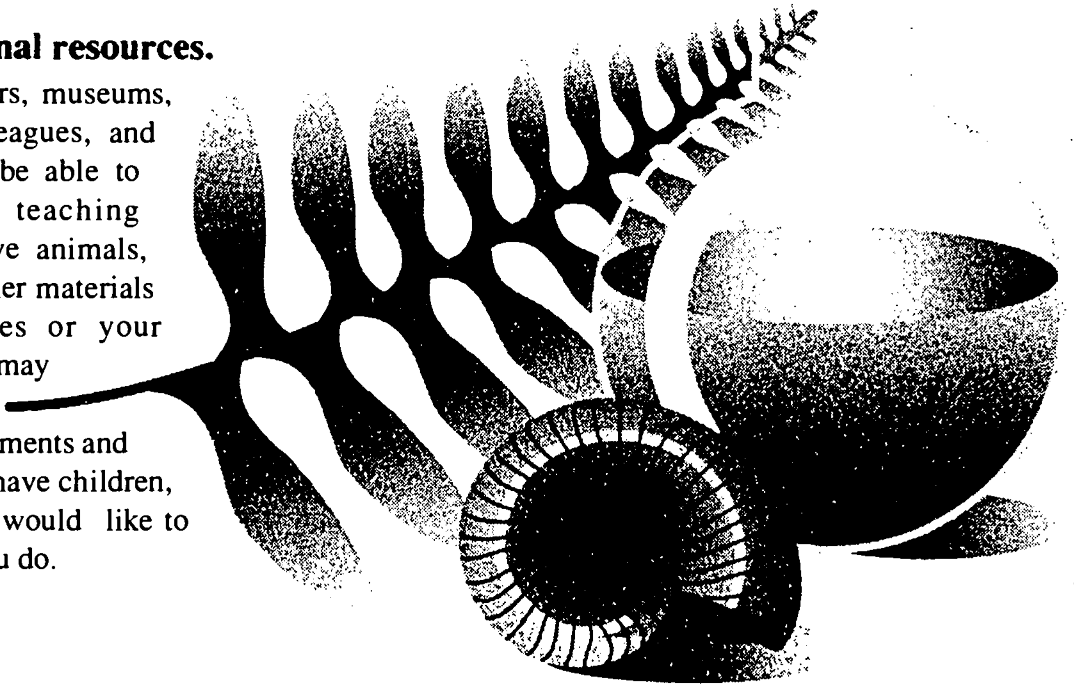
- **Prepare your activity based on children's needs and abilities.**
  Ask the teacher what students already know. *"Typical Science and Technology Topics"* on page 6 will give you a general understanding of what students typically learn at different grades. You can also check with the teacher about local curriculum and/or texts.

  Know the age of the class you are visiting and their *"Thinking and Learning Characteristics"* (page 7).

- **Be prepared for student reactions and behavior.**
  Keep in mind that teachers and parents may have concerns about how sensitive issues, such as evolution or reproduction, are presented to their children. If you have questions about appropriate ways to present your subject, discuss your plans with the teacher.

- **Know when and where you will be visiting.**
  Verify the time, place, and length of the visit. Be sure to get phone numbers for the teacher and the school. If you don't know where the school and classroom are, ask for directions.

- **Look for additional resources.**
  Local science centers, museums, libraries, your colleagues, and other sources may be able to provide hands-on teaching materials, films, live animals, activity kits, and other materials to use. Colleagues or your professional society may be able to give you good ideas for experiments and things to do. If you have children, ask them what they would like to know about what you do.



GET SET!

- **Assemble your notes and materials in advance.**
  If each student is to have a handout or materials, make sure you have enough of each. See that materials are organized. Do a test run of experiments, games, or any other activities you plan to do.

- **Prepare to use terminology that is appropriate for the students.**
  If there are a number of words or concepts students would benefit by knowing in advance, give them to the teacher and (s)he can help students learn them.

- **Allow yourself enough time to get to the school and to find the classroom.**

COMMIT TO THE CHALLENGE

Learn about and support science related activities in your local community and those sponsored by state and national organizations. Here are some resources:

Each year the **National Science Foundation** (NSF) designates the last full week in April as National Science & Technology Week. NSF provides instructional kits with student activities, educational posters, and other materials. It encourages teachers, scientists, and others to participate through school activities, community projects, and public lectures. National Science & Technology Week will be celebrated in 1992 on April 26-May 2.

The **Association of Science-Technology Centers** and its member science museums promote experiences in science and technology for children, families, and the general public. Science centers and museums feature hands-on exhibits, science activities, and teacher training workshops and serve as educational resources to their communities. Contact your local science center to offer your support. ASTC can refer you to museum contacts in your state. Call (202) 783-7200 for assistance.

The **American Association for the Advancement of Science** (AAAS) sponsors activities through its Committee on the Public Understanding of Science and Technology including a project which encourages scientists to volunteer at science and technology centers and other places of science. Call (202) 326-6602.

Many professional societies lend support to local schools, museums, and other community institutions. Check with your national organization to find out what programs or materials are available.

Developed by the North Carolina Museum of Life and Science based on numerous publications, guidelines, and other sources drawn from all over the United States. Non-commercial duplication is encouraged. We want to know how you use this guide and any suggestions you have for improving it. Contact: Georgiana M. Searles, Director of Education, North Carolina Museum of Life and Science, P.O. Box 15190, Durham, North Carolina 27704.

The North Carolina Museum of Life and Science gratefully acknowledges funding support from:

National Science Foundation
American Association of Pharmaceutical Scientists
American Mathematical Society
American Society for Microbiology
Apple Computer, Inc.
E. I. duPont de Nemours & Company
Schering-Plough Research

North Carolina
Museum of Life and Science

Printed on recycled paper

GO!

- **Share yourself.**

  Let the children know you are a real person with a fa an anthropologist, an engineer, . . . Was there a s experience, a book, a visit to a museum — that ar average day? What is interesting or unique about

- **Involve the students in doing.**

  Bring an attention grabber if you can. Keep in mind to know more. The tools of your profession may be even fascinating to most of the students (and teachers) you meet. When possible, let students handle models, equipment, samples, plants, prisms, stethoscopes, rocks, or fossils.

- **Involve students in the process of science.**

  Do a simple experiment in which the students participate. The process skills of science — observing, identifying, classifying, measuring — are the skills that enable students to apply science to everyday problems.

- **Stimulate thinking by asking questions.**

  Questions that ask students to make a prediction, to give an explanation, to state an opinion, or to draw a conclusion are especially valuable. Be sure to allow time for each student to THINK before anyone gives answers.

- **Use language the students will understand.**

  Be conscious of vocabulary. Try not to use a difficult word when a simple one will do. Define words students may not know. For example, don't say, "I am a cytologist" and begin a lecture on semipermeable cell walls. Rather, ask students if they know what a cell is and then tell them you study cells, how they are built, and how they act, and that you are called a cytologist.

- **Make what you are talking about real to the students.**

  Show the students that the area of science or technology you work with every day is part of their everyday lives, too. How has what you and your colleagues have learned up to this time changed how we do things or understand things? How will what you do make the students' lives better or different in the future? How does what you do and know relate to what they are learning in school?

- **Prepare the students for the unexpected, if appropriate.**

  Unexpected loud noises, bright lights, unusual odors, graphic photographs, and similar experiences that evoke strong emotion or fright can disturb some children. It may be wise to warn students that a surprise or something unusual is coming even when evoking a degree of surprise is one part of your goal.

- **Leave more than a memory behind you.**

  Help set up an experiment that students can continue after you leave. Hand out an assignment — find out how many birds live in the local area, gather samples of leaves from local trees, make a cardboard glider — for the students to complete on their own or with their families. Invite them to write to you with questions — and plan on answering those letters quickly!

- **Ask for an evaluation of your efforts.**

  Ask the students what they liked (and didn't like) about your visit. Ask the teacher to critique your presentation and help you improve your in-class skills.

- **Schedule your next visit!**

Message to all members of the scientific and engineering communities concerned about improving science education in the nation's schools:

I encourage practicing scientists and engineers to share personally some of their knowledge and experience with school children.

In September of 1989, President Bush convened the historic Education Summit with the Nation's Governors in Charlottesville, Virginia. The National Education goals developed following the Summit established targets for American educational achievement by the year 2000. The National Science Foundation and other Federal agencies, in partnership with the States, school districts, academic institutions, private industry and professional organizations, are generating the systemic reforms needed to realize these national goals as they apply to mathematics and science achievement for all students. Yet these reforms, which include improved curricula and better teacher preparation, cannot in themselves convey fully the excitement and dynamics of modern science. There is no substitute for personally meeting real scientists and engineers in the classroom and learning first-hand about what they do.

Many of you may have little formal teaching experience. Others who are teachers may never have taught at the grade school level. Some may question their ability to convey their knowledge and experience adequately to school age children. Yet each of you has a unique and important story to tell. This pamphlet provides reliable, time-tested guidance as to what to expect when you enter the classroom, how to support and complement the school curriculum, and how to make your visit a valuable, enriching experience for the students. You will find that it can be a deeply rewarding personal experience for you as well.

I urge each of you to contribute in this unique way to the enrichment of mathematics and science education in our schools. By doing so, you can help today's students to lead fuller and more productive lives in the future. You might also help to inspire and motivate the students who will become the next generation of professional scientists and engineers.

Luther S. Williams

Assistant Director for Education and Human Resources
National Science Foundation

Thinking and Learning Characteristics of Young People

Early Elementary (K-2)

As a thinker . . .

- Learns through manipulating objects.
- Believes what he or she sees.
- Can't trace steps back from a conclusion.
- Sees parts, not the whole.
- Does not understand that making physical changes in an object does not change its amount.

As a learner . . .

- Is expansive, adventurous, curious, eager to learn, energetic, always in motion, loud, and emotional — has mood swings.
- Wants to please adults.
- Has difficulty controlling impulses and regulating behavior.
- Is very "me" centered. Seeks attention. Loves praise.
- Likes to work in groups, but will need assistance.
- Can sit still and listen 10-15 minutes; needs frequent change of pace.

Late Elementary (3-5)

As a thinker . . .

- Although still somewhat tied to seeing in order to believe, begins to understand concepts as well as objects.
- Understands hierarchical classification systems.
- Can combine, sort, multiply, substitute, divide.
- Begins to generalize, formulate hypotheses, use systematic problem-solving strategies.
- Likes to memorize, to learn facts.

As a learner . . .

- Understands rules and can follow them.
- Likes group activities and excursions. Is a great socializer and eager to fit in.
- Considers fairness to be important.
- Takes initiative and is self motivated.
- Is becoming an independent learner.
- Is a perfectionist who will practice the same thing over and over again.
- Avoids opposite sex.
- Can sit still and listen 20-30 minutes (variety increases attention span).

Middle Grades (6-8)

As a thinker . . .

- Can hypothesize, create propositions, and evaluate.
- Can conceptualize in the abstract and understand probability.
- Begins to understand multiple causation.
- Developing understanding of ethical principles.

As a learner . . .

- Is emotional, restive, and eager to get moving.
- Is easily bored.
- Challenges rules, routines, and authority.
- Is beginning to have an interest in the opposite sex.
- Is typically more oriented to small group activity.
- Has a vulnerable ego, is very self-conscious and concerned about how he/she is perceived by others.
- Can handle 30-40 minute sessions.

TEAC

Make eye contact with the students beca

Smile and feel comfortable telling amusi

Organize all materials in advance becaus

Use student volunteers to help you set up and distribute materials, samples, pictures, and handouts because kids love to feel important.

Require that students raise their hands to participate because they will probably all want to talk at once.

Call on many different members of the class because everyone wants to be involved.

Model good safety practices because kids learn by following role models.

Give specific directions when distributing specimens because kids sometimes disagree about who has been holding an object the longest.

Use a prearranged signal to get students' attention during activities (clapping, flipping light switch, etc.) because it is too hard to give good directions unless students are quiet.

Stop and wait for students to let you continue speaking if they get noisy because they have probably heard the "cold silence" before and know that it means they need to be less noisy.

Wait to give handouts to students until it is time to read or use them because if the students have the handouts while you are speaking they will be distracted.

Wait several seconds before calling on students to answer a question because the whole class needs time to think about the question before someone answers it.

Praise attentive or helpful behavior because this is the behavior you want to encourage.

Enjoy the students, their enthusiasm, and their sense of wonder because they have a fascinating perspective on the world!

Typical Science and Technology Topics

	Kindergarten	First and Second	Third and Fourth	Fifth and Sixth
Animals	Many kinds Have different coverings Eat different kinds of foods	Are alike and different Move and grow Different homes Different sounds Care of pets	Adaptations to the environment Defense mechanisms Helpful and harmful animals	Animal classification Selective breeding Interaction with the environment Balance of nature
Plants	Many kinds Grow in different places Vegetables and fruits	Characteristics of plants Collecting parts of plants Seeds become plants Uses of plants	Classification of plants Effect of soil, water, air, and light on growth Conservation Prehistoric plants	Parts and functions Life processes Plant movements Adaptation
Weather	Days can be sunny, cloudy, rainy, and snowy Four seasons	Air occupies space, has weight Atmosphere Air has pressure Wind is moving air	Effect of sun on earth Temperature and thermometers	Evaporation and condensation Precipitation Air masses Forecasting and instruments Factors affecting climate
Physical & Chemical Properties	Things have colors, sizes, shapes Classifying objects Hot and cold Serial ordering	States of matter Different types of matter Dissolving Movement of things in air, water Sinking and floating	Expansion and contraction Heat Fuels Producing sound Music	Atoms Chemicals Mixtures and compounds Matter and energy Sources of energy Reflection/refraction Lenses
Electricity & Magnetism		Sources of electricity Uses of electricity Safety	Magnets Simple compass Uses of magnets	Static electricity Nature of electricity Simple circuit Batteries Series and parallel circuits Safety
Earth & Space Science	Moon Day and night Water Soil	Sun, moon, earth Stars Day and Night	Heat and light Seasons Day, night, year Tides and eclipses Solar system Gravity, inertia and orbit Comets, meteors and meteorites Space exploration	Ecology Pollution Recycling Constellations Space travel Flight Oceans Water cycle Properties of water

Science is Everybody's Business

BY R. RAY RANDLETT

Paul Held wasn't sure at first of what he could contribute to his company's new partnership with schools. He now knows. Turning to face a classroom of eager first-graders, he creates what every child loves and most parents abhor — the gooey, messy playstuff known as "slime."

For 38 years, Held has tested materials for Battelle Memorial Institute, a non-profit corporation in Ohio that helps industry and government develop, implement, and commercialize technology. His demonstration serves an important purpose. Not only is he teaching these youngsters how matter changes from a liquid to a solid in a way that's interesting and exciting, he's also showing them that scientists are people just like everyone else.

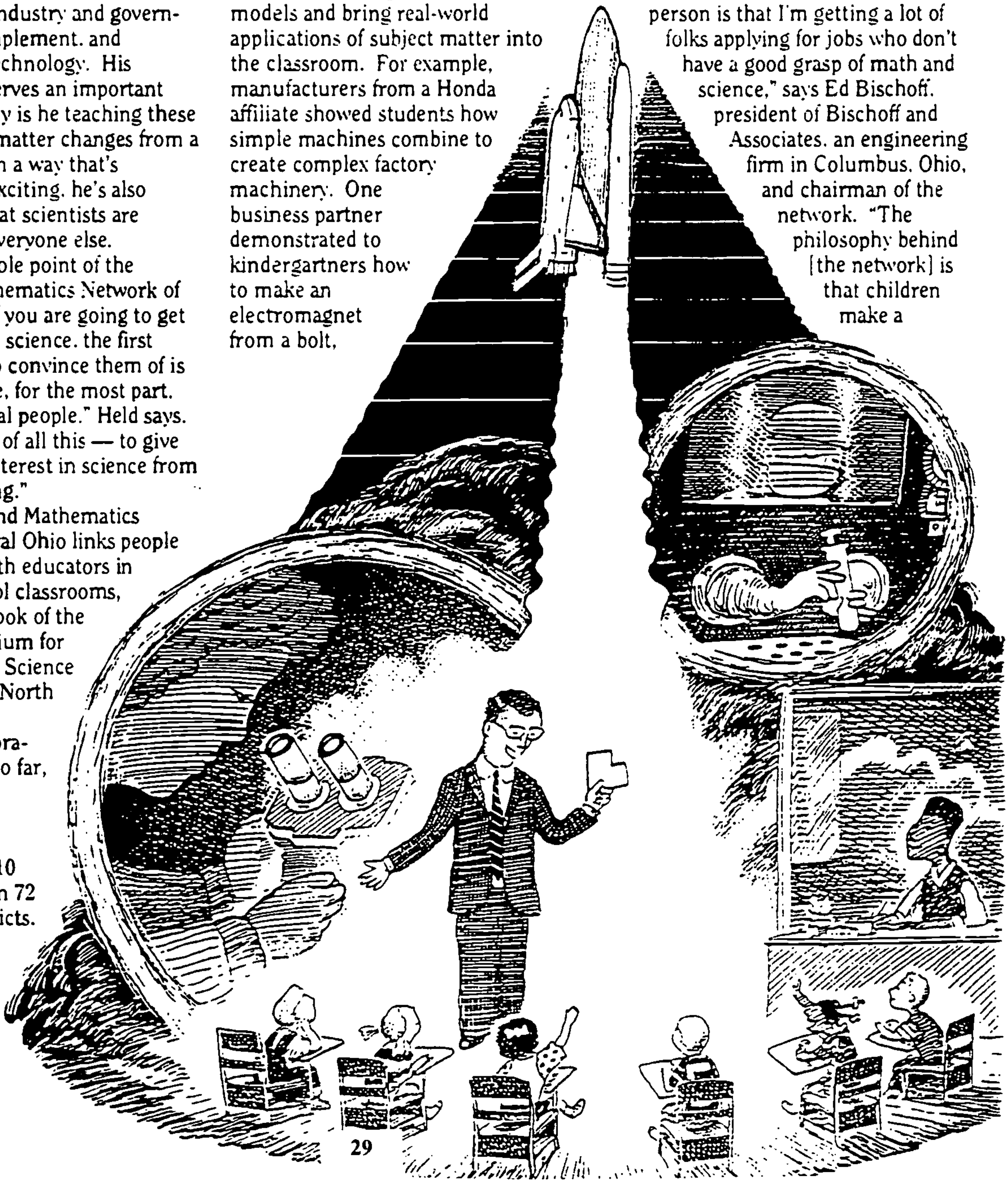
This is the whole point of the Science and Mathematics Network of Central Ohio. "If you are going to get kids interested in science, the first thing you have to convince them of is that scientists are, for the most part, reasonably normal people," Held says. "That's the point of all this — to give kids at least an interest in science from the very beginning."

The Science and Mathematics Network of Central Ohio links people from business with educators in elementary school classrooms, explains Cathy Cook of the Midwest Consortium for Mathematics and Science Education at the North Central Regional Educational Laboratory (NCREL). So far, the network has brought together more than 7,000 educators with 110 business people in 72 Ohio school districts.

Cook says that these business partnerships go well beyond the "adopt-a-school approach" that most businesses take in helping education. These partnerships really believe in a philosophy of "work with" rather than "work on." Business partners and teachers work together to develop classroom-based goals and then they collaborate to achieve those goals through hands-on activities that get children excited about mathematics and science.

The activities give students role models and bring real-world applications of subject matter into the classroom. For example, manufacturers from a Honda affiliate showed students how simple machines combine to create complex factory machinery. One business partner demonstrated to kindergartners how to make an electromagnet from a bolt, wire, and battery. A technician from an electrical utility showed a fifth-grade class how electricity works in a house. An engineer helped students build structural shapes that they then loaded with marbles and other weights to test relative strengths.

The Central Ohio Network emerged from a concern that businesses weren't getting involved in mathematics and science education early enough. "The problem that I have as a business person is that I'm getting a lot of folks applying for jobs who don't have a good grasp of math and science," says Ed Bischoff, president of Bischoff and Associates, an engineering firm in Columbus, Ohio, and chairman of the network. "The philosophy behind [the network] is that children make a



n: R&D Preview, November 1994 . Published by Council for Educational Development and Research, Washington, D.C.

decision about themselves pretty early. Most programs that business gets involved in are at the high school level, some at the middle school level, and very few at the elementary school level. This is where we felt work needed to be done."

The Midwest Consortium for Mathematics and Science Education worked with the network to come up with a strategic plan and to clarify the group's vision, mission, and activities. It is now helping to evaluate the program.

Some partnerships involve one teacher and one business partner; others involve several teachers with a business partner or several partners from the same company. Still others involve an entire school with business partners. The strongest partnerships involve the school principal and a manager from the business: "If the principal does not believe in this concept, the partnership will not succeed," warns Barbara Sills, director of community and education relations at Battelle. The same is true for senior business management.

Typically, the business partners are in the classroom once a month but there's at least one case where the partner came to class every Friday. "[The partnerships] build a relationship between the teacher and the partner and between the partner and the students," says Pat Barron, executive director of the Central Ohio Network. "I think it's not the singular activity that's the powerful piece, it's the relationship."

While some business partners have chosen to add a small financial component to their support, partners are neither encouraged nor expected to provide funds. Barron notes that the really important things that business people bring to the classroom are role modeling and real-world applications of the subject matter.

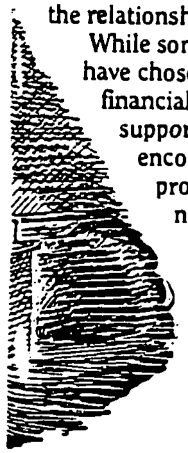


Illustration: Kenny Higdon

The benefits of these partnerships don't flow only into the schools, however. Bischoff has observed immediate satisfaction among his business colleagues: "They come back just shining." In many cases, he continues, what they are doing in the classroom also helps them do their work better. They run meetings a little differently, or interact with their peers more effectively. Moreover, the companies involved also gain positive public visibility.

To prepare for the classroom partnerships, each February and June the network sponsors a two-day institute where teachers and business representatives team up to design activities around the goals they have set for themselves. Follow-up sessions during the year and experienced mentors who give an extra boost when necessary are also part of the package. The network covers the cost for both business and education participants.

But what do you do in a rural or suburban school district where there aren't many businesses and finding diverse business partners is difficult? The Central Ohio Network has devised an innovative answer to this question, too. Thanks to a grant from the state Eisenhower Science and Mathematics program, the network is creating partnerships between teachers and employees of the Ohio Department of Natural Resources (DNR), which governs the state's 12 environmental divisions.

This year, the department has 23 individuals involved in 20 partnerships, each emphasizing the role of mathematics and science in environmental programs. Diane Cantrell, deputy chief of the Division of Soil and Water and the department's partnership coordinator says, "One of the advantages my agency has over other agencies, or even over some businesses, is that just by the very nature of our work, we are very involved in public education."

Cantrell is particularly proud of DNR's role in breaking stereotypes and creating positive role models for students. She cites one example in which a teacher told students repeatedly about the engineer who was coming to work with them. "[I]n walked Beth and a little girl looked up and said, 'But you can't be an engineer. You're a woman.'"

DNR employees are even putting in extra time to make the partnerships work. "They feel a tremendous sense of personal growth," says Cantrell. Employees find it professionally rewarding on several levels: they are building a future constituency for environmental programs; they feel they are conveying a positive message to the students about the environment and students' own responsibilities; and they find that as they improve their teaching skills with youth, they are better able to communicate with adults at work.

This enthusiasm extends throughout the program, as Battelle's unexpected lesson in partnering illustrates. Unlike many companies, Battelle does not provide "release" time to take part in the network. Its employees do partnership activities on their own. However, says Sills, "the fascinating thing is that when we have talked to other companies that have a paid release policy, people will give time up to that ceiling and then that's where it will stop.

"Our people — where we've asked them to work it in based on what they think they can give — just give and give and give, and it far exceeds anything we would have asked of them," she continues. "We're finding that by actually giving them ownership in this by not defining how much time we think this will take — probably the rewards are better for everybody."

The Central Ohio Network welcomes inquiries. Contact executive director Pat Barron at the Science and Mathematics Network of Central Ohio, 445 King Avenue, Columbus, OH 43201; (614) 421-9800.

BEST COPY AVAILABLE

An Alliance for Science

When teachers join with scientists, students benefit from their combined expertise.

By Laura Nault Massell and Georgiana M. Searles

ADD FIVE DROPS OF THE purple liquid to each of your samples. What changes do you observe?" Amidst the buzz of discovery in a fourth-grade class, two adults walk around the room checking students' investigations, encouraging careful observations, responding to questions, and prompting discussions.

More than a simple hands-on water test, this lesson is part of a month-long stream study developed and cotaught by a teacher and a water quality technician from a local paper company. Increasingly, scientists and teachers are forming partnerships like this one to provide better, more effective science instruction for children.

Such partnerships bring together the expertise of scientists and teachers to enrich learning for all students. Scientists bring sharpened skills of observing, asking questions, experimenting, and raising new inquiries when "something goes wrong." Classroom teachers bring delivery know-how—they know what material is age-appropriate and how to manage groups. In addition, they possess insights on gauging student understanding and comprehension.

For over a decade, the Museum of Life and Science in Durham, North Carolina, has helped to set up these partnerships. During this process the museum staff has developed a series of guides, *Sharing Science with Children*, to ensure that teachers, scientists, and parents receive the full benefit of these collaborative efforts.

Being teacher-educators at the museum, we witnessed the flood of requests that came in for the guides. We heard from scientists who wanted to get involved with schools but were hesitant about confronting a room full of children; from teachers who wanted to identify potential science partners; from parents who were eager for a specific way to support the science program at their school; and from corporations, universities, scientific professional societies, and other organizations who were also searching for ways to strengthen science learning.

The sheer variety and quantity of demand compelled museum staff to find out more about the partnership trend. We spoke with dozens of people involved in partnerships around the country who were redefining traditional boundaries between schools and the workplace. This article highlights some of our findings and discusses how to go about setting up a successful partnership of your own.

Benefits of a Partnership

Hands-on science thrives. Classrooms involved with scientist-teacher partnerships usually feature interactive, hands-on learning.

Students might explore properties of mixtures with a research chemist, examine X rays with a health professional, or work alongside an engineer as he or she constructs a model bridge.

Moreover, increased contact with scientists and science-driven institutions often brings additional supplies, equipment, and publications into classrooms. "I could provide petri dishes and other materials that the teacher didn't have at her fingertips," remarked a microbiologist matched with a sixth-grade class. "In fact," she went on, "many laboratories have surplus or slightly outdated equipment that functions quite well in a school setting."

Teachers rediscover science. "I originally participated in the partnership to build confidence in my students," explained one teacher, "but I've become 'hooked,' too. I've taken extra inservice and university courses, and I'm even co-leading an inservice training for teachers in my system. Yet, I've never thought of myself as a 'science person.'"

A "community" of scientists is revealed. Every community is home to a variety of scientists and science-users who might be interested in forming a partnership with a class-

CHARLES BEYL

room teacher and students. Consider research scientists who work in industry, government, or universities; individuals who use science in their work, such as architects, beekeepers, city planners, dieticians, electricians, and farmers; and hobbyists who study astronomy, plants, animals, rocks and minerals, or fossils.

Forming partnerships with scientists from a variety of fields can be a terrific opportunity to dispel stereotypes of just who is (and who *becomes*) a scientist. Typically, elementary students think of scientists as white males wearing laboratory coats. When children meet and work with scientists who do not fit these stereotypes, they often are as curious about the *scientist* as they are about the science that he or she practices.

A Partnership in Action

Fourth-grade teacher Mary Willis knew of a stream within walking distance of her school, and she had an ecology unit in her science curriculum. Eager to expand the hands-on aspect of her program, but lacking expertise, she telephoned an agricultural extension office for guidance. Staff there referred her to a technician in the local paper company's water-quality division.

The technician, Steve Taylor, volunteered to meet Mary at school the following week. In the interim, Mary asked him to think of stream-related activities that could enrich her students' learning experience.

While Mary originally had planned on only a single visit with Steve, their brainstorming session revealed several age-appropriate activities—analyzing water samples, measuring stream flow, and exploring aquatic life—that Steve wanted to pursue with her students. Mary also envisioned opportunities to integrate mathematics, social studies, and language arts. A month-long unit began to take shape. They divided responsibilities for gathering supplies and clarified their roles. As this was Steve's first classroom experience, he asked Mary to take the lead with classroom management, while he would introduce the activities and outline necessary safety procedures.

By their third weekly visit, both teacher and scientist felt increasingly comfortable and, in fact, were surprised when the other confided how nervous he or she had been at the onset of the project. Invigorated by their work together and by the students' enthusiastic response, Mary and Steve soon began revising the unit in anticipation of repeating it with next year's class.

Try One of Your Own

If you would like to participate in a teacher-scientist partnership at your school, the first step is to think creatively about what you would like to accomplish. Ask yourself, "Is there a particular area of the curriculum in which I would like support? Does my local environment or community offer special resources? Have my students shown a strong interest in certain science topics?" Once you have considered your options, the following steps outline the process of how to get started.

Identify a scientist or science-user. You might contact a potential partner scientist directly, or better yet, seek help through the growing network of institutions actively arranging such partnerships (your local or state education department should know the one closest to you).

Decide together what to do. Discuss what the volunteer can do to enrich your science program. Explore what experiences, activities, and information would be of interest to your students and which would be appropriate to your curriculum. Agree on one or more activities that will en-

CHARLES BEYL

gage your students' attention.

Plan adequately. Set goals and objectives for the experience. Decide in advance what each person will do. Ask yourselves, "Who will gather materials? Will any special equipment be needed? When and where will the activity take place? What kind of follow-up is necessary?"

Take care of logistics. Find out when and how each of you prefers to be contacted. Include back-up phone numbers. Provide directions to the school and parking information. Describe how the scientist will be greeted. Inform appropriate school administrators.

Get ready. A few days before the visit, call the volunteer to confirm your plans. Explain to your students who the guest will be and what you expect to happen during the visit. Prepare name tags so the scientist can call on students by name. If group work is involved, assign teams ahead of time. Select a team of students to welcome the volunteer and help carry any necessary equipment.

During the visit, remain actively involved. When you show interest, your students will be more likely to do the same.

Keep It Going

Once your partnership is underway, the suggestions below may help you to maintain it successfully.

Keep lines of communication open. Be sure to clarify roles and expectations. Ask yourselves, "Is there anything I can do or ask for in order to make this partnership function more smoothly? Does the time allotted seem reasonable? What do we learn from student feedback?"

Incorporate appropriate assessment. Use results to gauge the progress of your students as well as the overall effectiveness of the partnership. For example, students conducting the stream study kept journals containing their data and drawings, as well as questions that they wanted to investigate further. Each class began with a review of past discoveries and sharing of questions. Teams also charted their results on a bulletin board outside the classroom, which sparked schoolwide interest in the project.

Emphasize a long-term commitment. While some scientists may wish to visit just once, a long-term partnership helps to avoid the "field trip" mentality and tends to be more productive for children. Depending on people's interest and schedules, consider arranging daily visits for a week, weekly visits during a month-long unit, or monthly visits throughout the school year. Regardless of duration, however, be sure to emphasize follow-through on any prearranged agreements.

Obtain support from local institutions. Institutional support helps connect and sustain productive teacher-scientist partnerships. Local "brokerage firms" who know the people and resources of an area are uniquely suited to meet their community's needs. These third party facilitators can range from science centers, such as the Cranbrook Institute of Science's EduMentor Program (Bloomfield Hills, Michigan), to professional groups, such as the Puget Sound Engineering Center (Seattle, Washington), to state-sponsored networks, such as the Research Triangle Science and Mathematics Partnership in North Carolina. Some scientific corporations and school systems also operate "partnership clearinghouses" on a local basis.

Follow through. Extend appreciation to the scientist volunteer. Thank-you notes, drawings, or photographs are always appreciated and are ideal opportunities for students to express what they learned or what most interested them. Complete any experiments left by the scientist and let him or her know the results. Share your experience with parents, colleagues, and school administrators.

Partnerships are part of a wide-

CHARLES BEYL

Partnerships Take On a Variety of Forms

Classroom. In either a single visit or a series, science professionals and teachers develop and present hands-on demonstrations and interactive activities, provide individual or small group mentoring, and help students conduct experiments.

Workshops. In training workshops, scientists learn what to expect in classrooms and how to develop age-appropriate lessons, and teachers expand their science knowledge and process skills.

Industry Internships. Internships with industry provide teachers with hands-on science experience. This perspective enhances a teacher's ability to facilitate rich science learning experiences.

Special Programs. Science professionals can participate in family/community science days, help with science fairs and festivals, host field trips, or supervise student research projects.

spread trend toward greater collaboration in improving science education in our schools. They are not a panacea for today's educational struggles, but they can provide tangible and lasting support as educators and community members work toward developing a nation of critical and creative thinkers who are scientifically literate.

Resources

Atkin, J.M., and Atkin, A. (1989). *Improving science education through local alliances.* Santa Cruse: Network Publications.

Information Technology Foundation. (1993). *Roadmap to success 2000: A guide to business/education partnering.* Arlington, VA: Dataquest.

Nault Massell, L. (1993). *Sharing science with children: A guide for parents.* Durham, NC: Museum of Life and Science. (This guide and the two resources that follow are all available from the Museum of Life and Science, Attn.: Sharing Science, P.O. Box 15190, Durham, NC 27704.)

Searles, G.M. (1990). *Sharing science with children: A survival guide for scientists and engineers.* Durham, NC: Museum of Life and Science.

_____. (1991). *Sharing science with children: A survival guide for teachers.* Durham, NC: Museum of Life and Science.

Sussman, A. (Ed.). (1993). *Science education partnerships.* San Francisco: University of California.

National organizations that may be of help are the National Association of Partners in Education, Inc., 209 Madison St., Alexandria, VA 22314, which is oriented toward business-school partnerships, and the Triangle Coalition for Science and Technology, 5112 Berwyn Rd., Third Floor, College Park, MD 20740, which specifically supports science alliances.

Also in S&C

DeBruin, J., Bollner, C., Flaskamp, R., and Sigler, K. (1993). Science investigations mentorship program. *Science and Children, 30*(6), 20–22.

Miller, L.M., Thompson, W.A., and Denk, J.P. (1992). A medical school–elementary school science alliance. *Science and Children, 30*(3), 27–29.

Moryan, J. (1994). The corporate connection. *Science and Children, 31*(8), 18–19, 38.

LAURA NAULT MASSELL is a teacher-educator and GEORGIANA M. SEARLES is vice president for education and programs, both at the Museum of Life and Science in Durham, North Carolina.

Needs & Resources

Georgian Heights Alternative School
Needs

1. Volunteers
   - A. Tutoring — Long-term involvement
     1) Vocabulary improvement
     2) Hands-on science
     3) Math enrichment
     4) Extra "ears" to listen to stories
     5) Adult role models/mentors/pen pals
   - B. Special projects assistance — Short-term involvement
     1) Assist students with science fair projects
     2) Present at career day
     3) Assist students with mini-courses
     4) Present special programs
2. Real-world science/math opportunities and applications
   - A. Teacher training for science labs
   - B. Assistance from experts in science lab
   - C. Assistance from experts on field trips
   - D. Assistance for teachers and students on economic, environmental and consumer-related issues
   - E. Audio-visual resources
   - F. Excess electrical or other potential science lab materials
   - G. Shadowing by fifth-grade students
3. Improved school image
4. Secondary needs that may be addressed later in the partnership:
   - A. Excess office equipment
   - B. Transportation (field trips, parent buddy system)
   - C. Physical fitness center

Columbus Southern Power/ American Electric Power
Resources

1. Volunteers — tutors, role models, mentors, presenters and helpers
2. Depth of science/engineering/math/technology
3. Variety of career experiences to share
4. Real-world science opportunities and applications
5. Special presentations such as "Black Profiles: Living History" and "Thomas Edison"
6. Video expertise
7. Share our corporate environmental decision-making process
8. Established tour and speaker programs for schools
9. Film, tape and materials library for educators
10. Vehicle for showcasing student creativity
11. Possible outdated or excess supplies

112

Needs & Resources

Columbus Southern Power/ American Electric Power *Needs*

1. Strong community and educational system
2. Better prepared future workforce
3. Better educated consumers (parents and students)
4. Replication and sharing of Georgian Heights experiences with other schools in company service area
5. Improved company image
6. Effective teaching techniques for business volunteers and Communicators (i.e., how to interact with students)
7. A school to work jointly with CSP/AEP on community service and volunteer projects (can recycling, Operation Feed, etc.)
8. Use of student art, writing and musical programs

Georgian Heights Alternative School *Resources*

1. Expertise in effective teaching techniques to share with business volunteers (i.e., how to interact with students) provided by school staff and district training center
2. Pioneering teaching ideas on science, math and environmental education that can be shared with others
3. Future and current consumers (students and parents) and potential employees (students)
4. Vehicle for CSP/AEP to serve the community and to become more involved in the educational process
5. Student art, writing and musical programs
6. School-organized community service and volunteer projects (i.e., can recycling, Operation Feed, etc.)
7. PTA, Parent/Community Advisory Council (PCAC) involvement opportunities
8. Social activities open to CSP/AEP (i.e., potluck dinner, PTA carnival)
8. Parent classes sponsored by Georgian Heights (i.e., how to help improve student vocabulary, explaining special education programs, how to make homework effective)

PARTNERSHIP PLANNING IDEAS

Needs That You Have	"Resources" to Offer a Partner

Action Plan for Partnership

1. What are the specific goals or objectives of your partnership?

2. What significant changes in the teaching/learning environment do you hope to achieve through your partnership?

3. Diagram your web here or attach it to the action plan.

4. Outline the activities you plan to carry out (a tentative timeline would be helpful). Include both a description of the activity and an assessment strategy you might use.

5. How will you introduce the partnership to the class, parents, staff, etc.?

6. With two or more teachers and only one partner, how will you structure your activities so the students from each class get to know the partner, but the time required is not prohibitive?

7. Which specific unit(s) or topic(s) from your course of study will be addressed?

8. In what ways does the school hope to benefit and what will it be contributing?

9. In what ways do the partners hope to benefit and what will they be contributing?

10. How do you plan to create parental awareness of and involvement in the partnership?

11. Anything else that would be helpful to record here?

Continuum of Teaching Methods

Introduction

Different teaching methods can be described based upon their position on a continuum from "exposition" to "inquiry." Exposition refers to an approach where information is delivered to the learner in final form. Inquiry refers to an approach where the learner generates the form of the information.

Exposition	**Inquiry**
Teacher-centered	**Learner-centered**
***Teacher active**	***Teacher facilitates**
***Learner passive**	***Learner active**
Content emphasis	**Process emphasis**

In general, exposition is considered teacher-centered with an emphasis on content delivery while inquiry is considered learner-centered with the emphasis on the process of learning. In a typical learning situation, this suggests that for exposition, the teacher is actively involved (e.g., lecturing, reading aloud, showing a video) and the learner is passively taking in the information (e.g., listening, reading an overhead, watching a video). In contrast, learners engaged in inquiry are actively involved (e.g., conducting investigations, processing information and data) while the teacher helps to facilitate the process of learning.

Since learners learn differently, it is important to use a variety of teaching methods that fall along this continuum. The following eight major methods illustrate the progression from exposition to inquiry and highlights some of the uses and benefits of each as well as problems and concerns.

1. Exposition

Definition

Exposition includes those verbal methods in which some authority or expert (textbook, speaker, film, video) presents information without overt interaction taking place between the expert and the students. Common examples of the expository method are a lecture or textbook reading.

Uses and Benefits

*To present information especially when time is limited
*To give directions
*To wrap up and activity

Problems and Concerns

*Verbal presentations are difficult for children in elementary grades to follow. They need concrete materials in order to understand concepts and ideas.
*Verbal presentations are limited by the learner's attention span. Visual aids help.
*Verbal learning tends to be passive.

*Any verbal presentation is organized according to the teacher's idea of logical order. This may not be the same as the students' logical order, especially with culturally diverse groups of learners.
*What is said is not always what is heard, and verbal presentations are open to interpretation.

2. Exposition with Interaction

Definition
Exposition with interaction is a method of teaching in which the teacher both presents information verbally and asks questions to determine whether the information is understood. The questions provide interaction between the teacher and learners.

Uses and Benefits
*To review previously learned content material and check for understanding
*To present new content material

Problems and Concerns
*It is still a verbal method; visual aids help learning.
*It is a passive method. While learners are active through the questions, this usually does not encourage students to develop their own ideas.
*Because not all learners answer questions, the teacher's determination of understanding is sketchy at best.
*The teacher must plan for non-understanding and be ready with new examples and ways to clarify the information; that is, the teacher must have a thorough knowledge of the subject matter.

3. Discussion

Definition
A discussion is an open forum in which students express their opinions as well as review factual material. It is a natural opportunity for students to build skills in communication, inference, application, synthesis, and drawing conclusions. In a true discussion, students talk as much or more than the teacher. Types of discussions include the following:
*Open discussion -- learners determine the topic and the role of the teacher is to ask those questions which will lead the learners to consider various ideas. The teacher may need to define terms and encourage differing points of view.
*Planned discussion -- the teacher determines the content of the discussion, plans the questions in advance, and guides the students toward some predetermined goal or conclusion.
*Formal debate -- students present opposing viewpoints usually in a structured format.

Uses and Benefits
*To help learners make inferences, draw conclusions, communicate, and express values and attitudes
*To introduce a unit or topic
*To involve students cognitively
*To address controversial issues and help students clarify values and positions
*To encourage research

Problems and Concerns

- *It is a verbal approach.
- *It can be controversial, even to the extent of blocking learning.
- *Discussions can be dominated by one or a few students. Some students will not participate, especially in a culturally diverse learning situation.

4. Socratic Method

Definition

The Socratic method is a way of asking questions designed to draw information out of the students rather than pouring it into them. The lesson consists almost entirely of questioning, probing for deeper answers and interpretation, and leading students to conclusions rather than telling them.

Uses and Benefits

- *To develop content information
- *To help learners develop a definition or a simple concept, especially where learners already have some concrete experience with the definition or concept

Problems and Concerns

- *The teacher must know the audience thoroughly.
- *Questions must be well planned, well written, and carefully sequenced.
- *Questions or the sequence of questions may need to suddenly change because no answer is offered or because the answer is strange or unanticipated.
- *Some students may try to present lengthy monologues which stop the flow of the questioning and discussion.
- *The teacher must be prepared to present the final point if the students are not able to reach the precise endpoint desired.
- *An alternative plan may be needed if the questioning strategy does not work with a particular group of students.

5. Ordinary Demonstration

Definition

During a demonstration, the teacher stands before the class, shows something, then tells what happened. The teacher is the only one involved. The emphasis is on content.

Uses and Benefits

The teacher should demonstrate:

- *when there is danger involved.
- *how to use something.
- *to begin or end a unit of study.
- *when the action needs to be stopped periodically to show important changes or to point out specific points.
- *when there is not enough equipment and substitutions cannot be made, but the demonstration is particularly appropriate for illustrating a concept.

A student should demonstrate:

- *when he or she has developed an activity that will help the rest of the class understand a particular concept.

*when it will help the student get a point across which he or she has difficulty expressing in words.
*to develop communication skills and self-confidence in speaking before a group.

Problems and Concerns

*Demonstrations don't always work.
*Students may become restless and inattentive.
*Students may have difficulty seeing the demonstration.

6. Discovery Demonstration

Definition

A discovery demonstration is a method of teaching the process of problem solving in which the teacher silently conducts the demonstration and the students attempt to determine why what is shown occurs. This is especially effective with a discrepant event, e.g., when the demonstration goes against common sense, such as a rock that floats (pumice). The emphasis is on process rather than content.

Uses and Benefits

*To develop problem solving skills
*To grab students' attention before introducing a concept or unit
*To actively, mentally engage students in a lesson

Problems and Concerns

*It is difficult to locate demonstrations which are difficult enough to challenge the learners yet simple enough to allow for possible solutions.
*Because the class asks questions to obtain more information, the demonstrating teacher needs to know precisely what happened and the cause.
*Teachers often find the silence and the "no-telling" aspects of this method difficult.
*The lack of closure in the discovery demonstration is a problem for many teachers. The emphasis is on problem solving rather than reaching one "right" answer.
*It may be difficult to manage the demonstration in terms of materials and time because students tend to suggest other demonstrations or extension activities.

7. Guided Discovery

Definition

Guided discovery is a method by which learners develop skills in inquirying and processing information. The learners are totally involved with materials, people, and the environment and use these to develop concepts and facts without reading or listening to verbal information from the teacher.

Uses and Benefits

*To encourage learners to explore the content through the use of concrete experiences
*To allow learners to use process skills to generate content information
*To develop intrinsic rather than extrinsic motivation since the rewards (excitement, discovery) come from the activity itself
*To release the teacher from the role of authority and giver of knowledge to become a facilitator and fellow investigator

*To replace the notion that the teacher must know all the answers

Problems and Concerns

*Leanrers are not inherently good investigators nor do they automatically know how to work appropriately, especially in small groups. Collaborative and investigation skills need to be taught in order for guided discovery to be fully effective.

*Because learners work independently, time is a problem. Some students finish early, others take "too long."

*Because learners are developing their own exploration activities, different and incorrect answers frequently result. Because the final outcome of guided discovery is the teaching of content, such differences and deviations may cause confusion.

*Sometimes students develop guided discovery activities which are not relevant to the problem at hand. These are tangents to the original problem and may lead to confusion, or at least not to the content which the students are intended to learn.

*The method is time consuming. Investigation, activity development, and drawing conclusions all take time.

*Management of students and materials must be carefully planned in advance and monitored to prevent chaos as students begin to investigate challenging questions.

8. Open Inquiry

Definition

Open inquiry provides a degree of freedom not found in any of the previous methods. In open inquiry, the teacher presents a problem, provides materials that could be used to solve the problem, then allows the students to use any method they wish to arrive at a solution. Open inquiry focuses exclusively on process; it cannot be used to teach specific content.

Uses and Benefits

*To teach problem solving skills

*To allow students to develope creative solutions to the problems presented

*To provide learners with the freedom to solve a problem any way they can with safety, materials, and access being the only constraints

*To enable students to use processes in a genuine problem solving situation

*To provide a no-fail opportunity in which students can develop self-confidence

Problems and Concerns

*It tends to look, and sometimes be, chaotic as children discuss their findings and demonstrate their activities to one another.

*It requires lively curiosity and williingness to share what is found.

*Anticipating and locating enough materials can be problematic.

*As with guided discovery, open inquiry requires time.

*Evaluation poses a problem, especially in schools where grades are required.

SWEEP
ACTIVITY

CONTINUUM OF TEACHING METHODS

Overall Purpose

The following series of "activities" demonstrates how concepts related to "watershed" can be taught using the different teaching methods described in the continuum of exposition to inquiry. Since the "activities" on the exposition half of the continuum model strategies frequently used by teachers, we spend very little time on them. We spend much more time on guided discovery and inquiry because they model the strategies we emphasize in SWEEP.

ACTIVITY 1: EXPOSITION

Lecture on the Concept of Watershed

Materials:

Transparencies that demonstrate watershed concepts
Poster of watershed

Note: There are a number of colored posters available from different agencies that show watersheds, the water cycle, land use, and sources of pollution. We use "Groundwater and Land Use in the Water Cycle" which is available from the Bureau of Water Resources Management, Department of Natural Resources, Box 7921, Madison, WI 53707.

Procedure:

Using overhead transparencies and a poster, deliver a mini-lecture on the concept of "watershed." Some of the main points which you might briefly cover include:

- A "watershed" is the land area where all precipitation from that area drains to a common outlet. This land area, or geographic area, is often called a "drainage basin." Note: Two analogies can be used to illustrate this concept: 1) Two hands openly cupped together form a watershed – where all water hitting the outer rim either flow into the cupped hands (i.e., a watershed) or outside the hands (i.e., into a different watershed). 2) A divided sink represents two watersheds. Water hitting the middle divider, or watershed border, flows (i.e., sheds) into one watershed or the other.
- Water concentrates in the lower parts of the watershed, or drainage basin in a wetland, stream, river or lake. Note: In the sink analogy, it drains to the bottom of the sink basin and then through the drain (acting like a river) to a larger watershed (e.g., the Scioto River watershed to the Ohio River watershed to the Mississippi River watershed).
- The borders of the watershed equal the divides where water "sheds" into one watershed or another. Many little watersheds make up bigger watersheds (e.g., Ohio has anywhere from two watersheds – Ohio River and Lake Erie – to over 1,000 depending on how big or small of a unit you what to use).

- Water moves through a watershed in a never ending water cycle.
- When a watershed drains, the water carries with it sediment, pollutants and dissolved materials.

ACTIVITY 2: EXPOSITION WITH INTERACTION
Lecture and Discussion on the Water Cycle and Land Use

Materials:

Wisconsin poster (see note above)

Procedure:

Using the poster, ask questions and provide additional content that addresses how this poster shows part of a watershed, the role of the water cycle in the watershed, and the relationship between land use practices and water quality.

1. What are some of the ways that water moves through this watershed?
2. What are some of the land use practices indicated in this watershed?
3. How might these impact the quality of surface and groundwater?

ACTIVITY 3: DISCUSSION
Issues in Your Watershed

Materials:

Papers and pencil for recorder

Procedures:

1. In your groups, decide who is going to be the recorder, reporter and facilitator.
2. Discuss the following two questions:
    - What is the most important environmental issue in your watershed? Why?
    - What can you do as individuals to help protect your watershed?
3. Have the reporters briefly share.

ACTIVITY 4: SOCRATIC METHOD
No Example Used

ACTIVITY 5: ORDINARY DEMONSTRATION
No Example Used

ACTIVITY 6: DISCOVERY DEMONSTRATION
Ground Water Flow Model

Materials:
Ground Water Flow Model

Procedure:
Using a ground water flow model, demonstrate how some of the water from a watershed flows through the earth as the groundwater and show the relationship between land use practices and ground water quality. Inject colored water into the model and observe how the water flows and what affects this flow (e.g., porosity, confining layers). Using another color, demonstrate the flow of pollution from a leaking landfill and an injection well. Before each demonstration, ask participants to predict what will happen. Ask other appropriate questions throughout the procedures.

ACTIVITY 7: GUIDED DISCOVERY
Incredible Journey

Materials and Procedures:
See copy of "Incredible Journey"

ACTIVITY 8: OPEN INQUIRY
What Can You Learn About a Watershed?

Materials and Procedures:
See copy of "What Can You Learn About a Watershed?"

Summary Discussion of the Continuum of Teaching Methods:
1. What did this series of "activities" demonstrate?
2. How did your role change from activity to activity?
3. When did you feel the most comfortable as a learner? Why?
4. Why is it important to teach using the whole continuum of teaching methods?

The Incredible Journey

Grade Level:
Upper Elementary, Middle School

Subject Areas:
Earth Science

Duration:
Preparation time: 50 minutes
Activity time: two 50-minute periods

Setting:
A large room or playing field

Skills:
Organizing (mapping); Analyzing (identifying components and relationships); Interpreting (describing)

Charting the Course
Other water cycle activities include "Water Models" and "Imagine!" In-depth investigations of how water moves can supplement this activity: condensing and evaporating ("Water Models"), filtering through soil ("Get the Ground Water Picture"), traveling over Earth's surface ("Branching Out!"), and moving through the atmosphere ("Piece It Together").

Vocabulary
condensation, evaporation, electromagnetic forces

Where will the water you drink this morning be tomorrow?

Summary

With a roll of the die, students simulate the movement of water within the water cycle.

Objectives

Students will:
- describe the movement of water within the water cycle.
- identify the states of water as it moves through the water cycle.

Materials

- *9 large pieces of paper*
- *Copies of **Water Cycle Table*** (optional)
- *Marking pens*
- *9 boxes, about 6 inches (15 cm) on a side* (Boxes are used to make dice for the game. Gift boxes used for coffee mugs are a good size or inquire at your local mailing outlet. There will be one die [or box] per station of the water cycle. [To increase the pace of the game, use more boxes at each station, especially at the clouds and ocean stations.] The labels for the sides of the die are located in the *Water Cycle Table.* These labels represent the options for pathways that water can follow. Explanations for the labels are provided. For younger students, use pictures. Another option is to use a spinner—see the activity "A Drop in the Bucket" for spinner design. It is necessary to design a spinner for each station.)
- *A bell, whistle, buzzer, or some sound maker*

Making Connections

When children think of the water cycle, they often imagine a circle of water, flowing from a stream to an ocean, evaporating to the clouds, raining down on a mountaintop, and flowing back into a stream. Role-playing a water molecule helps students to conceptualize the water cycle as more than a predictable two-dimensional path.

Background

While water does circulate from one point or state to another in the water cycle, the paths it can take are variable.

Heat energy directly influences the rate of motion of water molecules (refer to the activity "Molecules in Motion"). When the motion of the molecule increases because of an increase in heat energy, water will change from solid to liquid to gas. With each change in state, physical movement from one location to another usually follows. Glaciers melt to pools which overflow to streams, where water may evaporate into the atmosphere.

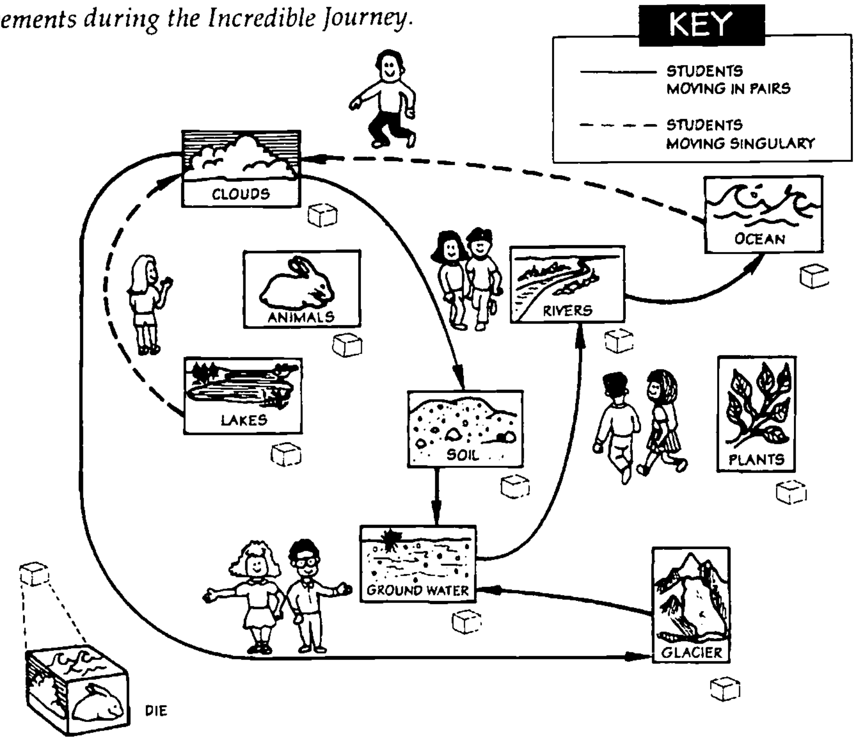
Gravity further influences the ability of water to travel over, under, and above Earth's surface. Water as a solid, liquid, or gas has mass and is subject to gravitational force. Snow on mountaintops melts and descends through watersheds to the oceans of the world.

One of the most visible states in which water moves is the liquid form. Water is seen flowing in streams and rivers and tumbling in ocean waves. Water travels slowly underground, seeping and filtering through particles of soil and pores within rocks.

Although unseen, water's most dramatic movements take place during its gaseous phase. Water is constantly evaporating, changing from a liquid to a gas. As a vapor, it can travel through the atmosphere over Earth's surface. In fact, water vapor surrounds us all the time. Where it condenses and returns to Earth depends upon loss of heat energy, gravity, and the structure of Earth's surface.

***The Incredible Journey* is used with permission from the Watercourse/Montana State University and the Council for Environmental cation (CEE) from the *Project WET Curriculum and Activity Guide*. For further information about Project WET (Water Education for hers), contact the national office at (406) 994-5392 or fax (406) 994-1919.**

Using station illustrations, create a one page graphic on which students record their movements during the Incredible Journey.



Water condensation can be seen as dew on plants or water droplets on the outside of a glass of cold water. In clouds, water molecules collect on tiny dust particles. Eventually, the water droplets become too heavy and gravity pulls the water to Earth.

Living organisms also help move water. Humans and other animals carry water within their bodies, transporting it from one location to another. Water is either directly consumed by animals or is removed from foods during digestion. Water is excreted as a liquid or leaves as a gas, usually through respiration. When water is present on the skin of an animal (for example, as perspiration), evaporation may occur.

The greatest movers of water among living organisms are plants. The roots of plants absorb water. Some of this water is used within the body of the plant, but most of it travels up through the plant to the leaf surface. When water reaches the leaves, it is exposed to the air and the sun's energy and is easily evaporated. This process is called transpiration.

All these processes work together to move water around, through, and over Earth.

Procedure

▼ *Warm Up*

Ask students to identify the different places water can go as it moves through and around Earth. Write their responses on the board.

▼ *The Activity*

1. **Tell students that they are going to become water molecules moving through the water cycle.**

2. **Categorize the places water can move through into nine stations: Clouds, Plants, Animals, Rivers, Oceans, Lakes, Ground Water, Soil, and Glaciers. Write these names on large pieces of paper and put them in locations around the room or yard. (Students may illustrate station labels.)**

3. **Assign an even number of students to each station. (The cloud station can have an uneven number.) Have students identify the different places water can go from their station in the water cycle. Discuss the conditions that cause the water to move.** Explain that water movement depends on energy from the sun, electromagnetic energy, and gravity. Sometimes water will not go anywhere. After students have come up with lists, have each group share their work. The die for each station can be handed to that group and they can check to see if they covered all the places water can go. The *Water Cycle Table* provides an explanation of water movements from each station.

4. **Students should discuss the form in which water moves from one location to another.** Most of th movement from one station to another will take place when water is in its liquid form. However, any time water moves to the clouds, it is in the form of water vapor, with molecules moving rapidly and apart from each other.

5. **Tell students they will be demonstrating water's movement from one location to another.** When they move as liquid water, they will move in pairs, representing many water molecules together in a water drop. When they move to the clouds (evaporate), they will separate from their partners and move alone as individual water molecules. When water rains from the clouds (condenses), the students will grab a partner and move to the next location.

6. **In this game, a roll of the die determines where water will go.** Students line up behind the die at

heir station. (At the cloud station hey will line up in single file; at the rest of the stations they should line up in pairs.) Students roll the die and go to the location indicated by the label facing up. If they roll **stay**, they move to the back of the line.

When students arrive at the next station, they get in line. When they reach the front of the line, they roll the die and move to the next station (or proceed to the back of the line if they roll *stay*).

In the clouds, students roll the die individually, but if they leave the clouds they grab a partner (the person immediately behind them) and move to the next station; the partner does not roll the die.

7. **Students should keep track of their movements.** This can be done by having them keep a journal or notepad to record each move they make, including *stays*. Students may ecord their journeys by leaving ehind personalized stickers at each station. Another approach has half the class play the game while the other half watches. Onlookers can be assigned to track the movements of their classmates. In the next round the onlookers will play the game, and the other half of the class can record their movements.

8. **Tell students the game will begin and end with the sound of a bell (or buzzer or whistle). Begin the game!**

▼ *Wrap Up and Action*

Have students use their travel records to write stories about the places water has been. They should include a description of what conditions were necessary for water to move to each location and the state water was in as it moved. Discuss any *cycling* that took place (that is, if any students returned to the same ation).

Provide students with a location (e.g., parking lot, stream, glacier, or one from the human body—bladder) and have them identify ways water can move to and from that site. Have them identify the states of the water.

Have older students teach "The Incredible Journey" to younger students.

Assessment

Have students:

- role-play water as it moves through the water cycle (step 8).
- identify the states water is in while moving through the water cycle (step 4 and *Wrap Up*).
- write a story describing the movement of water (*Wrap Up*).

Extensions

Have students compare the movement of water during different seasons and at different locations around the globe. They can adapt the game (change the faces of the die, add alternative stations, etc.) to represent these different conditions or locations.

Have students investigate how water becomes polluted and is cleaned as it moves through the water cycle. For instance, it might pick up contaminants as it travels through the soil, which are then left behind as water evaporates at the surface. Challenge students to adapt "The Incredible Journey" to include these processes. For example, rolled-up pieces of masking tape can represent pollutants and be stuck to students as they travel to the soil station. Some materials will be filtered out as the water moves to the lake. Show this by having students rub their arms to slough off some tape. If they roll *clouds*, they remove all the tape; when water evaporates it leaves pollutants behind.

Resources

Alexander, Gretchen. 1989. *Water Cycle Teacher's Guide*. Hudson, N.H.: Delta Education, Inc.

🍎 Mayes, Susan. 1989. *What Makes It Rain?* London, England: Usborne Publications.

🍎 Schmid, Eleonore. 1990. *The Water's Journey*. New York, N.Y.: North-South Books.

Where will this student go next on water's incredible journey?

Water Cycle Table

STATION	DIE SIDE LABELS	EXPLANATION
Soil	one side *plant*	Water is absorbed by plant roots.
	one side *river*	The soil is saturated, so water runs off into a river.
	one side *ground water*	Water is pulled by gravity; it filters into the soil.
	two sides *clouds*	Heat energy is added to the water, so the water evaporates and goes to the clouds.
	one side *stay*	Water remains on the surface (perhaps in a puddle, or adhering to a soil particle).
Plant	four sides *clouds*	Water leaves the plant through the process of transpiration.
	two sides *stay*	Water is used by the plant and stays in the cells.
River	one side *lake*	Water flows into a lake.
	one side *ground water*	Water is pulled by gravity; it filters into the soil.
	one side *ocean*	Water flows into the ocean.
	one side *animal*	An animal drinks water.
	one side *clouds*	Heat energy is added to the water, so the water evaporates and goes to the clouds.
	one side *stay*	Water remains in the current of the river.
Clouds	one side *soil*	Water condenses and falls on soil.
	one side *glacier*	Water condenses and falls as snow onto a glacier.
	one side *lake*	Water condenses and falls into a lake.
	two sides *ocean*	Water condenses and falls into the ocean.
	one side *stay*	Water remains as a water droplet clinging to a dust particle.

Water Cycle Table, continued

STATION	DIE SIDE LABELS	EXPLANATION
Ocean	two sides *clouds*	Heat energy is added to the water, so the water evaporates and goes to the clouds.
	four sides *stay*	Water remains in the ocean.
Lake	one side *ground water*	Water is pulled by gravity; it filters into the soil.
	one side *animal*	An animal drinks water.
	one side *river*	Water flows into a river.
	one side *clouds*	Heat energy is added to the water, so the water evaporates and goes to the clouds.
	two sides *stay*	Water remains within the lake or estuary.
Animal	two sides *soil*	Water is excreted through feces and urine.
	three sides *clouds*	Water is respired or evaporated from the body.
	one side *stay*	Water is incorporated into the body.
Ground Water	one side *river*	Water filters into a river.
	two sides *lake*	Water filters into a lake.
	three sides *stay*	Water stays underground.
Glacier	one side *ground water*	Ice melts and water filters into the ground.
	one side *clouds*	Ice evaporates and water goes to the clouds (sublimation).
	one side *river*	Ice melts and water flows into a river.
	three sides *stay*	Ice stays frozen in the glacier.

SWEEP

ACTIVITY

WHAT CAN YOU LEARN ABOUT A WATERSHED?

Purpose:
This activity models an open-inquiry approach to investigating a small area within a larger watershed.

Materials:
To introduce the activity:

USGS Topographic maps of your watershed
Overhead transparency or flip chart of "Watershed Inquiry" KWL chart
Note: KWL Chart (see example) asks for what participants already Know, what they Want to know or find out, and what they have Learned.

For the outdoor investigation, each group needs:

- Clipboard
- Assignment sheet
- Paper
- Pencil

For the outdoor investigation, the following supplies are readily available in quantities adequate for all groups:

- Levels
- Buckets
- Watering cans
- Yardsticks
- Measuring tape
- Skewers
- Surveyors' tape
- Clinometers
- String
- Hoses and water
- Milk jugs
- Graph paper
- Small plastic jars
- Compasses
- Other general supplies

Procedures:
Introduction: Show the whole group the topographic map of your watershed and indicate your exact location. Discuss how your local stream or river connects to larger watersheds (e.g., Deer Creek ⇒ Scioto River ⇒ Ohio River ⇒ Mississippi River ⇒ Gulf of Mexico). Draw an analogy between a patchwork quilt made up of many smaller patches and a larger watershed made up of many smaller watersheds.

1. For this activity, you are going to explore an area that represents part of one small "patch" in this watershed – the area immediately surrounding this building. To begin, what do we already know about the watershed immediately surrounding this building? (Fill in KWL

Chart as a group). What do you want to find out about the watershed immediately surrounding this building? (Fill in KWL Chart as a group)

2. In your group, decide who is going to be the materials manager, recorder, reporter and facilitator. Review the list of things to find out and decide what you want to investigate.
3. Based upon the equipment available to you (see list), design and conduct an outside investigation about something you want to find out about the watershed immediately surrounding this building. Describe what you did and what you found out.
4. After all groups have completed their investigations, share results.

Discussion:

1. What did you learn about the watershed surrounding this building that you did not know before your investigation? (Finish completing the KWL Chart as a whole group by listing what was learned)
2. What processes did you use to conduct your investigation?
3. What difficulties did you encounter? What other equipment do you wish you had?
4. What would you do differently if you did your investigation again?
5. What else would you like to know about this watershed and how might you find it out?
6. How would you modify or adapt this watershed inquiry activity?

Watershed Inquiry
Group Assignment

<table>
<tr><th>What We Already Know</th><th>What We Want to Find Out</th></tr>
<tr><td></td><td></td></tr>
<tr><th colspan="2">What We Learned</th></tr>
<tr><td colspan="2"></td></tr>
</table>

Watershed Inquiry Task

Directions:

Based upon the equipment available to you, design and conduct an outside investigation focusing on something you want to find out about the watershed immediately surrounding this building. Describe what you learned and how you found it out.

Equipment

Each group
Clipboard
Assignment sheet
Paper
Pencil

Other materials to chose from
Levels
Buckets
Watering cans
Yardsticks
Measuring tapes
Skewers
Surveyors' tape
Clinometer
String
Hoses & water
Milk jugs
Small plastic jars
Compasses
Other general supplies

What We Learned	How We Found it Out

APPENDIX C-6

Variety of Teaching Strategies From Exposition To Inquiry

A wide variety of teaching strategies should be used to meet the diverse learning styles and needs of learners. These should encompass the full range along a continuum from exposition to inquiry.

Possible Strategies

(loosely organized from exposition to inquiry)

Exposition
  Textbooks, fiction, non-fiction, other print materials, movies, videos, slide shows, web pages, lecture, guest speakers, storytelling, dramatization
Computer-assisted instruction
Discussion
Demonstrations
Drill and practice
Recitation
Guided imagery/simulated field trips
Brainstorming
Sensory awareness/observation activities
Investigations and experiments (hands-on, minds-on)
  Directed laboratory
  Guided discovery
  Open inquiry
Concept mapping
Webbing
Writing process
Games and simulations
Role playing
Individual/group projects and performances*
  Examples: poster, mural, diorama, bulletin board, sculpture, skit, public service announcement, puppet show, bumper sticker, political cartoon, comic strips, parade, exhibit, video, slide show, photo essay, original song or musical piece, hyperlearning stack, journal, research report, poetry, newspaper article, graph, model, invention.
Peer teaching/multi-age teaching
Debates
Surveys, questionnaires, interviews
Case studies
Issue analysis and investigation
Moral dilemmas and value analysis
Community studies
Problem solving/decision making
Action projects aimed at problem solving and citizen participation
Open-ended inquiry

*These should take on many forms which are reflective of multiple intelligences (i.e., musical, bodily-kinesthetic, logical mathematical, linguistic, spatial, interpersonal, intrapersonal)

Helpful Teaching Aids

(The above teaching strategies can be greatly enhanced by the use of a variety of teaching aids)

Animals
Artifacts
Audio-visuals
Costumes
Equipment
Games
Manipulatives
Maps
Models
Photographs
Plants
Print material
Props
Supplies/junk
Technology
Tools

Cantrell, D.C., & Barron, P.A. (Eds.). (1994). Integrating environmental education and science: Using and developing learning episodes. Akron, OH: Environmental Education Council of Ohio, PO Box 2911, 44309.

SAPA · ESS · SCIS

INQUIRY/ DISCOVERY REVISITED

Howard H. Birnie
Alan Ryan

Recent research demonstrating the successes of teaching science in elementary school through hands-on activities also includes suggestions that teachers give programs like SAPA, ESS, and SCIS another, critical, look.(1,4)* And this look should be broadened to include an examination of inquiry/discovery methods in general.

Those who define "inquiry" usually call it an effort to discover something new to the inquirer—though not necessarily new to the world. Other definitions of inquiry include the following propositions:

- Inquiry is the process of investigating a problem.
- Inquiry is a search for truth or knowledge that involves critical thinking.
- The end product of inquiry may be a discovery, but discovery is only a part of inquiry.
- Inquiry involves making observations, asking questions, performing experiments, and stating conclusions.
- Inquiry can be idiosyncratic and creative. An individual may develop his or her own strategies and may take intuitive approaches to the problem.

A common element in all of these statements is the use of thinking skills to attain new knowledge or solve a problem. So, if a student is able to acquire a new fact, concept, principle, or solution through the inquiry, the student is making a discovery.

A Hands-off Activity

While inquiry in science is often associated with experiments, learning by inquiry may not require any hands-on activities. A well-known problem that develops students' skills in scientific inquiry without hands-on experience goes as follows:

> A man lives on the fourteenth floor of an apartment building. When he goes to work in the morning, he gets on the elevator, travels down to the ground floor, and then walks to his place of work. When he arrives home at night, he takes the elevator to the twelfth floor, gets off, and walks up the last two flights to his fourteenth-floor apartment. Why doesn't he take the elevator to the fourteenth floor on his return?

A teacher can help students find a logical explanation through various inquiry methods. One approach is to have students play detective by asking questions that the teacher can answer with only a "yes" or "no." Through their questions, students may produce one or more possible explanations.** Though students do not need equipment or materials to solve this problem, its explanation involves inquiry and discovery.

Patterns of Inquiry

Teachers often wonder whether they are using the inquiry approach and to what extent. Before approaching this question, we need to recognize that there are various patterns of inquiry. The patterns depend on whether the teacher or the student controls the steps of the inquiry. The chart on the following page lists the steps of problem solving and indicates who directs each step within the various patterns. (A "T" indicates the teacher is in control; an "S" shows that the students have control.) The patterns themselves are designated by capital letters.

How the Patterns Vary

In Pattern A, the teacher controls all steps except for performing the activity and gathering the data. The teacher formulates even the conclusion because the problem is merely a verification exercise in which the statement of the problem reveals the conclusion. For example, the instructions for an experiment may ask students to show that there is no temperature change while ice is melting in water. This method is a structured or guided inquiry and is the pattern most laboratory guide books employ, especially at the secondary level. Pella (from whom this chart is borrowed) describes Pattern A as appropriate for verifying laws, concepts, and principles, and for reinforcing skills.(3) The teacher, assuming a position as a dispenser of knowledge, controls the students' level of thinking; consequently, students will be thinking pretty much along the same lines.

---

*See References.

**One explanation is that the man is very short. Though he is tall enough to reach the elevator button for the twelfth floor, he cannot reach the button for the fourteenth

Science & Children Vol. 21 by Birne & Ryan. Copyright © 1984 by NSTA. Reprinted by permission of NSTA via the Copyright Clearance Center.

In an inquiry exercise that follows Pattern C, the teacher controls only the first two steps by stating the problem and formulating hypotheses. For example, the teacher may point out that the leaves of two plants are different shades of green and ask the students to explain why. In order to guide their inquiry, the teacher will suggest some hypotheses to test, such as variation in sunlight, temperature, amount of water, and type of soil. But once the teacher has stated the problem and formulated the hypotheses, the students take over the inquiry.

The student both identifies the problem and directs the solving process in Pattern E. Because this is a freer form of inquiry than the ones already discussed, the student has an opportunity to consider a broader range of hypotheses independently and apply research methods. It is this pattern of inquiry that develops independent learners. Though the freer forms of inquiry are desirable, they are probably rarely used in science classrooms. Indeed, one of the weaknesses of our educational system is that students who come to us in elementary school using Pattern E are, by the time they get to high school, often more comfortable and more successful when they use Pattern A.

An Independent Review

Often teachers use Pattern A or B for review of a unit or topic, but as Carin and Sund demonstrate, even a review can employ some of the freer methods of inquiry.(2) Below are some review questions they have developed that would require the students to think about what they have learned and identify their own research problems.

1. If you were the teacher of this class, and you were going to select the most exciting things to investigate this term, what would they be?
2. What are some problems related to our community that you would like to study?
3. Now that you have studied salts, algae, light, heat, pollution, animal behaviors, or whatever, what problems can you come up with that you would like to investigate individually or in teams?
4. Now that you have finished this experiment, what other experiments can you think of and which of them would you like to do?
5. What problems do you see in the community—for example, pollution—that you would like to bring to the attention of the class and discuss?
6. What kind of science fiction story would you like to write?

Science activities that require some form of inquiry develop thinking skills applicable in all fields of study. Though structured inquiry may be the mainstay of a science program, a teacher who provides students with experiences in free inquiry will help them think more independently in the future.

References

1. Bredderman, Ted. "Activity Science—The Evidence Shows It Matters." *Science and Children* 20:39–41, September 1982.
2. Carin, Arthur A., and Robert Sund. *Teaching Science Through Discovery.* 4th ed. Toronto: Charles E. Merrill Publishing Co., 1980.
3. Pella, Milton O. "The Laborat[illegible]d Science Teaching." *Readings in Science Education for the Secondary School.* Ed. Hans O. Andersen. New York: Macmillan Co., 1969.
4. Shymansky, James A., et al. "How Effective Were the Hands-on Science Programs of Yesterday?" *Science and Children* 20:14–15, November/December 1982.

Howard H. Birnie is a professor of science education at the University of Saskatchewan, Saskatoon, Canada. Alan Ryan is associate professor of curriculum studies at the same university. Artwork by Darshan Bigelson.

A Continuum of Inquiry Learning Patterns

Steps	A	B	C	D	E
1. Stating the problem	T	T	T	T	S
2. Formulating the hypotheses	T	T	T	S	S
3. Developing a working plan	T	T	S	S	S
4. Performing the activity	S	S	S	S	S
5. Gathering the data	S	S	S	S	S
6. Formulating the conclusions	T	S	S	S	S

Shifting from Activitymania

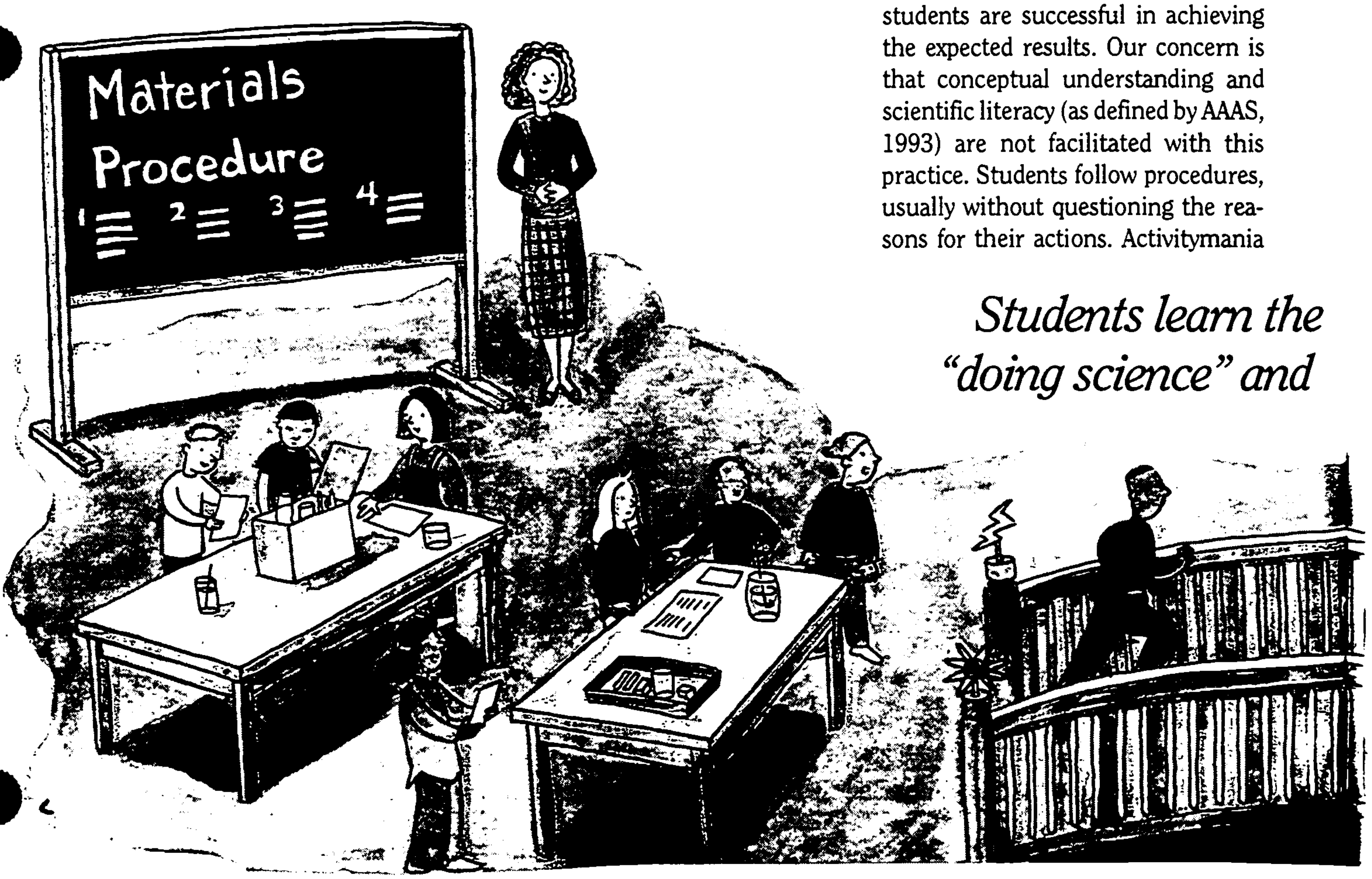
OFTEN, WHEN SCIENCE instruction occurs in some elementary classrooms, it is in the form of a barrage of activities—what we call "activitymania." Using surveys and interviews of practicing and prospective teachers, we explored classroom practices in different districts at the K–12 level. We found that some factors need to be recognized and addressed prior to making a shift from activitymania to inquiry science teaching and learning (National Research Council, 1996).

Activitymania—What Does It Mean?

Activitymania is an approach to teaching elementary science that involves a collection of prepackaged, hour-long (or less), hands-on activities that are often disconnected from each other. Each activity has a definite beginning, middle, and end. In contrast, inquiry is the process of searching for patterns and relationships in the world around us. Inquiry cannot be prepackaged as it takes different directions according to students' interests and questions related to the concept being studied. (See Table 1 on page 17 for essential differences between activitymania and inquiry.)

Activities can be engaging for students and easy for the teacher. The outcome is usually defined and most students are successful in achieving the expected results. Our concern is that conceptual understanding and scientific literacy (as defined by AAAS, 1993) are not facilitated with this practice. Students follow procedures, usually without questioning the reasons for their actions. Activitymania

Students learn the "doing science" and



Science & Children Vol. 35 by Moscovici & Nelson. Copyright © 1998 by NSTA. Reprinted by permission of NSTA via the Copyright Clearance Center.

to Inquiry

By Hedy Moscovici and Tamara Holmlund Nelson

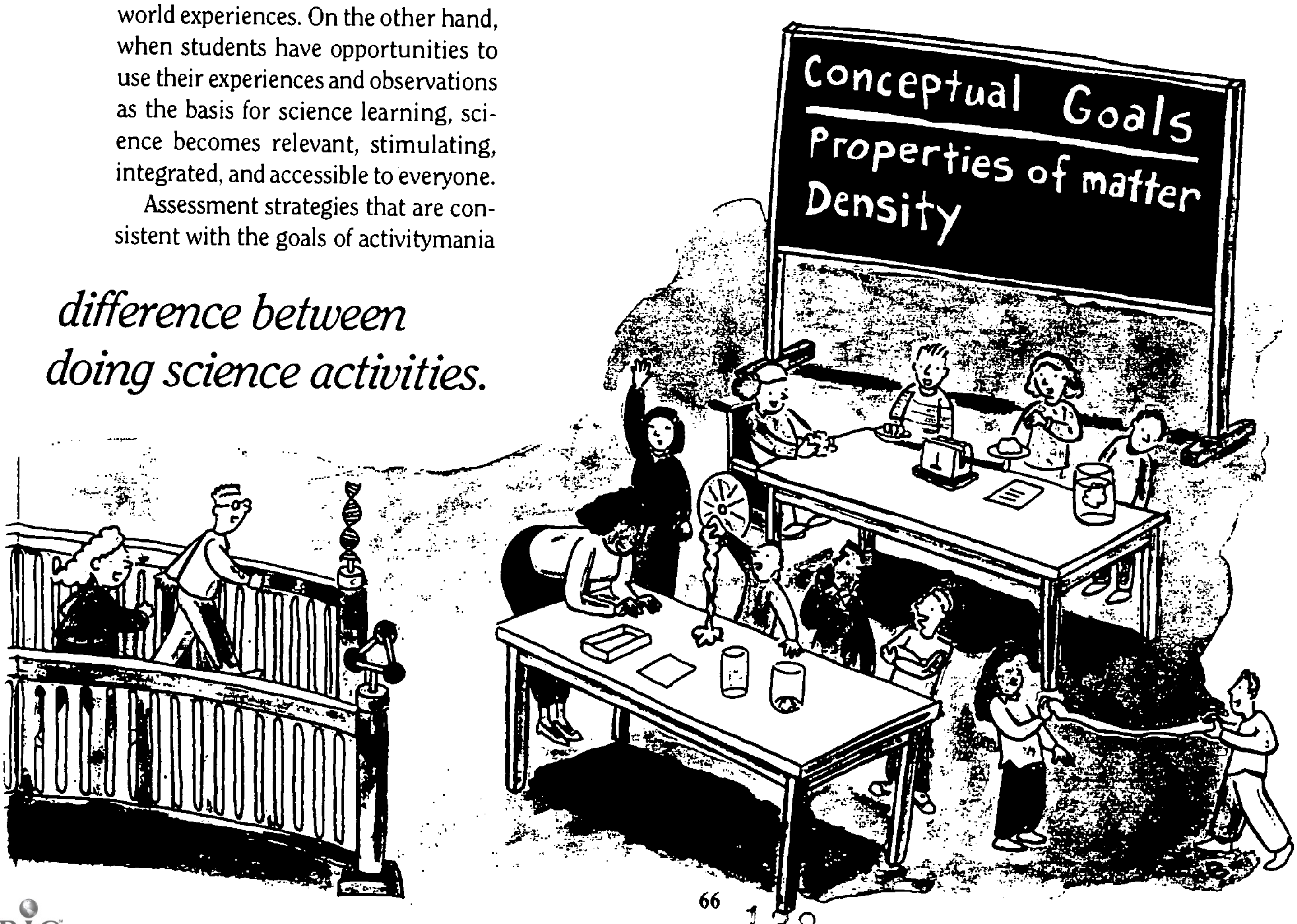
is not consistent with constructivist learning theory (Tobin and Tippins, 1993).

In activitymania, the working hypothesis is clearly defined by the teacher prior to experimentation, while in inquiry, it arises from students' questions and is based on their experiences. During activitymania, the students learn to disregard results that do not match teachers' expectations rather than question and analyze their data; science is perceived as disconnected from students' real-world experiences. On the other hand, when students have opportunities to use their experiences and observations as the basis for science learning, science becomes relevant, stimulating, integrated, and accessible to everyone.

Assessment strategies that are consistent with the goals of activitymania are inconsistent with the goals of inquiry. Activitymania calls for immediate, product-oriented, right-answer assessments, whereas inquiry supports long-term, process-oriented evaluations. Inquiry calls for the development of rubrics that authentically assess students' learning throughout the scientific investigation.

For example, one rubric might be related to the development of research questions, while another addresses experimentation. The individual teacher develops various rubrics and allocates points according to the goals and processes explored in his or her classroom (Moscovici and Gilmer, 1996). There are numerous reports in the literature of students developing assessment rubrics. For example, Lundberg (1997) reported how students in her class defined quality work and developed rubrics that helped her grade open-ended, problem-solving

difference between doing science activities.



CHARLES

laboratory experiments. Inquiry assessment goes beyond the final exam to include components such as exhibitions, debates, community problem-solving projects, and Internet communications.

[illegible]

In our study, we explored perceptions expressed by practicing teachers with regard to their use of activities in science teaching. We also looked at the elements of teacher preparation programs contributing to the implementation of activitymania.

> *In order to promote inquiry, teachers should clearly define conceptual goals and the relationships to students' lives and interests prior to selecting classroom activities.*

A large number of teachers reported to us that they want science to be enjoyable for students. Hands-on activities provide for small group interaction and accommodate different learning styles.

Some activities that are easy to set up can be repeated. The step-by-step approach usually ensures control and a somewhat smooth progression toward an expected outcome. The prepackaged aspect makes the information easy to transfer. Teachers perceive that such practice supplies students with a basic knowledge of the science topic in a neatly laid out procedure.

The National Research Council (1996) recommends that science be taught in every classroom at every grade. The activitymania approach ensures science concepts will be addressed in the classroom. Activities also provide a large measure of satisfaction for those teachers who are unhappy with the textbook and lecture format.

Teacher preparation programs tend to reinforce using a barrage of activities for teaching science concepts. Often, activities are used by science education instructors to model pedagogical methods, such as how to distribute materials, take a field trip, or manipulate equipment. Unfortunately, many preservice teachers misunderstand that the purpose of the activity is to model a certain teaching strategy. Instead, they adopt and transfer this activity approach to their own classrooms.

The same result is achieved when activities are used to develop a science concept. Preservice teachers are motivated by the excitement and pleasure of the manipulation of the materials but may not have opportunities to question, explore, and develop conceptual science.

There is a definite difference between "doing science" and doing science activities. Often, preservice teachers have few opportunities to work with real scientists to develop an understanding of the nature of scientific inquiry. They attend undergraduate science lecture courses that are heavy in factual information and recall. The laboratory sections in these courses consist of a series of disconnected activities that don't build toward a conceptual understanding of science. When, in a science methods course, preservice teachers encounter enjoyable activities in which they feel successful, it is understandable that they choose to emulate the activity approach.

What Next?

We propose a shift from activitymania to inquiry in order to better develop students' higher order cognitive skills (Zoller, 1993). This shift *doesn't* mean throwing out the kits and manuals. Instead, we ask teachers to clearly define conceptual goals and the relationships to students' lives and interests prior to selecting classroom activities.

Teachers should ask questions such as "Why are magnets important to my students?" "How do my students relate to plants?" or "What are my students' experiences and questions related to weather?" Once these overall goals are established, supporting activities that link and build understanding can be identified.

These supporting activities can be used in a variety of ways:

- *To engage the students.* A relevant activity will provide students with a fundamental background and stimulate questions that lead to further investigation. For example, a hands-on experience with oobleck, mud, shaving cream, and similar combinations can lead to investigations about properties of matter.
- *In skill development.* For example, students can measure volume and mass in order to explore density and buoyancy.
- *As an idea for modification and extension.* Clough and Clark (1994) adapted a cookbook-type laboratory activity to engage students in inquiry. Rather than supplying the students with the expected result, they facilitated students' inquiry through the use of guiding questions.
- *To provide students with common experiences to address their questions during their inquiry.* For example, evaporation and condensation can be illustrated in the context of the water cycle and weather.
- *As a method by which students demonstrate their understanding of the concept and related scien-*

(continued on page 40)

Table 1. A Summary of Essential Differences Between Activitymania and Inquiry.

	Activity	Inquiry
Time	• short (approximately 50 minutes)	• long (more than 5×50 minutes)
Planning	• definite, allows preplanning	• flexible, general preplanning
Materials	• ready to go (e.g., kit)	• upon students' request
	• teacher's responsibility	• students' and teachers' responsibility
Results	• known by the teacher, published by text, and most times known by students	• unknown by teacher, students, or text
	• one expected and accepted result	• multiple results will be negotiated and discussed
Working Hypothesis	• well defined by teacher prior to experimentation	• arising from students' questions and based on their experiences
Teacher's Feelings	• in control (high power)	• sharing control (lower power)
	• unchallenged intellectually (assimilation mood)	• intellectually challenged (accommodation mood)
	• relaxed—low energy level	• learning a lot—perturbed
	• expert (students asking him or her for reinforcements)	• experienced co-learner (students discussing findings with teacher and students alike)
	• having fun	• enjoying the intellectual challenge
		• perturbed by the intellectual challenge
Students' Feelings	• following prescribed procedures	• developing procedures and a list of materials and equipment
	• matching personal findings with expected findings (teacher's)	• interpreting results as there are no prescribed findings
	• working on teacher's question	• working on personal or group question(s)
	• the teacher knows the right answer	• as students developed the question, the teacher does not know the answer
	• one right answer	• multiple answers accepted
	• passive	• motivated—using "I want (or we want) to find out"
		• perturbed
		• challenged intellectually and looking for equilibration (Piaget)
Assessment	• immediate	• long-term
	• product-oriented (right/wrong answer)	• process-oriented
	• technical	• developing rubrics
Students' Learning	• technical skill (follow procedures) and develop low order cognitive skills	• observation and develop higher order cognitive skills
	• disregard results that do not match teacher's expectations	• disregard data for reasonable and scientific reasons
		• use discrepancies as entry points for inquiry
	• science is done and understood by special people (intellectually gifted)	• everybody can get involved in doing and understanding science
	• perpetuate the idea of science as magic	• science as patterning the world
	• science as discontinuous, one-time shots that are difficult to explain and usually do not "work" anyway	• science as integrated, continuous, and even predictable
	• one needs a lot of knowledge in order to do and understand science	• one builds knowledge while doing and learning science

(Activitymania, *continued from page 17)*

tific ideas. This may be a final assessment in which student groups design and present an activity that models their scientific understanding.

Moving Toward Inquiry

Activitymania is one way science has entered elementary classrooms. It is a step away from teacher-directed, textbook-centered elementary science. It is now time to go a step further and make the shift toward inquiry. Modifications can be made to existing science programs (e.g., kits, texts) to meet criteria for inquiry science as suggested in Table 1. This movement will better ensure the development of scientifically literate citizens who will use science when making decisions to solve tomorrow's problems.

Resources

American Association for the Advancement of Science (AAAS). (1993). *Benchmarks for Science Literacy*. New York: Oxford University Press.

Clough, M.P., and Clark, R. (1994). Cookbooks and constructivism. *The Science Teacher, 61*(2), 34–47.

Lundberg, R. (1997). Student-generated assessment. *The Science Teacher, 64*(1), 50–53.

Moscovici, H., and Gilmer, P.J. (1996). Testing alternative assessment strategies: The ups and downs for science teaching faculty. *Journal of College Science Teaching, 25*(5), 319–323.

National Research Council. (1996). *National Science Education Standards*. Washington, DC: National Academy Press.

Tobin, K., and Tippins, D. (1993). Constructivism as a referent for teaching and learning. In K. Tobin (Ed.), *The Practice of Constructivism in Science Education* (pp. 3–22). Washington, DC: AAAS.

Zoller, U. (1993). Are lecture and learning compatible? Maybe for LOCS: Unlikely for HOCS. *Journal of Chemical Education, 70*(3), 195–197.

Also in S&C

Iwasyk, M. (1997). Kids questioning kids: Experts sharing. *Science and Children, 35*(1), 42–46, 80.

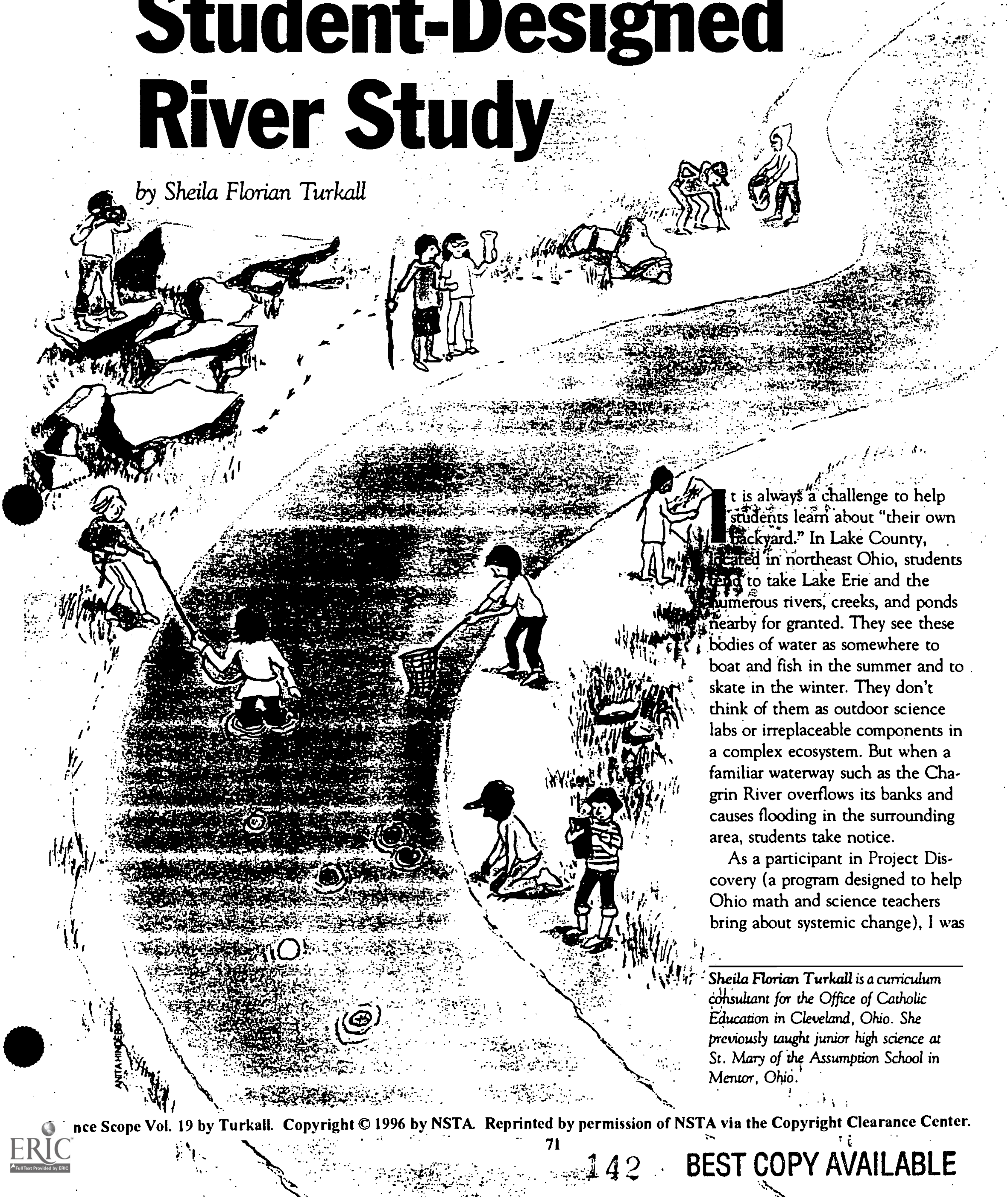
Maxim, G. (1997). When to answer the question "Why?" *Science and Children, 35*(3), 41–45.

Shiland, T.W. (1997). Decookbook it! *Science and Children, 35*(3), 14–18.

HEDY MOSCOVICI is an assistant professor and science education consultant at Western Washington University in Bellingham. TAMARA HOLMLUND NELSON is a high school science teacher in the Snohomish (Washington) School District.

Student-Designed River Study

by Sheila Florian Turkall



It is always a challenge to help students learn about "their own backyard." In Lake County, located in northeast Ohio, students tend to take Lake Erie and the numerous rivers, creeks, and ponds nearby for granted. They see these bodies of water as somewhere to boat and fish in the summer and to skate in the winter. They don't think of them as outdoor science labs or irreplaceable components in a complex ecosystem. But when a familiar waterway such as the Chagrin River overflows its banks and causes flooding in the surrounding area, students take notice.

As a participant in Project Discovery (a program designed to help Ohio math and science teachers bring about systemic change), I was

---

Sheila Florian Turkall is a curriculum consultant for the Office of Catholic Education in Cleveland, Ohio. She previously taught junior high science at St. Mary of the Assumption School in Mentor, Ohio.

connected via a computer network to teachers and classrooms throughout Ohio. So when I heard a weather forecaster suggest that there was a relationship between the number of inches of snow on the ground and the number of feet the Chagrin River would rise, I e-mailed Ken Reed, a Project Discovery math teacher-leader from Wellington Middle School in north central Ohio, to ask what he thought about the forecaster's statement. Ken was not sure of the relationship, but he did suggest that it would be a great topic for students to explore in an integrated student-designed investigation.

I asked Louise Formica, a math teacher at my school, if she would like to work together to guide a student-designed investigation of the river. She agreed, and together we challenged our eighth-grade students to design a study of the Chagrin River and the flooding problem. We explained that they could investigate the problem in any way they chose, but they had to incorporate math, science, and computer networking in the process. We would provide guidance when necessary, but they would work cooperatively to make all the decisions. As a culminating activity, we would take a trip to the river in the spring to conduct field research.

We invited Ron Wolfe, a Project Discovery physics teacher-leader from Beachwood Middle School in Cuyahoga County, to join the project. Through this collaboration, Ron's eighth-grade students also studied the Chagrin River near their school, and the two classes shared information over the Discovery computer network. As the project progressed, we also shared information with three other math and science classes from eastern and central Ohio as well.

Wading in

To begin, students brainstormed to identify and state the problem, discuss what they already knew about rivers, particularly the Chagrin River, and identify resources of additional information. Louise and I suggested that students start with two important resources: the Army Corps of Engineers, which is responsible for all rivers in the United States, and the U.S. Geological Survey, which could provide the necessary maps of the area.

Students also decided to take advantage of the information in the library, newspapers, microfilm, and an online bulletin board operated by Cleveland's Metropark System. In addition, they decided to interview various people including scientists, college professors, business people, flood victims, weather forecasters, and personnel from science centers, parks, and museums. Students also began researching and comparing data on the river's water levels before and after several recorded floods.

Students soon discovered that it would be difficult, if not impossible, for them to establish a relationship between the number of inches of snow on the ground and the amount the river would rise. Preliminary interviews and research produced no concrete information for stating a hypothesis or designing an exploration. But students had become intrigued with many other aspects of the river, which they had never before seen through the eyes of a scientist.

The class divided into groups to study several different aspects of the river, such as water flow, plant life, topography, animals, water quality, and people. As teachers, Louise and I realized that we had to be very flexible while students designed their study. They did not always have a clear plan, and often veered off on tangents.

The parameters of the study were continually adjusted through classroom discussions and joint decisions. Sometimes we were afraid the project would get out of hand because students had so many ideas, but they were learning and they were excited, so we allowed them the freedom to pursue their interests.

In full swim

Students had already come up with plenty of scientific topics to investigate, but they were having trouble figuring out how to incorporate math. To help them, we asked what they had learned in math that might have some connection. Students named several concepts including measurement, metrics, volume, mean and mode, and geometry (using parallax to determine the width of the river). Louise and Ken Reed worked out a way to use the slope of the land along the river to help calculate runoff. Ken also suggested that students investigate the relationship of the slope to the time it took for water to get to the river. Through e-mail, the different classes involved shared open-ended math problems designed to stimulate discussion. Students also gathered data and sent it to the other classes, who would then formulate math problems using this information.

Social studies entered into the study as students learned about property values in different areas on the river, insurance, and the environmental and social impact of the flooding in both wealthy and low-income areas. Two students visited with flood control consultants and brought back maps, data, drawings, articles, and a promise to speak to the entire class. When these consultants came, they gave the kids some background on flood plains, hydraulic jumps, and how storms are classified in relation to flooding probability. They answered questions and drew diagrams to help students understand why a river floods.

In science class, students studied population in communities, learned how to use a random sampling to calculate the size of these populations, and discussed the impact of producers, consumers, predators, and prey on an environment. They made a list of animals and plants found on and near the banks of the river and in the water itself, and they practiced conducting water quality tests for hard and soft water, calcium sulfate, iron and sodium content, and pH.

At the water's edge

To prepare for the field work along the river, students had to make decisions about methods and materials. The budget for the project was small, so students decided to make many of the instruments themselves. For example, to determine the velocity of the river, students tested an orange, an apple, and a green pepper as acceptable flotation devices because they wanted something biodegradable. Students made plankton nets from old hosiery and clothes hangers, and a surber square (a square sieve for sampling plant and animal life in the river) from discarded wood and an orange bag.

Materials were borrowed or constructed; topographic maps of the area were purchased; and a camcorder and cameras were loaned by the school and other teachers. Students collected about 20 field guides on trees, insects, fish, animals, plants, and rocks from libraries, teachers, and home.

Each group wrote up a specific plan for their activities at the site (see Figure 1 for two plans). For example, the water flow group would take measurements to calculate velocity and average depth. The plant life group would use metric squares to count random samplings of populations of plants on and near the banks, and plankton nets to determine the types of plants that grew in the water and on the rocks near some small rapids. The topography group would investigate why the river floods only so far from the mouth and not all along the river, identify the types of buildings, housing, pavement, and similar structures near the flood plains, and use clinometers to determine elevation on the banks. The animal group would observe and identify birds and make casts of animal tracks. The water quality group would perform dissolved solids tests and use two types of indicators for pH. The people group would observe housing and assist other groups, as most of their economic, political, and insurance research was completed prior to the river trip.

Finally, we reviewed safety rules such as wearing surgical gloves, water galoshes, tennis shoes, and jeans, and using ropes to anchor students in the river to a tree on the bank. A student who would wear waders practiced how to remove them rapidly if they took in water. Students also contacted the local authorities to obtain permission to conduct research at the chosen sites.

Before the day of the field trip, Louise, two mothers, the student group leaders, and I went on a scouting trip. We timed the travel between the farthest and nearest sites and discovered that one site was inaccessible due to the steepness of the bank and another site was too far away to be practical. Then we had the group leaders practice each of the tests and procedures to work out all the kinks ahead of time.

The big day

The day of the trip, 22 students, two parents, Louise, and I eagerly piled into the bus and set off to our first destination, Chagrin Falls. Each group carried a bucket of necessary supplies, and one student used a camcorder to film throughout the day. Students were immediately busy since they only had 45 minutes to take water samples, population counts, and photographs. The kids were able to determine the velocity of the river, use the plankton net they had constructed, and find the average depth of the water. We could have spent another two hours there.

At the next site, students did all the same tests. The topography group used clinometers to map the features of the land. Students found some fish, lots of insects, a strange little green worm, a gorgeous blue heron, some kind of larva, and Canada Geese. They found an unusual population of young trees in sand and took plaster casts of two

FIGURE 1. Field work plans

Animals

1. Observe tracks, scat, and other signs to determine what animals live around the river and how they may be affected by flooding. What impact might they have on flooding?
2. Find out what types of fish live in the river. Check with the water quality group to find out if the water can support animal life.
3. Conduct a surber square sample test at various points to find out what small animals or plants are moving through the river. Always start downstream so as not to disturb the test sites upstream.
4. Make plaster of Paris prints of animal tracks. Label them to identify the animal.
5. Make a list of the animals that could possibly be seen near or in the river during the day, and those that you might see at night. Remember to include birds.
6. Keep accurate notes. Make sure each test is done in exactly the same manner to ensure accuracy.
7. Take photographs, draw sketches, and collect other necessary materials for your presentation.

Water quality

1. Test the quality of water in the river. Make sure to test at various intervals for accurate comparisons. Make observations to support your conclusions. Be sure to start downstream so as not to disturb data at different intervals of the river.
2. Measure the pH factor of the water. Sample various points in the river to ensure accurate data.
3. Conduct a dissolved solids test. In a test tube, add two drops of liquid soap to a sample of river water. Shake 20 times vigorously, then measure the suds. After recording, put the test tube and soapy water into a coffee can for proper disposal at school.
4. Keep accurate notes and recordings. Make sure each test is done exactly the same for accuracy.
5. From your results, draw some reasonable conclusions to share with the other schools.
6. Take photographs, draw sketches, and collect other necessary materials for your presentation.

kinds of tracks. Students also tested the soil on the river bank.

Student groups continued their research at two other sites, then headed back to school for a preliminary debriefing. Through the field research, students learned that the topography of the area was hilly, so the river only floods at certain points. The water flow group discovered a very strong current that was not visible on the surface. They also found that the velocity of the river was slower above the falls than below. The water quality group sparked more questions and repeated testing because one site had a pH of only 4.5 (the other sites registered a pH of 6 or 7). The water was very low at that site and we found two dead trout. But when I returned two weeks later, the water was higher and the pH was 7.

Students wrote journal entries about the trip and formulated more open-ended math problems from their data. Students' journals reflected their enthusiasm about the trip, for example

- "Today I believe went really well for the first time doing hands-on science at the exact place. I mean it's different and more fun than to read it out of a textbook."
- "By following our plans and working together we accomplished what needed to be done. . . . It was fun and exciting walking across the river observing different rock formations, plant life, and animals."

After the trip, we hosted a symposium for the students from Beachwood Middle School. The groups made displays with models, photographs, graphs, and charts, and everyone spoke for a few minutes about the project. Then students watched parts of the video of our field trip and the Beachwood students showed the slides of their own trip to the river. The next day, the students went online to send thank-you messages for a very successful project.

I believe the project was so successful because the kids played such a major role in developing the study. We trusted them, and they came through. Our students saw the connections between science and math and social studies and language arts. They learned to research beyond the walls of their school and the limits of their city. And they developed that yearning every teacher hopes for: They wanted to go back to the river to test more carefully and double-check their observations. But most of all, students designed a study of a familiar environment and rediscovered a vital, beautiful river in their own backyard. ☐

Inquiring Minds Want to Know

by *Carolyn W. Keys*

Allowing students to design their own science investigations is an idea that is gaining popularity in upper elementary and middle schools because it increases motivation and encourages a high level of engagement with the curriculum. When students think about appropriate questions and procedures for an investigation, they are working much like professional scientists. As they plan tests and observations, students have opportunities to solve problems, develop science process skills, and build conceptual understanding. In addition, math and technology come into play as students learn how to analyze and graph their data.

Reform publications such as *Benchmarks for Scientific Literacy*[1] suggest that children should have plenty of experience doing science so that they can develop an understanding of the scientific process itself. To this end, the science teachers at Crawford Long Middle School in Atlanta, Georgia, have been working on ways to facilitate student-designed investigations in their sixth- and seventh-grade classes since the spring of 1994. As their university partner, I have worked with them through inservice sessions and in their classrooms.

Carolyn W. Keys is an assistant professor in the Middle-Secondary Education and Instructional Technology Department at Georgia State University in Atlanta.

An investigation model

We use a three-step model for student-designed investigations. Working in cooperative learning groups of four with assigned roles, students accomplish the following tasks:

1. *Exploration*—Students engage in an introductory activity and raise questions for investigation.
2. *Investigation*—Students plan, carry out, and record the results of their own investigations.
3. *Reflection*—Students prepare and present their findings to others in the class.

When we began our project, we soon discovered that the most critical part of the process was guiding students to ask questions that can actually be investigated in the classroom. Once students have created an appropriate investigation question, then designing the experiment, collecting and analyzing data, and presenting findings come naturally. Without a good question to investigate, the entire process bogs down and students become frustrated. We also found that, at first, students tended to ask questions that could easily be answered by a trip to the library because they were not used to thinking of inquiry as a method of answering questions. With a little practice, however, students learned how to ask questions that led to interesting investigations. In fact, as the project progressed, they began to think of increasingly creative topics that linked science to their own real-world interests.

FIGURE 1. Sample inquiry questions

Descriptive inquiry questions

How tall does a plant grow in a few days after the seed is planted?

What kinds of plants grow on the school grounds?

How does the five-day forecast compare to the actual weather for the next five days?

How does the amount of rainfall for this week compare to the amount of rainfall for the whole year?

Which state has the coldest weather this week?

How much litter is on the school grounds?

What do animal bones look like on the inside?

Experimental inquiry questions

Does the amount of soil affect the growth of plants?

Do plants grow better in fluorescent light or sunlight?

What is the pH of rain water and tap water?

What is the difference in temperature between a shady area and a sunny area in the morning and the afternoon?

Which material makes the best insulator: plastic, cardboard, wood, foil, or cloth?

How hot does Styrofoam get at different distances from a lamp?

Who has the bigger lung capacity: boys or girls?

Created by the sixth- and seventh- grade students at Crawford Long Middle School, Atlanta, Georgia.

Asking the right questions

Middle school students tend to think of three distinct kinds of science questions:

- *Fact-based questions*—Questions that can be answered by reading the textbook or library reference books. For example, "What are the parts of the circulatory system?"
- *Conceptual questions*—"How" and "why" questions that may be very interesting, but cannot be answered with a classroom investigation. For example, "How does your brain get you to remember certain things?"
- *Inquiry questions*—Questions that can be used as a basis for student-designed investigations. For example, "Which group has a higher heart rate after exercise: boys or girls?"

The teacher's role in student-designed investigations is to guide students away from fact-based questions and toward inquiry questions. Modeling this type of questions for the class may help students understand what makes a good inquiry question (see Figure 1).

Facilitating good questioning

Building on our experience, we have created the following guidelines for others who would like to try student-designed investigations in their own science classes:

- Focus all groups in the class on a common topic, such as plant growth and development, heat and insulation, or the ecology of the school grounds. This will allow students to understand other groups' investigation questions and learn from their results. It also allows you to accomplish common curriculum objectives with the entire class.

- Introduce a topic with a teacher-designed activity to engage students and orient them to the concepts and materials for that topic. For example, when initiating weather investigations, you might conduct a guided activity for observing temperature, relative humidity, cloud cover, wind direction, and so on. New questions on the topic of weather become a natural outgrowth of the post-activity discussion.

- For the first few student-designed projects, discuss appropriate questions as a class. A "T-chart" with two columns labeled "What do we already know?" and "What would we like to know?" can be a useful tool for generating questions in a large group. After compiling a list of questions on the chart, you can go through the list of "would like to know" questions and evaluate each one's potential as an investigation question. Groups can then select one of the class-generated questions or come up with a new question on their own.

- Another way to start student ideas flowing is to lead the class in creating a concept map or web of related terms. Begin by writing a key term such as *sound*, *heat*, *plant growth*, or *community* in the center of the board and drawing a circle or box around it. Students can then brainstorm related concepts, which may be attached to the key term or form other branches. After all ideas have been exhausted, the class can generate a list of investigation questions based on this map.

- Sometimes students are tempted to recreate science "experiments" that they have seen on television or heard about, asking for example, "How can you form a cloud in a jar?" We have found that activities like these, which are actually science demonstrations with specified procedures, do not make good student-designed investigations. Students will learn far more about inquiry processes, such as collecting and analyzing data, if they design their own procedures for a topic they want to learn more about. You may want to discuss the difference between a demonstration, which illustrates something that is already known, and an investigation, which gathers new information.

- Many students will think of good questions that can be answered by descriptive investigations (What kinds of invertebrates live in the soil besides worms? What will the height of the plants be by the time they have flowers?). Descriptive investigations have just as much potential for science learning as experimental investigations. Encourage students to generate both descriptive inquiry and experimental inquiry questions.

- The best inquiry questions are (1) feasible within the limits of classroom time, space, and resources; (2) genuine in the sense that students do not know the outcome prior to conducting the investigation; (3) authentic in the sense that they draw on the students' real-world knowledge (What species of plants are on our school grounds?); and (4) have potential to develop important science concepts (How will plants grown with fertilizer be different from plants grown without fertilizer?).

- Experiments can be thought of as trying to find potential differences between two groups that are different in only one way. When helping students generate experimental questions, it is important to have students completely clarify what will be different about the groups and what will be kept the same (manipulated and controlled variables). When discussing this concept with students, explain the idea of a "fair test"—keeping all variables the same except one. Experimental inquiry questions can be sharpened by asking students to verbalize what it is they are interested in comparing.

Because most students have never attempted to ask investigation questions or design their own experiments before, they may find it challenging at first. Fortunately, the excitement that goes along with conducting original investigations will carry them over the rough spots. And with practice, students will soon learn to ask excellent questions about the world around them. ❑

Reference

1. American Association for the Advancement of Science. (1993). *Benchmarks for Science Literacy*. New York: Oxford University Press.

What is a Watershed?

"KILLBUCK CARE" NEWSLETTER

Terry Beck
Assistant Professor
Extension Agent, Agriculture
Wayne County

You and Your Watershed

A watershed by definition is a geographic area that contains a common outlet into which water, sediments and dissolved materials drain.

No matter where you live, you are in a watershed. A watershed area many times is also called a drainage basin. In a basin, water drains from the higher areas of the basin land area to the lower land areas. This water that drains into the lower part of the basin generally concentrates into a wetland, stream, river or lake.

A watershed knows no boundaries except its own. That means it knows no political, land use or ownership boundaries. Your watershed may be made up of farmland, suburban development, industry and or urban areas. All the people and animals that live in the watershed can have an impact on the water quality in nearby wetlands, streams, rivers and lakes.

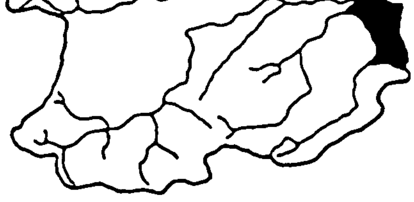
Everyone should be aware of their daily activities and how they might impact the watershed they live in.

Understanding how these activities can impact water quality in a watershed is the first step to watershed awareness.

How is the water quality affected in a watershed?

Everyday activities can generate pollutants from such sources as lawns, gardens, construction sites, roadways, septic systems and agricultural areas. From these activities such items as road salt, soil sediment, oils, pesticides, excess fertilizer and other nutrients can be carried by stormwater runoff to nearby ponds, lakes, streams, and rivers.

Many are aware that these pollutants affect the biological balance of a watershed causing algae growth, cloudy water and many times excess weed growth. When such an imbalance occurs, it can negatively impact recreational activities such as boating, fishing, swimming and the like.



More or less water

Many landowners do not realize that changes in land management may affect not only the quality of water but also the quantity of water in a watershed.

For example, when more homes are built, woodlands are cleared or permanent pastures are plowed, water runoff is increased and intensified. Many do not give land changes much thought. Generally, the land use changes occur so slowly that the runoff does not increase rapidly. When excess runoff is noticed is when projects are being completed and there is an abnormally heavy rainfall.

Without natural protective barriers, greater quantities of water enter ditches, streams and ponded areas faster. The result is a higher more rapid water flow, during storm events, which can trigger flooding and the erosion of stream banks. This rapid flow actually carries more water away leaving less for dry weather periods. Obviously, these changes are detrimental to fish and plant life.

The following is a list of practices that will help protect the water quality in your watershed. Notice that it is broken into agricultural rural and urban use.

Remember, all landowners are responsible for and affect the water quality in watershed areas. Take a look at the items listed and see if there is a practice that you can do to help the quality of the water in your watershed.

PRACTICES THAT PROTECT WATER QUALITY IN YOUR WATERSHED

For agricultural areas:
- Farming on the contour
- Using conservation tillage
- Rotating crops
- Installing grassed waterways
- Catching runoff from animal lots with vegetative filter Strips
- Retiring highly erodible cropland
- Practicing sound pesticide and fertilizer management
- Establishing buffer strips between land in production and water bodies
- Checking and maintaining septic systems, ensuring properly cased wells
- Handling and applying animal waste appropriately
- Restricting livestock from riparian areas

FOR RURAL AND SUBURBAN AREAS:
- Maintaining vegetative (plant) cover or a tree canopy to reduce erosion
- Mulching gardens and exposed soil
- Directing runoff from roof-tops through downspouts to grassy areas
- Minimizing paved surfaces
- Protecting soil disturbed during construction
- Maintaining natural vegetation or planting vegetation to form a buffer zone along the water's edge
- Checking and maintaining septic systems
- Using no-phosphate soaps and detergents
- Collecting and recycling used oil
- Disposing household waste properly

151

Written and edited by
Kay Addington-MacDonald and Tim Gates

Illustrations by Nikki McClure

Production and printing funded by:

WASHINGTON STATE DEPARTMENT OF ECOLOGY

KEY BANK
Washington
Waters
Fund

Published by and for Washington Coastweeks

WASHINGTON COASTWEEKS

Printed on recycled paper.

WASHINGTON COASTWEEKS

THE WAYS OF WATER

TOUR GUIDE

tips and hints

for touring your watershed

1 Start in a small area close to home. You don't have to follow the sequence of this tour guide, but do visit all the areas identified.

2 Share your discoveries! Explore with your family and friends.

3 Stay in public areas or ask permission to go on private land. Always obey posted signs.

4 Take along maps, or draw your own maps as you go.

5 Dress for the weather and bring along some drinking water.

6 Get up close. Get down on your hands and knees. Feel, sniff and listen. Inspect under logs and rocks, then leave them as you found them.

7 Have fun!

explore your watershed!

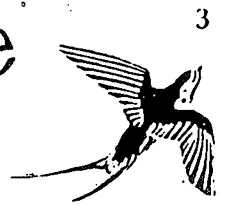
This booklet is a tour guide to help you explore your watershed. Watersheds are defined as the land area drained by a particular stream. So, if you live on land, you live in a watershed! Within your watershed, water travels from rain to the ground, past your house, into the nearest stream or lake, and finally into Puget Sound or the Pacific Ocean.

We all use the water that flows through our watershed. We need to keep it clean for drinking, cleaning, cooking, and taking baths. Without clean water, we couldn't have gardens or farms, or cool places to play on hot summer days. Fish and wildlife need clean water, too.

The first step in protecting your watershed is to get to know it. This guide will help you and your family explore some of the ways of water in your neighborhood and beyond.

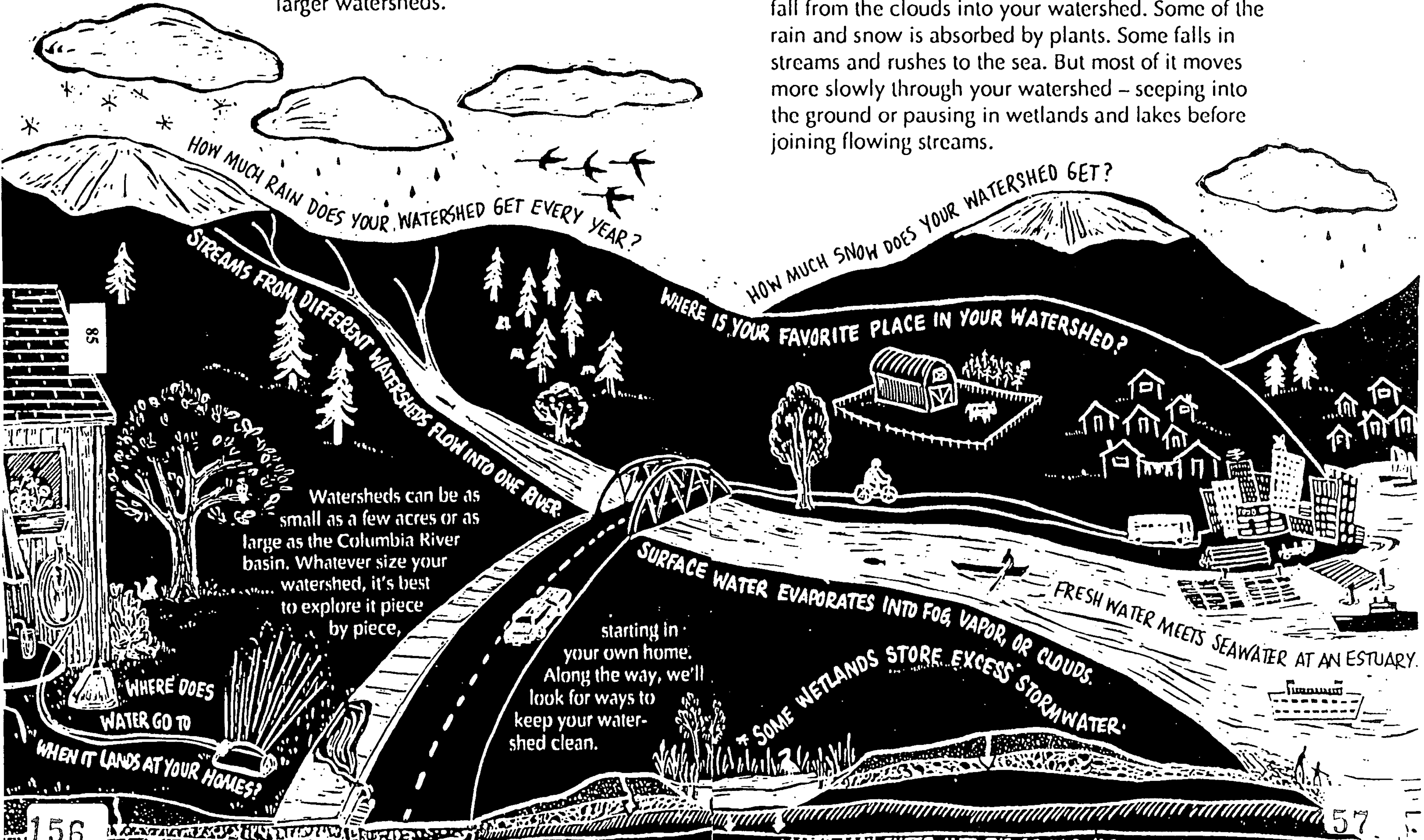
First, let's take a look at how watersheds work.

Watersheds and the water cycle



A watershed is the entire land area drained by a stream or river. The borders of watersheds are called "divides", because they divide up the water's flow. In the gently sloping terrain where most people live, divides may be hardly noticeable. Many small watersheds contribute to larger watersheds.

Water moves through a watershed in a never-ending cycle. Water in oceans, lakes and rivers is heated by the sun and evaporates into clouds. Rain and snow fall from the clouds into your watershed. Some of the rain and snow is absorbed by plants. Some falls in streams and rushes to the sea. But most of it moves more slowly through your watershed – seeping into the ground or pausing in wetlands and lakes before joining flowing streams.



Watersheds can be as small as a few acres or as large as the Columbia River basin. Whatever size your watershed, it's best to explore it piece by piece,

starting in your own home. Along the way, we'll look for ways to keep your watershed clean.

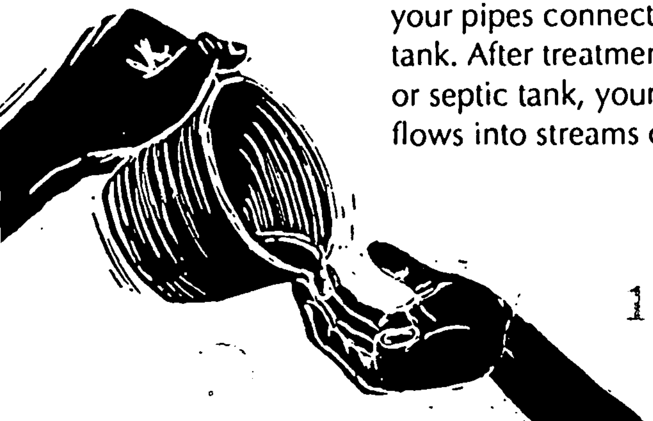
watersheds in your home

Start your tour in the kitchen.

To understand watersheds, start at your kitchen sink. Think of your sink as a watershed. The sides are the divides that make the boundaries. They "shed" water. All the water inside falls down into the same basin and through the same drain. Two sinks side by side make neighboring watersheds.

Cup your hands and pour water down your fingers into your palm. Your fingers are like the ridges of a hill or mountain. Water drains from them like streams running through a watershed. It meets in the cup of your hand the way streams meet in a lake. One large watershed can contain many smaller watersheds, like your cupped hands inside the sink.

In a way, your house is a watershed. The pipes that carry your water are the rivers and streams of your household watershed. In cities, your pipes are connected to pipes from your neighbor's houses and your water ends up in a sewer treatment plant. In the country and some suburbs, your pipes connect to a septic tank. After treatment in the plant or septic tank, your treated water flows into streams or bays.



watershed housekeeping

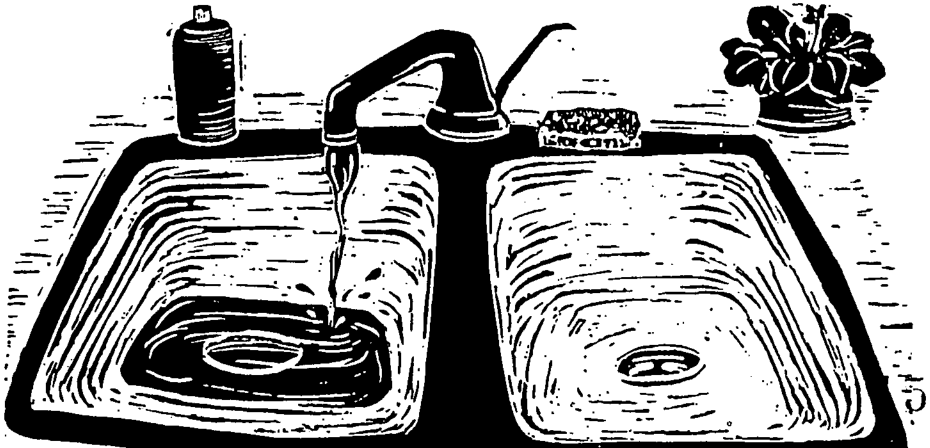
Does the water flowing from your house contain hazardous waste? Many kinds of chemical cleaners, solvents, and paints can end up killing fish downstream because sewer systems can't treat them.

One of the best ways to protect your watershed is to use safe alternatives to toxic substances and harmful pollutants. Here are some examples.

Instead of:	**Use a non-toxic substitute:**
Drain cleaners	Pour 1/4 cup baking soda, followed by 1/2 cup vinegar into clogged drain. After 10 minutes, rinse with a pan of boiling water.
Bleach	Use borax, oxygen bleaches, or the sun, if you can find some.

(Helpful tip: Call 1-800-RECYCLE and ask for a free list of alternatives to household hazardous substances.)

Now go outside to explore your neighborhood.



neighborhood watersheds

Look around your yard and block. You live in a neighborhood inside the borders of a larger watershed.

Look for the highest points you can see – roofs, ridges and hills. They are the divides that guide rainfall and running water in your neighborhood.

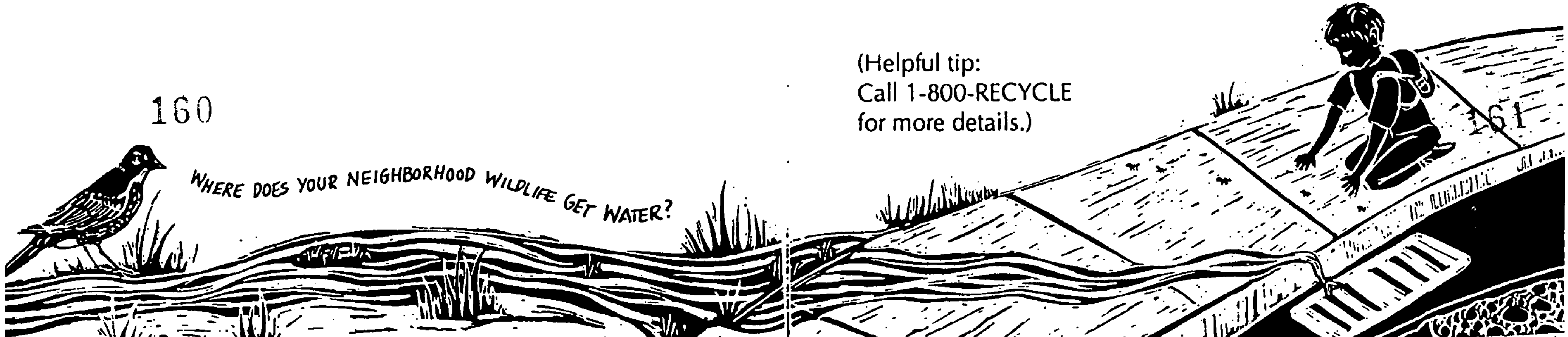
Look for hard surfaces – places where water runs off roofs, parking lots, car tops, yards and streets. Water that doesn't soak into the ground usually flows into rectangular storm drains. Hard surfaces send rain into these drains very quickly, which can cause floods downstream. Trees, shrubs and lawns help slow the path of water.

In most Washington cities, water that flows into storm drains doesn't get treated on its way to streams or bays. So everyone in your neighborhood watershed needs to help keep pollutants out of the path of running water!

Here are some tips to keeping neighborhood pollution out of your watershed.

- Wash your car on your lawn so soap doesn't rush into storm drains.
- Change oil carefully so it doesn't end up on the ground. Dispose of waste oil at local recycling centers. Many gas stations and tune-up services collect waste oil.
- Apply only the correct amount of fertilizers so excess doesn't run off.
- Call your local Washington State University Cooperative Extension office for alternatives to landscaping chemicals such as herbicides, pesticides, and slug bait.
- Stencil your neighborhood storm drains with the message "Dump no waste, drains to stream."

(Helpful tip:
Call 1-800-RECYCLE
for more details.)

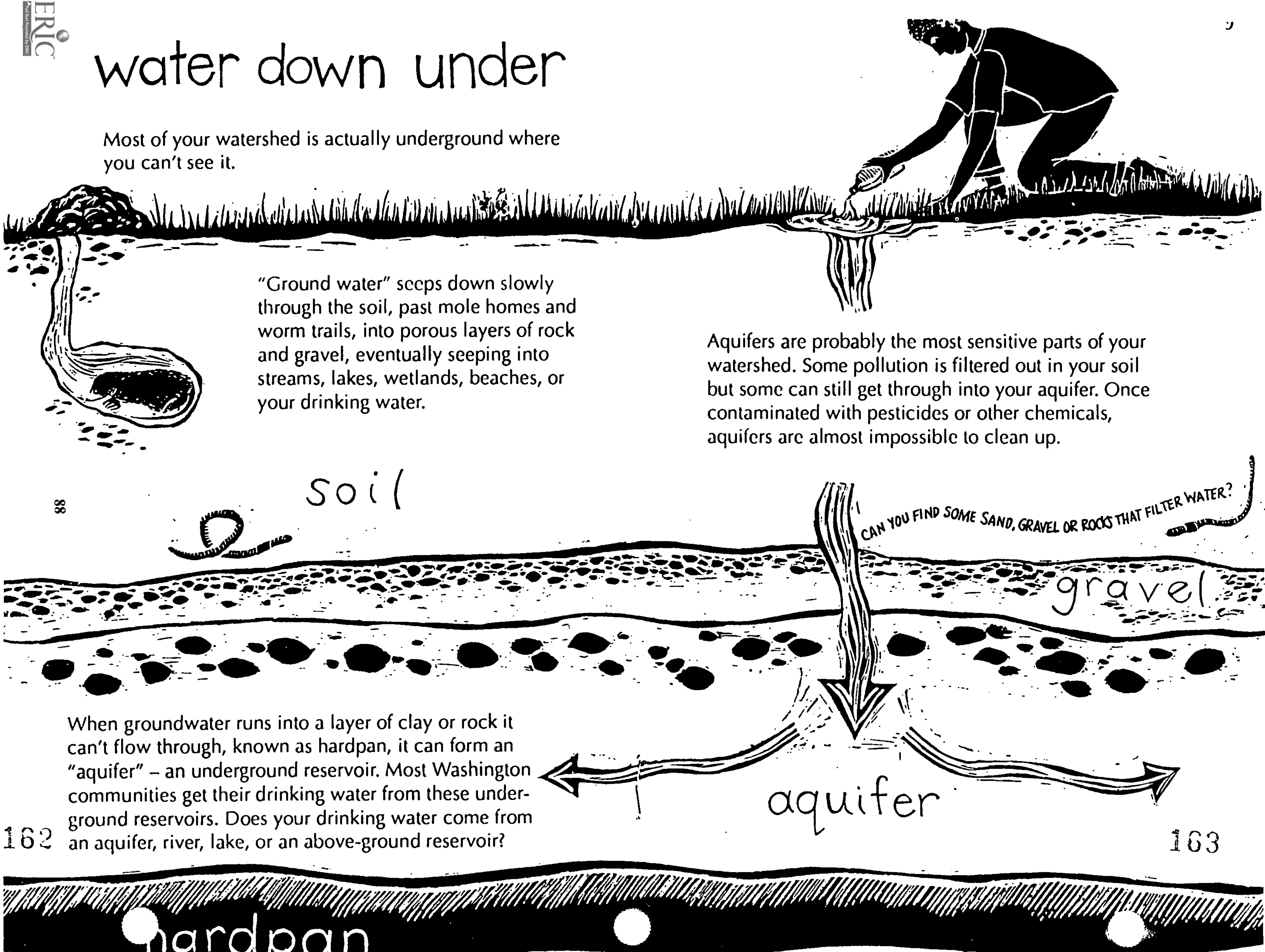


water down under

Most of your watershed is actually underground where you can't see it.

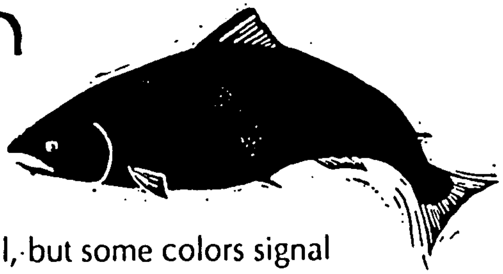
"Ground water" seeps down slowly through the soil, past mole homes and worm trails, into porous layers of rock and gravel, eventually seeping into streams, lakes, wetlands, beaches, or your drinking water.

Aquifers are probably the most sensitive parts of your watershed. Some pollution is filtered out in your soil but some can still get through into your aquifer. Once contaminated with pesticides or other chemicals, aquifers are almost impossible to clean up.



When groundwater runs into a layer of clay or rock it can't flow through, known as hardpan, it can form an "aquifer" – an underground reservoir. Most Washington communities get their drinking water from these underground reservoirs. Does your drinking water come from an aquifer, river, lake, or an above-ground reservoir?

streams, rivers, and salmon



Streams and rivers are the central connecting elements of your watershed. Your largest watershed is usually named for the river that drains it; smaller watersheds are named for their largest stream.

Getting to know your local stream takes time and patient observation. Find all the public access spots to your stream and visit during different times of year. As you learn about how your stream works, you'll find many ways that humans can help or harm it.

Is your stream clear or cloudy?
Cloudiness is often caused by fine particles of soil suspended in the water. Even riding a bike through a stream can stir up loose soil. This loose soil, called sediment, can clog the sensitive gills of fish and cover up the gravel beds that salmon need to lay eggs.

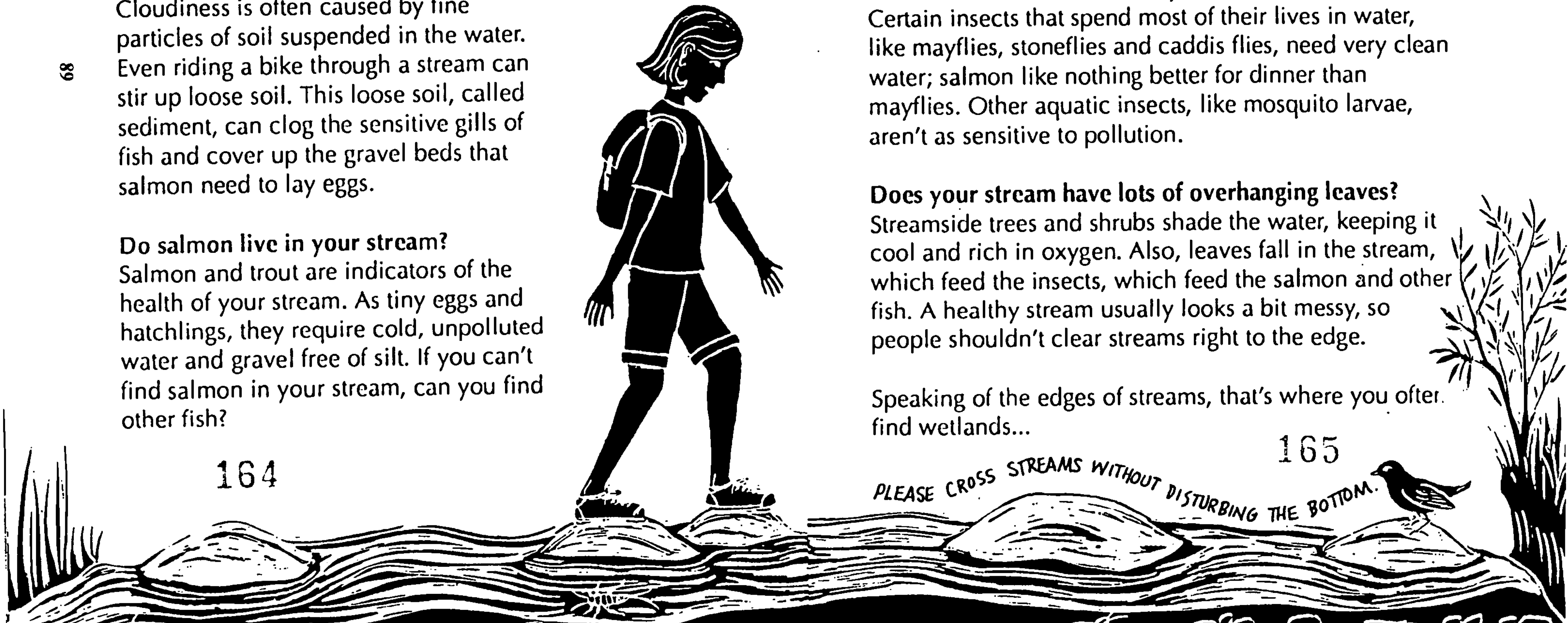
Do salmon live in your stream?
Salmon and trout are indicators of the health of your stream. As tiny eggs and hatchlings, they require cold, unpolluted water and gravel free of silt. If you can't find salmon in your stream, can you find other fish?

What color is your stream?
Some color in streams is natural, but some colors signal that pollutants are present. Greenish color can result from algae blooms fed by lawn fertilizer. If lots of algae are using up oxygen in the stream, there is less for oxygen-loving salmon and trout. Foam could have come from people washing cars on hard surfaces. A multi-colored oily sheen could be from roads where oil or gas spilled.

What kinds of insects live in your stream?
Certain insects that spend most of their lives in water, like mayflies, stoneflies and caddis flies, need very clean water; salmon like nothing better for dinner than mayflies. Other aquatic insects, like mosquito larvae, aren't as sensitive to pollution.

Does your stream have lots of overhanging leaves?
Streamside trees and shrubs shade the water, keeping it cool and rich in oxygen. Also, leaves fall in the stream, which feed the insects, which feed the salmon and other fish. A healthy stream usually looks a bit messy, so people shouldn't clear streams right to the edge.

Speaking of the edges of streams, that's where you often find wetlands...



wetland walk

Next, visit some wetlands in your watershed. A wetland can be the edge of a stream, pond, or lake, or even a soggy field. You can usually tell it's a wetland by its wetness and mud, but it might not be wet year round. Look for places where plants like cattails, skunk cabbage, rushes or willows grow. Do you see signs of seasonal changes in water level?

Search for signs of animals – can you find tracks, trails, bones, feathers, nests and nibbled leaves? Sit still and listen. Wetlands are great places to see birds, mammals, amphibians, and reptiles.

Notice how far the wetland's edge is from the nearest road, building, yard or farm. This land in between is called the buffer zone. The ground in this zone helps filter and clean water draining off neighboring lands. Wetland animals nest, feed and hide here.

Even the smallest wetlands in your watershed are important. They help prevent floods by storing water and releasing it slowly into streams. Also, some wetland plants absorb certain nutrients and poisons, serving as a protective filter for groundwater.

Now let's go to a final destination of the water in your watershed...

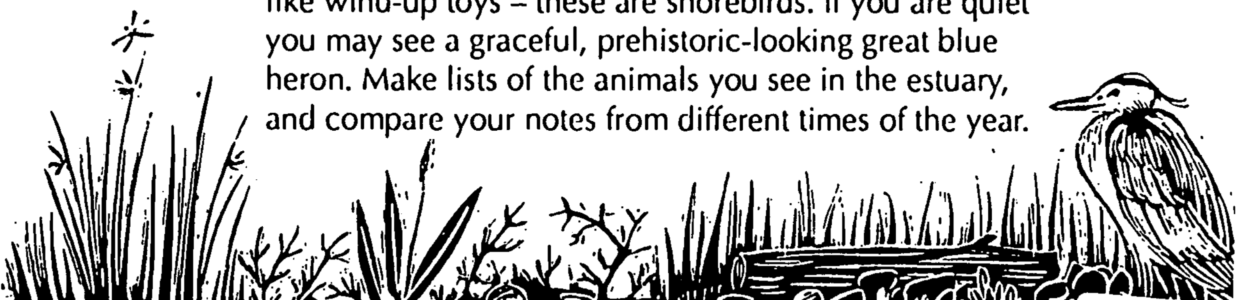
seashore stroll

"Estuaries" are where fresh water meets salt water, where the central river or stream of your watershed flows into a place like Puget Sound, Hood Canal, Grays Harbor, or Willapa Bay.

If all the water draining from the watershed is unpolluted, all the good nutrients gathered along the way settle in the estuary, like the rich, yummy slurry at the bottom of a cup of chocolate milk. These nutrients are small pieces of plants, dead bugs and other natural stuff; lumped together it is called "detritus." Detritus is great food for wildlife, but only if pollutants have not been mixed in along the way.

To explore your estuary, go to a beach or tide pool at low tide. Turn over rocks to find out what lives underneath. Then return the rock to its place, topside up. Carefully dig holes to find worms, crabs and clams. If you put them in a clear plastic container you can watch how they filter water and sand to get food. When you put them back in their holes watch how they bury themselves. Please remember to cover your holes afterward.

What other kinds of animals can you find in the estuary? Look for little birds at the water's edge that scurry around like wind-up toys – these are shorebirds. If you are quiet you may see a graceful, prehistoric-looking great blue heron. Make lists of the animals you see in the estuary, and compare your notes from different times of the year.



people in your watershed

Now that you've begun to explore your watershed, take another look at how your community fits in. Investigate ways people have changed your watershed. You'll need to visit libraries, museums, and cultural centers, or talk with people who have lived in your watershed a long time. See if you can answer these questions:

What kinds of jobs do people have in your watershed today?

How did people make a living here fifty years ago?

How about 100 years ago? 150 years ago?

How has transportation changed your watershed? List all the ways people get around in your watershed today.

How did people move through your watershed 100 years ago? 150 years ago?

living in your watershed

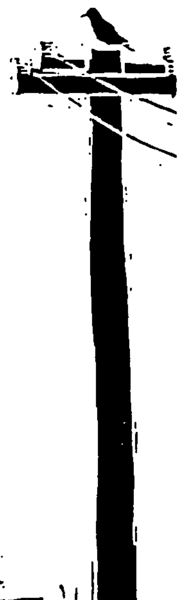
List three things you enjoy doing in your watershed:
(Examples are fishing, biking, going to an ice cream store, digging clams, shopping, watching wildlife.)

1.
2.
3.

List some things you would like to do in your neighborhood watershed but can't:
(For instance, harvesting shellfish or fishing in streams may not be recommended in parts of your watershed.)

1.
2.
3.

Does your city or county government have a plan to preserve the health of your watershed?
What's being done to put the plan to action? You can find out and get involved by contacting your planning department.



Watershed caretakers

Take time to appreciate your place in the watershed.

Make a family plan to take care of water in your home, your neighborhood, your watershed.

Write down things you will do to keep your watershed and its water clean. For example, you could decide to use safe alternatives to hazardous household products, or join a local stream monitoring group.

Choose things you know you will follow up on.
As you learn more about protecting your watersheds, make your list longer.
Share your list with friends.

1.

2.

3.

4.

5.

learn more about the ways of water

Each person who lives in a watershed makes choices everyday that effect the health of the watershed. You can make a difference, if you know how.

To explore your watershed, join in Coastweeks events near you during the month of September. Every year, 200 activities are offered to help you explore the ways of water. For a Coastweeks Journal of Events, call 1-800-424-4EPA beginning mid-August.

For alternatives to household hazardous products, call the Department of Ecology at 1-800-RECYCLE.

For information on protecting Puget Sound, call the Puget Sound Water Quality Authority at 1-800-54SOUND and ask for a a list of free publications.

To learn how kids can help keep the Puget Sound watershed clean, join Kids for Puget Sound at 1-800-PEOPLE2.

To learn about streams and how you can monitor and protect your local stream, join Adopt A Stream. Their number is 1-206-388-3487.

For information on wetlands, send a postcard to Department of Ecology, Wetlands Section, PO.Box 47690, Olympia, WA 98504-7690, and ask for a free list of wetlands education materials.

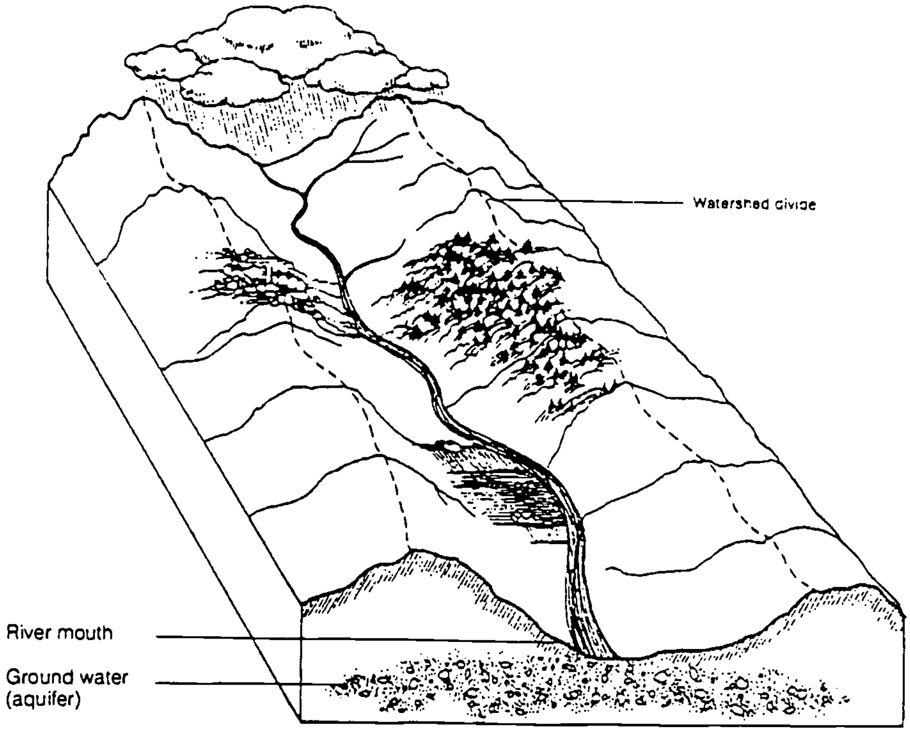
For tips on protecting water quality around your home or work, contact your local county Cooperative Ex ion office.

What Is a Watershed

Do you know your watershed address? No matter how far you live from a river or lake, you always live—indeed everyone—lives in a watershed. However, unless you tried to manage where and how water flows across the land, you may not have noticed. A watershed is an area of land from which all the water drains (runs downhill) to the same location such as a stream, pond, lake, river, wetland, or estuary.

A watershed can be large, for example, the Mississippi River drainage basin, or very small, such as the 40 acres that drain to a farm pond. Large watersheds are often called basins and contain many smaller watersheds. How you characterize your watershed depends on what you want to do. If a small lake that serves as your community's drinking water supply is threatened by pollution, you will need to define (and manage) a much larger watershed than if your goal is to protect a 20-acre wetland site that the school uses for an outdoor classroom.

What a Watershed Is



Source: Puget Sound Water Quality Authority.

"Clean water in your watershed: A citizen's guide to watershed protection, **copyright 1993 by Terrene Institute, Alexandria, VA."**

CITIZEN ACTIONS Take a drive or walk across town, around the block, or across the farm. See if you can discover how and where water drains. Find the creek at the bottom of the hill and follow it to a larger stream. Observe what happens to the water, to the streambanks, to the land and plants that surround the creek as the water speeds up or slows down. Once you have "sensed" how water flows across the landscape and how varied the landscape can be in just a short distance, you will not only have a more valid appreciation of the task ahead; you will also be a more valuable member of the watershed team.

173

How to Delineate a Watershed

Understanding A Contour Line

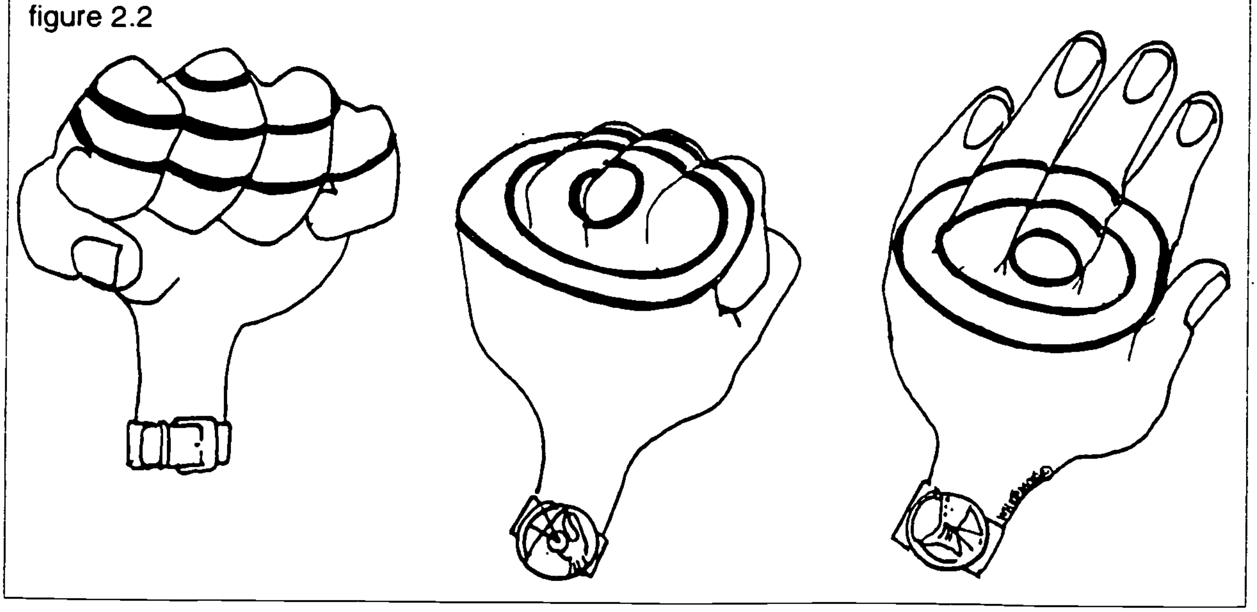
Maps are flat, but the areas they represent are filled with hills, valleys, mountains and plains. Contour lines represent points of equal elevation. The lines allow mapmakers to show the "lay of the land" very clearly. The following exercise will help those of you who have a hard time seeing three dimensions on a flat map. It is taken from the 1990 Boy Scout Handbook, which also has great tips on other vital Streamkeeper mapping skills, like how to use a compass.

"To understand how contour lines work, make a fist with one hand. A fist has width, length, and height, just like the land. With a water soluable pen or magic marker, draw a level circle around your highest knuckle. Draw a second circle just below that one. Start a third line a little lower. Notice that to stay level, the pen may trace around another knuckle before the third circle is closed. Continue to draw circles, each one beneath the last. Lines will wander in and out of the 'valleys' between your fingers, over the 'broad slope' on the back of your hand and across the 'steep cliffs' above your thumb. After all the lines are drawn, spread your hand flat. Now it has only width and length, just like a map. But by looking at the contour lines you can still imagine the shape of your fist. Small circles show the tops of your knuckles. Lines that are close together indicate steep areas. Lines farther apart show the more gentle slopes of your hand. The contour lines of a map represent terrain in the same way. Small circles are the tops of hills. Where the lines are far apart, the ground slopes gently. Where they are close together, a hillside is steep."

Take this exercise a step further. Repeat the procedure with your other hand. Putting your two fists side by side demonstrates the boundaries of a watershed. You will have two high areas or ridges, with a valley in between. The bottom of the valley is where you would expect to find a stream.

Understanding how the contour lines represent valleys and ridges may be the most challenging thing about reading topo maps. Contour lines that represent a valley or depression usually are V- or U-shaped, with the tips of the V's pointing toward higher elevations. Lines that show a ridge are also shaped like V's or U's, but the tips point toward lower elevations. Water flows through the valleys perpendicular to contour lines.

figure 2.2



t (and artwork) provided courtesy of the Adopt-A-Stream Foundation From *The Streamkeeper's Field Guide*, all rights reserved.

Determining the Boundaries of Your Watershed

1. Locate the outlet point of your watershed. It will be the lowest elevation in your watershed and in most cases will be the mouth of your stream.

2. Trace the stream from its mouth to its tributaries. Using a pencil, make marks along the stream and its tributaries every inch or so, dividing them into one inch sections.

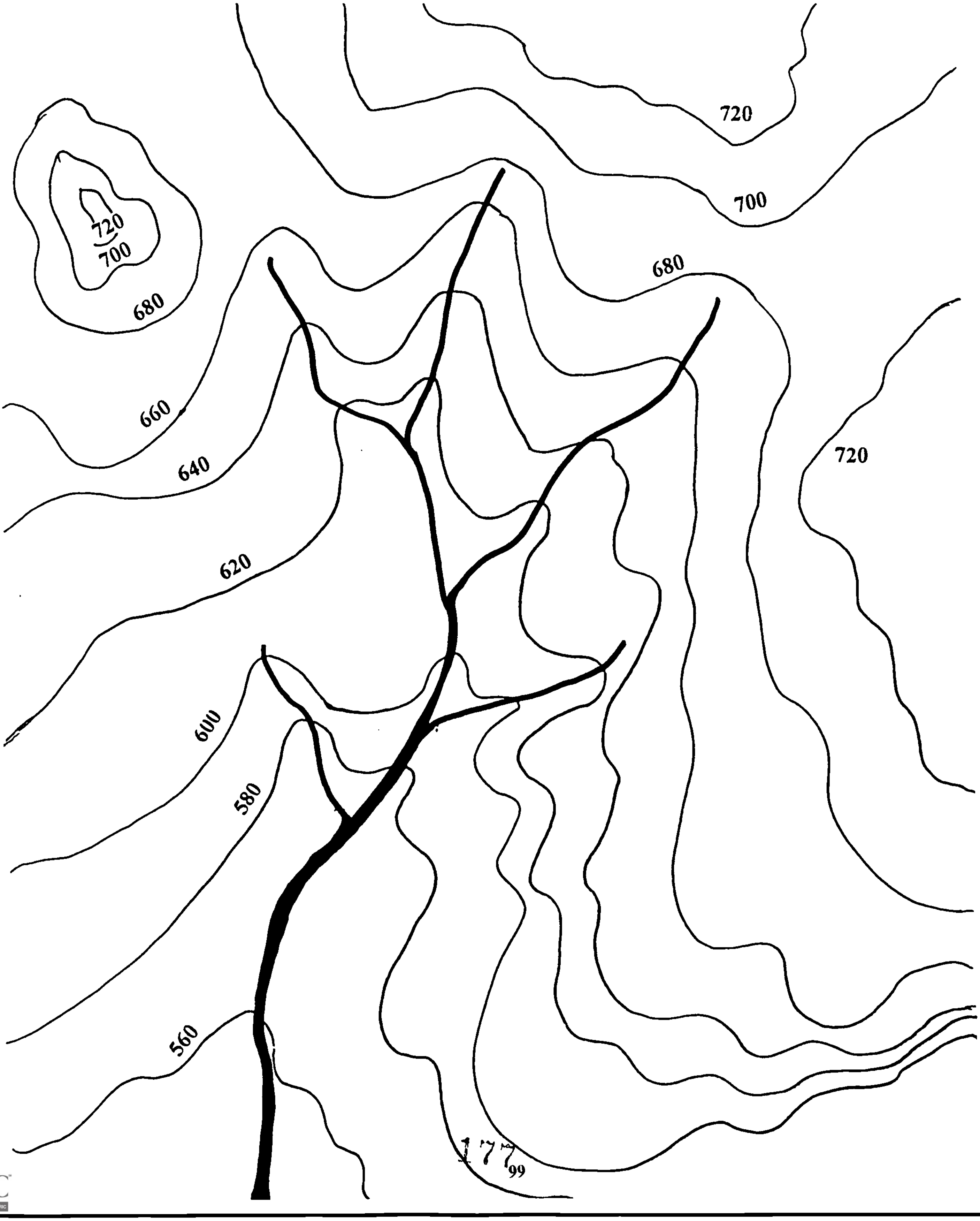
3. At each mark, draw a line perpendicular to the stream or tributary, running out in both directions.

4. Follow each line out from the stream or tributary until you reach a maximum elevation. Mark all these high elevations with an "X."

5. Locate the beginning of each tributary or the place where the stream's water originates. Extend a line out from each of these locations, in the direction opposite to the flow of water. Follow these lines until you reach a maximum elevation. Mark the high points with an "X."

6. Connect all the high points with a line, following ridges and crossing slopes at right angles to contour lines. The line resulting from "connecting the dots" will be the boundary of your watershed. Double check your boundaries to ensure accuracy, and then mark them with a pen or magic marker.

Determining the Boundaries of a Watershed: Practice Map



Investigating
a
Watershed

178

A LESSON PLAN FOR MEASURING SOME ASPECTS OF WATER QUALITY

Note to Facilitators: In selecting a site consider safety, accessibility, presence and variety of aquatic life, room for several small groups to work, and room to measure stream flow.

Set the stage for this investigation by reviewing quickly what will take place in the allotted time. For example: “During this investigation of a water environment we will gain some new skills in investigating, become more aware of the importance of water and how we can improve the way water is used and managed.”

Before the session you might want to read the behavioral objectives at the end of this lesson plan. Refer to them as an evaluation of the session.

I. DETERMINING WATERSHED BOUNDARIES

Questions and discussion:

1. What is your definition of a watershed? Accept all comments.

Working in groups of three or four develop group definitions of a watershed.
Distribute maps of the area, one per person, and Task Card A.
Do Task A. (15 minutes)

TASK A: Work in small groups. Use your definition of a watershed.

Find this creek (pond, lake) on the map. Find your location.
Where does the water come from? Trace upstream to its source.
Draw lines around the boundaries of our watershed. We’re in the ___________watershed.

II. OBSERVING THE WATER ENVIRONMENT

As you approach the water, distribute Task B Cards. Assign and do Task B. (10-15 minutes)

TASK B: Work by yourself or in small groups.

As you approach the water, observe and record your observations about the stream environment:
(use all your senses)

plants______________________________

animals______________________________

air______________________________

rocks______________________________

water______________________________

Pager, J. (1993). Teaching Materials for Environmental Education: Investigating Your Environment: A Process Approach. Portland, OR: U.S. Forest Service.

Questions and discussion:

1. What did you notice about the surrounding environment?
2. What did you notice about plants? Air? Rocks? Animals? Other?
3. What differences were there in different locations?

III. OBSERVING AND COLLECTING AQUATIC LIFE

Questions and discussion:

1. What are some factors that affect the lives of animals in water?
2. Where would you expect to find animals in a water environment?
3. How can we be sure to get as many different kinds of animals as possible?

Discuss what to do with animals to keep for observation, rocks that are overturned, and what to do with animals when the session is over.

Assign Task C. (30-40 minutes)

TASK C: Work by yourself or in groups.

Using collecting equipment (screens, jelly cups, etc.), collect as many types of aquatic animals as possible. Put them in the white pans for observation by the group. (Keep the pans in a cool place.)

Note to Instructor: Go from group to group to see how they're doing. At the end of the allotted time reassemble the group.

IV. IDENTIFYING AND RECORDING AQUATIC ANIMALS

Distribute Task D Cards. Do the Task. (20-30 minutes)

TASK D: Work by yourself or in groups.

Using the "Golden Nature Guide Pond Life" books or similar field manuals and attached picture keys, generally identify the specimens you found.

List or sketch the animals you found below.

Description of where found	Type (name or sketch)	No.	Name

Return animals to water as soon as finished.

180

Questions and discussion:

1. What animals did you find?
   Compile a group list, (preferably on a chart). Each person should record the group list on his own work sheet, (Task D).
2. Where did you find most of the specimens?
3. What similarities and differences are there among the specimens?
4. What could we do with this list of animals?
5. How could we classify the aquatic animals we found?
6. What other life would you expect to find in this stream?
7. Would we be likely to find the same specimens in a different aquatic environment? Why or why not?

V. PREDICTING WATER CHARACTERISTICS FROM AQUATIC ANIMALS FOUND

What were some things we said affected the lives of aquatic animals? (Review earlier discussion.)

Assign the following task:

Distribute Task E Cards. Task takes 15-20 minutes.

TASK E: Work by yourself.

Based on the aquatic animals you found, and the tables below in the Aquatic Data section predict the following characteristics of this stream:

I predict:
the water temperature will be ________ because ______________________________
the air temperature will be ________ because ______________________________
the pH will be ________ because ______________________________
the dissolved O_2 count will be ________ because ______________________________
Keep these predictions for future use.
Predict air temperature __________

AQUATIC DATA

pH RANGES THAT SUPPORT AQUATIC LIFE

	MOST ACID						NEUTRAL						MOST ALKALINE	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Bacteria	1.0												13.0	
Plants (algae, rooted, etc.)						6.5						12.0		
Carp, suckers, catfish, some insects						6.0			9.0					
Bass, crappie						6.5		8.5						
Snails, clams, mussels							7.0		9.0					
Largest variety of animals (trout, mayfly, stonefly, caddisfly)						6.5	7.5							

Task E:--Continued on next page.

DISSOLVED OXYGEN REQUIREMENTS FOR NATIVE FISH AND OTHER AQUATIC LIFE

	D. O. in parts per million or milligrams per liter
Cold-Water Organisms including (salmon and trout)(below 68° F.)	
Spawning	7 ppm and above
Growth and well-being	6 ppm and above
Warm-Water Organisms (including game fish such as bass, crappie) (above 68° F.)	
Growth and well-being	5 ppm and above

TEMPERATURE RANGES (APPROXIMATE) REQUIRED FOR CERTAIN ORGANISMS

Temperature (Fahrenheit)		Examples of life
Greater than 68°. (warm water)		Much plant life, many fish diseases. Most bass, crappie, bluegill, carp, catfish, caddisfly.
Less than 68° (cold water)	Upper range (55 - 68°)	Some plant life, some fish diseases. Salmon, trout. Stonefly, mayfly, caddisfly, water beetles.
	Lower range (Less than 55°)	Trout, caddisfly, stonefly, mayfly

Questions and discussion:

1. As a group, discuss the range of predictions.
2. What criteria did you use to arrive at your predictions?
3. How can we test out our predictions?

VI. MEASURING AND RECORDING WATER CHARACTERISTICS TO TEST OUT PREDICTIONS

Directions to group:

We can test out the predictions we just made using these kits (Hach O_2 pH Testing Kit or equivalent). Open kit. Mention that instructions are inside lid. There are lots of jobs to be done in testing (clipping, squirting, swirling, dipping, counting, reading, etc.) so make sure everyone in the group has a job to do.

Work in groups of 5-6 people each. Each group take a kit. Send groups to different parts of the stream.

Note to Instructor: It is not necessary to demonstrate the use of the kit. Let the participants read the instructions and learn to use the kit as they collect the data. You should check among the groups as they work and make sure they use the right bottles, chemicals, etc.

Distribute Task F cards. Do Task F. (20-30 minutes)

TASK F: Work in groups of 4-6 people.

MAKE SURE EVERYONE IN THE GROUP GETS INVOLVED IN THE TESTING.

Using the water test kit, determine the water temperature, dissolved oxygen count, and pH of the stream. Also record the air temperature.

Record the data below: Also record predictions from Task E to compare.

Location of water sample (edge or middle of stream)	*Time taken*	*Temperature*				*pH*		*Usable oxygen (ppm)* (mg/liter)	
		Water		*Air*					
		My prediction	*Actual test*	*My prediction*	*Actual test*	*My prediction*	*Actual test*	*My prediction*	*Actual test*

Questions and discussion:

Have each group report the results of their tests to the entire group. Compare results. (A flip chart may be used to display results and preserve for comparison with other group results.)

1. What might account for any differences in results from each group?
2. How did the test results compare to the predictions?
3. Is it necessary to have sophisticated equipment to determine temperature, oxygen, pH, etc.? Why?
4. What can we say about the quality of the water in this stream?
5. What else would we need to know to decide whether or not to drink this water? (Relate back to Task A.)
6. Under what conditions might we expect to get different results than we did today?

VII. MEASURING STREAMFLOW

Questions and discussion:

1. Predict how many people could be supported in their domestic water use by the volume of water available here.
2. What measurements do we need to know in order to determine the amount of water in this stream? Discuss how to make different measurements. Hand out Task Card G.

Distribute cards and do Task G.

TASK G: (45 minutes)

DETERMINATION OF STREAMFLOW

Instructions for collecting and recording streamflow measurements.

a. Measure and mark a 100-foot distance along a straight section of your stream. If you can't find a 100' section, use 25' or 50'. Throw a stick (2 or 3 inches long) in the water above the upstream marker. Record the number of seconds it takes to float downstream between the markers. Record below. Now divide the 100-foot distance by the total seconds it took the stick to float between the stakes. Do this three times and use the average time.

1st measurement 100 ft. ÷ ______________ = ________________ ft. per second.
(distance) (total seconds to float 100 ft.) (number of feet stick floated each second)

2nd measurement 100 ft. ÷ ______________ = ________________ ft. per second.
(distance) (total seconds to float 100 ft.) (number of feet stick floated each second)

3rd measurement 100 ft. ÷ ______________ = ________________ ft. per second.
(distance) (total seconds to float 100 ft.) (number of feet stick floated each second)

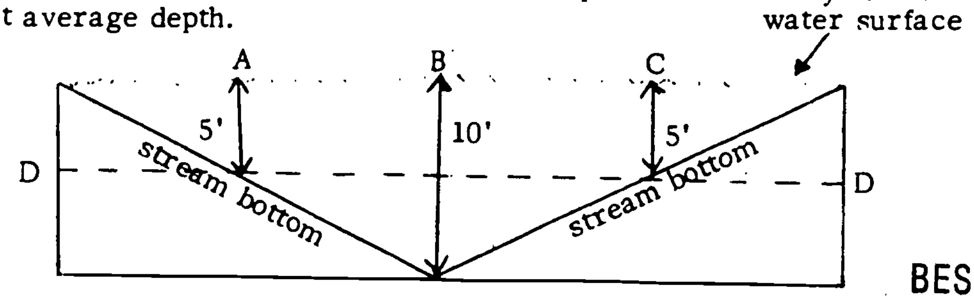
b. Find the average width of your section of the stream. Measure the width of the stream at 3 places within the 100-foot area. Divide the total by 3 to get the average width of the stream.

First measurement ______________ feet.
Second measurement ______________ feet.
Third measurement ______________ feet.
Total ________________ feet ÷ 3 = ______________ ft. (average width)

c. Find the average depth of your section of the stream. Measure the depth of the stream in 3 places across the stream in a straight line. Divide the total by 4 to get the average depth of the stream.

First measurement ______________ feet.
Second measurement ______________ feet.
Third measurement ______________ feet.
Total ________________ feet ÷ 4 = ______________ ft. (average depth)

Note: The reason you take 3 depth measurements then divide by 4 is to take into account the shallow areas of the stream. It can be explained by the following example of a drawing of a stream cross-section. If depth in 3 places is A(5'), B(10') and C(5'), (total 20') find an average by dividing by 3 then 20' ÷ 3 = 6 2/3'. Now look at the mean or average depth (D) which is 5'. Take total of depths and divide by 4. 20' ÷ 4 = 5', the correct average depth.



G:--Continued on next page.

d. Find the cubic feet of water per second. Multiply the average width, average depth, and the number of feet the stick floated each second.

ft.	X	ft.	X		=	
Average width		Average depth		Number of feet per second		Cubic feet of water flowing per second

Note: A cubic foot of water is the water in a container 1 foot wide, 1 foot high and 1 foot long, and contains 7.48 gallons.

In order to find out how many people could live from the water in this stream, complete the following calculations.

	X	7.48	=					
Stream flow in Cu. ft. per sec.		Gallons in 1 cu. ft. of water		Gallons of water per second				
	X	60	=					
Gallons per second		Seconds in minute		Gallons of water per minute				
	X	1440	=		÷	*200 Gals.	=	
Gallons of water per min.		No. minutes in a day		Total gallons water per day		Amount of water one person uses per day		Total No. people who could live from water in this stream

* The average person uses about 200 gallons of water a day for home use. This does not reflect each persons share of water used for industrial, public services, and commercial.

Note to Instructor: If you are short of time you may tell participants that the figure 3231 is the result of the calculation 7.48 x 60 x 1440 ÷ 200. So 3231 can be multiplied by the cubic feet of water per second (d) to give the total number of people the volume of water will support.

Questions and discussion:

1. How many people in a community could live off the water in this stream?
2. How did your prediction compare with your measurement?
3. What would happen to this environment if we piped all the water at this point to a community?
4. If we were going to use some of this water, how much should be left to flow down stream? Why?
5. What might affect the amount of water in this stream?
6. How important is this stream to our (a) community?
7. What are some ways that water is used in our community?
8. What are some inferences we might make about the way water is used in our community?
9. What are some implications about the way we use water now in relation to future long range water needs?

VII. MEASURING VOLUME OF WATER IN A POND OR LAKE (Alternate)

Questions and discussion:

1. Predict how many people could be supported in their domestic water use for one day by the volume of water in the pond.

2. What measurements do we need to know in order to determine the volume of water in this pond?

Hand out Task Card G (Alternate). Do the Task. (45 minutes)

TASK G: (Alternate)

Instructions for collecting and recording volumes of water in ponds and lakes.

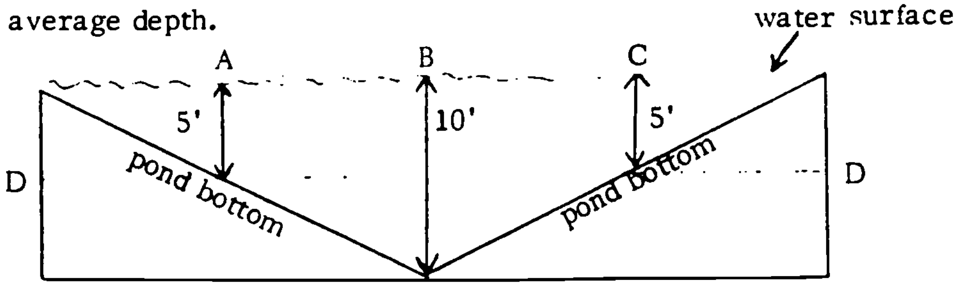
a. Pace length and width of pond to get average diameter in feet. Use the formula 3.14 x radius squared to get the area of the pond in square feet.

Area of Pond or Lake ______________

b. Find the average depth of the pond or lake. Measure the depth in 3 places along a line (transect) across the pond, as near the middle as possible. Add these depths and divide by 4 (see explanation below) to get the average depth. (If additional accuracy is desired, repeat this process along additional transects and average results.)

First measurement ___________ feet.
Second measurement ___________ feet.
Third measurement ___________ feet.
Total ______________ feet ÷ 4 = ______________ ft. (average depth)

Note: The reason you take 3 depth measurements then divide by 4 is to take into account the shallow areas of the pond. It can be explained by the following drawing of a pond cross-section. If depth in 3 places is A(5'), B(10') and C(5'), (total 20') and you find an average by dividing by 3 then 20' ÷ 3 = 6 2/3'. Note that the actual mean or average depth (D) is 5'. Take total of depths and divide by 4. 20' ÷ 4 = 5', the correct average depth.



c. Formula for computing volume.

1. ____________ X ______________ = ______________ Cubic feet
Area of pond   Average depth   Volume in Cubic feet

2. ______________ Cu. Ft. X 7.48 = ______________
Volume in Cu. Ft.   No. Gals. water in pond

Note: A cubic foot of water is the water in a container 1-foot wide, 1-foot high, and 1-foot long and contains 7.48 gallons.

Task G:--Continued on next page. (Alternate)

* * *

ANOTHER FORMULA for computing the volume is with the use of acre feet.

1. ______ X ______ = ______
Area of pond in feet · Average depth in feet · Volume Cu. Ft.

2. ______ = ______ Acre Feet
Vol. ÷ 43,560

3. ______ X 395,900 = ______
Acre Feet · Gal./Acre foot · No. Gallons

* * *

d. In order to find out how many people could get their domestic needs for one day from the water in the pond, complete the following calculations.

______ ÷ *200 gals. = ______
Gallons of water in the pond · Amount of water one person uses per day · Total No. people who could live one day from this water

* The average person uses about 200 gallons of water a day for home use. This does not reflect each person's share of water used for industrial, public services, and commercial.

Questions and discussion:

1. How many people could live for one day (domestic use only) off the water in this pond?
2. How did your prediction compare with your measurement?
3. What would happen to this aquatic environment if we drained this pond?
4. If we were going to use some of this water, how much should be left to minimize damage to the pond environment?
5. What might affect the amount of water in this pond?
6. How improtant is this pond to our (a) community?
7. What are some ways water is used in our community?
8. What are some inferences we might make about the way water is used in our community?
9. What are some implications about the ways we use water now in relation to future water needs?

VIII. COMMUNICATING FEELINGS, AWARENESS, AND VALUES ABOUT WATER

Distribute Task H Cards. Task takes 10-15 minutes.

TASK H: Work by yourself.

1. Describe in writing how you feel about the aquatic environment at this site:

2. Describe at least one action you can take in your everyday life to help improve the way water is managed:

   (a) in your home: ______________________

   (b) in your community: ______________________

   (c) in your consumer habits: ______________________

3. Describe the benefits of each action in #2.

Summary Questions:

1. What did we find out about water from our investigations today?
2. Why is water important to the ecosystem?
3. How can we summarize our discussions and investigations?
4. What methods and processes did we use in our investigations today? (Use for first group only.)

Behavioral Outcomes in Knowledge:

As a result of this session, you should be able to:

Identify the boundaries of the ______________ watershed on the map provided.

Predict the pH, temperature, and dissolved oxygen count of the stream, using the list of aquatic animals found and the water interpretation charts provided.

Demonstrate ability to test out the above predictions using the water testing kit.

Measure the cubic feet of water per second flowing in the stream, and determine what size community of people could live off the water in the stream.

Describe three ways this stream is important to the surrounding environment.

Behavioral Outcomes in Feelings, Awareness, Values, and Action

As a result of this session, you should be able to:

Describe in writing how you feel about man's effect on the aquatic environment at this site.

Describe at least one action you can take in your everyday life to help improve the way water is managed:

(a) in your home
(b) in your community
(c) in your consumer habits

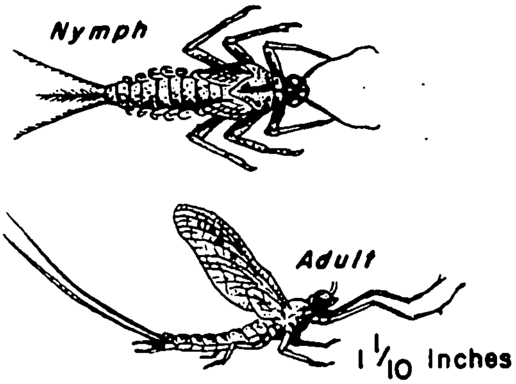
Describe the benefits of each of the above actions.

Equipment Needed: (for a class of 30 people) (two groups of 15)

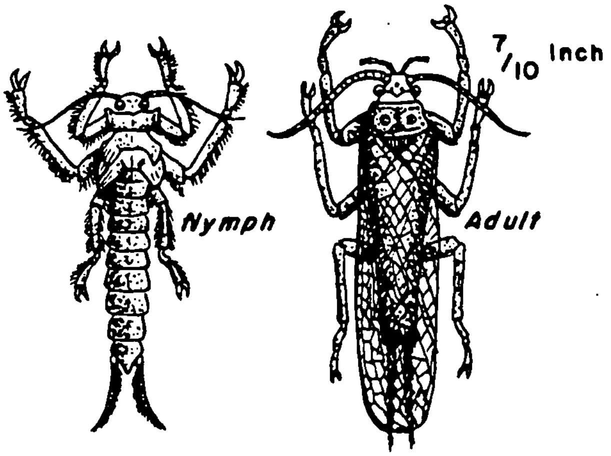
4 water testing kits (Hach Co. or equivalent)
4 thermometers
4 white dishpans
30 sets of lab sheets
30 jelly cups
30 hand lenses
15 Pond Life books (Golden Nature Guides)
30 maps of the area
4 50' or 100' tapes
4 screens (optional)
magic markers
chart paper

** One part per million (ppm) is equal to one milligram per liter (mg/l).

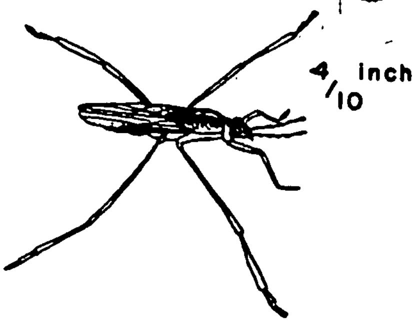
AQUATIC INSECTS



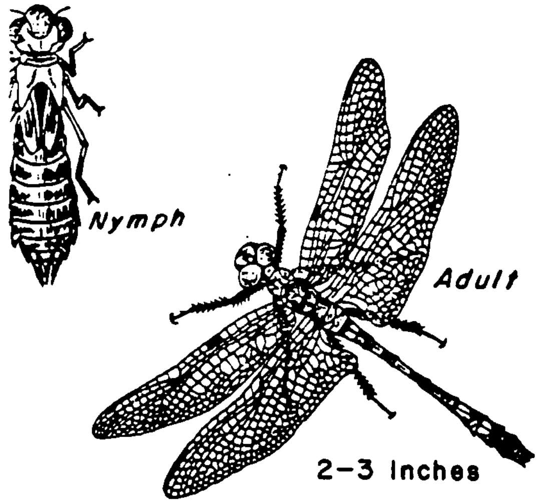
MAYFLY



STONEFLY

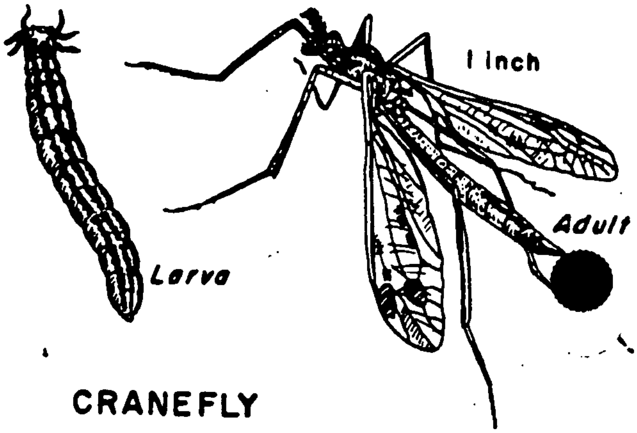


WATER STRIDER

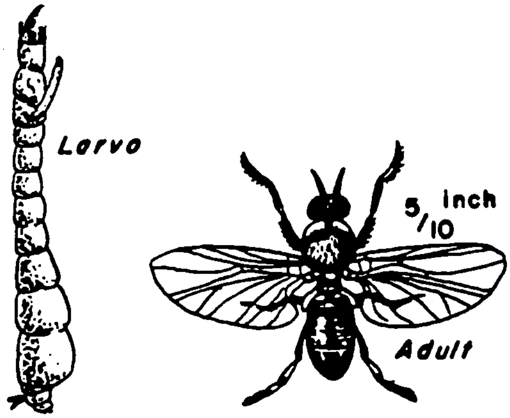


DRAGONFLY

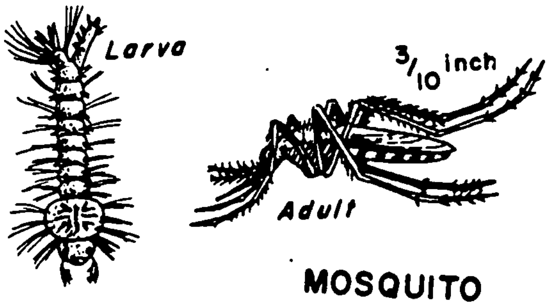
WHIRLIGIG BEETLE



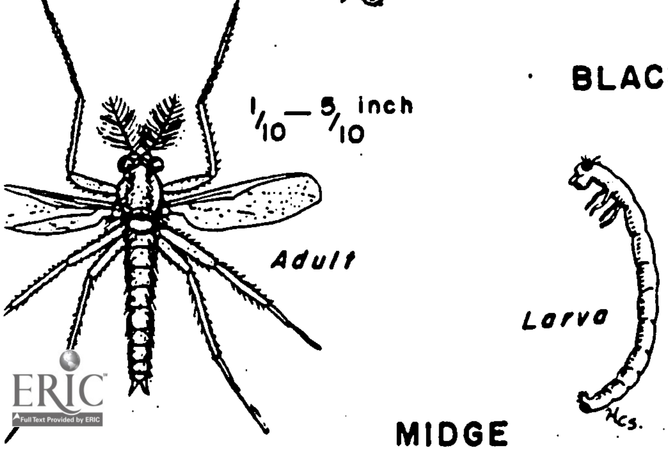
CRANEFLY



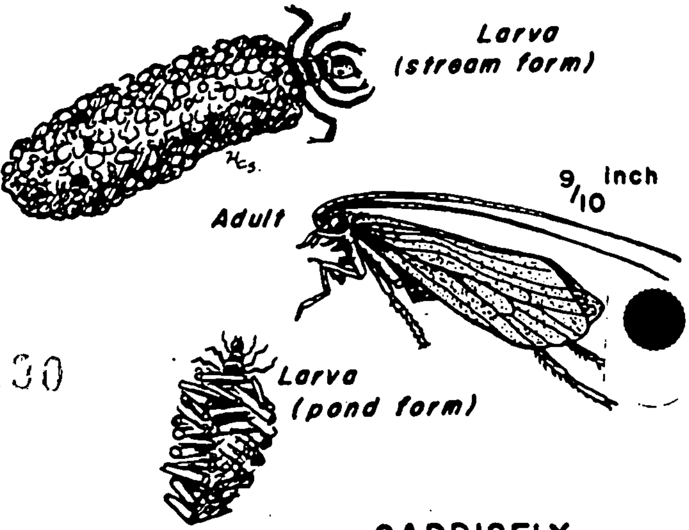
BLACK FLY



MOSQUITO



MIDGE



CADDISFLY

130

Investigating Issues in a Watershed

INVESTIGATING ENVIRONMENTAL ISSUES IN THE WATERSHED

Diane C. Cantrell
Ohio Department of Natural Resources

A major goal of SWEEP is to have learners investigate environmental issues of concern in their local watershed. If you analyze different definitions and discourses on environmental education, you will find that investigating issues and taking informed, responsible action are common elements; although views on when and how this should happen varies among practitioners.

To begin these discussions it is important to differentiate between "environmental problems" and "environmental issues." **Environmental problems** are related to people, the environment and the interaction between the two. **Environmental issues** are *environmental problems* about which two or more parties cannot agree. For example, a flood spilling onto an undeveloped flood plain is usually not considered an environmental problem. If the flood plain is developed, it can become a problem for those people affected if the floodwaters damage property or take human life. It can become an environmental issue if parties disagree about whether future development on the flood plain should be stopped.

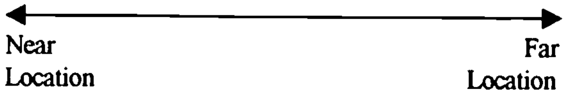
There are several concerns about involving learners in the investigation of local issues and action taking. While young people rank the environment among their top concerns, they tend to be misinformed, often by popular culture and sometimes by well-intentioned educators, about the facts surrounding environmental issues. Assuring that learners are working with the most accurate and current information is critical to any study of a current environmental issue.

Second, it is equally important to examine the issue from diverse perspectives. Learners' limited understanding of the different sides of the issue can further compound their lack of information or misinformation. Realizing that different sides view the issue differently and can present conflicting facts and scientific data demonstrates an understanding of the complexity of many environmental issues.

Third, concerns have been raised about the age-appropriateness of involving young children in investigating issues. Some educators believe that young learners do not have the higher level thinking skills needed to analyze issues. Others fear that it is too great a burden for children to face real-life environmental problems – that instead of children building a sense of wonder about the natural world they may be building a sense of despair about the world.

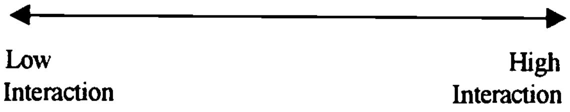
The above concerns are mentioned not to suggest that students should not investigate issues and take action but to emphasize that activities that focus on issues need to be built on a firm foundation of knowledge, skills and positive attitudes. Part of the SWEEP program involves learners investigating local issues. It also encourages learners to take responsible action based upon informed decisions. How this occurs and at what age needs to be determined by the partnership team within the context of the school and community.

How learners become involved in investigating issues in the watershed may vary greatly. The evaluation of one environmental education program (Cantrell, 1990) identified three criteria, explained in the form of three continua, that describe variations in involvement. The first continuum indicates how near or how far away from the classroom the activity occurs in location. The classroom on the one end represents "near." As the continuum progresses, it moves from in the classroom, to outside the classroom, to the whole school, to outside the school, to home, to the neighborhood, to the community on the other end which represents "far."

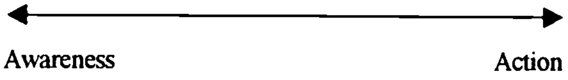


For example, writing a class letter to the local newspaper would be located on the "near" end of the continuum but visiting the local newspaper to interview the editor would be located toward the "far" end.

The second continuum describes the amount of interaction learners have with people in the community. This ranges from "low" interaction such as reading about the mayor or writing to the commissioner to "high" interaction such as circulating petitions or testifying at a hearing.



The third continuum ranges from awareness to action, with the right side representing passive involvement and the left side active involvement.



Students on the "awareness" end may discuss issues but not go beyond that to read information, write to a government agency for materials, or poll the community on its attitudes toward an issue.

Together these three continua provide criteria for describing the extent to which learners in this project were involved in the community as they investigated local environmental issues. As a second part of the evaluation, specific activities conducted by teachers were categorized and placed along a composite continuum ranging from "low involvement" to high involvement." Figure 1 summarizes this analysis. "X" represents the number of teachers who used this approach; each teacher may have used the approach more than once (e.g., one teacher could have taken four field trips).

This study provides one way of looking at learner involvement in investigating issues in the community. As you plan your SWEEP activities, consider the three continua (location, interaction and awareness to action) and decide to what extent your students should be immersed in the watershed and actively involved in analyzing and seeking solutions to local issues.

Cantrell, D.C. (1990). Final evaluation Report for the Southern Highlands Environmental Project. Newark, OH: The Ohio State University

Figure 1

Continuum of Community Involvement

High Involvement

Frequency of Use	Type of Activity
XXXXXX	Implement community action project
XXX	Conduct community study
XXXXXXX	Conduct survey/interview outside of school
X	Attend public hearing
XXXXXXXXXXX	Go on a field trip
XXX	Implement school-oriented action project
XXXXXXX	Do class activities reaching beyond the school
XXXXXX	Involve parents
XXX	Conduct survey/interview inside of school
XXXXXXXX	Listen to guest speaker
X	Write to agency
XXXX	Read and/or watch local media
XXXXXXXXXXXXXX	Do classroom activities/projects

Low Involvement

trell, D.C. (1990). Final evaluation report for the southern highlands environmental project. Newark, OH: The Ohio State University.

SWEEP
ACTIVITY

COMMUNITY INVESTIGATION

Purpose:

This activity uses an inquiry approach to investigate a community and its connection to the watershed and increases participants' knowledge about how their daily activities impact the watershed. It also explores strategies for doing an investigation and use of non-traditional resources.

Materials:

Copies of 3-Stage Data Collecting Chart
Art supplies for making visual aids for group report
Stop watches and time cards for oral reports

Procedures:

1. Divide into groups of 4-5.
2. Your task is to select a topic to investigate within the state park lodge and park area and discover its connections to the watershed. Each group will have a different topic. As soon as your group decides on a topic, write your group's name next to the topic on the list – first come, first served.

Posted Topics
Housekeeping
Grounds-keeping
Food service
Water treatment and sewage
Solid waste disposal
Parking lot and roads
Boating and marina
Camping
Recreation (not including boating or golfing)
Energy
Dam and reservoir
Golf course

3. You will use a *3-Stage Data Collecting Chart* to help you plan your investigations (see example).

Topic: Cultivated Plants In and Around the Lodge
Key Question: How is this topic connected to the watershed?

What we want to find out	How to collect it	How to Record it
• What kinds they use	Observation ID book Interviews	Take notes Tape record
• Why they use these	Interviews	Take notes, Tape record
• Where are they native to	Library research Personal knowledge	Take notes

4. In your small groups, brainstorm as many ideas as you can on your topic using your 3-Stage Chart.
5. Select 1-3 items from Column 1 of your chart and design a sample data collecting and recording device for each item. Data must be:

    - Observable
    - Collectible
    - Recordable

6. Develop a plan of action to conduct your investigation (e.g., who will do what where).
7. You have approximately two hours to conduct your investigation.
8. When you return from doing your investigation, you have approximately 30 minutes to plan your 3-minute group presentation and prepare your visual aids.

    The purpose of the presentation is to report on the investigation **PROCESS**, not on the content of what you found out. Your group report should:

    - Describe what you did and how you did it.
    - Describe how you modified your procedure, methods, recording devices, etc.
    - Complete the sentence: The most important thing we learned about investigating a watershed topic is...
    - Complete the sentence: The most interesting thing we learned about our topic **AND** its connection to the watershed is...

Discussion (after all group presentations are given):

1. As a result of this activity, what did you learn about doing a community study?
2. Based upon listening to all of the presentations, what were some common problems that groups encountered? Unexpected events?
3. What were some of the non-traditional resources and approaches used? What were some benefits of using these?
4. How do this state park and the daily activities that occur here impact the watershed? What, if anything, did you find out that you did not know before?

Adapted from:
Pager, J. (1993). "A Lesson Plan for Investigating a Community" in Teaching materials for environmental education: Investigating you environment: A process approach. Portland, OR: U.S. Forest Service.
Cantrell, D. C., & Barron, P.A. (Eds.). (1994). "Shopping Around a Mall for Environmental Activities" in Integrating environmental education and science: Using and developing learning episodes. Akron, OH: Environmental Education Council of Ohio, PO Box 2911, 44309.

Integrated Approach: How to Develop a Web

Web a Learning Episode Based Upon a Curriculum Model

Some learning episodes are short-term with a specific focus while others are long-term with a very broad focus. When developing the latter, it is particularly helpful to use a holistic planning strategy. For example, the curriculum models presented in the first section, "The Big Picture," are based upon a process known as webbing. When webbing, you use brainstorming to generate a schematic representation of an idea. This product is known as a web.

A web is an excellent planning tool. While it can be used to map out the ideas and skills within a single learning episode, it is also very effective for showing the relationship among a number of episodes which represent a larger piece of the curriculum (i.e., one of the models). Webs are particularly helpful when using an integrated approach.

As with the previous approach, the web should be based upon your course of study, instructional objectives, and the interests and natural curiosity of learners. In addition, it should be broad-based enough to incorporate a rich array of ideas, resources, and learning opportunities but narrow enough for learners to see the interconnections.

No set procedure exists for producing a web. The process, however, lends itself exceptionally well to a learner-centered approach which would involve learners in the entire development process. The following steps are suggested as guidelines for the process:

1. Select a focus based upon a curriculum model—topic, theme, issue, concept, event, person, book, etc.
2. Brainstorm everything that comes to mind in connection with the central focus—i.e., topics, ideas, and questions which explore and extend the focus.
3. Group the ideas into broad categories. Brainstorm and research additional categories or subcategories.
4. Identify interdisciplinary instructional objectives.
5. Identify a rich array of teaching strategies, activities and resources.
6. Develop the "final" web as well as appropriate learning episodes which
    - set the stage and peak interest,
    - introduce the main focus,
    - provide multiple opportunities for learning, and
    - culminate, summarize and extend.
7. Continually revise the web.

On the following pages, an example is provided of a web on winter, "Winter Wonders," which is used here to model the webbing process. The product of each of the steps outlined above are illustrated on pages 130-133.

Once developed, the richness of this type of web allows for multiple ways to implement it depending on purpose, interest, time and other considerations. The leader and/or learners may decide to only implement part of a web or all of it. For example:

- A classroom could complete the "whole" web by having everyone experience all of the learning episodes for each arm (subtopic) or by dividing into small groups and having each group focus on only one arm.
- A classroom could complete part of the web by doing only a few of the learning episodes from each arm or all of the learning episodes from one arm.
- A school could complete the whole web by having each grade level do a different arm or each grade complete several learning episodes from all arms.

Once an approach is selected, a strategy for keeping track of learners' work and progress is important. For example, each learner can maintain a folder which contains a photocopy of the web. Each time a learning episode is completed by a learner individually, in a small group or by the whole class, he/she should color in or cross off the episode on the web. Evidence of the completed work is then placed in the folder (e.g., poem, drawing, notes from investigation, completed assessment form for a project or presentation).

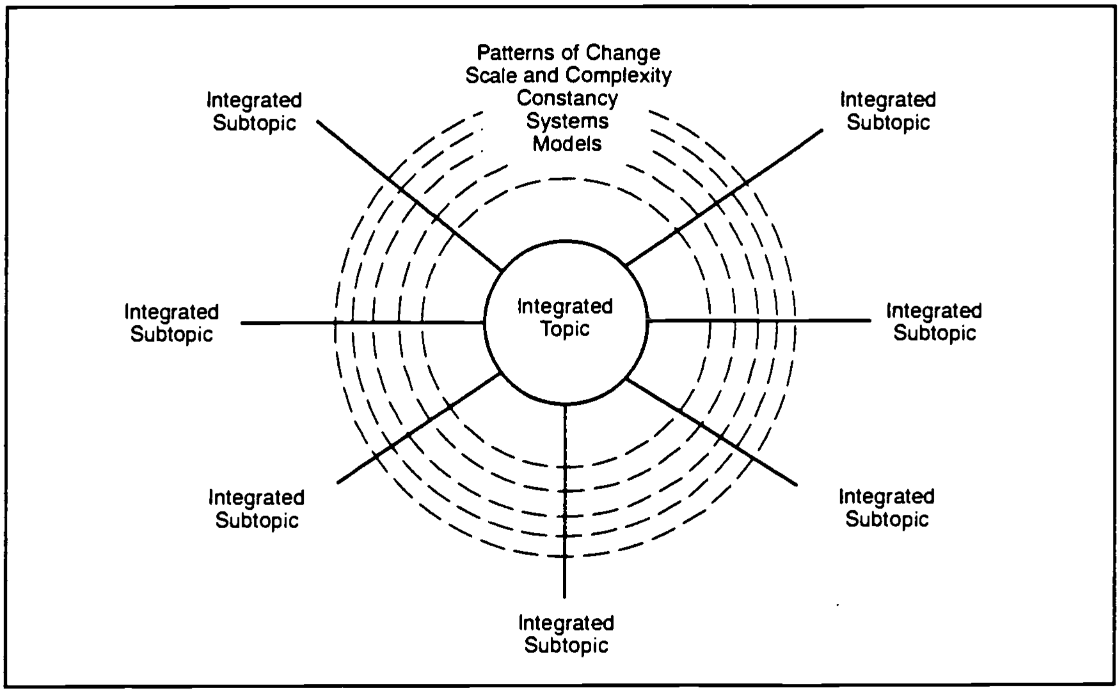
In addition to serving as an organizational tool, the folder can facilitate assessment. Items placed in the folder can be based upon learner contracts where the leader and learners decide which learning episodes will be completed and what criteria will be used to assess them. Some of these, in turn, can be added to the learner's portfolio. In addition, other ideas for assessment can be gleaned from the various learning episodes in the previous section.

Appendix G contains several "blank" models and webs to help you keep branching out. Start now to develop your own ideas into a learning episode using an approach discussed here or one of your own.

STEP 1

Select Focus Based on Curriculum Model

There are many possibilities for curriculum models as indicated by the continuum on page 4. This web, called "Interdisciplinary: Integrated Topic," is based upon a variation of one described in "The Big Picture" and would come between Model 3 and Model 4. This interdisciplinary model focuses on an "integrated topic" with the rays of the web extending to "integrated sub-topics." These sub-topics draw upon different subject areas, blurring the disciplinary boundaries. The emphasis is on the different topics with the five themes interwoven throughout the investigations and explorations of the topics. Based on this model, the focus of this web is on the topic "Winter Wonders."



139

STEPS 2-3

Brainstorm, Categorize, Brainstorm Further

Once the focus is selected, in this case "Winter Wonders," the leader and learners brainstorm ideas. These are then categorized and labeled. Further brainstorming and research can expand the initial web.

WINTER WONDERS

SOCIETY & CULTURE

- Utilities/Energy Conservation
- Services
  - snow removal
  - care for seniors, homeless
  - emergency
- Livable winter cities
- Farm Life
- Food
  - winter fruits/vegetables
  - maple syrup
- Recreation and Games
- Winter Around the World

SHAPERS OF THE EARTH

- Glaciers
- Snow Slides & Avalanches
- Effects of Freezing & Thawing
  - soil formation
  - heave sidewalks
  - crack walls
  - break pipes, gutters

WEATHER & CLIMATE

- Reason for Seasons
- Weather Patterns
- Wind Chill
- Wind Effect
- Temperature
- Snow Distribution
- Winter Storm Safety Rules

SNOW AND ICE

- Snowflakes
- Frost
- Icicles
- Showdrifts
- Sublimation
- Amount of Snow to Water
- Freezing and Melting
- Condensation & Evaporation
- Snow Cover and Temperature
- Signs of Pollution

SURVIVAL, SAFETY & HEALTH

- Winter Storm Safety Rules
- Travel (auto)
- Hypothermia
- Clothing
- Ice & Snow Safety
  - food
  - shelter
  - make snowshoes

AWARENESS & AESTHETICS

- Scavenger Hunt
- Perceptions & Attitudes
- Personal Expression

ANIMALS

- Migration
- Hibernation
- Physical Adaptations
  - color
  - coats
- Food
  - storage
  - feeding
- Shelter
- Tracks and Tracking
- Insects

STREAMS, PONDS & LAKES

- Mapping
  - ice thickness
  - depth of water
  - temperature
- Light Penetration
- Water Currents
- Plankton Collecting
- Bottom Vegetaion
- Water Sampling
- Ice Fishing
- Ice Safety

PLANTS

- Trees
- Weeds
- Evergreen plants
- Growth under the Snow

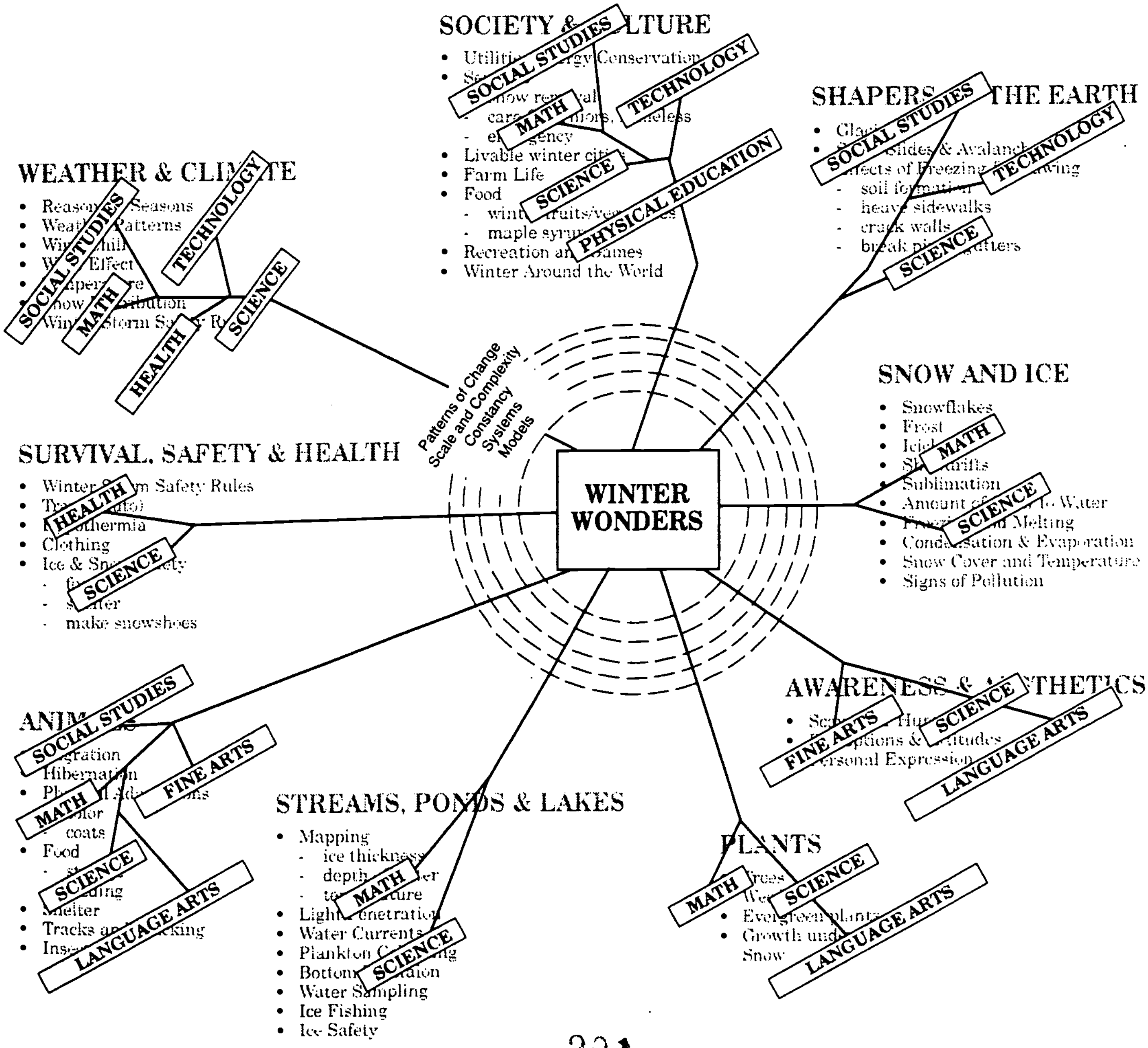
230

STEP 4

Identify Interdisciplinary Instructional Objectives

This figure shows the integrated topic and subtopic with the interdisciplinary connections. Instructional objectives would not only reflect this integration but also incorporate the themes (e.g., patterns of change, constancy). Objectives would only be written for the specific parts of the web which leaders/learners decide to implement.

Example objective: Working in collaborative groups, learners will explore patterns of change in migratory birds in their community over the last twenty years.



201

STEPS 5-6

Identify teaching strategies and develop "final" web

This figure is based upon the subtopic "Animals" from the previous web (Step 4). It illustrates the different learning episodes which could be used to teach this arm of the web. Some of these would be adapted from existing materials, some would be developed by the leader of learners, and some by the learners. Table 2 lists the sources of these learning episodes. If the class is going to do another arm, a similar web would be developed (e.g., weather and climate). The number of subtopics developed and the number of learning episodes identified per subtopic depends upon many factors including time and interest of learners.

WINTER ANIMALS--SUGGESTED ACTIVITIES

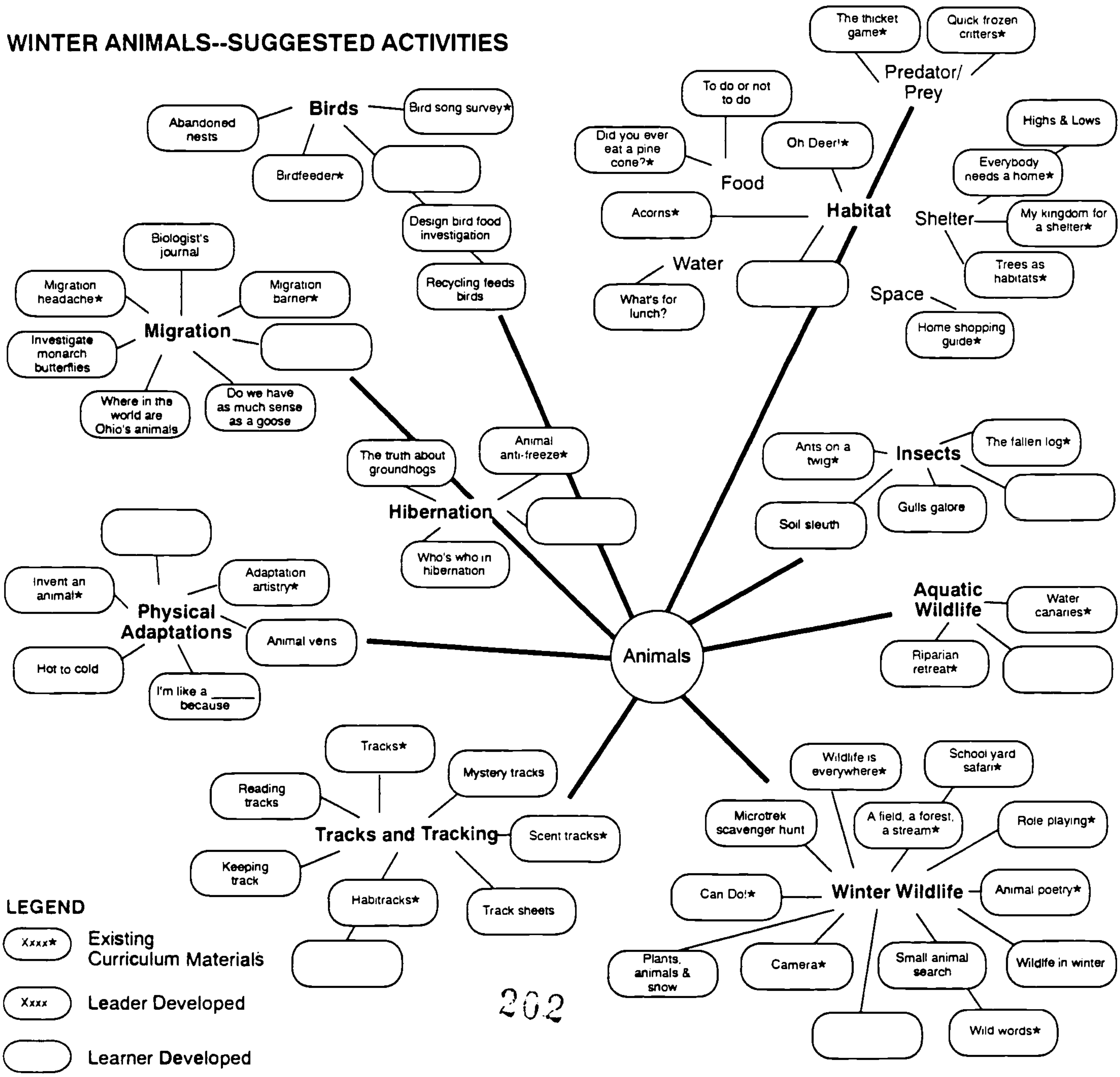


TABLE 2

Winter Animals – Suggested Activities

Migration

Existing: Migration Barriers (Project WILD); Migration Headache (Aquatic Project WILD)

Teacher Developed: Investigate migration of monarch butterflies; Where in the World are Ohio's Animals in Winter (project); read "Do We Have as Much Sense" (extensions); Biologist's Journal (write journal as if following a migrating animal).

Hibernation

Existing: Animal Anti-freeze (OBIS)

Teacher Developed: The Truth About Groundhogs (project); Who's Who in Ohio Hibernation (project)

Physical Adaptations

Existing: Invent an Animal (OBIS); Adaptation Artistry (Project WILD)

Teacher Developed: Hot to Cold (propose adaptations for desert animal evolving to cold climate); I'm like a _____ because...(choose an animal and explain in writing how your winter adaptations are the same and different); Animal Venns (compare winter adaptations for two animals)

Tracks and Tracking

Existing: Scent Track (OBIS); Tracks; Habitracks (Project WILD)

Teacher Developed: Reading Tracks (cards give students a "track task" to do in unbroken snow—hop on one foot; other students try to figure out); Keeping Track (select site and observe tracks over time); Mystery Tracks (decipher story depicted by tracks); Track Sheets (data sheets for observing tracks)

Winter Wildlife

Existing: School Yard Safari; A Field, a Forest and a Stream (Project Learning Tree); Wildlife is Everywhere; Microtrek Scavenger Hunt; Animal Poetry; Wild Words; Can Do! (Project WILD); Role Playing (Sharing Nature); Camera (Sharing Joy of Nature)

Teacher Developed: Small Animal Search (data sheet); read "Wildlife in Winter" (questions); Plants, Animals and Snow (task cards)

Aquatic Wildlife

Existing: Riparian Retreat; Water Canaries (Aquatic Project WILD)

Insects

Existing: Fallen Log (Project Learning Tree); Ants on a Twig (Project WILD)

Teacher Developed: Soil Sleuth (bring in "frozen" soil and observe); Galls Galore (investigation)

Habitat

Existing: Acorns (OBIS); Trees as Habitats; Did You Ever Eat a Pine Cone (Project Learning Tree); Everybody Needs a Home; My Kingdom for a Shelter; Oh, Deer!; The Thicket Game; Quick Frozen Critters (Project WILD)

Teacher Developed: To Do or Not To Do (debate the role of humans in feeding animals during winter); Highs and Lows (find warm home by taking temperature; data sheet); What's for Lunch (investigate animal eating habits); Home Shopping Guide (write ads telling features of different animal homes)

Birds

Existing: Birdfeeder (OBIS); Bird Song Survey (Project WILD)

Teacher Developed: Abandoned Nest (find and identify bird nests; map locations; observe site in spring for birds); Recycling Feeds Birds (use "trash" to make feeders); design investigation on bird food and feeding habits

MAKING A WATERSHED WEB

Purpose:

This activity demonstrates how to develop a web as a planning tool for an integrated approach to teaching and learning. A web is a schematic representation of an idea or concept, in this case, the concept of a "watershed."

Materials:

For each group
- 50 sheets of 8 ½" x 11" white paper
- Markers (two different colors, broad tipped)

For the large group
- 10-15 sheets of 8 ½" x 11" colored paper
- "Watershed" printed in large letters on a different color of paper

Procedures:

In small groups (Instructions for participants)

1. Brainstorm everything that comes to mind when you think of the word "watershed." Write each idea on a separate sheet of white paper, using no more than 1-2 words. Be sure to write in big, bold lettering so that it can be read from across the room. Have more than one person writing down your group's ideas, using the same color of marker.
2. When you have exhausted all of your ideas, group your sheets of paper into broad categories of similar or related ideas. On sheets of white paper, label these in a different colored marker.
3. Brainstorm any additional categories or ideas that come to mind.

As a large group (Instructions for group facilitator)

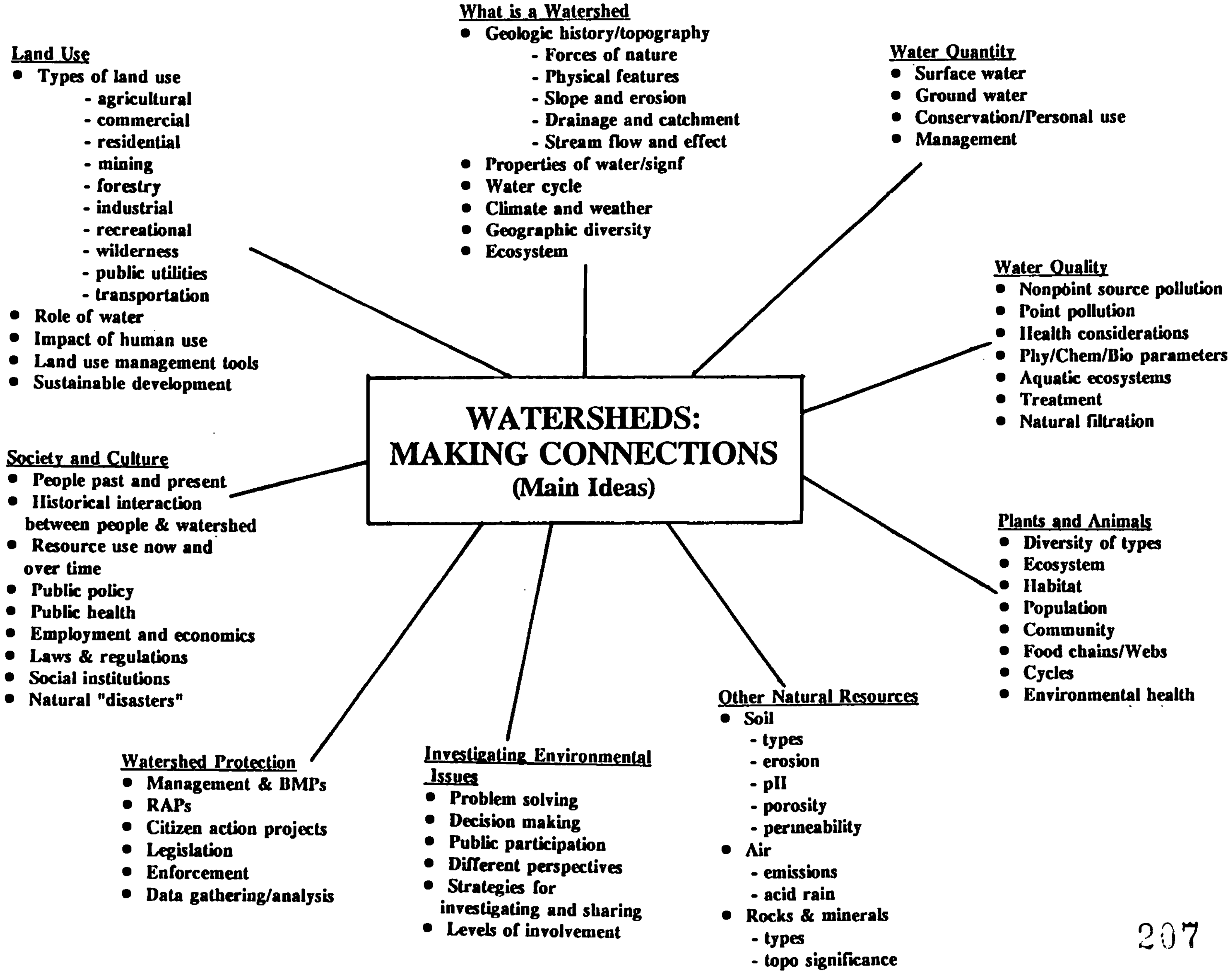
1. Stand in a circle in an open area large enough to accommodate the whole group.
2. Select one group that seems to have rich categories and ideas to present theirs to the whole group.
3. Begin by putting the colored paper with the word "watershed" in the center of the circle on the floor. Ask your selected group to write one of its categories on a colored sheet of paper and lay this next to the word watershed. Then have them lay out all their sub-ideas, coming off the center like a spoke of a wheel. They should BRIEFLY explain their category and ideas. Have them continue to present each category with ideas, forming more spokes, until they have laid out their whole web.
4. Ask each group to look at this web and compare it to the categories and ideas they developed in their small groups. They should look for three things:

- Which of their categories or ideas are duplicates – set these aside.
- Which of their ideas are not already laid down and would fit under an existing category.
- Which categories with ideas are new and need to be added on to the web.

5. After they have time to process this, have groups come up one at a time to place their new ideas under existing categories and then add new categories and ideas until all of their thoughts have been incorporated into this one web.
6. Finally, ask the group as a whole if there are any changes that they would like to make – move ideas to a different category, combine categories, rename a category, develop subcategories under a main category, and/or add another category.

Discussion:

1. Looking at this web, what can you say about watersheds?
2. How does this web compare to the one developed for SWEEP?
3. How can a web be used as a tool for teaching and learning?



WATERSHEDS: MAKING CONNECTIONS
(Main Ideas)

What is a Watershed
- Geologic history/topography
  - Forces of nature
  - Physical features
  - Slope and erosion
  - Drainage and catchment
  - Stream flow and effect
- Properties of water/signf
- Water cycle
- Climate and weather
- Geographic diversity
- Ecosystem

Water Quantity
- Surface water
- Ground water
- Conservation/Personal use
- Management

Water Quality
- Nonpoint source pollution
- Point pollution
- Health considerations
- Phy/Chem/Bio parameters
- Aquatic ecosystems
- Treatment
- Natural filtration

Plants and Animals
- Diversity of types
- Ecosystem
- Habitat
- Population
- Community
- Food chains/Webs
- Cycles
- Environmental health

Other Natural Resources
- Soil
  - types
  - erosion
  - pH
  - porosity
  - permeability
- Air
  - emissions
  - acid rain
- Rocks & minerals
  - types
  - topo significance

Investigating Environmental Issues
- Problem solving
- Decision making
- Public participation
- Different perspectives
- Strategies for investigating and sharing
- Levels of involvement

Watershed Protection
- Management & BMPs
- RAPs
- Citizen action projects
- Legislation
- Enforcement
- Data gathering/analysis

Society and Culture
- People past and present
- Historical interaction between people & watershed
- Resource use now and over time
- Public policy
- Public health
- Employment and economics
- Laws & regulations
- Social institutions
- Natural "disasters"

Land Use
- Types of land use
  - agricultural
  - commercial
  - residential
  - mining
  - forestry
  - industrial
  - recreational
  - wilderness
  - public utilities
  - transportation
- Role of water
- Impact of human use
- Land use management tools
- Sustainable development

WATERSHEDS: MAKING CONNECTIONS
(Teaching Activities)

What is a Watershed
- Mapping*
- Rainy Day Hike (WET)
- School drainage/watershed*
- Stream table (River Cutters)*
- NatureScope Geology
- Branching Out (WET)
- Incredible Journey*

Water Quality
- Garbage Bag Watershed (ODNR)*
- Help Save the Birds (AIMS)
- Mini Water Treatment (AIMS)
- Would You Drink this Water (MinnAqua)
- The Lake Game (MinnAqua)
- Oil Spill (Ohio Sea Grant)*
- Deadly Waters (Aquatic WILD)

Water Quantity
- Ground Water Flow Model (ODNR)*
- Water's Going On (WILD)
- Wet Land in Wetlands (Two H's and an O)
- Capture, Store & Release
- A Water Plan of Action (Two H's and an O)
- Water Figures (Living Lightly)

Plants and Animals
- Habitat Lap Sit (WILD)
- Deadly Links (WILD)
- Webbing (Sharing Nature)
- Habitats of the Pond (OBIS)
- Hold IT (OBIS)
- Great Lakes Food Web (JASON)

Other Natural Resources
- A Piece of Our World (Hug a Tree)
- Wash Out (Hug a Tree)
- Soil Soakers (AIMS)
- Soil as a Filter (Two H's and an O)
- Rain Away (AIMS)
- Acid Rain (GEMS)
- Something in the Air (Water, Stones, Foss Bones)

Investigating Environmental Issues
- Decision Tree*
- Community Study (u.S. Forest Service)*
- Shopping Around the Mall (Integrating EE & Sci)*
- Model Opinionnaire (Roth and Lockwood)
- Viewpoints (Roth and Lockwood)
- Idea Pools (WET)*
- Healthy and Unhealthy
- Water Quality/Watershed Studies*

Watershed Protection
- Water Actions (WET)
- The Monday Group (WILD)
- Litter Alert (Water, Stones, Fossil Bones)*
- Give Water a Hand: School Site Action Guide (4-H)

Society and Culture
- From Out of the Past–Interviews (Roth/Lockwood)
- Watered Down History (Aquatic WILD)
- Water Crossings (WET)
- Common Water (WET)
- Research Primary Source Documents
- AfterMath (WET)
- The Thunderstorm (WET)

Land Use
- Develop regional plan for year 2020
- Dragonfly Pond (WILD)*
- To Dam or Not To Dam (WILD)
- Janet's Dilemma (Roth/Lockwood)

* Institute Activity

Teaching Teachers

Science Is Part of the Big Picture

By Anita Greenwood

Recently, while leading a science workshop for elementary teachers, I experienced that "Aha!" moment of understanding that we educators always hope our students will have.

During a break, one workshop participant had described to me the demands being placed upon teachers in her school. "We are being told to use whole language, to try portfolio assessment, to teach hands-on science, to prepare thematic units, and to integrate mathematics and science," she said. "I don't even know where to start! There are so many things to do that it's like being asked to complete a jigsaw puzzle when each piece comes from a different puzzle and nothing seems to fit together." Her comments lead me to believe that I might finally understand one reason why inservice workshops often fail to impact science teaching, and why even experienced teachers relegate science to the end of the day or avoid it altogether (McShane, 1995).

What Needs to Change?

Teachers consistently tell me that even though they know that letting children do hands-on science is beneficial, they nevertheless avoid teaching it or treat it as an add-on to the "core" of the elementary school curriculum. These teachers, typified by the workshop attendee who had given me such insight, do not see the links among the many new things they are being asked to incorporate into their teaching. Other workshop participants expressed the opinion that ideas presented to teachers during staff-development sessions are often just the latest fads, which tend to fizzle and die like spent firecrackers on the fourth of July. Then and there, I recognized that I, too, had failed to provide these teachers with the theoretical background that informs practice. In other words, I had launched into the "how to" of science teaching and had ignored the "why."

As a result, I restructured my workshop series so that teachers would become real science *learners*, struggling with their own ideas about the phases of the moon, seasons, living and nonliving things, and so on as they designed experiments and shared theories with their peers. Teachers designed experiments to test their *own* ideas, and they discussed their old and new conceptions in relation to scientifically accepted models.

For example, in a workshop relating to density, teachers generated two competing ideas for why objects float and sink: objects float because they contain air, and objects sink because they have more mass than objects that float. To test their ideas, one group of teachers took jars and filled them with varying amounts of rocks until the jars sank; however, as everyone could see, the jars still contained air. Another group of teachers tested objects of the same mass but of different shape, and they discovered that mass alone was not the determining factor in sinking or floating. Working with their own ideas, teachers were more willing to search out alternative explanations, leading them eventually to conclude that while sinking and floating are related to mass and to the space taken up by an object, they are dependent on an object's density, which is reduced with the inclusion of air.

In another workshop, teachers kept a moon journal and generated a list of related "I wonder" questions, including

- I wonder where the moon is when I cannot see it;
- I wonder if the moon rotates, because I always seem to see the same face;
- and, I wonder what causes a lunar eclipse.

The teachers then explored each question through the use of models, working in a darkened room with an electric light representing the sun and a large plastic-foam ball on a wooden stick representing the moon. By holding the ball at arm's length and passing it around their own bodies, which represented Earth, the teachers were able to observe the reflection of light simulating the phases of the moon. This activity caused teachers to conclude that a lunar eclipse occurs every month! Knowing that this was not the case, the teachers used their models and further discussion to work out for themselves that the orbit of the moon around the Earth must be tilted with reference to the Earth's axis.

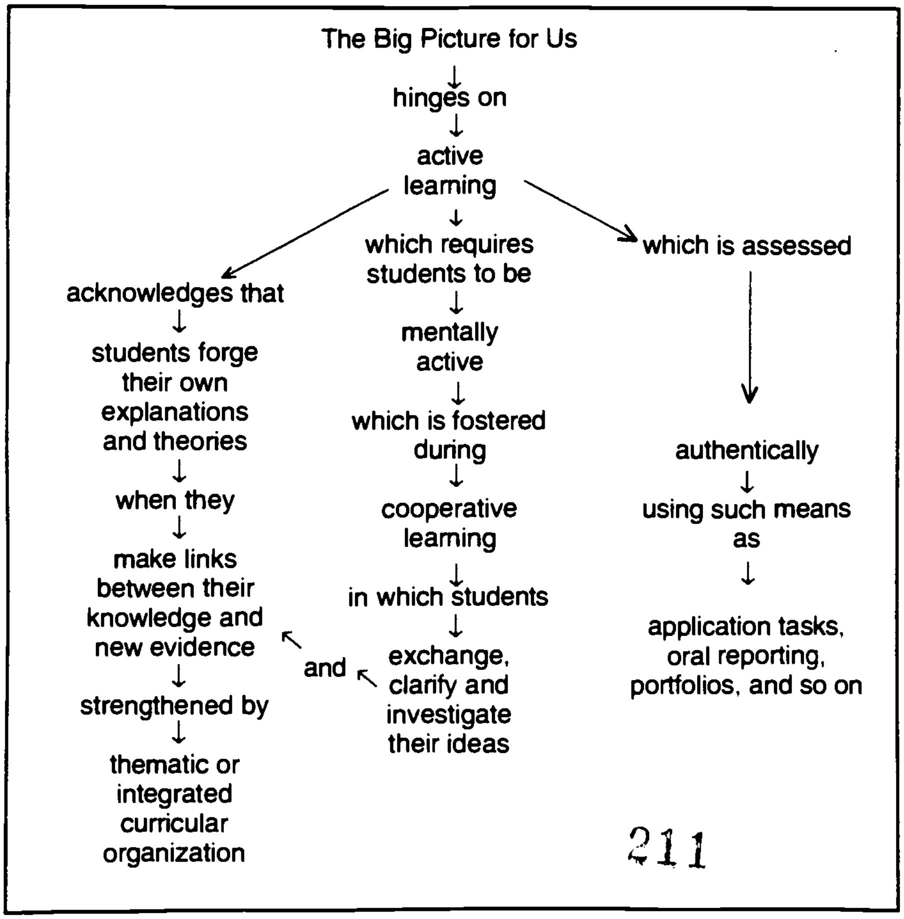
Through additional modeling and discussion, the teachers were able to resolve their conceptual difficulties related to the moon's phases and its rotation.

At the end of these redesigned workshops, we discussed what it was like to learn science and how that experience would affect their own classroom teaching. Through this new approach, teachers in my workshops began to recognize the "big picture" that frames the pedagogical changes they are being asked to implement.

Science Methods in Motion

If you believe that children are constantly attempting to explain all that they see and do, that they are trying to come up with theories about their world that make sense to them, then you already acknowledge that they are *active learners.* Active learning refers not only to physical activity, but also to mental activity. The teacher's role is to spark this mental activity by helping students connect what they already know with new experiences encountered in the classroom. This view of learning is part of the movement in science education known as *constructivism* (Driver and Oldham, 1986). When learning is recognized as a constructive activity, it provides a rationale for using cooperative grouping, alternative assessment, thematic teaching, and active learning in science.

This concept map shows how pedagogical ideas are linked.



The move toward thematic teaching acknowledges that children do not naturally categorize what they learn by subject; rather, they separate their knowledge into "little boxes" because of the way we organize the school day. By the time they reach high school, students so compartmentalize their learning that they don't relate the mathematics they learn during second period to the mathematics skills they need for their sixth-period science class! Making science part of a thematic or interdisciplinary unit helps students to forge appropriate connections and makes their learning more meaningful.

How, then, should we go about designing the science part of such inter-

◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆

TEACHING TEACHERS presents practical teaching methods for preservice and inservice teachers. If you have an idea that you think could benefit your fellow teachers in their understanding of science and/or teaching, send your manuscripts to column editor Michael Kotar, Department of Education, California State University, Chico, CA 95929; e-mail mkotar@oavax.csuchico.edu.

ANITA GREENWOOD is an assistant professor of science education at the University of Massachusetts Lowell.

◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆

disciplinary units? One way to start is by probing students' prior knowledge. Research has shown that students come to class with their own theories about how the world works (Asoko, 1993; Driver, Guesne, and Tiberghien, 1985). Such strategies as concept mapping, poster development, predict-observe-explain, line drawings, and sequence chains can elicit children's ideas (White and Gunstone, 1992), and then the teacher can focus instruction accordingly.

Most teachers believe that science lessons should involve students in inquiry, but they do not know how to change textbook exercises into active, challenging investigations. One approach is to rephrase as a question the title of a textbook exercise. In the primary grades, questions should lead to children developing their science process skills. The teacher might ask, for example, "What can you find out about feathers using a ruler, a hand lens, an eyedropper, a timer, and graph paper?" In grades 5–8, an appropriate question would be, "What factors affect how well lemonade crystals dissolve in water?"

Children should work cooperatively in groups to investigate these questions—exploring their ideas with peers, developing ways to test their thinking, and presenting findings from their data to the class. Activities that contradict children's misconceptions (identified by the teacher through the probing strategies described above) will lead students to question their prior understandings. From these initial explorations, students themselves generate more questions leading to further investigation.

Of course, there are questions that classroom investigations cannot answer. Such questions may become the subject of a student research project or a carry-over to their work in science the following year, or they may provide fodder for a conversation with a scientist through the Internet.

Children should review their learning by revisiting the concept maps or other work they created at the beginning of a given unit of study and then revising these materials in light of what they've learned. This gives students concrete evidence of their learning and provides the teacher with a useful assessment tool.

Finally, there is little point in encouraging students to think, share, investigate and develop explanations if they are only going to fill in the blanks on a test sheet. Instead, teachers should use authentic assessment, in which students can apply their learning and teachers can evaluate their performance—to what degree they follow directions, organize the data they collect, use measuring instruments appropriately and accurately, and develop explanations for their observations. In addition, portfolios are an excellent way for students to select evidence and maintain a record of their developing skills and knowledge.

Teachers as Learners

Once I had restructured my workshops so that the attending teachers experienced science as *learners* would, workshop participants began to consider changing their own instructional strategies. They recognized that when their ideas were challenged and sometimes shown to be false, the teachers became intensely interested in their learning. Additionally, workshop attendees saw how the pedagogy advocated in a variety of professional development workshops assisted them in learning science. For example, cooperative learning is more than a grouping strategy; it provides an atmosphere conducive to the exchange of ideas and to inquiry.

By becoming active learners themselves, these teachers recognized that science is part of the "big picture," and they were able to link newly constructed ideas about active learning to other pedagogical initiatives (see figure). At the same time, I learned a valuable lesson, too: that I must not neglect theory if the teachers I train are to develop a model that assists them in modifying their instructional approaches and makes sense of professional development activities.

Resources

Asoko, H. (1993). First steps in the construction of a theoretical model of light: A case study from a primary school classroom. *Proceedings of the Third International Seminar on Misconceptions in Science and Mathematics Education.* Ithaca, NY: Misconceptions Trust.

Driver, R., Guesne, E., and Tiberghien, A. (Eds.). (1985). *Children's ideas in science.* Milton Keynes, United Kingdom: Open University Press.

Driver, R., and Oldham, V. (1986). A constructivist approach to curriculum development in science. *Studies in Science Education, 13,* 105–122.

Grennon Brooks, J., and Brooks, M. (1993). *In search of understanding: The case for constructivist classrooms.* Alexandria, VA: Association for Supervision and Curriculum Design.

McShane, J. (1995). Editor's note: Science is a priority. *Science and Children, 32*(4), 4.

White, R., and Gunstone, R. (1992). *Probing understanding.* Bristol, PA: The Falmer Press, Taylor and Francis.

Adopt-A-Watershed™ Curriculum Unit Matrix

Bold units have been completed.

Suggested Grade	Unit Title	Concept	Long-Term Field Study	Action Project	Community Education
K	**What is a Watershed?**	**The earth contains objects which are observably different and that change.**	**Tree height and diameter/succession study.**	**Tree planting.**	**Field trip booklet for family and community. Children explain to family what a watershed is.**
Estimated completion date 2000	Creature Features	Living and non-living things have observable characteristics.	Butterflies of watershed.	Plant native flower seeds butterflies use such as milkweed.	Building a butterfly garden on the school grounds.
1	**An Apartment in the Woods**	**There is great diversity in living things and their habitats.**	**Mast production study.**	**Acorn planting or habitat enhancement.**	**Mural or puppet show depicting living things that depend on trees.**
	Significance of Soil	**Different forces reshape the earth.**	**Soil erosion study.**	**Erosion control.**	***Significance of Soil* brochure.**
2	**Trees**	**Living things have characteristics and structures enabling them to live and interact in different environments.**	**Tree height and diameter/succession study and/or trees changing color and budding out.**	**Growing and planting willows.**	**"Build a Tree" mural displayed for community at open house, science fair, or watershed fair.**
	Animals	**Same as for Trees unit with an emphasis on animals.**	**Deer and/or butterfly population study.**	**Wildlife enhancement project.**	**"Animals of Our Watershed" mural display for open house, science fair, or watershed fair.**
3	**The Streamside Community**	**Living things interact with each other and their environment in many ways forming interdependent systems.**	**Amphibian study.**	**Riparian ecosystem restoration.**	**Display of leaves and seeds from indicator plant species found in a riparian ecosystem.**
4	**Landforms and Geology**	**Natural forces are at work causing the earth to change.**	**Soil erosion study.**	**Erosion control.**	**Share watershed relief map and aerial photos at open house, science fair, or watershed fair.**
Estimated completion date 6/30/98	Wade into Watersheds	Organisms successfully adapted to their environment are more likely to live and pass on their traits. Matter has specific properties and can be changed.	Water quality monitoring including aquatic insect population study stream temperature, photo station and stream flow.	Student/Community generated action project to help restore water quality.	Media day or open house to share action projects.

Adopt-A-Watershed™ Curriculum Unit Matrix

Bold units have been completed.

Suggested Grade	Unit Title	Concept	Long-Term Field Study	Action Project	Community Education
5	**Plants Solve Problems of Survival**	**Through their structures and functions, organisms solve problems of survival (emphasis on plants).**	**Hula hoop plant survey.**	**Growing and planting native plants.**	**Wild flower awareness day and native plant sale.**
	Birds: Adaptations and Variations	**Same as for Plants unit with an emphasis on birds.**	**Bird census, amphibian, deer, and butterfly population studies.**	**Student/Community generated wildlife enhancement project.**	**Endangered species poster.**
6	**Forest Ecosystem**	**Living things interact with their environment forming interdependent systems which transmit energy through different networks.**	**Tree height and diameter/succession study.**	**Student/Community generated Forest Ecosystem action project.**	**Plan a tree celebration day in conjunction with Arbor Day and completion of a forest mural.**
Estimated completion date 2000	Sustainable Society: What Is It? What Was It?	Same as Forest Ecosystem unit with an emphasis on human interaction with the environment throughout history.	Diversity index and changes in resource use over time. Testing sustainable indicators.	Students research and implement projects which make their watershed more sustainable, such as recycling projects.	Students display research and implement projects which make their watershed more sustainable.
7	**Watershed Geologic History**	**The earth is dynamic and constantly changing.**	**Soil erosion study and stream channel profile.**	**Student/Community generated geology/ soils action project.**	**Work with 1st grade on *Significance of Soil* brochure and display of action project.**
	Wildlife	**Natural selection favors those organisms best adapted to their environment and leads organisms to evolve over time.**	**Bird census, amphibian, deer, and butterfly population studies.**	**Student/Community generated wildlife enhancement project.**	**Board game produced on endangered species.**

Adopt-A-Watershed™ Curriculum Unit Matrix

Bold units have been completed.

Suggested Grade	Unit Title	Concept	Long-Term Field Study	Action Project	Community Education
8 Estimated completion date 2000	Ecosystems and the Physical Environment	The physical environment affects living things.	Tree height/diameter and succession study, pH study on rain, soils, streams, and/or comparative ecosystem study.	Restore an ecosystem where a physical change is impacting the success of that ecosystem, such as providing shade for a stream channel that has lost its canopy cover.	Play production on acid rain.
Estimated completion date 2001	Water Cycle	The water cycle is a dynamic system which interacts with the land causing change.	Stream flow.	Help irrigators conserve water.	Attend public meetings on water use and/or help 4th grade complete brochure on water quantity problems and solutions.
	Aquatic Ecosystems	**Species are maintained and changed through cellular structures and processes. A population's survival depends upon its adaptations to the environment.**	**Stream survey & water quality monitoring photo station.**	**Student/Community generated action project to help restore water quality.**	Watershed art show.
High School Estimated completion date 2000	Matter and Energy	Matter and energy cycles through ecological systems.	Productivity studies. Tree height and diameter/succession study.	Restoration to increase productivity of an impacted system.	Research and presentation to community on best management practices for a specific ecosystem
	Water Quality	**Water Quality: Chemistry, Biology, Language Arts, Math, Geography, and Earth Science.**	**Water quality monitoring.**	**Student/Community generated action project to help restore water quality.**	**Watershed congress for community and public officials with "State of the Watershed: Problems and Solutions" as subject.**

Adopt-A-Watershed™ Curriculum Unit Matrix

Bold units have been completed.

Suggested Grade	Unit Title	Concept	Long-Term Field Study	Action Project	Community Education
High School	**Watershed Physics**	**Force and energy interact with matter to produce change.**	**Individual projects in watershed geomorphology.** **Completion of soil erosion study.**	**Variable, dependent on long-term studies.**	**Watershed congress for community and public officials with "State of the Watershed: Problems and Solutions" as subject.**
High School Ag. Science Estimated completion date 2002	Watershed Agriculture	Natural resource management and agriculture.	Stream channel profile.	Work with ranchers to find solutions to agricultural impacts and restore area impacted by agriculture; e.g., fencing a stream bank, placing fish screens on irrigation ditches, etc.	Work with ranchers to find solutions to agricultural impacts to watershed and produce slideshow on problems and solutions to present at watershed congress.
Estimated completion date 2001	Watershed Vegetation Management	The culture and management of vegetation with an emphasis on forestry and native plants.	Complete tree height/ diameter and succession study Complete soil erosion study.	Help kindergarten students plant trees and begin succession study.	Learn about and participate in environmental assessment process including best management practices.
Estimated completion date 2000	Watershed Wildlife	Wildlife management.	Complete wildlife studies (amphibian study, bird survey and deer population study).	Students help children at younger grade levels complete their wildlife enhancement projects.	Students choose a wildlife management subject relevant to their watershed, research the subject, and develop a presentation on the subject to give to younger grade levels, at the watershed congress and campfire programs.

A River Runs Through Science Learning

Tap community resources to create an integrated science and social studies unit.

By Lois R. Stanley

IT'S RAINING HARD NOW, BUT no one seems to notice. Wearing slickers, rain hats, and boots, fifth-grade students look at a white enamel pan in which a rock, cold and wet from the river, is beginning to show signs of movement. Squeals of "Gross!" are interspersed with shouts of "Awesome!" as students observe dragonfly and caddis fly larvae move down the rock and back toward the water. The parent-volunteer is as curious as the children, alternately thrilled and startled as another part of the rock seems to move. This is river science at its best.

Does that sound like a typical day at your school? With a little planning and community support, it could be. You can transform your schoolyard and its vicinity into an arena in which students explore the history of the community and learn about their local environment and ecosystem management. We did, and a study of rivers is now an important part of our school's curriculum.

(Opposite) This is a stylized version of the kind of map used to specify activity sites along the river walk.

COURTESY OF THE AUTHOR

Students tested and compared soils from different areas along the river.

The Source

The river program in our area—Wilton, Connecticut—grew out of a project begun by the Junior League in the early 1970s. This group saw the need for a school program highlighting the importance of clean, fresh water and recognized the importance of letting students learn through an integrated, hands-on approach. As a volunteer organization, the league also recognized the potential of involving community members in the program as river guides, thus providing additional "teachers" and more one-on-one time with students. To develop the program, league members researched the scientific and historical background of the area and published *The River Book* as a handbook for volunteer river guides in local schools. The book includes a list of suggested concepts for fall and spring walks, a sample trail map, and an identification key for native plants and animals.

The Junior League's efforts 20 years ago created a framework for the popular outdoor program that continues in area schools today. Recently, I met with a committee of interested teachers and parents associated with Cider Mill School to take a fresh look at the river study. Together, we devised an updated approach, and now the revamped program is in place. Designed for students in fourth and fifth grades, it focuses on the history and natural environment of our area; includes firsthand interaction with a local river, the Norwalk; and emphasizes parent-volunteers (four per class) who donate more than three hours time in the classroom and also lead small groups (five or six students

STEVE BUHMAN

Children investigate a slower-moving part of the river.

Our local environment holds evidence of river formation, the passage of glaciers, and the presence of Native American and colonial settlements. We decided that our program should encompass all of these elements.

each) on two 90-minute river walks, one in the fall and one in the spring. The volunteers also work with students to build a representation of the Norwalk River's watershed. As the science resource teacher, I trained the volunteers and scheduled the walks and watershed presentations.

Here is how we worked together to update the existing program.

First Things First

To begin, we analyzed the schoolyard and community resources with the school's science and social studies curricula in mind. We discussed ways that we might use our surroundings to simulate a time or place that the children study. At our school, students in the fourth and fifth grades study American history, and their science lessons include units on communities (interdependencies between plants and animals) and energy sources. Our location is rich in early American history, and we are close to a river that empties into the Long Island Sound. The surrounding environment holds evidence of river formation, the passage of glaciers, and the presence of Native American and colonial settlements. We decided that our outdoor learning program should encompass all of these elements.

Once we decided on the elements, we needed to choose the major topics to be included. We wanted the topics to be

- closely tied to the science and social studies curricula;
- helpful in showing the connections between the two disciplines;
- better understood through outdoor activities than through indoor ones;
- directly related to our local environment;
- easily illustrated by props or natural phenomena in our schoolyard or nearby river site;
- and related to current environmental issues.

After much brainstorming, debate, and discussion, my colleagues and I chose the following topics:

- river formation and glaciation;
- the components of a river system, including the elements of flood plains, marshes, aquifers, and the estuary link to the sea;
- the water cycle and its connection to the river system;
- ways that humans, through time, have used and misused the river;
- and ways that plants and animals depend on the river system and interact in the river community.

Our next step was to select activities to illustrate the concepts, such as making glaciers and modeling their movement over land and rock; testing different soils to see how well each type filters water and then comparing the soils tested to samples from the marsh and floodplain; and locating watersheds on which students live and identifying the aquifers closest to them on maps from our town hall.

Parent-volunteers were a big help during this phase of the program. Because they were so involved with this unit and its content, the parent-volunteers began to leave relevant magazine articles, books, and videotapes on my desk on a regular basis. My job was to sort through the material, choose what to use, and distribute those items to my colleagues.

After the activities were chosen, we mapped out the area we wanted to use for our outdoor classroom. We drew a one-page map of the river trail and carefully marked the specific sites for each activity. Then, on separate

Outline for Site Two, the Wooded Area

Materials

For the activities at this site, you will need two thermometers.

Activities

(1) Begin by taking the river water temperature. (2) Take the air temperature. (3) Remove a rock from the river and inspect it closely. (4) Examine the river's edges for erosion.

Discussion Topics

- Trees help prevent the river from eroding its banks.
- Water flows in the path of least resistance; water slows down on the inside curves of a meandering river and flows with speed on the outside curves.
- White water provides oxygen and food for water insects and will not freeze.
- Water temperatures do not fluctuate as much as air temperatures do.

Parent-volunteers were provided with a brief outline of activities to conduct and topics to discuss for each site along the river walk.

pages, we outlined the concepts to be discussed and the activities to be completed at each site.

Indoors and Out

Another key component of our river unit was conducting classroom activities that supported the outdoor learning. For example, students created model watersheds from sand and a water-drip system to discover how rivers form and the effects of flooding. In addition, they studied glaciers and built models of them from sand, pebbles, and water frozen in paper milk cartons. Students also studied the water cycle, completing a number of activities from the book *Water Precious Water* (Hillen, Weibe, and Youngs, 1988).

For the culminating indoor activity, students gathered around the model watershed to reenact the history and formation of the Norwalk River. (For instructions on how to build a watershed model, see *The River Book* [Willis, Norton, Foster, and Forrester, 1977].) This volunteer-led discussion prepared students for the river walk and introduced humans and history into the geophysical study of rivers.

First, students observed a Wisconsin glacier move toward Long Island Sound, transforming a V-shaped valley into a U-shaped one. Then, with clay, students constructed a river winding through the valley and discussed the terms *source, flood plain, meanders,* and *estuaries.*

Next, they covered the board with forest and had the first inhabitants of Connecticut, the Native Americans, arrive. Students discussed Native Americans' use of the river, choice of village sites, and impact on the ecosystem. As colonists and then modern populations moved onto the model watershed, we discussed the same points. "Why did the colonists build where they did? How did they use the river? What effects did the building of dams and mills, large-scale farming, domesticated animals, and increased human population have on the ecosystem?"

As roads, schools, office buildings, and parking lots covered the model's forests and farmlands, children recognized the need for even more space. They drained swamps and straightened the river to make more room. They placed businesses and homes on the flood plain and discussed how that action would affect the river's ability to clean water, feed aquifers, and regulate floods.

But the students did not leave feeling discouraged about the demands on our resources. As we discussed state and local laws concerning wetlands, students recognized the need for regulations concerning building sites, water purification, waste processing, and other issues that impact wetlands and water quality.

After our classroom activities, students were ready to investigate the real thing—the Norwalk River.

On the Trail

Our first outdoor activity was a walk from the school to the river. During the walk, parent-volunteers explained how Native Americans, and later colonists, used plants for survival, as they pointed out vegetation that possessed nutritional or medicinal qualities. A woodchuck conveniently had made a mound on a spot along the trail, so students and volunteers also discussed hibernation.

Where the trail meets the river, students ground corn on the rocks as the Native Americans had, and then discovered that the rocks they were using were the remains of a stone dam and water-powered mill. Students discussed methods of grinding corn, comparing the Native Americans' way to the colonists' use of the wheel to harness the river's power.

The water moves fast at this spot, bubbling over rocks, so here the children discussed another way animals survive winter—*diapause.* The volunteer asked, "Why are insect nymphs found on these rocks and not in the slower-moving water ahead?" Then the group discussed how the faster-moving water provided oxygen and

(continued on page 58)

(River, continued from page 15)

food for the insects, and they talked about how this water will not freeze because it is moving rapidly.

We walked along the river to the place where it widens and the water becomes calm and sluggish. Here, students compared the fast-moving water at the old mill site and the slower-moving water here. We asked them, "Where was there more evidence of erosion? Is there a difference in the substrate of the river, in the number and kinds of trees along the banks? What about changes in elevation?"

At a footbridge crossing to a small island, we paused to contemplate the human influence on the balance of nature in this river community. We discussed mink and muskrats, for example, and the effects of trapping. The mink is the muskrat's natural predator, so when the mink population decreases in size because of trapping, the muskrat population increases in size. In fact, the burrowing of an over-population of muskrats led to the collapse of a dam in our area; we talked about a recent newspaper article reporting that event.

The island was our final stop on the outdoor trail. Ducks often migrate to this part of the river, so the group discussed migration as a means of winter survival and the need for wetlands along waterbirds' migration routes. Then a volunteer presented students with the following scenario:

> It is late fall and winter snows will soon cover the ground. You have just landed on this island after months at sea. What do you see in the way of materials, plants, and evidence of animals that might help you to survive until spring?

Students responded by offering information about plants' nutritional and medicinal values, and they suggested creative ways to capture some of the native animals they learned about during their walk.

Assessment Measures

After the walk, each parent-volunteer and student completed an evaluation form. In addition, students were tested on content.

To assess the program's overall effectiveness, we considered the following questions:

- Were concepts from science and social studies integrated successfully? Could students, for example, verbalize or give examples of the connections between human history and the river?
- How well did the outdoor segment clarify and/or expand concepts? Could students, for example, understand the colonists' need for water power? Could students identify the plants and animals they observed during the walk? Could they name ways in which these plants and animals depend on the river? Did they recognize that weeds and insects sometimes thought of as pests have a purpose in the river ecosystem?
- Were the students involved and interested in the program?
- Did students gain a different perspective because of the integrated, outdoor approach?

Volunteers are an important component of this program. They are invaluable in gathering materials and ideas, making props, and leading children through the program. The fact that the volunteers are also parents adds validity to the program and sends the message, "This is important. My parent has taken time from other obligations to be here."

The volunteers are all willing learners and their enthusiasm adds to the children's excitement. Through participation in the program, many parent-volunteers become advocates for the school and for the goals of the study. As one parent said, "We were fighting the town for the right to fill a marsh in order to subdivide our property. After participating in the river unit, we could not with clear conscience continue the appeal."

In fact, after this program, neith parent nor child will ever view a ri in quite the same way. This river study left students, teachers, and parents with a better understanding of and sense of responsibility for their local environment, particularly the river.

Resources

Children's Television Workshop, 3-2-1 Contact. (1991). *Down the drain* [videotape]. Berkeley, CA: Author.

EME Corporation. (1989). *Glaciers* [videotape]. Danbury, CT: Author.

Hillen, J., Weibe, A., and Youngs, D. (Eds.). (1988). *Water precious water: A collection of elementary water activities* (Book A). Fresno, CA: AIMS Education Foundation.

Kaufmann, J.S., Knott, R.C., and Bergman, L. (1989). *River cutters.* Berkeley, CA: Lawrence Hall.

National Geographic Kids Network. (1989). *Acid rain* [kit]. Washington, DC: Author.

______. (1991). *What's in our wat* [kit]. Washington, DC: Author.

Thier, H.D., Karplus, R., Lawson, C.H., Knott, R., and Montgomery, M. (1978). *The Rand McNally SCIIS program.* Chicago: Rand McNally.

Willis, L., Norton, B., Foster, S., and Forrester, J. (1977). *The river book.* Wilton, CT: Six Town River Board. (Available from Barbara Findley, President-elect, Six Town River Board, 82 Middlebrook Farm Rd., Wilton, CT 06897-2016).

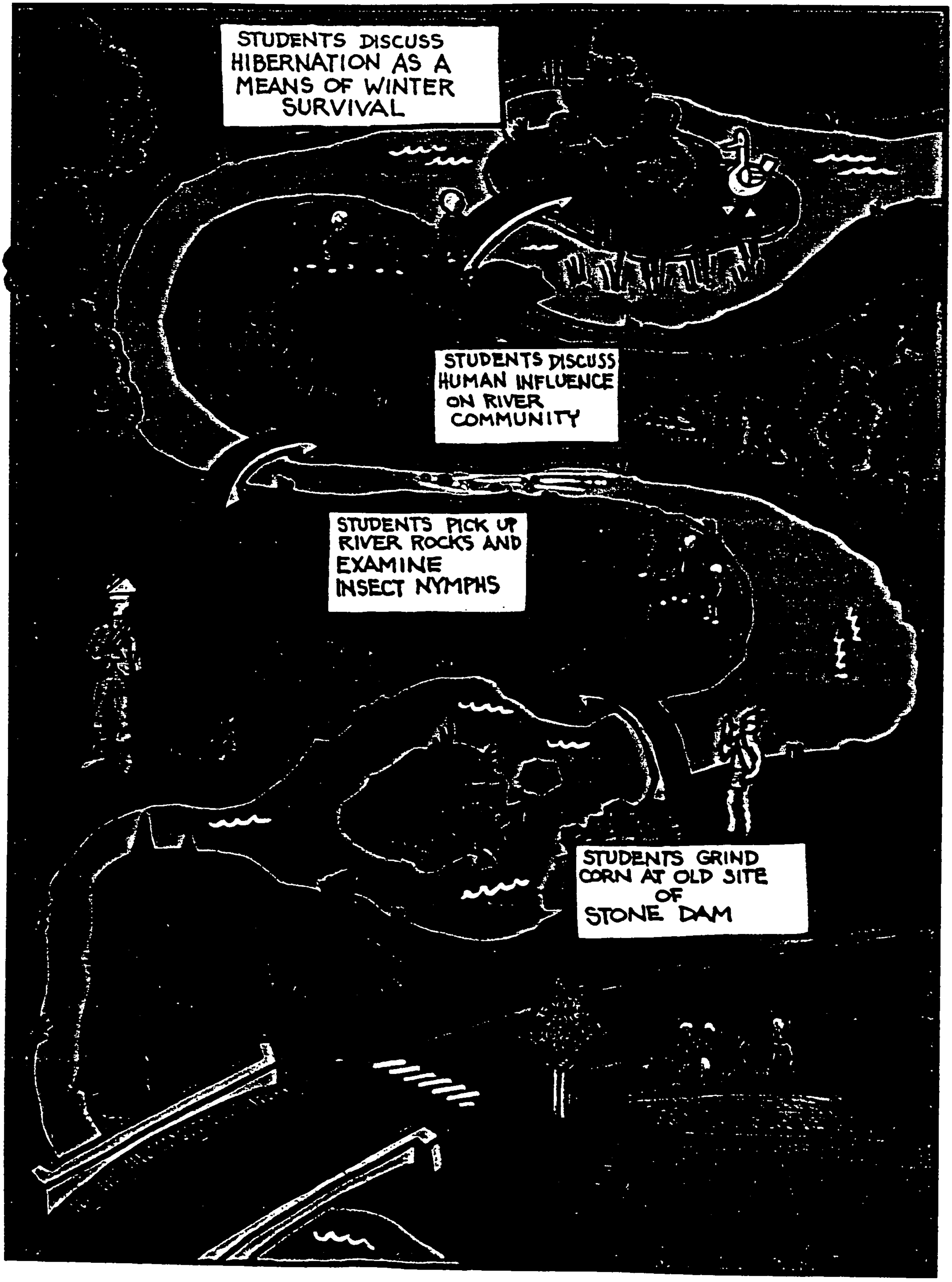
Also in **S&C**

Friedman, A. (1991). A big lesson in a small pond. *Science and Children, 28*(5), 27–29.

Vandas, S. (1992). Wetlands: Water, wildlife, plants, and people [article and foldout]. *Science and Children, 30*(1), 39–41.

Voorhis, K. (1993). Taking a course in nature. *Science and Childre* *31*(3), 23–26.

LOIS R. STANLEY was a K–6 science resource teacher at Cider Mill School in Wilton, Connecticut.


STUDENTS DISCUSS HIBERNATION AS A MEANS OF WINTER SURVIVAL
STUDENTS DISCUSS HUMAN INFLUENCE ON RIVER COMMUNITY
STUDENTS PICK UP RIVER ROCKS AND EXAMINE INSECT NYMPHS
STUDENTS GRIND CORN AT OLD SITE OF STONE DAM

Child Development

Introduction

A key to the effectiveness of your partnership will be to identify and implement concepts and activities appropriate for the age level of the students with whom you are working. This is not always easy, and it requires an understanding of how children think about, process, and develop concepts differently at various ages.

It is particularly challenging to teach children to understand concepts rather than to merely memorizing facts and information. Concepts are the building blocks of knowledge and responsible action.

Maps are among the most important data sources for orienting ourselves in our environment. To understand maps effectively, students must understand a number of basic but abstract concepts. These concepts must be developed in a sequential manner over time. Experts recommend that children begin learning mapping concepts by using three-dimensional globes and then transitioning to two-dimensional maps.

Specifically, if they are taught in concrete rather than abstract ways, students tend to be ready to begin learning mapping concepts at the following grade levels.

Mapping Concept	Grade Level
Features	**K-1**
Representations	**1-3**
Symbols	**2-3**
Perspective	**3-5**
Topography	**5-6**

Adapted from the 1966 Edition of Scott, Foresman's
These Are Your Children, a child-development text by Gladys Gardner Jenkins, M.A;
Helen S. Schacter, Ph.D.; William W. Bauer, M.D.

A Summary of Normal Development

But allowance must always be made for individual differences

THE INFANT

Physical Development

Continued neuromuscular development.
Progression from head downward--gains control of eye movements, swallowing, smiling and using hands before he gains control of leg movements.
Most rapid growth rate of any period--often triples birth weight by age one.
Develops from crying as only form of language expression to smiling, cooing, laughing, babbling, using one or two words.
Gradually develops some motor control--from random movements to ability to pick up small objects with fingers.
Begins to cut teeth by six or seven months.
Sleep pattern changes from almost constant sleep to twelve hours a night and one or two naps.
Learns to eat solid food, drink from a cup.

Characteristic Behavior

Develops from no social perception to recognizing parents, brothers, sisters, environment, and routine.
Responds to people he knows. Usually withdraws from strangers.
Gradually becomes social--likes watching people and being played with, talked to, or held.
May be startled or cry at sudden, loud sounds or voices. May pull back or cry at strange objects. Disturbed by sudden movements.

Special Needs

Physical care--is dependent on adults for satisfaction of all physical needs. Should have prompt response to his needs.
Certainty of parents' love. Consistency and patience in handling. Cuddling, holding, rocking.
Consistent care by one or two people.
Verbal response to his babbling to help his language development.
Activity, opportunity to move about and to develop the large muscles.

THE TODDLER

Physical Development

Growth rate slower than during infancy.
Decrease in appetite from infancy.
Walks between twelve and eighteen months. Runs awkwardly and may fall.
Tries to feed himself, but manipulating spoon and cup still difficult. Finger feeds. Will be messy.
Constantly in motion. Into everything. Explores his environment--pushing, pulling, climbing, dragging, lifting everything within reach.
Learns by touching, feeling, and putting in mouth.
Short attention span.
Vocabulary increase in second half of year. May use words, but can't always express his wants.

Characteristic Behavior

Responds to his mother and likes to be near her. Enjoys his father and siblings, but usually wants his mother to do things for him.
Unable to play cooperatively with others.
Likes simple stories about himself, jingles, rhymes and picture books.
Beginning to be negativistic and may develop some fears. Developing likes and dislikes.
Becomes angry when frustrated.

Special Needs

Love, affection, and a secure, happy relationship with parents.
Acceptance of his constant activity. Patience and encouragement as he tries to learn to do things for himself.
Training with a light touch rather than by commanding and scolding.
A safe environment in which to explore, with dangerous objects put out of reach. Also a fenced-in, outdoor play area. Playpen outgrown near beginning of period.
Recognition that the toddler is not old enough to be responsible for himself, even though he may seem to understand directions.

THE RUNABOUT

Physical Development

Motor skills unevenly developed--marked development in large muscle coordination, but small muscles and eye-hand coordination still not well developed.

Full set of temporary teeth by three years.

Gradually acquires ability to feed and dress himself with greater skill.

Rapid language development--from a few words to an average of 2000.

Change in sleep pattern--twelve hours needed at night with daytime naps gradually given up. But still needs rest period because children of this age fatigue easily.

Toilet habits establish. Child usually takes care of his own needs by end of period.

Characteristic Behavior

Learning to understand his environment and comply with many of its demands.

Often negativistic at beginning of period, but gradually becomes able to accept necessary limits and restraints. Wants adult approval.

Likes to be close to his mother, but his father is becoming increasingly important to him.

Like to help around the house.

Imitative in language, manners, and habits.

Constantly active, but capable of longer stretches of quiet activity toward end of period.

Shows fatigue by being irritable or restless.

Gradually learning what is acceptable behavior and what is not.

Great curiosity. Asks countless questions.

Special Needs

Security for love and affection from parents.

Guidance and pattern of behavior to follow.

Time, patience, understanding, and genuine interest from adults.

Simple, clear, routines. Limited choices.

Opportunity to learn to give and take, to play cooperatively with other children.

Wider scope of activity. Limited freedom to move about and to move away from immediate home environment by end of period.

ABOUT FIVE

Physical Development

Period of slow growth. Body lengthens out and hands and feet grow larger. Girls usually about a year ahead of boys in physical development.

Good general motor control, though small muscles not so fully developed as large ones.

Sensory-motor equipment usually not ready for reading. Eye-hand coordination improving, but still poor. Apt to be far-sighted.

Activity level high.

Attention span still short, but increasing.

Little infantile articulation in speech.

Handedness established.

Characteristic Behavior

Stable--good balance between self-sufficiency and sociability.

Home-centered.

Beginning to be capable of self-criticism. Eager and able to carry some responsibility.

Noisy and vigorous, but activity has definite direction.

Purposeful and constructive--knows what he's going to draw before he draws it.

Uses language well, enjoys dramatic play.

Can wash, dress, eat, and go to the toilet by himself, but may need occasional help.

Individuality and lasting traits beginning to be apparent.

Interested in group activity.

Special Needs

Assurance that he is loved and valued.

Wise guidance.

Opportunity for plenty of activity, equipment for exercising large muscles.

Opportunity to do things for himself, freedom to use and develop his own powers.

Background training in group effort, in sharing, and in good work habits that he will need next year in first grade.

Opportunity to learn about his world by seeing and doing things.

Kindergarten experience if possible.

224

ABOUT SIX

Physical Development

Growth proceeding more slowly, a lengthening out.
Large muscles better developed than small ones.
Eleven to twelve hours of sleep needed.
Eyes not yet mature, tendency toward far-sightedness.
Permanent teeth beginning to appear.
Heart in period of rapid growth.
High activity level--can stay still only for short periods.

Characteristic Behavior

Eager to learn, exuberant, restless, overactive, easily fatigued.
Self-assertive, aggressive, wants to be first, less cooperative than at five, keenly competitive, boastful.
Whole body involved in whatever he does.
Learns best through active participation.
Inconsistent in level of maturity evidenced--regresses when tired, often less mature at home than with outsiders.
Inept at activities using small muscles.
Relatively short periods of interest.
Has difficulty making decisions.
Group activities popular, boys' and girls' interests beginning to differ.
Much spontaneous dramatization.

Special Needs

Encouragement, ample praise, warmth, and great patience from adults.
Ample opportunity for activity of many kinds, especially for use of large muscles.
Wise supervision with minimum interference.
Friends--by end of period, a best friend.
Concrete learning situations and active, direct participation.
Some responsibilities, but without pressure and without being required to make complicated decisions or achieve rigidly set standards.
Help in developing acceptable manners and habits.

ABOUT SEVEN

Physical Development

Growth slow and steady.
Annual expected growth in height--two or three inches. In weight--three to six pounds.
Losing teeth. Most seven-year-olds have their six-year molars.
Better eye-hand coordination.
Better use of small muscles.
Eyes not yet ready for much close work.

Characteristic Behavior

Sensitive to feelings and attitudes of both other children and adults. Especially dependent on approval of adults.
Interests of boys and girls diverging. Less play together.
Full of energy but easily tired, restless and fidgety, often dreamy and absorbed.
Little abstract thinking. Learns best in concrete terms and when he can be active while learning.
Cautious and self-critical, anxious to do things well, likes to use hands.
Talkative, prone to exaggerate, may fight verbally instead of physically, competitive.
Enjoys songs, rhythms, fairy tales, myths, nature stories, comics, television, movies.
Able to assume some responsibility.
Concerned about right and wrong, but often prone to take small things.
Rudimentary understanding of time and monetary values.

Special Needs

The right combination of independence and encouraging support.
Chances for active participation in learning situations with concrete objects.
Adult help in adjusting to the rougher ways of the playground without becoming too crude or rough.
Warm, encouraging, friendly relationships with adults.
Acceptance at own level of development.

ABOUT EIGHT

Physical Development

Growth still slow and steady--arms lengthening, hands growing.

Eyes ready for both near and far vision. Nearsightedness may develop this year.

Permanent teeth continuing to appear.

Large muscles still developing. Small muscles better developed, too. Manipulative skills are increasing.

Attention span getting longer.

Poor posture may develop.

Characteristic Behavior

Often careless, noisy, argumentative, but also alert, friendly, interested in people.

More dependent on his mother again, less so on his teacher. Sensitive to criticism.

New awareness of individual differences.

Eager, more enthusiastic than curious. Higher accident rate.

Gangs beginning. Best friends of same sex.

Allegiance to other children instead of to an adult in case of conflict.

Greater capacity for self-evaluation.

Much spontaneous dramatization, ready for simple classroom dramatics.

Understanding of time and of use of money.

Responsive to group activities, both spontaneous and adult-supervised.

Fond of team games, comics, television, movies, adventure stories, collections.

Special Needs

Praise and encouragement from adults.

Reminders of his responsibilities.

Wise guidance and channeling of his interests and enthusiasms, rather than domination or unreasonable standards.

A best friend.

Experience of belonging to peer groups--opportunity to identify with others of same age and sex.

Adult-supervised groups and planned after-school activities.

Exercise of both large and small muscles.

ABOUT NINE OR TEN

Physical Development

Slow, steady growth continues--girls forge further ahead. Some children reach the plateau preceding the preadolescent growth spurt.

Lungs as well as digestive and circulatory systems almost mature. Heart especially subject to strain.

Teeth may need straightening. First and second bicuspids appearing.

Eye-hand coordination good. Ready for crafts and shop work.

Eyes almost adult size. Ready for close work with less strain.

Characteristic Behavior

Decisive, responsible, dependable, reasonable, strong sense of right and wrong.

Individual differences distinct, abilities now apparent.

Capable of prolonged interest. Often makes plans and goes ahead on his own.

Gangs strong and of one sex only, of short duration and changing membership.

Perfectionistic--wants to do well, but loses interest if discouraged or pressured.

Interested less in fairy tales and fantasy, more in his community and country and in other countries and peoples.

Loyal to his country and proud of it.

Spends a great deal of time in talk and discussion. Often outspoken and critical of adults, although still dependent on adult approval.

Frequently argues over fairness in games.

Wide discrepancies in reading ability.

Special Needs

Active rough and tumble play.

Friends and membership in a group.

Training in skills, but without pressure.

Books of many kinds, depending on individual reading level and interest.

Reasonable explanations without talking down.

Definite responsibility.

Frank answers to his questions about coming physiological changes.

THE PREADOLESCENT

Physical Development

A "resting period," followed by a period of rapid growth in height and then growth in weight. This usually starts sometime between 9 and 13. Boys may mature as much as two years later than girls.

Girls usually taller and heavier than boys.

Reproductive organs maturing. Secondary sex characteristics developing.

Rapid muscular growth.

Uneven growth of different parts of the body.

Enormous but often capricious appetite.

Characteristic Behavior

Wide range of individual differences in maturity level.

Gangs continue, though loyalty to the gang stronger in boys than in girls.

Interest in team games, pets, television, radio, movies, comics. Marked interest differences between boys and girls.

Teasing and seeming antagonism between boys' and girls' groups.

Awkwardness, restlessness, and laziness common as result of rapid and uneven growth.

Opinion of own group beginning to be valued more highly than that of adults.

Often becomes overcritical, changeable, rebellious, uncooperative.

Self-conscious about physical changes.

Interested in earning money.

Special Needs

Understanding of the physical and emotional changes about to come.

Skillfully planned school and recreation programs to meet needs of those who are approaching puberty as well as those who are not.

Opportunities for greater independence and for caring more responsibility without pressure.

Warm affection and sense of humor in adults. No nagging, condemnation, or talking down.

Sense of belonging, acceptance by peer group.

THE ADOLESCENT

Physical Development

Rapid weight gain at beginning of adolescence. Enormous appetite.

Sexual maturity, with accompanying physical and emotional changes. Girls are usually about two years ahead of boys.

Sometimes a period of glandular imbalance.

Skeletal growth completed, adult height reached, muscular coordination improved.

Heart growing rapidly at beginning of period.

Characteristic Behavior

Going to extremes, emotional instability with "know-it-all" attitude.

Return of habits of younger child--nail biting, tricks, impudence, day-dreaming.

High interest in philosophical, ethical, and religious problems. Search for ideals.

Preoccupation with acceptance by the social group. Fear of ridicule and of being unpopular. Oversensitiveness and self-pity.

Strong identification with an admired adult.

Assertion of independence from family as a step toward adulthood.

Responds well to group responsibility and group participation. Groups may form cliques.

High interest in physical attractiveness.

Girls usually more interested in boys than boys in girls, resulting from earlier maturing of the girls.

Special Needs

Acceptance by and conformity with others of own age.

Adequate understanding of sexual relationships and attitudes.

Kind, unobtrusive, adult guidance which does not threaten the adolescent's feeling of freedom.

Assurance of security. Adolescents seek both dependence and independence.

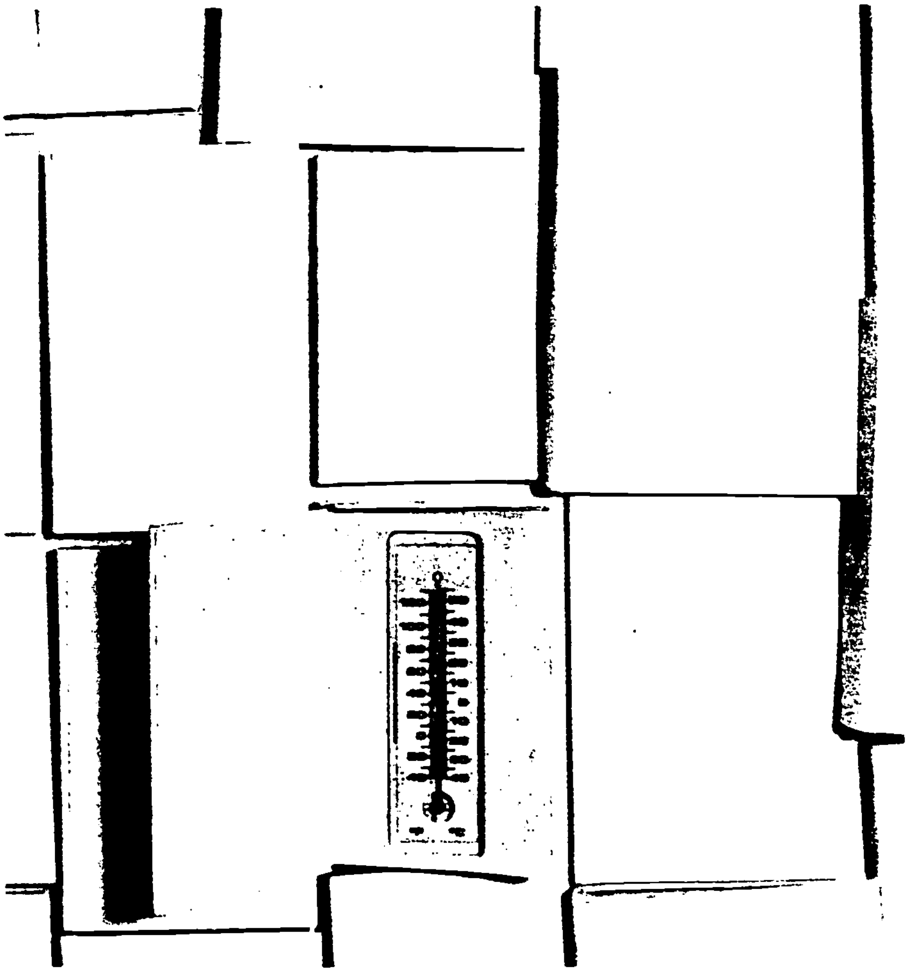
Opportunities to make decisions and to earn and save money.

Provision for constructive recreation. Some cause, idea, or issue to work for.

Teaching for Conceptual Change: Confronting Children's Experience

If Deb O'Brien had begun her lesson on heat in the usual way, Messrs. Watson and Konicek point out, she might never have known how nine long Massachusetts winters had skewed her students' thinking.

BY BRUCE WATSON AND RICHARD KONICEK



FOR NINE winters, experience had been the children's teacher. Every hat they had worn, every sweater they had donned contained heat. "Put on your warm clothes," parents and teachers had told them. So when they began to study heat one spring day, who could blame them for thinking as they did?

"Sweaters are hot," said Katie.

"If you put a thermometer inside a hat, would it ever get hot! Ninety degrees, maybe," said Neil.

"Leave it there a long time, and it might get to a hundred. Or 200," Christian added.

If Deb O'Brien had begun her lesson on heat in the usual way, she might never have known how nine long Massachusetts winters had skewed her students' thinking. Her fourth-graders would have learned the major sources of heat, a little bit about friction, and how to read a thermometer. By the end of two weeks, they would have been able to pass a simple test on heat. But their preconceptions, never having been put on the table, would have continued, coexisting in a morass of conflicting ideas about heat and its behavior.

However, like a growing number of educators at all levels, O'Brien periodically teaches science for "conceptual change." Her students, allowed to examine their own experiences, must confront

---

BRUCE WATSON, a former elementary science teacher, is a freelance writer living in Amherst, Mass. RICHARD KONICEK is a professor of science education at the University of Massachusetts, Amherst. *Funding for the research on which this article is based was awarded to the Five Colleges, Inc., Amherst, Mass., by the National Science Foundation. The Partnership in Elementary Science provided inservice education for 100 teachers from 1987 until 1990.*

rinted with permission of the *Phi Delta Kappan* (Vol. 71, pp. 680-685, 1990).

the inconsistencies in their theories. In the process they find the path toward a deeper understanding of heat, have a great time with science, and refine their thinking and writing skills.

O'Brien began with the simple question, "What is heat?" Using journals and the chalkboard to record their ideas, the students, with O'Brien's help, wrote down their "best thinking *so far*" on the subject of heat. Heat came from the sun, they wrote. And from our bodies. But when Owen spoke about the heat in sweaters, everyone else agreed. Sweaters were *very* hot. Hats, too. Even rugs got "wicked hot," the children said. Sensing the first of many naive conceptions, O'Brien stopped them and said the magic words in science, "Let's find out."

For two whole days the testing went on. Experience, that most deceptive of teachers, had to be met head on. With their teacher's help, Christian, Neil, Katie, and the others placed thermometers inside sweaters, hats, and a rolled-up rug. When the temperature inside refused to rise after 15 minutes, Christian suggested that they leave the thermometers overnight. After all, he said, when the doctor takes your temperature, you have to leave the thermometer in your mouth a long time. Folding the sweaters and hats securely, the children predicted three-digit temperatures the next day.

When they ran to their experiments first thing the next morning, the children were baffled. They had been wrong. Now they'll change their minds, and we can move on, O'Brien thought.

But experience is an effective, if fallible, teacher. The children refused to give up. "We just didn't leave them in there long enough," Christian said. "Cold air got in there somehow," said Katie. And so the testing went on.

CONCEPTUAL CHANGE AND HOW IT GREW

Since the late 1970s, the notion of "conceptual change" has been a pedagogical football among science educators. Arguing that reading and observing scientific principles will not alone move the mountain of "alternative frameworks" about science that children bring to the classroom, that even hands-on activities allow such thinking to go undetected, teachers are beginning from square one, helping children construct their own models of scientific principles.

If children base their thinking on what they have seen and felt, then their experience must be structured to challenge their erroneous beliefs. If alternative views of scientific principles are not addressed, they can coexist with "what the teacher told us" and create a mishmash of fact and fiction. When studying astronomy, for instance, if no one brings up the common belief in astrology, children can learn every available fact about the planets and still go away thinking that Venus somehow controls their destiny. But if each child is given a chance to test his or her own model of the universe and find its limits, then a deeper understanding, without the naive conceptions, can result.

As early as the 1920s John Dewey emphasized science as inquiry, and Gerald Craig in his landmark dissertation spoke eloquently in favor of teaching science as investigation.[1] Yet the texts and curricula of the 1950s told a different story. Science texts were reading books, punctuated by predigested demonstrations of various facts embedded in such obvious questions as, "Does air have weight?"

When the orbiting Sputnik I beeped to the world that the U.S. space program was second best, the golden age of science education began. Millions of dollars were made available for writing and implementing new science curricula. The National Defense Education Act (NDEA) of 1958 provided matching federal dollars for equipment purchased by schools. Probably most important, the new emphasis on science education gave scientists, psychologists, and educators the opportunity to combine efforts on a single task: improving science and mathematics education for all children.

Drawing on the work of such psychologists as Jerome Bruner, Robert Gagne, and Jean Piaget,[2] the emphasis in science education finally caught up with what Dewey, Craig, and others had been saying since the 1920s. Science is an inquiry-oriented subject; subjects should be taught and ultimately learned according to the structure of the discipline; children and how they learn should be at the center of the teaching of any subject.

Since the early 1960s science educators have tried to follow these tenets through times of financial feast and famine. The plethora of programs – from the 1960s: Science A Process Approach (SAPA), Science Curriculum Improvement Study (SCIS), Minnesota Mathematics and Science Teaching Project (MINNEMAST), Elementary Science Study (ESS); from the 1970s: Conceptually Oriented Program in Elementary Science (COPES), Science 5/13, Nuffield; and from the 1980s: Great Explorations in Math and Science (GEMS), TOPS, Activities in Integrating Math and Science (AIMS) – all subscribe, with mild variations, to the basic philosophies described above. Children are the focus, and science is viewed as a combination of content, process, skills, attitudes, and values.

> Sensing the first of many naive conceptions, O'Brien stopped them and said the magic words in science, "Let's find out."

These alphabetic programs, later published by commercial firms, made a modest impression on the market. Their ideas and activities were incorporated into such commercial texts as *Space, Time, Energy, and Matter (STEM)*, but even these books have made no more than a ripple in the ocean of school science. The latest generation of texts once again pays lip service to science as an inquiry-oriented discipline, but the books themselves resemble their ancestors of the 1950s more than they do those produced during that brief "golden age." Today's texts, which have the greatest influence on how science is taught in American schools, have come almost full circle, and teachers who rely primarily on them are little closer to teaching science as inquiry than were their counterparts in the 1920s. In too many classrooms across the U.S., science is still taught as a cohesive set of facts to be absorbed, and children are viewed as blank slates on which teachers are to write.

But in the last 20 years such people as David Ausubel, Joseph Novak, Rosalind Driver, John Clement, and others have begun to ask different questions about children's learning.[3] Cognitive psychol-

The substitution of one theory for another is not as easy as erasing the chalkboard. Certain preconditions must exist.

ogy and neo-Piagetian philosophy agree that knowledge, for both children and adults, grows and changes in very interesting ways. Learners bring their idiosyncratic and personal experiences to most learning situations. These experiences have a profound effect on the learners' views of the world and a startling effect on their willingness and ability to accept other, more scientifically grounded explanations of how the world works. Teachers who take a personal, adaptive view of knowledge are known as *constructivists* because their model of learning posits that all knowledge is constructed by the individual in a scheme of accommodation and assimilation.

Deb O'Brien is such a teacher. Her students, actively constructing their conceptual understanding of heat and its behavior, eagerly tackled their surprising data with yet another experiment.

THE INVESTIGATION HEATS UP

When the shock of the room temperature readings on the bundled-up thermometers wore off, the children went at it again. If, as they insisted, cold air had seeped inside the clothes overnight, what could they do to keep it out? While O'Brien would have preferred to focus on one variable at a time, the children's discussion brought out other naive conceptions. Remembering attics and cars, some of them said that closed spaces were hot. "How could you test that?" O'Brien wondered. Neil decided to seal the hat, with a thermometer inside, in a plastic bag. Katie chose to plug the ends of the rug with hats. Others placed sweaters in closets or in desks, far away from the great gusts of cold air they seemed to think swept through their classroom at night. With their new experiments snugly in place, time – that old heat maker – was left to do its job.

On Wednesday morning the children rushed to examine their experiments. They checked their deeply buried thermometers. From across the room, they shared their bewilderment. All the thermometers were at 68 degrees Farenheit. Confused, they wrote in their journals.

"Hot and cold are sometimes strange," Katie wrote. "Maybe [the thermometer] didn't work because it was used to room temperature."

Owen didn't know what to write, and Christian wrote simply, "I don't know why."

Meanwhile, O'Brien kept her own journal. This was one of her first attempts at teaching through conceptual change, and she wondered how long she should let these naive conceptions linger.

"The kids are holding on to and putting together pieces of what they know of the world. But the *time* we are taking to explore what kids think is much longer than if I told them the facts." If she told her students that hats didn't make heat, she knew that most would parrot her statement just to please her. Lacking the evidence to prove that fact, however, they would continue to prefer their own conceptions of their teacher's answer.

Surprises await the teacher who expects children to give up their conceptions at the first sign of a discrepancy. Stubbornness, a trait not limited to children, causes students to grasp at straws, O'Brien found. When the temperature inside a sweater rose even one degree, the students cheered and shouted, "Finally!" And if, as was more often the case, the thermometer stayed at room temperature, well, then, perhaps the thermometer was broken. Or perhaps the cold air got in somehow. Or maybe they just hadn't let the sweaters sit long enough. Christian wanted to seal a hat and thermometer in a metal box and leave it for a year. *Then* the temperature would be sure to rise.

Should she tell them the difference between holding heat and emitting heat, O'Brien wondered. Should she devise her own experiment on insulation? She decided to let the conceptions linger through one more round of testing. And so the sweaters, hats, and even a down sleeping bag brought from home were sealed, plugged, and left to endure the cold.

THE SLEEP OF REASON

While we often assume that reason is the guiding light of science, the history of scientific thought shows otherwise. When confronted with contradictory evidence, scientists are sometimes as puzzled as children. Through further testing, they seek additional evidence. If the results continue to disprove what they once thought, scientists often behave very much like children: they argue among themselves, they cling to their old theories, and they devise experiments that will reinforce the traditional way of thinking. As Thomas Kuhn showed in *The Structure of Scientific Revolutions*,[4] scientists are capable of holding contradictory theories about scientific concepts. Scientific communities, such as O'Brien's classroom, can take this a step further by dividing into camps that simultaneously believe several different explanations of the same event, often for many years' duration. When it comes to confronting the errors in one's thinking, scientists of all ages seem equally susceptible to certain barriers.

In theory, at least, when confronted with evidence that contradicts existing assumptions, rational observers will accommodate their thinking to fit the latest observations. A theory, says the philosopher of science Irme Lakatos, is judged on how well it solves problems.[5] If a theory generates problems that it can't solve or explain, Lakatos says, it is rejected in favor of a new theory that solves those problems and offers promise of further investigation. Even fourth-graders seek answers that can be explained by their theories. But the substitution of one theory for another is not as easy as erasing the chalkboard. Certain preconditions for conceptual change must exist if the barriers in the path to understanding are to be overcome.

We suggest several barriers to conceptual change, barriers strong enough to laugh in the face of discrepant events. Among schoolchildren the strongest of these obstacles is likely to be stubbornness, the refusal to admit that one's theory might be wrong. Children who are not often asked their opinions are especially reluctant to admit the errors in their thinking and will find ways to adjust old ideas before assimilating new ones.

Lakatos cites the varying strengths of scientific concepts as reasons why some beliefs are changed and others are not. "Hard-core ideas" take precedence over "protective-belt ideas," Lakatos posits. In the face of discrepant evidence, believers will change their "protective-belt ideas" in order to protect their hard-core beliefs, much as astronomers devised endless variations on cosmological theories, adding epicycles, altering distances, and so on just to keep the earth at the center of their cosmos. Katie was willing to believe that "hot and cold are sometimes strange," surrendering her belief in the consistency of temperature in order to build walls around the idea of "warm clothes." When children are unable to call on scientific knowledge to explain a piece of contradictory evidence, they will often call the discrepant event "magic." As many teachers know, tenacity in children makes scientists look downright flexible.

Another barrier to conceptual change is language. A teacher seeking conceptual change should be cautious about vocabulary. The difficulty of mastering new terms in addition to a new way of thinking about a concept can cause children to cling even more tenaciously to their old beliefs. Even the vernacular usage of nonscientific terms, such as "warm clothes," can cause confusion. There must be a reason why everyone calls them "warm," O'Brien's students conjectured.

Perception itself can block conceptual change as well. We tell children that "seeing is believing," but in science that often isn't true. Touch is an even more deceptive sense. Though O'Brien's thermometers had stayed at room temperature, each night the children kept warm beneath their blankets, just as each winter they had put on warm hats and sweaters and actually *felt* the warmth that the thermometers refused to register. A few days of surprising results in the classroom are not likely to change such deeply "felt" thinking. Teachers and students learn firsthand the inadequacy of empiricism as a theory of knowledge. As Eleanor Duckworth so aptly put it, "The critical experiments themselves cannot impose their own meanings. One has to have done a major part of the work already, one has to have developed a network of ideas in which to imbed the experiments."[6]

O'Brien and some of her abler students could have imposed their findings on the class, saying, "Look at the thermometer. Room temperature! *Now* do you believe that sweaters don't make heat?" Textbooks attempt to do just this, presenting events and critical experiments from the history of science up to the present day. But, to paraphrase Louis Pasteur, understanding favors the prepared mind. If the learner has done a major part of the work already and has developed Duckworth's "network of ideas in which to imbed" the new idea, an enlightened view is more likely to evolve. If not, the experience may mean nothing.

While children and adults face many of the same barriers to learning, a few of the obstacles to conceptual change are developmental. Children in the middle elementary grades are only beginning to use concrete operations. As Piaget's research showed, when confronted with new evidence, children in these grades tend to revert to the earlier stage – in this case the preoperational stage, characterized by an inability to conserve concrete properties, such as size and weight, and by difficulties in measurement and logical reasoning.

Children at this stage of development swear by their feelings in the face of the evidence and, having limited experience with the scientific method, trust their lifelong convictions more than they trust a thermometer. They are particularly susceptible to what researcher Judith Tschirigi calls "sensible reasoning."[7] Such reasoning, Tschirigi says, often takes precedence over Piaget's "concrete reasoning." Children will modify their experiments to accommodate their beliefs long before they will change their beliefs to fit the evidence.

Because children's minds are still "under construction," they must be treated with care where conceptual change is concerned. As O'Brien learned, expecting students to exhibit conceptual change after having observed a few discrepant events is bound to be frustrating for both teacher and students. A teacher who chooses to let students tackle their own misconceptions is well advised to consider Lev Vygotsky's "zone of proximal development,"[8] also known as a child's "construction zone." Such developmental factors as memory, skill acquisition, and reasoning ability affect a child's capacity to incorporate new knowledge into existing schemes of thought, Vygotsky said.

The "construction zone" encompasses what a child is developmentally ready to consider. Any new information or skills needed for conceptual change may lie outside the zone if the child is developmentally unprepared to learn them. O'Brien's students who cheered when the temperature inside the "warm" clothes rose a single degree evinced such unpreparedness. They failed to recognize that the single degree was an insignificant rise and may even have resulted from a misreading of the thermometer. Conceptual change can take place only within the

"Omigosh! My science project is gone!"

There are no prefabricated units to be assembled in mental constructions, though many science texts would seem to suggest otherwise.

"construction zone." Since children's scientific skills are constructed more slowly than many buildings, conceptual change in science will not happen overnight. Unfortunately for teachers, there are no prefabricated units to be assembled in mental constructions, though many science texts would seem to suggest otherwise.

Finally, science itself has "critical barriers" to understanding, which present difficult hurdles to children and adults alike, according to David Hawkins.[9] Along with the seemingly innate problems involved in understanding size, volume, weight, and elementary mechanics, Hawkins identifies the concept of heat as containing some of these critical barriers. The perception of things as "hot" and "cold" conflicts with the scientist's conception of heat as a measurable quantity contained by all objects, Hawkins says. Since scientists held misconceptions about heat for hundreds of years, Hawkins reminds us, understanding heat is a hurdle that will not be cleared by students in a single two-week unit.

FIGHTING THE GOOD FIGHT

With so many obstacles standing in the way, conceptual change in science might seem not merely difficult to achieve, but impossible, especially based on a few measly discrepant events. Yet certain teaching strategies have been devised that can help teachers overcome these obstacles.

When discrepancies between children's thinking and the evidence are laid on the table, the teacher assumes a crucial role. Far from being a passive observer, the teacher can actively promote new thinking patterns through a variety of methods.

1. *Stressing relevance*. Because children so frequently assume new information to be "stuff we learned in school," the teacher must connect new concepts to the child's everyday life. In the case of heat, O'Brien asked her students about times when they had felt heat coming from an object. She asked them if they could think of anything that trapped heat, that kept things warm without heating them. She asked them to think about animals that have "warm coats" and to consider whether those coats make heat. She asked them whether a handful of fur would stay warm if removed from the animal. Unless children appreciate the relevance of their experiments to their everyday life, they may just brush off a discrepant event as "some weird thing we saw in science."

2. *Making predictions*. Children who are asked to predict the results of their experiments are more willing to change their thinking than are children who function as passive observers. This neglected aspect of elementary science instruction is essential because it asks students to link their new knowledge with what they already know in order to form hypotheses. Through ample writing in journals, O'Brien's students predicted temperatures and gave reasons for their predictions. Even though they were often wrong, they had the chance to incorporate yesterday's thinking into today's task. The use of journals in O'Brien's class also facilitated what Piaget called "reflective abstraction"[10] – the chance to reflect on one's thinking, without which development does not occur.

3. *Stressing consistency*. Although nearly everyone lives quite comfortably while embracing a wealth of ideological and political contradictions, a teacher should encourage children facing new patterns of thought to be consistent in their thinking. A child can state categorically that the thickness of a sleeping bag "causes the heat inside" and that pressure "causes the heat inside" a rolled-up rug. Yet that same child can maintain that hats, which are neither thick nor compressed, will be hot for no reason at all.

The teacher should tactfully draw attention to the inconsistencies in children's thinking and ask them to consider how two contradictory statements could both be true. While some children will blithely ignore the illogic of contradictions, many will confront inconsistencies and change their thinking as a result. The development of logical, consistent thought is thus a by-product of teaching aimed at conceptual change, and developing an orderly view of the world can prevent the compartmentalization of knowledge that occurs when students think that nature works one way at home and another way at school. Katie reflected such inconsistency when she wrote that "hot and cold are sometimes weird." If she is encouraged to seek consistency, however, she will not be satisfied until she has seen some order in the world around her.

If one concept is to replace another, then certain conditions must prevail.[11] First, the old way of thinking must be challenged by direct observation, by a discrepant event. Next, a new explanation for the phenomenon in question must arise, an explanation that is understandable (take care with vocabulary) and plausible. Finally, the new explanation must lead to further testing. If these conditions can be created in the classroom, conceptual change can occur.

BRINGING IT ALL BACK HOME

Overcoming resistance to conceptual change in children is clearly an ongoing struggle. Children will not easily surrender their carefully constructed schemes of thought to the onslaught of new evidence, no matter how convincing it seems. Dedicated teachers using a variety of strategies, including infinite patience and the willingness to let children swim upstream toward an elusive understanding, can help their students overcome these barriers. But reluctance to change one's way of thinking is not limited to scientists and students.

Despite massive evidence suggesting that students learn by doing, by manipulating, by experimenting, the great bulk of science teaching is still based on textbooks. Some independent teachers have pursued conceptual change in their science classes, but doing so presents a number of monumental questions to curriculum builders, school administrators, textbook authors, and anyone whose job description includes monitoring the "coverage" of curriculum in any subject area.

- Is mere "coverage" of curriculum material a viable or reasonable goal?
- What is "growth" in science, and how will we assess it?
- What content should teachers know in order to be able to recognize and then challenge children's naive conceptions?

- How can teachers adapt texts and curriculum to meet the constructivists' challenge about how children learn?
- Are there appropriate grade levels for various science topics, and what content areas are appropriate at which levels?

Any teacher who has really tested his or her effectiveness by checking students' understanding of concepts faces a startling dilemma. Teaching science in a constructivist mode is slower and involves discussion, debate, and the re-creation of ideas. Rather than following previously set steps, the curriculum in a constructivist classroom evolves, depends heavily on materials, and is determined by the children's questions. Less "stuff" will be covered, fewer "facts" will be remembered for the test, and progress will sometimes be exceedingly slow. It is definitely a process of *uncovering* rather than covering.

The alternative is to cover the prescribed material, knowing full well that the students may be masking their lack of conceptual growth by solving the *teacher* rather than learning the *content*. In order to survive, students learn to give teachers what they want, whether memorizing and regurgitating book definitions of terms, completing lab reports in a certain format, or filling in the correct blanks on an exam.

Successful students have always done these things, and we suspect that they always will. It is their path to survival in schools. Nevertheless, their doing so presents teachers with an age-old dilemma: Do we cover the material, knowing full well that what we cover will be understood superficially at best – accommodated, but not assimilated? Or do we forget about coverage and work to help children test their untutored conceptions against the real world through challenging questions, predictions, and experiments, knowing that we will be sacrificing breadth for the sake of depth? We suspect that these questions will be central in the coming decade. Moreover, further study is needed to find out more about the social aspects of learning, about how students use their conceptual understandings outside the classroom, and about how their experience grows into scientific models that they find satisfactory.

One thing is certain. We need to study more deeply the views held by children, to learn the purposes they serve, to learn their innate structures, and to learn how they are formed and used. Perhaps then we will be better able to understand our role as teachers.

PUTTING STUDENTS IN THE HOT SEAT

For the third day in a row in O'Brien's classroom, the children rushed to their experiments as soon as they arrived. The sweater, the sleeping bag, and the hat were unwrapped. Once again the thermometers uniformly read room temperature. O'Brien led the disappointed children to their journals. But after a few moments of discussion, she realized that her students had reached an impasse. Their old theory was clearly on the ropes, but they had no new theory with which to replace it. She decided to offer them a choice of two possible statements.

"Choose statement A or statement B," she told them. The first stated that heat could come from almost anything, hats and sweaters included. In measuring such heat, statement A proclaimed, we are sometimes fooled because we're really measuring cold air that gets inside. This, of course, was what most children *had* believed at the outset. Statement B, of O'Brien's own devising, posed the alternative that heat comes mostly from the sun and our bodies and is trapped inside winter clothes that keep our body heat in and keep the cold air out.

"Write down what you believe," O'Brien told the class. "Then stand in this corner if you believe A and in that corner if you believe B. If you're not sure, stand here in front."

Pencils went to lips, and eyes studied the ceiling. Finally, after much thought, the statements were recorded in the journals. Students approached the chalkboard, ready to turn right or left. Katie turned left toward the B corner. Owen stood in the center for a moment, then followed Katie. Neil turned right and clung to his "hot hat" theory. Christian stood in the middle. One by one, the students took a stand. And when the cold gusts of approaching recess blasted through the classroom, O'Brien counted noses. A few children had joined Neil. Stubborn, perhaps, but O'Brien had to admire the strength of their convictions. Christian and one other child stood undecided in the center, while the rest of the class stood proudly with Katie and Owen, convinced by their own testing that "warm clothes" aren't really warm and that the heat that seems to come from them actually comes from the warm bodies they envelop.

"How can we test this new theory?" O'Brien asked. Immediately Neil said, "Put the thermometers in our hats when we're wearing them." And so the children went out to recess that day with an experiment under their hats.

As Deb O'Brien relaxed during recess, she asked herself about the past three days. Had the children really changed their minds? Or had they simply been following the leader? Could they really change their ideas in the course of a few class periods? Would any of their activities help them pass the standardized science test coming up in May? O'Brien wasn't sure she could answer any of these questions affirmatively. But she had seen the faces of young scientists as they ran to their experiments, wrote about their findings, spoke out, thought, asked questions – and that was enough for now.

---

1. John Dewey, *How We Think* (Boston: Heath, 1910); and Gerald S. Craig, "Certain Techniques Used in Developing a Course of Study in Science for the Horace Mann Elementary School" (Doctoral dissertation, Columbia University, 1927).
2. Jerome S. Bruner, *The Process of Education* (Cambridge, Mass.: Harvard University Press, 1960); Robert M. Gagne, *The Conditions of Learning* (New York: Holt, Rinehart & Winston, 1977); and Jean Piaget, "Cognitive Development in Children: Development and Learning," *Journal of Research in Science Teaching*, vol. 2, 1964, pp. 176-86.
3. David P. Ausubel, Joseph D. Novak, and Helen Hanesian, *Educational Psychology: A Cognitive View*, 2nd ed. (New York: Holt, Rinehart & Winston, 1978); Rosalind Driver and J. A. Easley, "Pupils and Paradigms: A Review of Literature Related to Concept Development in Adolescent Science," *Studies in Science Education*, vol. 5, 1978, pp. 61-84; and John Clement, "Students' Alternative Conceptions in Mechanics: A Coherent System of Preconceptions?," in H. Helm and Joseph D. Novak, eds., *Proceedings of the International Seminar: Misconceptions in Science and Mathematics* (Ithaca, N.Y.: Cornell University Press, 1983).
4. Thomas Kuhn, *The Structure of Scientific Revolutions* (Chicago: University of Chicago Press, 1962).
5. Irme Lakatos, *Proofs and Refutations: The Logic of Mathematical Discovery* (Cambridge: Cambridge University Press, 1976).
6. Eleanor Duckworth, *Inventing Density* (Grand Forks, N.D.: Center for Teaching and Learning, University of North Dakota, 1986), p. 39.
7. Judith E. Tschirigi, "Sensible Reasoning: A Hypothesis About Hypotheses," *Child Development*, vol. 51, 1980, pp. 1-10.
8. Lev S. Vygotsky, *Thought and Language* (Cambridge, Mass.: MIT Press, 1962).
9. David Hawkins, "Critical Barriers to Science Learning," *Outlook*, vol. 29, 1978, pp. 3-23.
10. Jean Piaget, *Structuralism* (New York: Harper & Row, 1968).
11. George J. Posner et al., "Accommodation of a Scientific Conception: Toward a Theory of Conceptual Change," *Science Education*, vol. 66, 1982, pp. 211-27. K

233

Surf 'n Sand

THIS INVESTIGATION deals with finding the ratio of water to land on the Earth's surface via any one of three activities. In Surf 'n Sand Count, squares of land and water will be counted on the world map included. In Surf 'n Sand Spin, latitude and longitude will be generated randomly by spinners, the location pinpointed on a map or globe, and a classification of land or water made. In Surf 'n Sand Toss, a beach ball globe will be tossed and a record made of land or water under the right index finger of the catcher. The circle graph worksheet can be used to summarize any of the activities. The continents and oceans worksheet may be used as an extension for the Spin and Toss versions. Choose the activity best suited to your needs or have different groups in the class do the various activities simultaneously and compare their results.

Surf 'n Sand Count

I. Topic Area

Land/Water area of the Earth

II. Introductory Statement

Students will discover the ratio of water to land on the Earth's surfaces by counting squares on a world map.

III. Social Science Processes

Predicting
Drawing conclusions
Working cooperatively
Communicating ideas
Reading maps

Science Processes

Predicting
Observing/Classifying
Comparing
Collecting/Recording data
Generalizing

Math Skills

Estimating area
Counting/Computing
Using calculators
Finding percent
Graphing with a protractor
Rounding

IV. Materials

Worksheets: Surf 'n Sand Count, circle graph
Calculators
Protractors
Colored pencils or crayons
Transparency of map worksheet, optional
Transparency of circle graph, optional
Transparent protractor, optional

V. Key Question

How do the surface areas of land and water on the Earth compare?

VI. Background Information

The Earth's surface is about 71% water and 29% land. See the fact sheet, "Land and Water on the Earth".

A Cylindrical Equal Space Projection is used here, flattening the Earth and putting it on an equally-spaced grid. The land masses near the Poles appear distorted in this type of projection.

When rounding squares that are 50% or more land or water, there will be approximately 60 squares of land and 180 squares of water. When visually estimating the squares the land would cover if compactly joined together in each column, there will be approximately 69 squares of land and 171 squares of water. Using the latter figures, land covers about 29% of the earth and water 71%. Your results may vary due to differences in estimating, but the total number of squares should be 240, the area of the map grid (10 x 24 cm). Even though using such a broad form of estimation, the results are fairly close to the real statistics. If the map grid squares were smaller, the results would be even more accurate.

To construct the circle graph, complete the computation at the top of the second worksheet. Using the latter figures, the rounded results would be:

360 x .29 (land) = 104 degrees
360 x .71 (water) = 256 degrees

VII. Management

1. Teams of two are recommended.
2. It will take about 60 minutes.
3. Land or water which is estimated to cover half or more of any square on the grid will be counted as a whole square for that classification. There is room for disagreement in some columns where the estimation is close, a good point for discussion. The final results will still be very similar. Land masses in a particular column may also be visually estimated according to how many squares they would take up if they were compactly joined together.

VIII. Procedure

Students will:

1. Predict and record the percent of water on the earth's surface.
2. Count and record the number of squares in each column which are half or more land or water. Totals should always equal ten. *Optional view*—Turn the paper sideways and count the long columns.
3. Add the total squares for land and the total squares for water.
4. Find the total area of the map grid and com-

be, A. (1990). Finding Your Bearings. AIMS.

plete the table by computing or using calculators.

The teacher will:

5. Lead a discussion comparing class results. The columns are labeled with letters for easy reference in case of differences of opinion. Consensus may not always be reached; allow any legitimate estimations. A transparency of the map worksheet is helpful.
6. Give guidance, if needed, in completing the table and in constructing the circle graph. A circle graph transparency and transparent protractor used on the overhead will help less experienced students get started.

Students will:

7. Fill in the number sentences to find the number of degrees which represent each percentage.
8. Construct and label the circle graph.
9. Summarize their information in written form.

IX. Discussion

1. What percent of the Earth's surface is water? (about 71%) How does this compare with your prediction?
2. Were all our results exactly the same? (probably not) Why not? (differences in estimation of area within a square, some squares can be argued for either land or water)
3. A graph title should tell others, in brief form, what the graph represents. What title did you pick? (Example—Surface Area of the Earth) Does it contain too much information? Too little?
4. We've expressed the results in decimals and percents, What other number forms could be used? (ratio: 7:3 water to land; fraction: 7/10 water and 3/10 land)

X. Extensions

1. Compare the area of the four major oceans using the same map grid. Make a table and rank them from largest to smallest.
2. Use the map grid to compare the area of the seven continents and rank them from largest to smallest. Draw the boundary between Europe and Asia.

XI. Curriculum Coordinates

Language Arts/Math: Brainstorm words describing water (liquid, blue, splash, float, molecules, pour...) and land (solid, mud, rock, cracks, molecules, brown...) Are there any words which describe both water and land? Make a Venn diagram with the words that have been collected.

Writing: Prepare an advertisement which will attract creatures from other planets to vacation on the Earth based on the fact that it is largely water.

Art: Color graph paper squares in a ratio of 7 to 3 (like the ratio of water to land) using two colors. The designs could be symmetrical.

Surf 'n Sand Spin

I. Topic Area

Land/Water area of the Earth

II. Introductory Statement

Students will discover the ratio of water to land on the Earth's surface by using spinners to randomly select latitude and longitude, finding the location on a world map, and classifying it as land or water.

III. Social Sciences Processes

Predicting
Working cooperatively
Communicating ideas
Drawing conclusions
Reading maps

Science Processes

Predicting
Classifying
Collecting/Recording data
Generalizing

Math Skills

Using probability
Plotting coordinates
Computing
Finding percent
Rounding
Graphing with a protractor

IV. Materials

Worksheets: Surf 'n Sand Spin, circle graph
Per group: 1 sheet of tag or a manila folder
2 large paper fasteners
2 large paper clips
1 or more globes or world maps with latitude and longitude markings (history textbook, atlas, etc.)
Protractors
Colored pencils or crayons

V. Key Question

How do the surface areas of land and water on the Earth compare?

VI. Background Information

The Earth is about 71% water and 29% land. The use of spinners to determine random latitude and longitude readings sets up a probability experiment that, if repeated a sufficiently large number of times, should result in numbers fairly close to the actual percentages. See the fact sheet, "Land and Water on the Earth".

VII. Management

1. Groups of four are recommended—a spinner, at least two map readers, and a recorder. It is important to cross-check latitude/longitude locations. Each map reader should have their own map; encourage the use of different kinds within the group.
2. The worksheet is set up for two sets of ten trials. If locating latitude and longitude is a difficult skill, one set of ten trials may be used per group. However, more trials yield greater accuracy in the final results.

3. The spinners should be prepared according to the directions before beginning the activity. Using the top of a manila folder for the spinners makes it easy to organize group worksheets inside.
4. Students may round their spins to the nearest five degrees. If more specialized practice is desired, they may estimate to the nearest degree. Set a standard before starting.

VIII. Procedure

Students will:

1. Predict the percent of water on the Earth's surface.
2. Spin both spinners, estimate and record the latitude and longitude readings with hemisphere abbreviations (Example: 45 N°, 30° W).
3. Find the latitude/longitude location on a map and record whether it is on land or in water.
4. Total the number on land and in water and report to the class.
5. Record each group's totals in Class Results and find the grand total. Add the grand totals to get the total number of spins.
6. Figure the percent of land and water using the bottom table. Ratio is written as the number of land counted over total spins and the number of water counted over total spins.
7. Fill in the number sentences to find the number of degrees which represent each percentage.
8. Construct and label the circle graph.
9. Summarize their information.

IX. Discussion

1. What percent of the Earth's surface is water? (about 71%) How does this compare with your prediction?
2. How close were our results to the actual facts? What factors might cause differences? (spinners not constructed to move freely or without bias and, therefore, not truly random; errors in map reading; not enough trials; etc.)
3. A graph title should tell others, in brief form, what the graph represents. What title did you pick? Does it contain too much information? Too little?

X. Extensions

Do the activity included for comparing the areas of the various oceans and continents.

XI. Curriculum Coordinates

See *Surf 'n Sand Count* for suggestions.

Surf 'n Sand Toss

I. Topic Area

Land/Water area of the Earth

II. Introductory Statement

Students will discover the ratio of water to land on the Earth's surface by tossing a beachball globe repeatedly and recording whether the right index finger touches land or water.

III. Social Science Processes

Interpreting data
Drawing conclusions
Reading maps

Science Processes

Collecting/Organizing data
Making inferences
Generalizing
Applying

Math Skills

Tallying
Setting up ratios
Finding percent
Graphing with a protractor

IV. Materials

Worksheets: Surf 'n Sand Toss, circle graph
Beach ball globe (available in toy stores)

V. Key Question

If a beach ball globe is tossed and caught, what percent of the time will the catcher's right index finger be on water? On land?

VI. Background Information

The Earth is covered by huge amounts of water. Over seventy percent of the Earth's surface is water, leaving less than thirty percent for land. In this activity the percentages will be calculated by doing a probability experiment in which a globe is repeatedly tossed and caught. With a sufficiently large number of tosses, the result of the probability experiment should come out fairly close to the actual percentages. See the fact sheet, "Land and Water on the Earth".

VII. Management

This activity should be done with the whole class. You may want to make some rules about how to toss and catch the ball. Spin the globe as it is tossed to insure randomness. Each student can make an individual tally as the ball is thrown or one person can make a tally on the board and the students can fill in the results after the three trials are done.

VIII. Procedure

The teacher will:

1. Discuss the key question.
2. Discuss the rules for tossing and catching the globe, and decide how the tallying will be done.

The students will:

3. Toss and catch the ball 50 times and keep a tally in the space for Trial 1. Use this information to fill in the percent table.
4. Repeat the process for Trials 2 and 3.
5. Find the average percent of land and water calculated from this activity.
6. Fill in the number sentences to find the number of degrees which represent each percentage.
7. Construct and label the circle graph.
8. Summarize their information and discuss.

IX. Discussion

1. What did you prove by doing this activity?
2. What factors could have affected the outcome?
3. If you were to get one toss and catch, where would you predict your finger would land?

X. Extension

Keep track of the ocean or continent on which your finger lands and calculate the percent of the water or land mass of each, using the activity sheet included.

XI. Curriculum Coordinates

See *Surf 'n Sand Count* for suggestions.

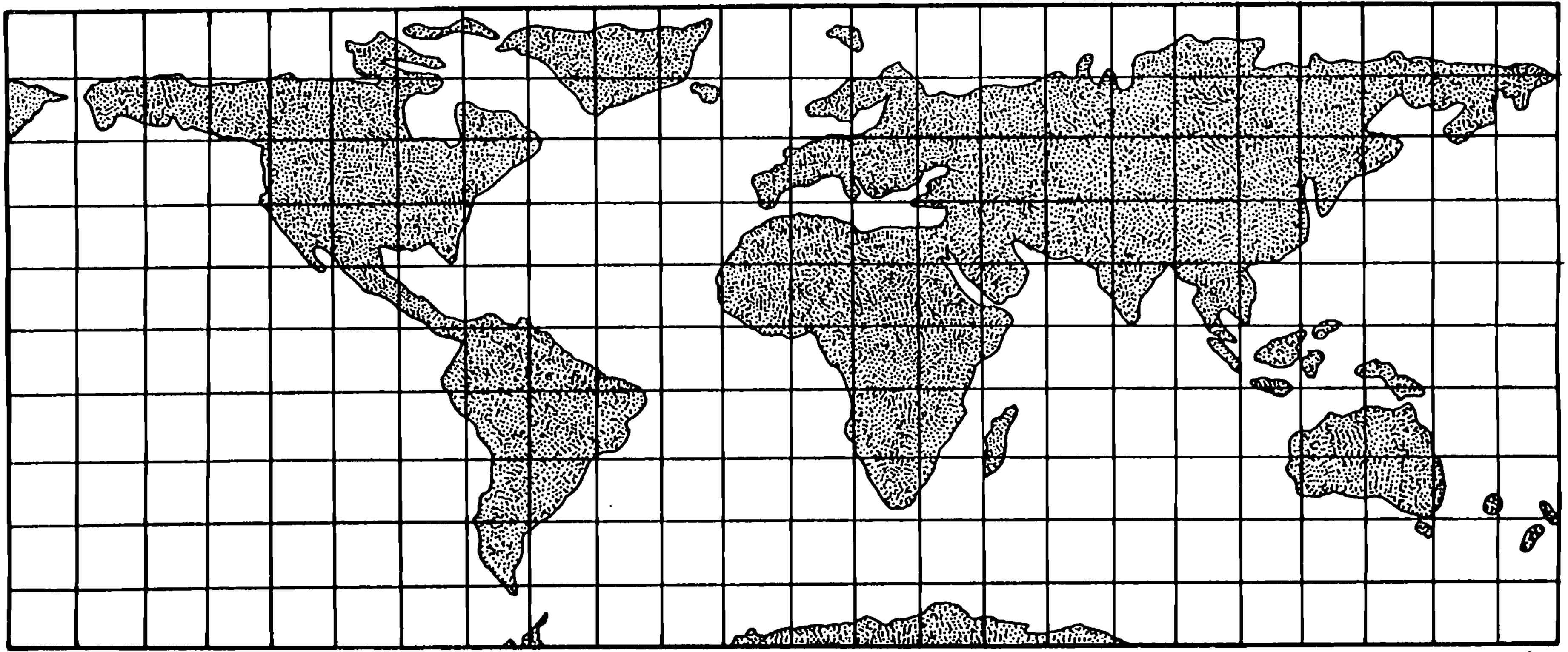
Surf 'n Sand Count

_______________ _______________
Names

PREDICT WHAT PERCENT OF THE EARTH'S SURFACE IS WATER.__________(0-100)

Count the number of squares of land and water in each column.

CYLINDRICAL EQUAL SPACE PROJECTION



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	TOTALS
LAND																									
WATER																									

TOTAL AREA OF MAP GRID IN CM

_____ × _____ = _____

	RATIO $\frac{\text{Sq. Count}}{\text{total area}}$	DECIMAL	PERCENT (decimal × 100)
LAND			
WATER			

Surf 'n Sand Spin

____
____
____
____
Names

Predict the percent of water on the Earth's surface. ________ (0–100)

Spin for latitude and longitude. Record the degrees and locate on a map or globe. Complete the tables.

LAT.	LONG.	LAND (L) OR WATER (W)?
		___
		___
		___
		___
		___
		___
		___
		___
		___
		___

LAT.	LONG.	LAND (L) OR WATER (W)?
		___
		___
		___
		___
		___
		___
		___
		___
		___
		___

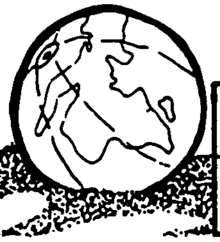
TOTAL # LAND ________

TOTAL # WATER ________

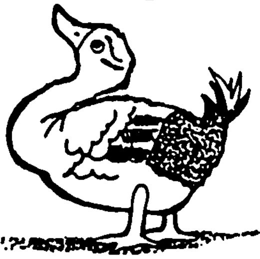
CLASS RESULTS

GROUP	A	B	C	D	E	F	G	H	I	J	GRAND TOTAL
# LAND											
# WATER											

________ TOTAL SPINS



	RATIO # counted / total spins	DECIMAL	PERCENT (decimal x 100)
LAND			
WATER			

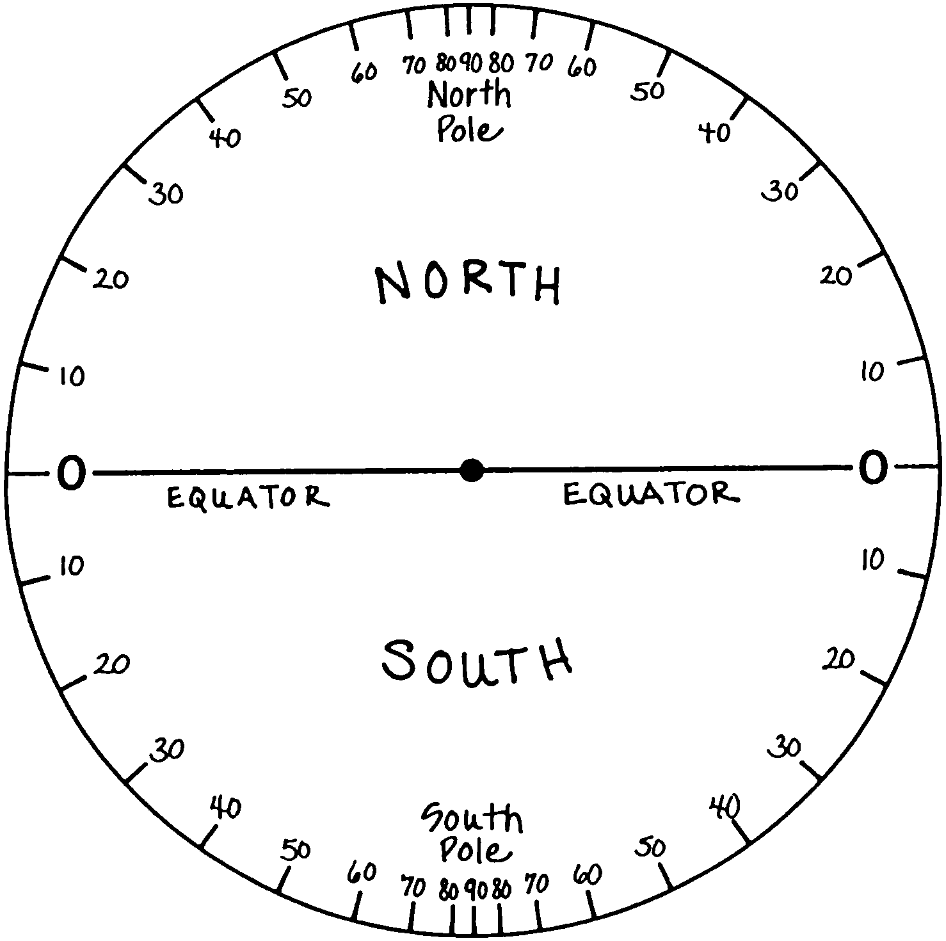


239

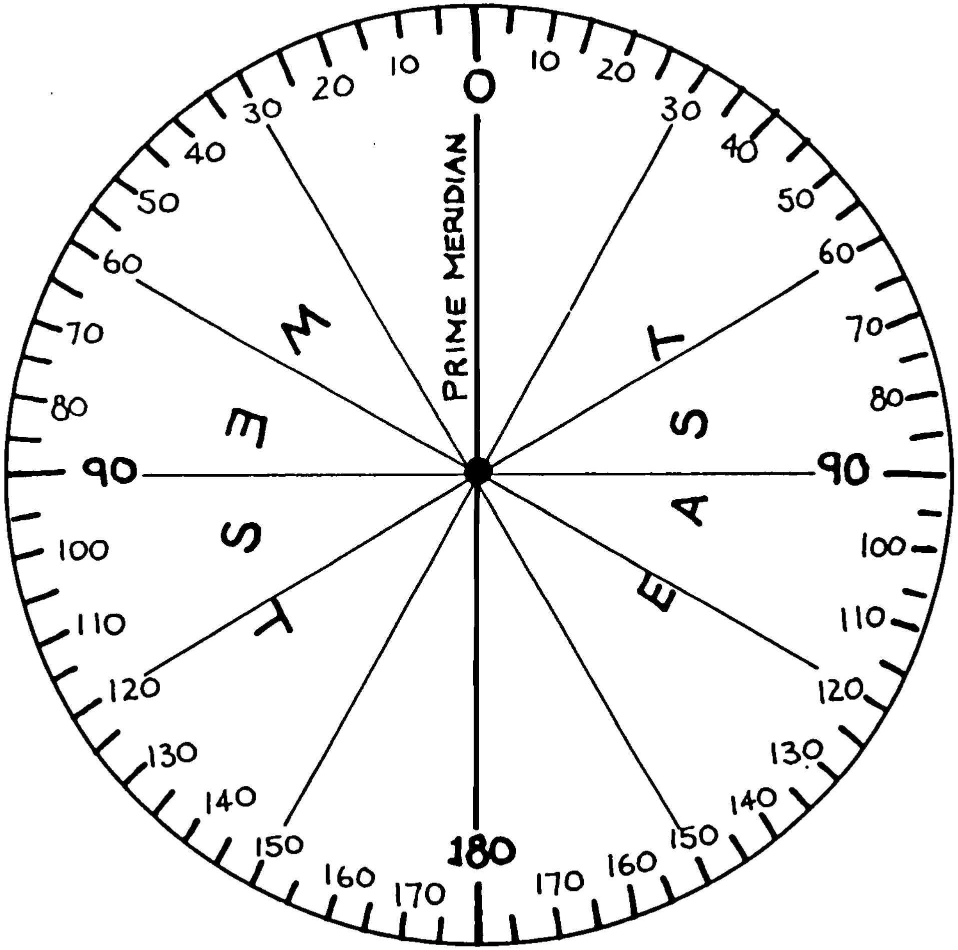
Surf 'n Sand Spin...

Mount on tag or a manila folder. Insert a paper fastener in each center with a large paper clip attached. Wrap a thin piece of tape around the tip of the paper clip and cut to make an arrow.

LATITUDE



LONGITUDE

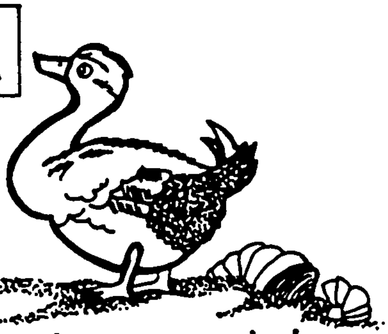


Surf 'n Sand

______________________ Name

CIRCLE GRAPH

Total degrees in circle	Decimal	# of degrees representing area



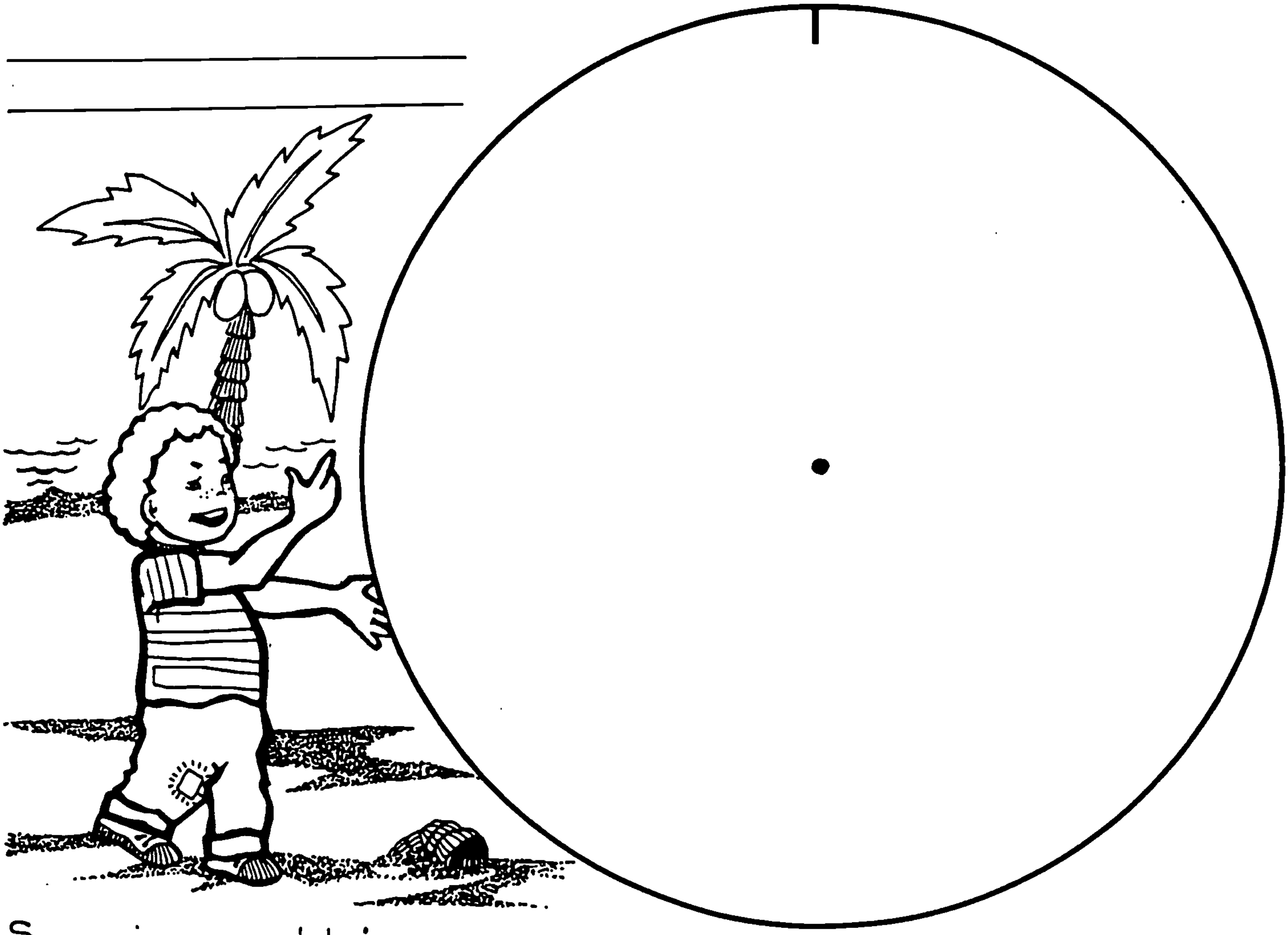
______ x ______ = ______
land

______ x ______ = ______
water

Use a protractor to construct a circle graph showing your data. Label and color the graph. Give it a title.

____

____



Summarize your data: ______________________

____

Name ____________________

Surf 'n Sand Toss

If a beach ball globe is tossed and caught, what percent of the time will the catcher's right index finger be on water?

Do three trials in which the globe is tossed and caught 50 times. Keep a tally of the results in the first table and then calculate the percents in the second table.

Tally

Trial	Land	Water
1		
2		
3		

Percents

Trial	Land/Total	Percent Land	Water/Total	Percent Water
1				
2				
3				
	Average		Average	

243

Surf 'n Sand Count

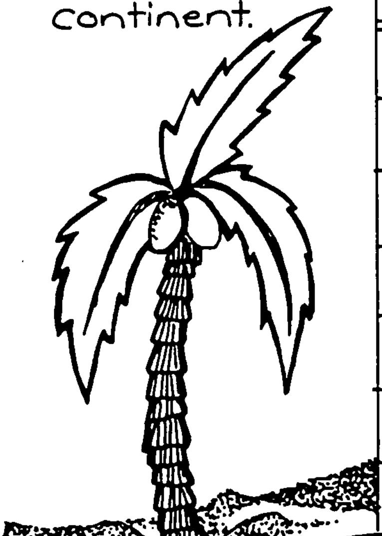
Name ______________________

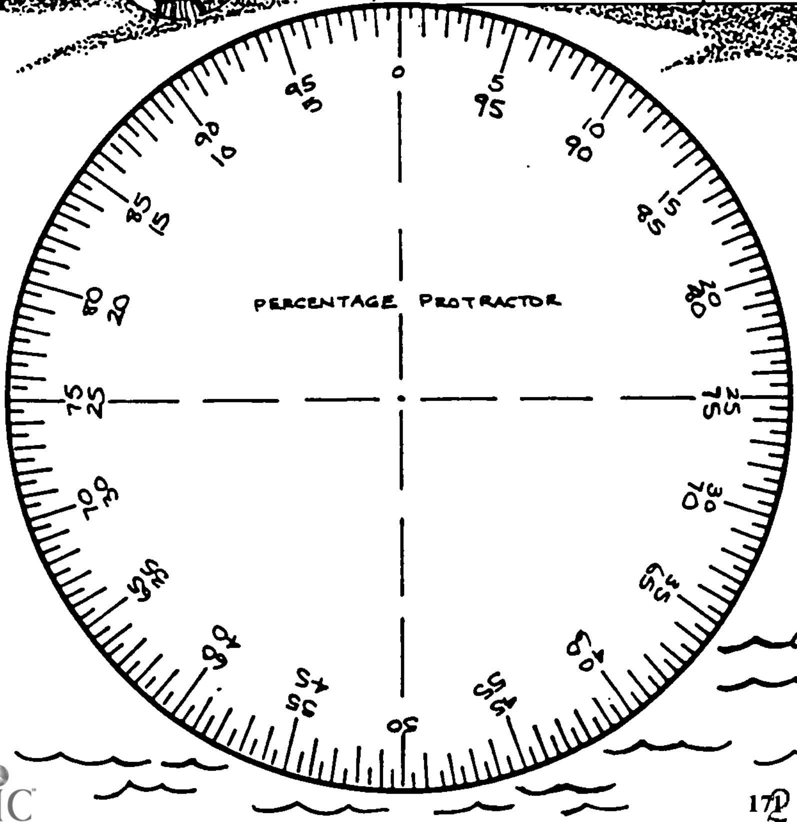
SPIN OR TOSS

How does the surface area of each ocean and continent compare?

Taking 100 spins or tosses, tally the number of times you land in each ocean or continent.

	TALLY	RATIO	%
ARCTIC			
ATLANTIC			
INDIAN			
PACIFIC			
AFRICA			
ANTARCTICA			
ASIA			
AUSTRALIA			
EUROPE			
NORTH AMERICA			
SOUTH AMERICA			
		TOTAL	





Graph the percents. Label and color.

MAKING ME MAPS

Purpose:

This activity is used to show how young children begin to learn representation and symbols, which are basic concepts in mapping.

Materials:

Each group has the following:

Large sheet of paper

> Note: Use butcher block paper with first grade children. For older students who have some understanding of maps, use white paper with grid lines (you may need to tape several sheets of paper together). Paper should be the length of a student's body.

Crayons

Procedures:

1. Assign students to groups of two or three. Each group should find a place on the floor and lay out their sheet of paper.
2. Trace the outline of one student's body on the paper.
3. Color the figure to look like the student, being sure to add facial features.

Tips:

- Consider using same-sex groups for this activity and be sensitive to students who may not want to have their bodies traced.

Extension:

1. With older students or as time permits, make the map a little more abstract by using paper with grid lines or by adding grid lines before drawing. Outline the student's head and shoulders. This time, put in the following symbols to represent the facial features and other prominent features.

@ = eyes   + = mouth

* = nose   ^ = freckles

= hair

2. Add a key to the map to interpret the symbols.
3. Have students label the vertical grid lines for the face with letters, starting with "A" at the top line. Have students number the horizontal grid lines at the top of their me maps, starting with "1" at the left.
4. Using the grid lines, have students write the grid locations of: the left eye, the right eye, the nose, and the mouth.

Discussion:

1. What mapping concepts does this activity teach or reinforce?
2. How could this activity be adapted to teach additional mapping concepts?
3. Why is it important to understand mapping concepts?

246

The Great Flood

49

BY CAROLE J. REESINK

Focus:

Using materials easily obtained from a grocery store, students will come to understand the nature of topographical maps and will practice the visualization skills needed to use these maps. The procedure in this activity is not, of course, the actual method used to construct topographic maps, but it simulates how a map could be made if there was a "Great Flood."

A topographic map is a two dimensional representation of a three dimensional landscape. Using a topographic map one can determine where hills and valleys are located and their elevations. A topographic map takes a normal road map a step further in information. Not only can one find various roads, streams, towns, and landmarks, but the topographic map allows us to "see" the elevation of the terrain as well. Many people use topographic maps, from vacationers to city planners. With a topographic map, hikers and cross-country skiers can locate their positions and plan a route of travel because they know, from looking at the map, where the steep hills, cliffs, and canyons are. Geologists and naturalists make extensive use of topographic maps to locate natural features of the terrain. Road planners and city planners also use topographic maps, designing road paths and locations of city facilities.

Materials and Equipment:

The whole class will need:

A metric ruler

Newspapers

Sponges

A mop

Each group of students will need:

A clear plastic box with a lid
(22.5 cm x 17.5 cm x 6 cm)
(These may be obtained from the produce or bakery departments of your local grocery store and are very inexpensive or even free if your grocer feels generous.)

An acetate overhead transparency

An overhead transparency marking pen

Onion skin paper for tracing

A metric ruler

Masking tape

A pencil

500 g non-hardening modeling clay

A simple topographic map
(figure 2)

Water to fill the plastic box

Challenge:

How can topographical maps help us decide where to build roads and trails? Could topographic maps help us find a good location to build a town or resort? If we were on a hike, could a topographical map help us decide where the easiest path lies?

Time: Several days to several weeks, depending on the depth of study desired

Procedure:

One-hill Terrain

1. Using about one-fourth of the modeling clay, build a single hill on the bottom of the plastic box, making sure that the hill is not taller than the box. For this first activity, instruct the students not to build arches, overhangs, or volcanoes with craters, nor should they put in vegetation or buildings.

2. Place a strip of masking tape vertically on the outside of

Reprinted with permission: Lind, K.K. (1991). Water, stones and fossil bones. Washington, DC: National Science Teachers Association.

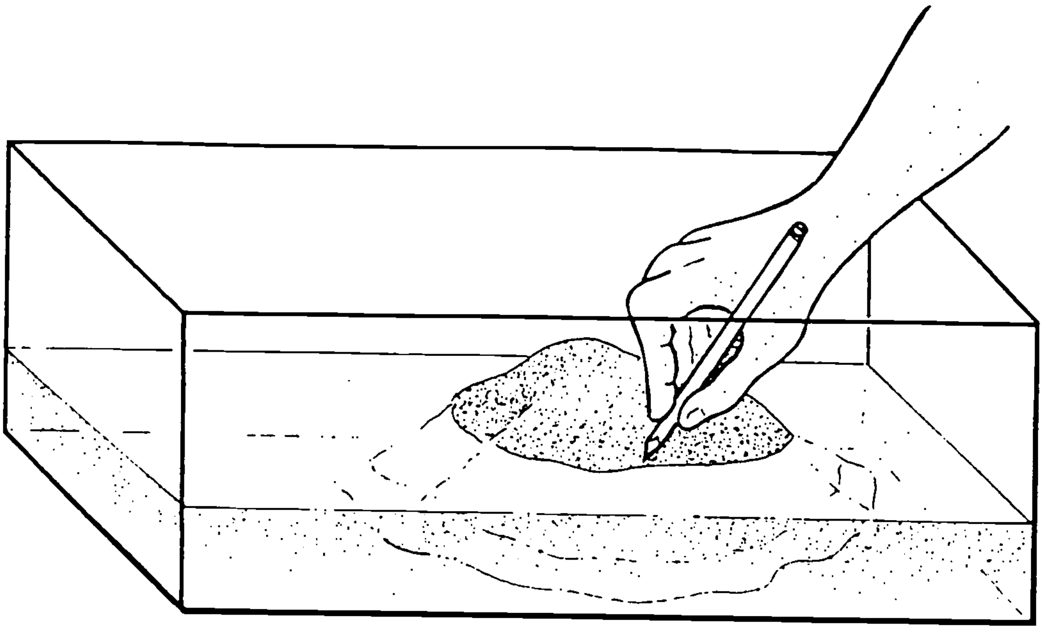


figure 1

the plastic box and mark off 1-cm increments on the tape, starting at the bottom. Next, carefully pour water into the box until the water level reaches the first mark on the piece of masking tape.

3. Using a pencil point or toothpick, make a groove in the clay at the water line, making sure the groove completely encircles the hill (see figure 1).

4. After making the groove along the first shoreline, add more water until the water reaches the second mark on the masking tape and etch a groove along this second shoreline. Continue filling the box with water and marking shorelines until the hill is totally submerged or "flooded."

5. Next, carefully pour the water out of the model while leaving the clay hill in the box. Then, place the lid on the box and tape a piece of clear acetate on top of the lid.

6. Using the overhead transparency pen, carefully trace all of the grooves in the clay while looking directly down on the hill. Try closing one eye and keeping the other eye directly over the pen. Trace the centermost contour lines first and work outward, making sure to trace all of the grooves. Finally, trace the acetate drawing—the new topographic map of the hill—onto a piece of onionskin tracing paper to keep.

7. On the masking tape side of the box, mark a scale of 1 cm = 100 m, starting at the bottom with zero. Now, on the topographic map mark the correct elevations on the contour lines. Mark an "x" on the highest elevation.

Although the students may have been exposed to scales in math and geography, some instruction in this area may be needed. Make the scales as simple as possible, using multiples of 10 or 100 for elevations. Note that with topographic maps, two scales are used—one is the horizontal scale used

Q What is the highest elevation in meters? If it falls between two lines, can you estimate the elevation (write the estimation by the "x")? Do any of their lines cross? Could they ever cross? Is the space between contour lines from a steep hill different from those on a gently sloping hill? How?

on ordinary road maps, and the other is a scale for vertical elevations.

This activity ties into math activities involving coordinate graphing and three-dimensional graphing. If students do not fully understand the first simple-hill map that they make, a second one may be necessary before attempting the three-hill system that follows.

Three-hill Terrain

8. Work in groups of two or three combining everyone's clay to build a three-hill terrain.

9. Repeat steps 3 through 6.

10. Find a place where a stream might flow downhill. Notice the "v" pattern of the contour lines, a characteristic of stream beds.

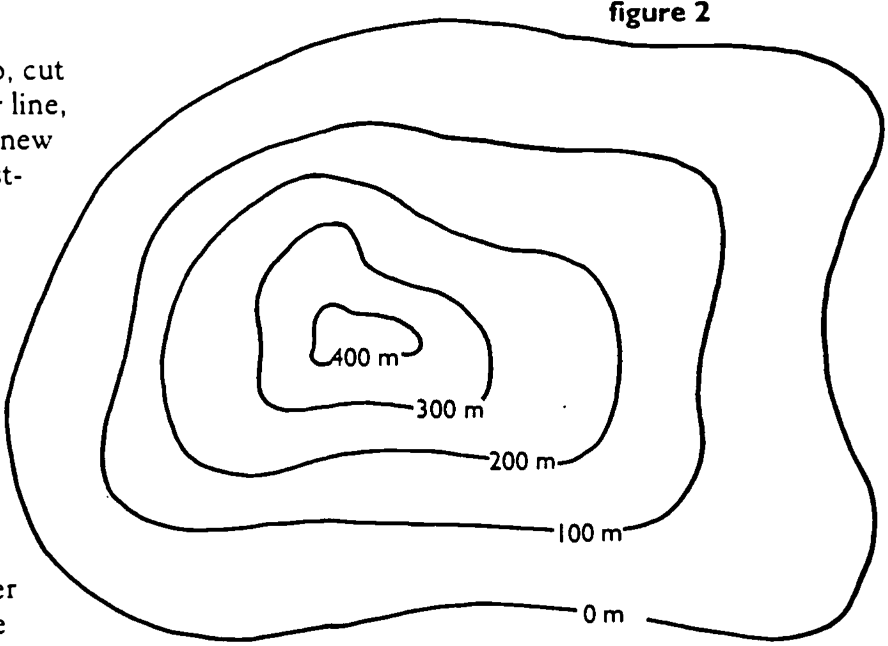
Q What is the elevation in meters of the highest hill, the next highest, and the next? How do you know where the low places are? Are smaller rings at the top or bottom of the hills? Can you tell where the hill is steep or gently sloped?

Building From a Topographic Map

11. From the simple topographic map provided by figure 2, reconstruct the terrain in the plastic box using the modeling clay. One approach is to first roll out the clay into layers 1 cm thick.

12. Cut out the paper map, and lay it on top of the clay. Then cut this contour shape out of the clay. This is the lowest elevation level.

figure 2



13. From the same cut-out map, cut around the next highest contour line, and repeat step 12, placing this new clay contour on top of the lowest-elevation clay contour.

14. Continue this procedure until all the elevation levels have been cut out of clay and a wedding-cake type of terrain has been built.

An alternative approach is to sculpt the terrain from a mound of clay. It is helpful to place graph paper, to serve as a grid, over the map and another one under the plastic box so the contours can be more accurately reconstructed. And to accurately measure elevations in the clay, poke a thin wire or pick-up stick into the clay to check how thick the clay has been built up.

Students come up with various methods for replicating the terrain from the map, but these are the two most frequently used.

15. Once the terrains are finished, repeat steps 3–6, and compare the student-made maps to the original map to see how accurately they replicated the terrain.

Q Is the peak in the same location as the original? Does the peak have the same elevation as the original map? How could you make more accurate models?

Further Challenges:

As an extension, build other geologic formations such as volcanoes, canyons, lakes, rivers, cliffs, and overhangs and make additional topographic maps. Find places on the map where a stream could flow down the hillside. Do the contour "v" lines on the map point upstream or downstream? How does a volcano's crater appear on the map? Were there any difficulties in mapping the crater? (Hint: a hole needs to be punched at the base of the crater so that water can flow into the crater, otherwise the crater only fills when the water level reaches the rim of the crater.)

Based on a simplified commercial topographic map (available from science suppliers), create a set of question cards. Some questions to ask include: Can you find the highest point on the map? The lowest? If you walked from Point A to Point B would you be walking uphill, downhill, or on level ground? Is it a steep or gentle hill? Can you find a stream? What direction is it flowing? Where might you build a bridge?

References:

Mapping. (1971). *Elementary science study teacher's guide.* Oklahoma City: McGraw-Hill.

The Author

Carole J. Reesink is a professor of education at Bemidji State University in Bemidji, MN.

PROCESS SKILLS AND INQUIRY

Diane C. Cantrell
Ohio Department of Natural Resources

Introduction

A familiar Chinese proverb captures the importance of process skills:

> Give people a fish and they can eat for a day.
> Teach them to fish and they can eat for a lifetime.

We might just as easily say, "Give learners a fact and they can answer the question of the day. Teach them process skills and they can answer questions for a lifetime." In other words, they can inquire throughout their lives.

Relationship between Inquiry and Process Skills

As previously indicated in the section on "Exposition to Inquiry," SWEEP emphasizes an inquiry approach to teaching and learning. At the heart of inquiry lie process skills. In fact, it is difficult to talk about inquiry without discussing process skills and vice versa. The following list of characteristics of inquiry shows how deeply process skills and critical thinking are embedded within inquiry.

Characteristics of Inquiry

1. Inquiry is carefully planned around a series of problem solving investigations that actively involve the learner.
2. Inquiry lessons follow a general pattern:
    - Question
    - Identify problem
    - Gather data through investigation
    - Analyze and interpret data
    - Draw conclusions
3. Inquiry is highly process-oriented and involves critical thinking
4. Teaching and learning are question centered and answers are not known in advance.
5. The end product may be a discovery but discovery is only a part.
6. Inquiry is learner centered.
7. Inquiry educators:
    - Model scientific attitudes
    - Are creative and resourceful
    - Are flexible
    - Use effective questioning strategies
    - Teach both skills and content
8. Time is not of prime importance

Adapted from:
Victor, E. (Oct. 1974). The inquiry approach to teaching & learning: A primer for teachers. Science and Children, pp. 23-25.
Birnie, H.H. & Ryan, A. (Apr. 1984). Inquiry/discovery revisited. Science & Children, pp. 31-32.
Rakow, S.J. (1986). Teaching science as inquiry. (Fastback #246). Bloomington, IN: Phi Delta Kappan.

Research Findings

Inquiry teaching, like Shakespeare's rose, has many other names – discovery, guided discovery, hands-on, activity-based – but they all have process skills at the heart. Research findings indicate positive benefits to using a hands-on, activity-based approach.

Research Findings

Research studies indicate that using a hands-on, activity-based approach to science:

1. Increases learning and achievement in science content.
2. Improves students' attitudes towards science.
3. Increases skill proficiency in processes of science.
4. Benefits academically or economically disadvantaged learners.
5. Helps in the development of language.
6. Enhances reading readiness and oral communication.
7. Encourages creativity in problem solving and promotes student independence.

Haury, D.L., & Rillero, P. (1992). Hands-on approaches to science teaching. Columbus, OH: ERIC Clearinghouse.

This discussion of the characteristics of inquiry and related research findings suggest several specific implications for educational practice.

Implications for Education

1. Involve learners with concrete materials
    - to match how they learn
    - to engage them (thinking, feeling, doing)

2. Use open-ended investigations
    - to provide more opportunity for success
    - to allow learners to work at their own level

3. Emphasize process over correct answer
    - to provide practice with procedure rather than memorization
    - to transfer across disciplines

4. Provide adequate time for tasks
    - to give learners time to process ideas and think at higher levels
    - to recognize that learners need time to engage in thinking if they are going to learn to think

5. Use teacher-learner interactions that promote inquiry
    - to encourage thinking and independence

Through the SWEEP activities, we try to model these practices as much as possible.

Identifying Process Skills

If we know that hands-on, activity based approaches work and that process skills are key to inquiry, then focusing on the teaching of process skills makes sense as one starting point. What are the process skills? There are a number of different lists, but the 1960's curriculum reform program, Science – A Process Approach (SAPA), offers an effective list divided between basic skills and integrated skills:

Basic Process Skills (Grades K-3)
Observing
Classifying
Using space/time relationships
Using numbers
Communicating
Measuring
Predicting
Inferring

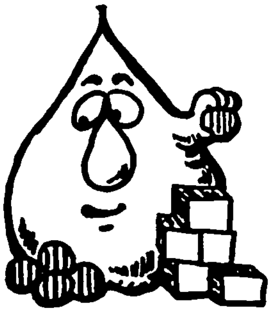
Integrated Process Skills (Grades 4-6)
Formulating Hypotheses
Controlling Variables
Experimenting
Defining Operationally
Formulating Models
Interpreting data

Teaching Process Skills

We can use a basketball analogy to suggest an effective way to teach process skills. Basketball coaches drill team members on individual skills – dribbling, passing, lay ups. But learning these skills only in isolation will not lead to effective team play. The coach also helps the players practice how to use these isolated skills in an integrated way during a game. The relationship between science process skills and inquiry is similar. We need to help learners focus on specific skills – hone their observation or predicting skills – while also helping them learn how to use their skills in an integrated way to conduct effective inquiry.

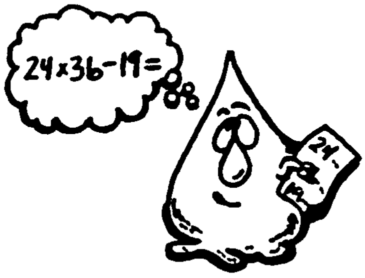
Observing

Classifying

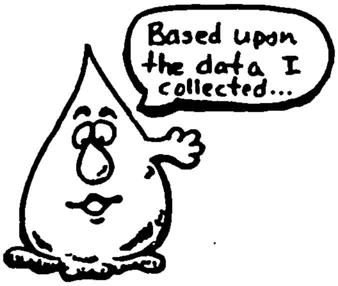


Using Time/Space Relationships

Using Numbers



Communicating



Measuring

Predicting

Inferring

Hypothesizing

Using Space/Time Relationships.

Young children find it difficult to comprehend phenomena that are outside of their immediate temporal or spatial experience. By helping students develop an awareness of phenomena and events outside of their immediate environment, they come to understand concepts in astronomy or earth science, for example.

Classifying.

Classifying involves the grouping of objects or events according to similar characteristics. Identifying and grouping by patterns of similarity is a frequently used skill in science.

Observing.

Observing refers to the use of the five senses to gather data about objects and events. Use of the five senses is important: students should be encouraged to use more than just their sense of sight when observing and gathering data.

Measuring.

Scientists gather and share data about the world by using common standards of measurement: length; (inches, feet, meters, light years); weight (pounds, grams); volume (quarts, gallons, liters); and time (seconds, hours, year). Students must be proficient in using these standards in order to communicate their results to others.

Communicating.

Communicating involves the use of spoken and written words, graphs, drawings, and diagrams to share information and ideas with others. Scientific discoveries have little value unless they are communicated to others. This process skill serves as a link between science and language arts.

Using Numbers.

Quantification is the essence of science. The ability to describe the world numerically is basic to all scientific endeavor. Science activities provide students with practical applications of the concepts they have learned in mathematics. This process skill serves as a link between science and mathematics.

Formulating Hypotheses.

An hypothesis is an educated guess that is then tested experimentally. The formulation of hypotheses is a key skill in the scientific method.

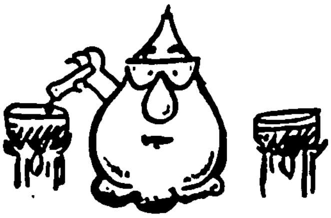
Inferring.

An inference is a logical Thought process to show a Relationship between two or more observations. Science seeks to identify relationships between phenomena by making observations and, on the basis of those observations, generating inferences about those phenomena.

Predicting.

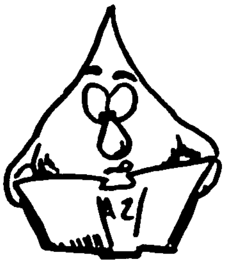
Predicting for the scientist is forecasting future events based on observations and inferences. Accurate predicting requires that the scientist know many pieces of information and how they interact. For example, scientists are seeking more information about the nature of earthquakes so that they can predict future earthquakes before they occur.

Controlling Variables

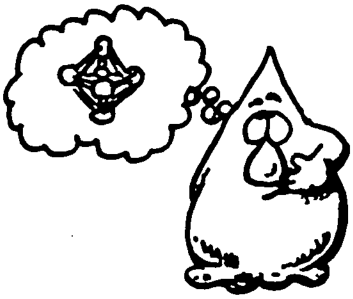


Experimenting

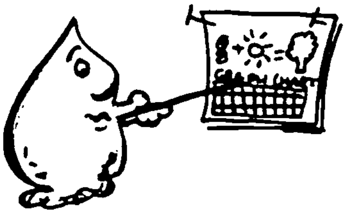
Defining Operationally



Forming Models



Interpreting Data



Defining Operationally. An operational definition is a definition framed in terms of students' experiences. For example, defining an acid as any substance that turns blue litmus red is an operational definition.

Experimenting. Experimenting combines all of the process skills used in conducting a scientific investigation.

Interpreting Data. Interpreting involves the analysis and synthesis of data to support or refute a hypothesis.

Controlling Variables. In a science experiment, two conditions, alike in every way but one, are compared to determine the influence of the one missing element. In designing and conducting science experiments, students must be able to identify and control the variables in order to determine their effect on the experiment.

Formulating Models. A model is a verbal, structural, or graphic representation of the physical world. Scientists develop models as a way of describing the world, then test and refine those models as more information becomes available.

APPENDIX C-1

Learning Skills

The following lists are provided to illustrate the wide range of skills which individuals need as lifelong learners and are able to develop as a result of well designed learning episodes.

Science Process Skills

- Observing
- Classifying
- Using space/time relationships
- Using numbers
- Communicating
- Measuring
- Predicting
- Inferring
- Formulating hypotheses
- Controlling variables
- Experimenting
- Defining operationally
- Formulating models
- Interpreting data

Critical Thinking Skills

- Observing
- Comparing and contrasting
- Classifying and categorizing
- Sequencing/ordering
- Distinguishing fact/opinion
- Distinguishing relevant/irrelevant
- Determining reliable/unreliable
- Questioning
- Inferring cause/effect
- Identifying assumptions/ambiguous claims
- Recognizing bias/points of view
- Reasoning inductively/deductively

Problem Solving Skills

- Identify and define the problem
- Gather information and data
- Organize and analyze information and data
- Identify possible solutions
- Analyze pros/cons of each
- Choose solution and develop plan
- Implement
- Evaluate and revise

Decision Making Skills

- Define the goal
- Identify alternatives
- Analyze positive and negative consequences
- Rank alternatives
- Evaluate the highest ranked alternatives
- Act on the "best" alternative(s)

Communication Skills

- Listening
- Speaking
- Writing
- Discussing
- Dramatizing
- Drawing and symbolizing
- Reading
- Nonverbal

Research Skills

- Conducting surveys, interviews, questionnaires
- Searching databases, card catalogs, etc.
- Using primary and secondary source documents
- Using reference books and materials

Cantrell, D.C., & Barron, P.A. (Eds.). (1994). Integrating environmental education and science: Using and developing learning episodes. Akron, OH: Environmental Education Council of Ohio, PO Box 2911, 44309.

Psychomotor Skills

Manipulating materials and equipment
Using fine/large motor skills

Mathematical Skills

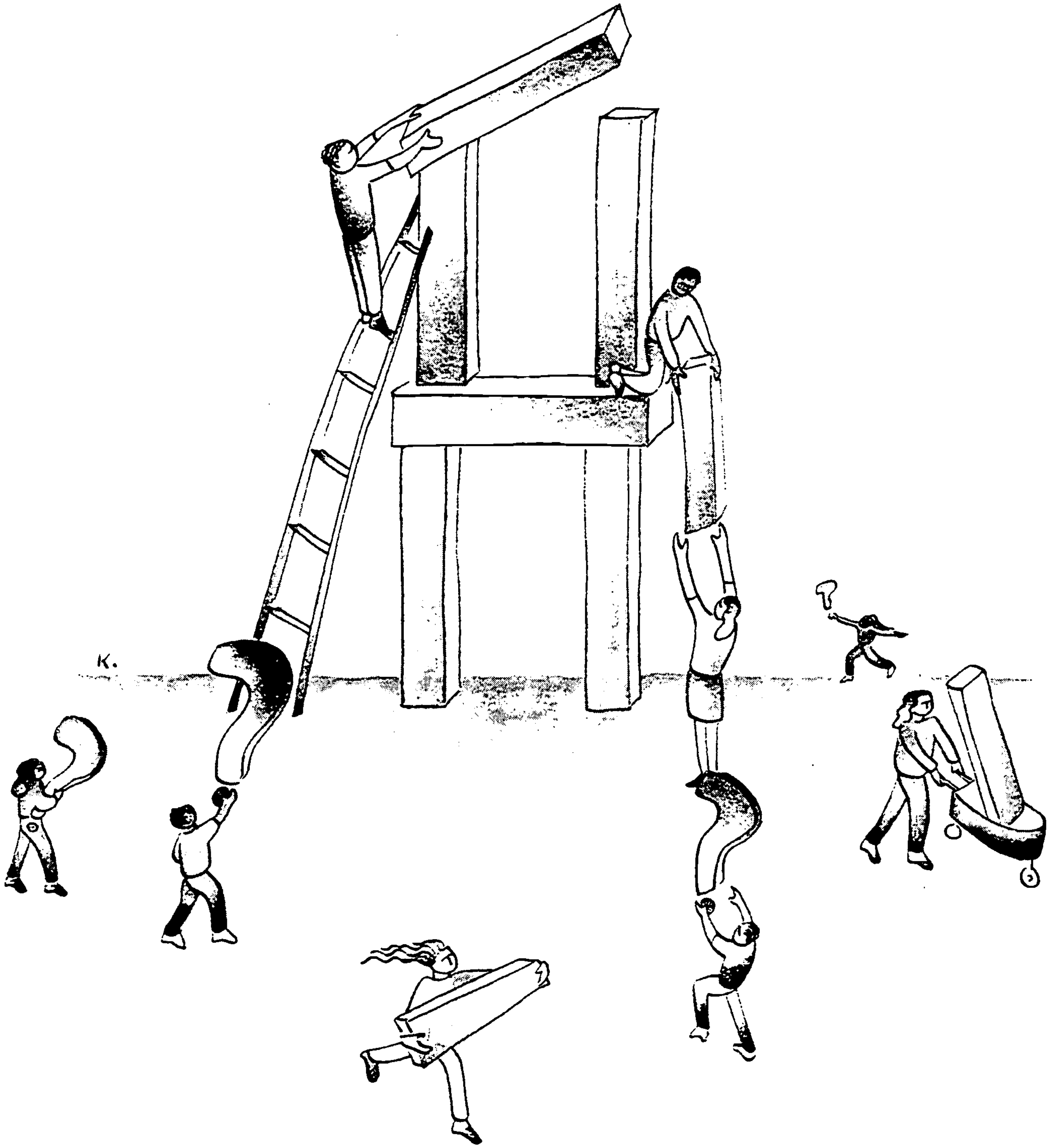
Computing
Estimating
Graphing/Projecting trends
Problem solving
Determining probability
Analyzing data

Interpersonal Relations Skills

Cooperating
Building consensus
Developing group process skills
Improving leadership skills

Adapted from:

Ohio Department of Education. (1985).
Energy and Resource Conservation.
Columbus, OH.



RUTH SOFAIR KETLER

Decookbook It!

Encourage inquiry by modifying traditional elementary chemistry laboratory activities.

TEACHERS CAN MODIFY many traditional elementary chemistry experiments to move students toward the *National Science Education Standards*. According to the *Standards*, elementary students should have certain abilities necessary for scientific inquiry, including being able to ask questions that can be answered by an experiment and to plan and conduct simple investigations to answer these questions in the manner of a "fair test," where only one variable at a time is changed (National Research Council, 1996, p. 122).

Some transitional activities are needed to bridge the gap between traditional "cookbook" activities and the type of inquiry envisioned by the *Standards*. Many students have enjoyed a number of cookbook activities—how can these activities be modified to move toward inquiry?

To help students become more familiar with inquiry, I have modified three familiar activities: paper chromatography, play dough, and the "Cat's Meow."

These transitional activities were used with three classes of fourth- and fifth-grade students during five mornings of an optional Saturday morning program. These students had been identified as being academically talented; however, **all** students would enjoy and learn as they participate in these three activities.

In this program, students expected to do interesting "hands-on" activities, but first we needed some ground rules. The program began with a discussion of safety and the habits of good scientists. Safety concerns were addressed by asking the students for rules to keep everyone safe during experiments. Students quickly volunteered that following directions and not tasting chemicals were important rules. I added that students should tell the teacher if they are hurt, and to be watchful of their neighbor, since we would be working in groups. I also added that certain activities may require eye protection, and I passed out goggles for students to use when needed.

In the same manner, I asked for the habits of good scientists. Students volunteered that good scientists ask questions and make careful observations. I added that working well in a group and trying to relate the experiment to something we already know were also important. The students wrote these habits and the safety requirements in the front of a small, inexpensive "lab notebook" they had been given.

Paper Chromatography

I introduced the students to experimental design with a paper chromatography experiment. To begin, I told the students the etymology of the word *chromatography*, "chroma" coming from the Greek word meaning color and "graphy" coming from the Greek word meaning writing.

The materials needed for each group of four are

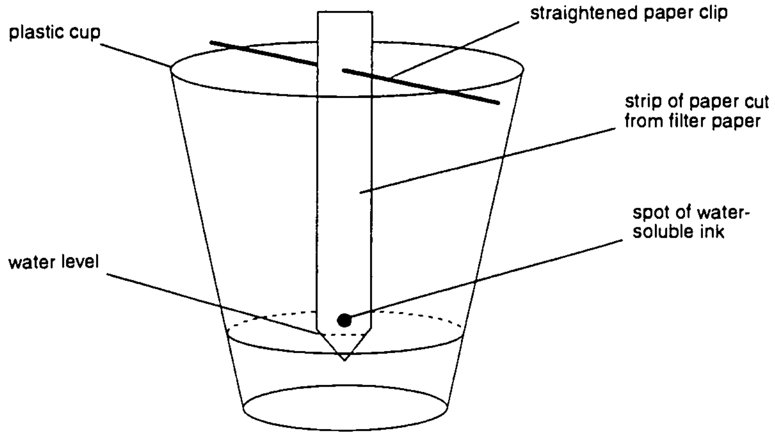
- a water-soluble, black pen,
- a container of water,
- four large paper clips,
- four clear plastic cups,
- four pairs of scissors,
- four small metric rulers,
- four pieces of filter paper,
- different-colored water-soluble pens (six different colors for the class),
- water at different temperatures,
- different types of paper,
- different types of liquids, e.g., rubbing alcohol (optional),
- and safety goggles, if liquids other than water are used.

Each student was instructed to cut out a strip of filter paper that was 12 cm long and 2 cm wide with a V-shape at one end. A diagram of this was put on the board for them to follow. The exact dimensions are not critical, but it gives them practice making measurements, which is part of the *Standards* expectations for this age group.

Using the water-soluble pen, students placed a dot of ink on the strip of filter paper at the top of the point (see Figure 1, next page). Students then put a straightened paper clip through the opposite end of the strip and placed the paper clip across the top of the cup. The pointed end of the strip was placed in the water with the dot just above the water.

While students waited for the ink pigments to separate, I introduced the topic of operational questions, which are questions that can be answered by experiment. To begin an understanding of operational questions, I asked students to list the things they could change (variables) in their experiment. Students gave responses that included the type of ink, water temperature, type of liquid, type of paper, size of dots, and number of dots.

Figure 1. Paper Chromatography.



Students were creative with their experiment designs. Some students asked, "What is the effect of making a heavier dot of ink on the paper?" and "What is the effect of making multiple dots?"

Having the students focus on what they can change is a way to get them thinking about the properties of the materials involved, which is a *Standards* goal for this age group. (For example, the paper used could be a paper towel, typing paper, newspaper, or cardboard. These materials have different properties that might affect the result.)

After about 10 minutes, the ink separated into different colors. The students were surprised that a black ink could produce different colors. I asked the students to make some observations and then refine their observations in writing.

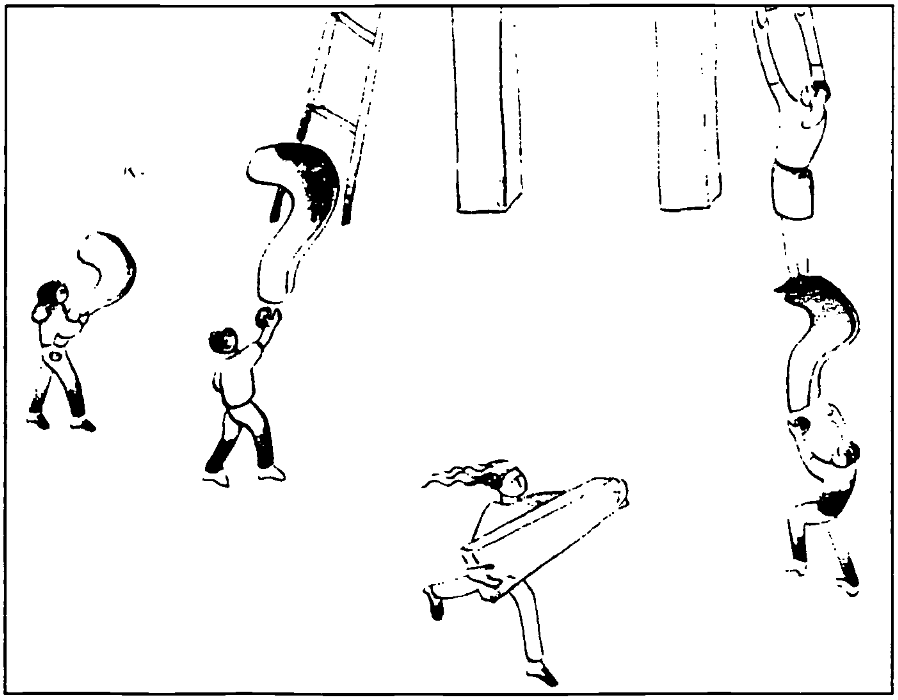
To help the students, I asked questions such as "Which colors traveled the farthest?" I also asked the students if the order of the colors was always the same (it was). Some students had placed their dot so that it was in the water, instead of just above it. This did not produce a nice separation of colors. I pointed out that the black ink was an example of a "mixture," a type of material that could be separated into parts.

I then asked students to write an operational question for each of the following categories: substitution, increasing/decreasing, or elimination (Allison and Shrigley, 1986). "Substitution" means to ask what would happen if something could be substituted for a variable. "Increasing/decreasing" means to ask a question concerning something that can be increased or decreased. "Elimination" means to ask what would happen if a variable was eliminated. The students were then asked to pick the question they liked best and identify all the variables that must be held constant.

The student-designed experiments were then carried out. Students were creative in their designs. For increasing/decreasing, some students asked, "What is the effect of making a heavier dot of ink on the paper?" and "What is the effect of making multiple dots?" Substitution questions included, "What is the effect of substituting a different paper for the filter paper?" and "What is the effect of substituting hot water for room temperature water or using a different liquid?"

It would be appropriate for students to use goggles. Teachers must review each question before the experiment is carried out to take **all** appropriate safety measures.

Eliminating variables was not a popular experiment, probably because the students expected nothing would happen.



Tips for Modifying Activities to Introduce Experimental Design

- Choose activities that are easily and cheaply modified. (For example, varying the type of cereal in investigating iron content can be expensive!)
- Anticipate variables ahead of time (e.g., needing hot water or ice water).
- Have students write out their plan as a condition to begin any experiment. Students are anxious to "do something" without the benefit of a written plan. At a minimum, their plan should include the question they are going to investigate, the variables they are going to hold constant, and what they will use to compare the results.
- Medicine cups (30 mL, graduated in a number of units) make excellent containers for an increase/decrease variable. I obtain these inexpensive cups from a medical supply store.
- Experimental design need not be the only type of laboratory experience the student has. As previously mentioned, it may too expensive to buy all the cereals necessary to have the students investigate a substitution question concerning iron in cereals, but it still may be worthwhile to see that some cereals have iron in them.
- Choose activities that are safe to vary and intrinsically interesting. Some activities may actually be too interesting—students lost interest in trying to make the *best* soap bubble mix because any type of mix created bubbles to blow out the windows!
- Experiments that do not work are a part of science and recording observations for them is as important as when they do work. My class is still searching for the right mix to make "moo glue," a glue from milk.

After the experiments were complete, students compared their new results with the original results. Students discovered that paper substitutions that were not absorbent, like cardboard, did not separate the ink well. Heavier dots and changing the width or the length of the paper did not affect the results dramatically. Certain types of water-soluble pens (red pens) did not separate into different colors.

An Optimal Play Dough

A second activity related to experimental design was to design an optimal mix of ingredients for "play dough." As in the first activity, key ideas in the *Standards* are being addressed. The students are asking questions that can be answered experimentally, planning investigations, and becoming familiar with the idea of a "fair test." They are making observations about the properties of materials; some of these properties require equipment to measure. This may be used to introduce the properties of solids and liquids.

For this activity, students in groups of four used

- a labeled coffee can of flour,
- a labeled coffee can of salt,
- a large container of water,
- four aluminum pie plates,
- two measuring cups,
- and vegetable oil (for possible modifications).

The recipe I provided used a two-to-one ratio of flour to salt, but the corresponding water amount was left out. I gave students a simple blank chart and asked them to fill in columns for the variables (flour, salt, and water) and the results.

> *In the Cat's Meow, students become familiar with posing questions that can be answered experimentally.*

Before students began, I instructed each student in a group to try a different amount of water. Each group reported its results on a chart on the blackboard for the class. Once again, students learned about the idea of a "fair test," holding all variables except one constant and making observations on the results of changing one variable, the water.

Students used the measuring cups to determine quantities of flour, salt, and water. They were also allowed to experiment with adding a small amount of vegetable oil, which most felt improved the mix. Students were then allowed to make up a larger batch of the "best mix," as determined by the class, to take home.

Cat's Meow

A third activity that proved successful in teaching experimental design was a modification of the "Cat's Meow." In this activity, students are becoming familiar with posing questions that can be answered experimentally, designing and conducting investigations, and communicating results.

For this activity, each student needed

- an aluminum pie pan,
- whole milk (enough to cover the bottom of the pan),
- food coloring,
- a toothpick,
- liquid dishwashing detergent (several different brands),
- and different types of milk (skim, 1 percent, or 2 percent) for substitutions.

Working individually, students cov-

Figure 2. Cat's Meow.

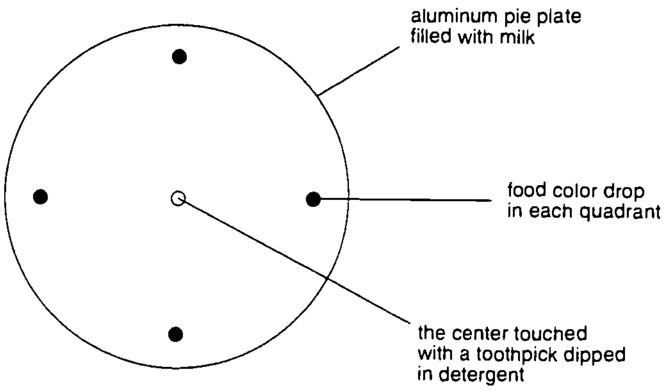


Table 1. Student Results.

Number of drops	Type of milk	Type of detergent	Results
1	skim	Price Chopper Blue	Good—green pushed others away
1	whole	Dove	Good—worked more than once
6	whole	Price Chopper Blue	Good—more color
12	whole	Price Chopper Blue and Dove	Good—awesome
1	whole	Dove	Spread a little
1	skim	Price Chopper Blue	Spread just like whole

ered the bottom of the pie pan with whole milk. Students put a drop of food coloring in each quadrant of the pan (see Figure 2).

The students then dipped a toothpick in detergent, touched it to the middle of the pan of milk, and made observations. Each student first performed the Cat's Meow activity using the same materials and made written observations.

This activity is particularly fascinating because the food colors swirl in different patterns across the surface of the milk due to the change in surface tension after adding the detergent.

Students were then asked to list the variables for the experiment across the top of a blank chart. Some variables they identified included the number of drops of food coloring, type of milk, and type of detergent. They were then asked to write an operational question involving one of the variables and test it themselves, using their initial results as a baseline.

Sample questions included, "What effect would three drops of each food coloring have? What effect would using skim milk have? What effect would changing the type of detergent have?" I was under the impression that the activity must be done with whole milk. The students discovered that skim milk works just as well. Volunteers were asked to share their results with the class, and the results were recorded on a transparency of the blank chart (see Table 1).

Assessment Methods

Assessment was not done in any formal means since this was a Saturday morning enrichment activity. Throughout each activity I attempted to determine how each group was doing. This was aided by having each group display their results at the conclusion of the activity.

One way to formally assess the activity would be to give students the description of an experiment they have not seen and have them:

1. Identify what can be changed (variables).
2. Propose a substitution, elimination, or increasing/decreasing question about one of the variables, and list the variables that must be held constant.
3. Design a plan to investigate the question.
4. Describe how they would communicate their results—what would their data table look like?

Such an assessment would be in agreement with the inquiry goals of the *Standards*.

[illegible]

By having students modify traditional activities, it is possible to introduce them to the principles of experimental design. The modification of familiar activities provides a way to structure activities to teach the skills of observation, controlling variables, and asking operational questions.

As students become more familiar with these skills, the structure could gradually be removed, and more open-ended problem solving could take place. With groups of students answering their own operational questions, the teacher's role becomes more that of a facilitator of scientific research.

Resources

Allison, A., and Shrigley, R. (1986). Teaching children to ask operational questions in science. *Science Education, 70*(1), 73–80.

National Research Council. (1996). *National Science Education Standards*. Washington, DC: National Academy Press.

THOMAS W. SHILAND is a chemistry teacher at Saratoga Springs (New York) Senior High School.

51 Litter Alert

BY ROBERT N. RONAU

Focus:

Litter items gathered from a designated public area can be classified, tabulated, and graphed to discover patterns and trends of littering.

Challenge:

How much litter is discarded in your neighborhood or in your favorite park? Is there a pattern of littering that can be used to estimate levels or trends of littering or to predict future littering at a given site, or at several designated sites?

Time: Five class periods over two to three weeks

Procedure:

1. Select an appropriate site, such as a roadside or public park, that is not regularly cleared of litter. If the site is too large for the class or the group assigned to the site to completely clear it of litter, then carefully, but discretely, mark the boundaries of the area to be investigated.

2. Collect all of the litter in this area. If the time since the site was last cleared of litter is unknown or litter removal from the site is not controlled, this sample would not be appropriate to use as part of the data set. This litter can be used, however, to help determine categories of litter for the site. Some possible sets of classifications might include the following:

Materials: paper, aluminum, glass, Styrofoam, plastic, other

Sources: fast food, household, beer/alcohol, industrial, vehicle parts, other

Effects on environment: years needed to biodegrade, effects on wildlife, health or safety hazard to humans, aesthetic impact, other

Value of collected items: bottles, cans, newspapers, Styrofoam, and non-recyclable items (Note that items are non-recyclable for different reasons; for example, it may still be less expensive to create new products, no reclamation center is nearby, or the by-products of recycling are too toxic.)

Other types of classifications are possible. The same collection of litter can and should be classified into several categories for study.

You may want to introduce information from the Environmental Protection Agency, the American Plastics Institute,

Materials and Equipment:

The whole class will need:

Computer with spreadsheet and graphing programs (optional)

Literature on solid waste disposal

A broom and dustpan for broken glass

Each student will need:

Containers for collecting litter (bags or boxes)

Gloves

Graph paper

✚Safety Note:

Students should immediately record and classify any broken glass, sweep it up, and put it directly in the nearest trash receptacle rather than trying to collect it for later classification. Be sure all students are wearing gloves when they collect trash. Also, make sure students wash their hands thoroughly after collecting and classifying.

rinted with permission: Lind, K.K. (1991). Water, stones and fossil bones. Washington, DC: National Science Teachers Association.

or other sources on the amount of time needed for different items to biodegrade, the dangers to plants and animals of human refuse, and the value of recyclable materials and recycled products.

3. Establish time frames for trash collection at the site including the time between collecting, the days of the week for collection, and the overall duration of the experiment (or number of collections). For example, collections could be made every other day for two weeks or every Monday and Friday for three weeks (this latter schedule isolates the weekend for special study).

Q What are the advantages and disadvantages of different collection schedules?

4. Collect litter on the specified days and sort it into the categories determined by the class. Be flexible because new types of trash may be discovered that do not readily fit into

the initial categories. Record the number of items (or weight of the items) found in each category. Tabulate and chart the data as the number of items (or weight) collected versus the category.

Q Is there a difference in litter found on different days of the week? Are there categories of refuse prevalent at one site but not another? Does a particular type of litter occur most frequently? Can you formulate a simple solution to diminish this form of litter?

5. Repeat the collecting, sorting, tabulating, and charting for the remaining collection days. From these investigations, search for patterns that might uncover trends of littering. A computer spreadsheet is particularly helpful for this step.

Categorize the litter in several ways. Does one presentation create more of an impact than another? For example, does classifying the litter by value have a greater impact than classifying the litter by number of items? What type of graph best conveys the environmental impact of the litter?

Further Challenges:

Predict, from the established pattern, the amount of litter that could be collected from the designated area over longer periods of time (six months, one year, two years, etc.). Assuming that the designated area is typical, estimate the amount of litter that is discarded throughout the neighborhood, park, city, or state. Again, a computer spreadsheet is helpful for this part. To extend participation beyond your class, form a partnership with another class in another school (possibly in another city or state) to compare similarities and differences in littering patterns.

The students could expand their analysis of these littering patterns and discuss the implications for the environment of the predicted littering. The class could devise a plan of action to limit littering in the area, particularly if the area is a sensitive one, and prepare a report to present to state or local officials.

Does your state have a container law? If so, does this affect the types of litter found? Compare your findings with those of a class in another state with laws different from yours.

The Author

Robert N. Ronau is an assistant professor of mathematics education at the University of Louisville.

Teaching Teachers

Managing Hands-on Inquiry

By Alan D. Rossman

In the past decade, we've seen hundreds of reports that call for sweeping changes in the ways and means of science education. Many of these reports call for a shift away from conventional teaching in favor of methods that actively involve students in hands-on, inquiry experiences. These methods, centered on student investigation and problem solving, cultivate positive attitudes toward science and learning in general.

A New Approach

We know that adopting hands-on, inquiry-based methods can bring great rewards. Teachers who use these methods successfully are almost guaranteed higher student enthusiasm and involvement, and deeper understanding of content and concepts. In addition, the autonomy students experience enables them to learn to think for themselves, both critically and creatively.

A recent, informal survey conducted by the Chicago Botanic Garden revealed an interesting and relevant paradox. The respondents (elementary teachers from Chicago's public schools) devoted only about 10 percent of their science-teaching time to the inquiry approach, yet 100 percent of these same teachers agreed that hands-on inquiry is the best way to teach science. Why, then, if teachers are so convinced of the benefits of inquiry teaching methods, are they reluctant to use them?

Understanding the Risks

Many teachers perceive hands-on inquiry methods as more "risky" than conventional teaching methods. They are often daunted by the possibility that "things could go wrong." It is true that as students manipulate science materials and inquire on their own, the element of risk increases. Yet these risks are manageable and should not prevent teachers from adopting an inquiry approach.

Navigating the risks means accepting a change in the relationship between teacher and learner. In contrast to conventional, didactic forms of teaching, hands-on inquiry redistributes the responsibility for learning to students and increases the importance of their interaction with materials. As the teacher's role changes from that of presenter to guide (facilitator), the role of the student changes from passive recipient of information to participant in the creation of understanding. Under these conditions, there is a fundamental shift from an emphasis on teaching to an emphasis on learning. From these shifting roles and the transfer of responsibility emerges the need for a different approach to classroom management.

Managing the Risks

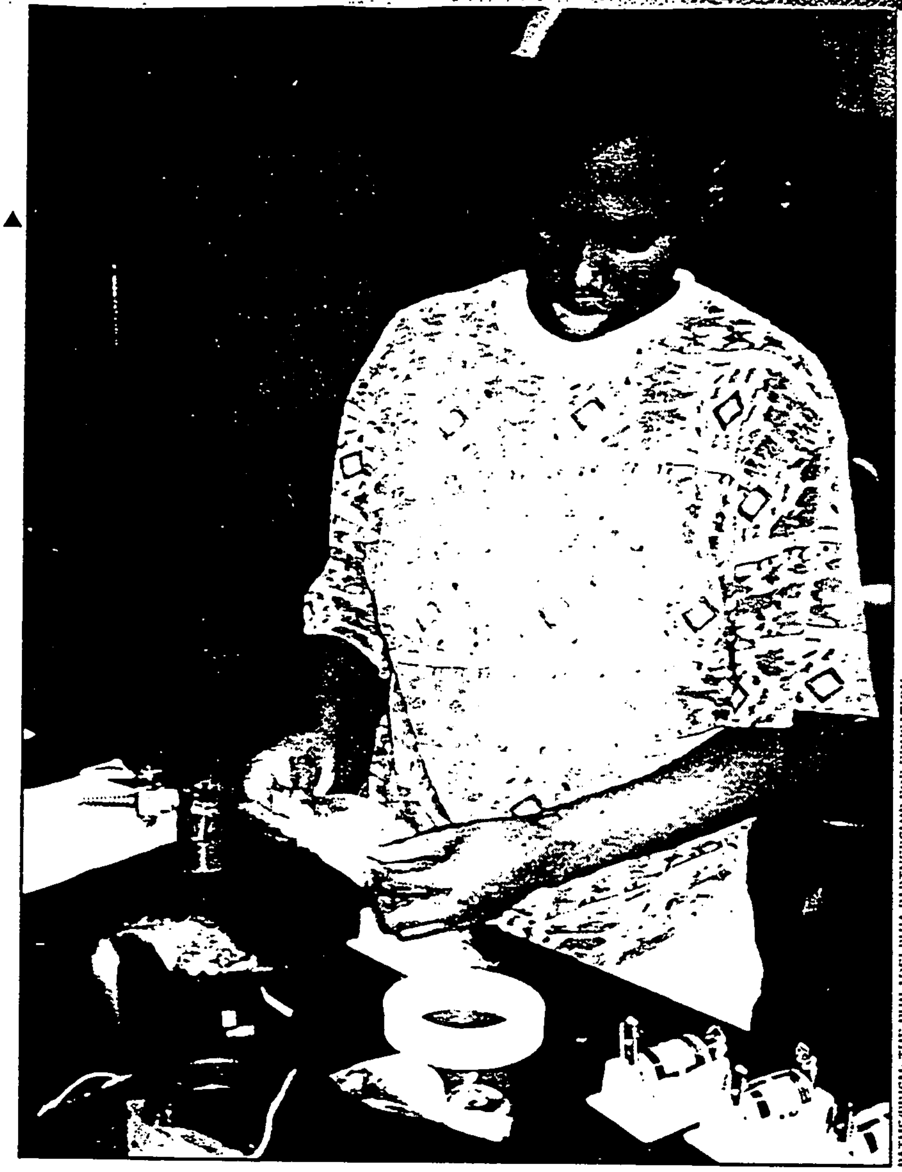
Effectively managing the hands-on, inquiry classroom can mean the difference between chaos and real learning. In order to break down the barriers and reduce instructional risks, the following guidelines should be con-

TEACHING TEACHERS presents practical teaching methods for preservice and inservice teachers. If you have an idea that you think could benefit your fellow teachers in their understanding of science and/or teaching, send your manuscripts to column editor Michael Kotar, Department of Education, California State University, Chico, CA 95929.

ALAN D. ROSSMAN, formerly associate director for teacher education at Northwestern University, now supervises science programs for children, adults, and teachers at the Chicago Botanic Garden.

sidered before, during, and after hands-on inquiry:

- ***Plan and prepare.*** Inquiry lessons need to be planned carefully. In order for students to take a more active and independent role in learning, your instructions must be clear. Planning will also help you use the available time most efficiently. Prepare and organize all materials before class begins. Pretest activities and materials so that you can anticipate and address difficulties and possible sources of confusion.
- ***Create problem intrigue.*** Problems to solve and questions to investigate are at the heart of inquiry. The problem should captivate students' attention, be meaningful, and allow a wide range of individual responses. It should also serve to enliven, extend, and reinforce the content under study. There will never be a shortage of suitable problems—just listen to students' questions and go from there!
- ***Give students the responsibility of solving the problem.*** Hands-on inquiry implies that students should be responsible for solving a given problem. To some degree, you must withdraw once the lesson is under way and accept a higher level of student self-direction, confusion, and noise. The role of "facilitator" may be unfamiliar, but it is essential in order to tap the true value of the inquiry approach. You must also ensure that all materials and resources that might be required by students in the course of the inquiry experience are available or attainable. In this manner, students are further enabled to approach problems independently.



PATHS/PRISM: THE PHILADELPHIA PARTNERSHIP FOR EDUCATION

Effective management can shape chaotic hands-on inquiry into real learning.

- ***Offer feedback and guidance.*** Students, especially younger children or those new to inquiry, require both individual and group feedback and guidance on a regular basis. Your feedback can make students aware of the strategies and ideas they are developing and applying. You must also strike the delicate balance between the chances for student success on one hand and the level of student dependence on the other hand. Finding this balance hinges on students' abilities, their familiarity with the method, and the nature of the problem under study.
- ***Debrief.*** Reserve time after the inquiry activity to evaluate the experience thoroughly. Through discussion, you can tie the results of the lesson to the ongoing classroom curriculum and explore the variety of student approaches and findings. This debriefing also provides an ideal forum for students to learn from each other and for you to assess their progress and build on their understanding.
- ***Anticipate, prevent, monitor, and adapt.*** Anticipate the range of management problems that *might* arise and then take whatever steps are necessary to prevent them. Be actively involved and ever vigilant, monitoring classroom activity throughout the lesson. This will allow you to identify and respond to any difficulties before they escalate. Adapt to any problems that

BEST COPY AVAILABLE

WILLIAM E. MILLS

LINDA C. HILLEMAN

Teachers unfamiliar with classroom management of hands-on inquiry should first gain confidence doing activities in a risk-free, supportive setting. Then they can try the technique with their own students.

arise once the lesson is under way, but keep the focus on the activity. Responding flexibly with "on the spot" management decisions is a regular aspect of life in the hands-on, inquiry classroom.

Teaching Risk-taking

Encouraging teachers to move away from traditional methods of teaching science to more student-centered, open-ended methods is not easy. The most persuasive reports, the most compelling data, and the most articulate advocates will do little to calm the very real and reasonable anxieties teachers may have. Instead, it is essential that inservice and preservice teachers witness firsthand the power of a well-managed, hands-on, inquiry classroom to inspire students and motivate them toward meaningful learning.

Naturalistic observations, modeling, demonstrations, and case-study videotapes can provide convincing evidence of the potential of these methods. Then, teachers need to try hands-on activities in a risk-free workshop or small, supportive teaching environment. With sensitive, insightful peer feedback and continued trials, the management principles for inquiry methods will become routine. Teachers can then confidently begin shifting their classroom orientation to include active, investigative, student-centered methods in their instructional repertoire.

J. Richard Suchman wrote, "Inquiry is more than a method of science. Inquiry is science. It is at the center of the scientific way of life" (1968). Hands-on inquiry should also be central to our science teaching. By demystifying the risk associated with the technique, we can encourage more teachers to try hands-on inquiry in their classrooms.

Resources

Suchman, J.R. (1968). *Developing inquiry in Earth science.* Chicago, IL: Science Research Associates.

Additional Topic Resources

Lehman, J.R. (1992). Preservice problem solving. *Science and Children, 29*(4), 30–31.

Orlich, D.C. (1989). Science inquiry and the commonplace. *Science and Children, 26*(6), 22–24.

APPENDIX C-8

Teaching Outdoors

Learning in the outdoors will encourage learners to respect themselves and their natural environment. Skills that promote these understandings are developed by participating regularly in many outdoor activities. Whether learning the secrets of successful tree planting or the effects of water quality on organisms found in a stream, learners can become more engaged and successful through the use of hands-on experiences in the outdoors.

Several strategies can make outdoor learning experiences more rewarding for both the learner and the leader of the experience. The following strategies can help you as you explore the outdoors with the learners.

Preparing the Activity

- In the beginning, choose the curriculum area which is your greatest strength to use as the basis for designing outdoor activities.
- Use an activity with a high percentage of success for learners. A variety of answers, diverse opinions, and different perspectives will generate a positive attitude.
- For the first several times that learners study outdoors, investigations that are short and focused are very effective.
- Use procedures and structures that learners are familiar with (recording data, grouping, using equipment, reporting, etc.).
- Be familiar with the collection laws in the area. The Department of Natural Resources or local extension service should have this information.
- Plan adequate time including going to and from the outdoor site (even if just outside of the school building).

Preparing the Learners

- Understand that some learners may not have had outdoor learning opportunities and may be uncomfortable. Some misbehavior may be due to this discomfort.
- Give learners advance notice before going outdoors so that they may dress appropriately for that day (comfortable shoes, rain gear, jackets etc.).
- Establish with the learners the objectives for learning outdoors.
- Before going outdoors, help the learners set appropriate guidelines for behavior.
- Select a partner or small group with which the learner must stay.
- Have learners gather and bring all necessary equipment.
- Set boundaries, time limits, and a place to meet.
- Agree upon a signal to call the group back together (raising a hand, setting time limits, clapping several times, making a bird call, etc.).

Cantrell, D.C., & Barron, P.A. (Eds.). (1994). Integrating environmental education and science: Using and developing learning episodes. Akron, OH: Environmental Education Council of Ohio, PO Box 2911, 44309.

Doing the Activity

- Introduce your activity and instructions appropriately and carefully. Choose the best spot. (You may be able to hold learners' attention better indoors).
- Allow learners time to explore the activity area with their group before actually beginning their time in the activity. This will help ensure that the learners are focused.
- When addressing the whole group outside, have them seated comfortably (dry, looking away from sun, not too hot/cold) and speak loudly.
- Respond to and encourage learner enthusiasm and curiosity. Share your own excitement whenever possible. Enjoy the outdoors with the learners!
- Understand that collecting plants or animals should only be done if necessary to observe over long periods of time.
- Model that all organisms are best observed in their natural environment without interference from observers.

Following the Activity

- Upon returning to the classroom, evaluate together the success of your outdoor experience. (What worked, what didn't work and why).
- Brainstorm and/or initiate extensions to continue the lesson.
- Clean and store the equipment used.

The more time learners spend in outdoor activities, the more appropriate their responses will be to the out-of-doors. Start out simple, and take learners outside regularly. Watch as the learners grow in respect and understanding of the outdoors.

Adapted from:

Szuhy, D.L., & Barron, P.A. (1982). Teaching outdoors: How to get started. Ohio Woodlands, (winter), 44-45.

American Forest Foundation. (1993). Project learning tree. Washington, DC.

272

Directions for setting up a garbage bag watershed:

1) Cover section of the table (about 3' x 3') with several layers of newspaper.

2) Arrange the cans (3-5) on the newspapers to form your hills and mountains.

3) Cover the cans with the towel (or rag) to simulate a more natural topography.

4) Cover the towel with the plastic trash bag and adjust to show hills and valleys, a ravine (for the stream) and a flat area or areas to simulate wetlands, ponds and lakes.

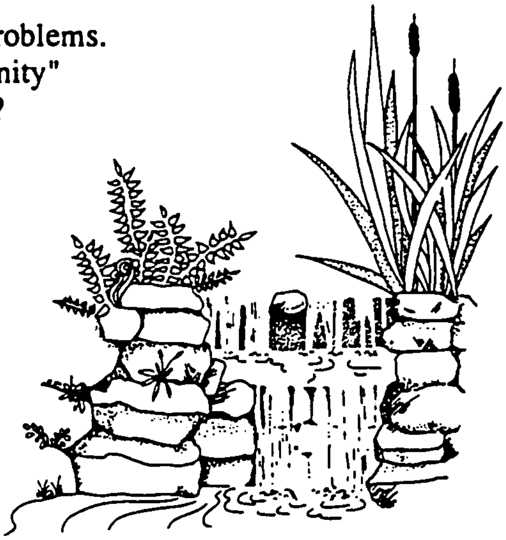
5) Use the permanent marker to define different land uses in your watershed, such as farm land, a park, roads, shopping centers, residential areas, golf courses, construction sites, industrial plants, etc.

6) Use the spray bottle to generate "rain". (Students could provide a weather forecast and sound effects such as thunder and wind). Point out and discuss the drainage patterns--can you see a stream or lake forming?

7) Sprinkle or drip the items in the small containers (kool-aid, cocoa mix, salt, food color, detergent) onto your watershed in the appropriate places to simulate the following nonpoint sources:
   lawn or crop fertilization (kool-aid)
   eroding soil from construction site or newly tilled farm field (cocoa)
   road salt spill (salt)
   automotive fluids washing off parking lots and roads (food color)
   detergent from car wash (detergent)
   household chemicals poured down residential storm drains

8) Create a second storm event to explore rain's role in transporting pollutants in your watershed, and discuss the problems associated with the stormwater runoff and pollutants.

9) Discuss possible solutions to the nonpoint source problems. Can you think of a way to rearrange your "community" to cause less of an impact on your water resources? What are the advantages and disadvantages of development in your watershed? What kinds of practices could you put in place to help prevent pollution?



Bush, J. (1992). Garbage bag watershed. Adapted from Garbage Bag Watershed activity developed by Jan Bush, Education Coordinator, Lake SWCD, Ohio.

QUESTIONING STRATEGIES

Diane C. Cantrell
Ohio Department of Natural Resources

Introduction

Effective questioning is the backbone of inquiry teaching and learning. When to ask questions, how to ask them, who asks them and about what are a few of the key issues.

One way to think about questioning strategies is as a formula:

Content of Question + Purpose of Question + Delivery and Follow-up = Your Questioning Strategy

Content of Question

The content has to do with the subject matter or focus of the question. Too often, we think of this as simply knowledge or facts, but this only represents one element. In general, a balanced curriculum or program has four major components or domains: knowledge, skills, attitudes and behavior. Questions should be asked by teachers and learners that address all four areas.

Purpose of Question

The purpose of the question has to do with what you are trying to accomplish by asking one type of question versus another type of question (i.e., your objective). There are two different approaches you might try. One is to use Bloom's Taxonomy of Educational Objectives. Benjamin Bloom developed a taxonomy of educational objectives for the cognitive domain that has six levels: knowledge, comprehension, application, analysis, synthesis and evaluation. You can use Bloom's hierarchy to guide the development of questions at different levels. For example, are you asking learners to recall facts or synthesize information? To apply knowledge or analyze interrelationships?

The other approach focuses on asking a combination of convergent (closed) and divergent (open) questions. **Closed questions** elicit a limited number of responses or "right answers." **Open questions** elicit multiple answers. While both play an important role in inquiry, open-ended questions support the divergent thinking that is core to inquiry.

Delivery and Follow-up

How you deliver or pose your questions has two elements: the sequence in which you ask the questions and the wait time between the question and answers.

Sequence

In terms of sequencing, it is important to pre-think what questions you will ask and in what order. The order is not as important as a conscious decision about that order – that it is in some way logical or achieves a specific purpose. One pattern that often works is one used by the U.S. Forest Service in its program "Investigating Your Environment." It begins with very **open** questions that elicit many responses and allow learners to feel confident because many answers are acceptable. From these responses, more **focused** questions are posed to narrow the scope of the discussion or investigation. This leads to **interpretive** questions that ask learners to process the information in some way. Finally, **summary** questions tie the discussion together.

Open:	What do you think of when I say "wetland"?
Focus:	What are some different types of wetlands?
Interpretive:	What is the difference between permanent & temporary wetlands?
Summary:	What can you tell me about wetlands?

Wait Time

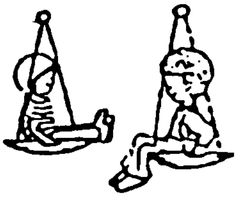
Wait time refers to the amount of time you allow between your question and the learner response – the opportunity to think about the question and to formulate a response. Because some learners think and reflect more quickly than others do, it is important to wait and allow all learners time to process their answer. Specifically Wait Time I refers to the amount of time the teacher pauses between the question and the learner's response. Wait Time II refers to the amount of time the teacher pauses between the learner's response and the opportunity for the learner to add to or modify the response (or for other learners to react to the response). While teachers typically wait only 0.5 or 1.2 seconds for an answer, research suggests that waiting 3 – 5 seconds has tremendous benefit for learners.

Follow-up

Your questioning can be enhanced further by effective follow-up. This may include paraphrasing learners' responses, providing correct answers, probing for specifics or to raise the level of the response, redirecting a question to another learner, or rephrasing a question.

Applying Bloom's Taxonomy of Educational Objectives to Question Writing

Ohio Department of Natural Resources
Division of Soil and Water Conservation

Level	Description	Examples of General Objectives
 KNOWLEDGE	Learners recall or recognize a wide range of material, from specific facts to complete theories, in a form similar to how the material was presented.	Know specific facts Know common terms Know basic concepts Know classifications & categories Know methods & procedures Know common criteria Know principles & generalizations Know theories and structure
 COMPREHENSION	Learners grasp the meaning of material based upon prior learning and can use it in different forms.	Understand facts & principles State meaning in own words Interpret verbal material Interpret charts & graphs Translate verbal material to mathematical formulas Estimate future consequences implied in data Justify methods & procedures
 APPLICATION	Learners use previously learned materials in new and concrete situation to answer a question, complete a task or solve a problem.	Apply concepts & principles to new situation Apply laws & theories to practical situation Solve mathematical problem Construct charts and graphs Demonstrate correct usage of a method or procedure
 ANALYSIS	Learners break down material into simpler parts, understand connections among parts and how the parts are organized.	Recognize unstated assumptions Recognize logical fallacies in reasoning Distinguish between facts & inferences Analyze organizational structure of a work Identify motives or causes Find evidence to support generalization
 SYNTHESIS	Learners combine elements such as information, ideas or parts to form a new whole such as a product, plan or proposal.	Combine knowledge & skills from two or more program areas Integrate learning from different areas into a plan for problem solving Formulate a new scheme for classifying objects Propose a plan for an experiment Give a well organized presentation Write a well organized theme/creative short story
 ALUATION	Learners make judgements about the value of material on the basis of specific internal or external standards and criteria.	Judge the logical consistency of written material Appraise the merit of solution to a problem Debate the validity of opinions and ideas Justify the adequacy with which conclusions are supported by data Judge the value or quality of a work (writing, art, music, research)

Action Verbs	Question Starters	Examples of Multiple Choice Questions
Define List Identify Describe Match Locate Name Select Label State Outline	Who...? What...? Where...? When...? How many...? Which...?	The pH of a solution is determined by the concentration of hydrogen ions. What scale is used to measure pH? a. -7 to +7 b. 0 to 7 c. 0 to 14 d. 1 to 100
Explain Summarize Describe Interpret Rewrite Convert Give example Distinguish Rewrite Infer Extend Generalize Defend Estimate Predict Paraphrase	What happened when you...(added another gear)? What is the main idea...(in the paragraph)? How does...(ground water become contaminated)?	Which lake is the more likely to be affected by acid rain? a. a lake at a high altitude b. a lake with a limestone bedrock c. a lake with a watershed with deep soils d. a lake surrounded by deciduous trees
Demonstrate Show Operate Construct Apply Change Modify Predict Produce Solve Compute Manipulate Operate Prepare Relate Use Discover	If..., then what...? How does...(your invention work)? How can you...(change the growth rate)?	On the table you will find pH test kits and 4 jars of water. Which sample of water is the most "basic"? a. Jar A b. Jar B c. Jar C d. Jar D
Compare Contrast Distinguish Discriminate Infer Analyze Categorize Differentiate Point out Select Subdivide Diagram Deduct Identify Relate Separate Illustrate Experiment	Why...(did the plant die)? How are...(these two different)? What evidence can you find...(to support that idea)? What alternatives can you suggest...(to increase scores)?	Pan A and Pan B contain samples of macroinvertebrates taken from two different sites (A & B respectively). What can you infer about the quality of the water? a. Site A and Site B have the same quality of water. b. Site A has a higher quality of water than site B. c. Site A has a lower quality of water than site B. d. The quality of the water cannot be determined based on the samples.
Create Suppose Design Plan Generate plan Combine Rearrange Categorize Compile Tell Devise Explain Organize Revise Compose Reconstruct Reorganize Rewrite Modify	Can you think up...(a way to test this)? How can we solve...(this problem)? How can we improve... (our research)? What will happen if...(the population increases)?	A company is proposing to develop a resort with a premier large mouth bass fishery. However, the lake water pH is currently too low to support a healthy reproducing population. Which of the following changes would result in the most successful bass fishery? a. Drain lake; put a layer of limestone rock on bottom of the lake. b. Establish a tree buffer strip along all tributaries to the lake and use conservation practices. c. Harvest the existing evergreen trees; add limestone to this area and replant with deciduous trees.
Discriminate Appraise Debate Criticize Support Compare Contrast Conclude Judge Explain Justify Interpret Relate Summarize Support Describe	Why do you believe that...(this is the best way)? Which...(proposal) did you like? Why? What does the author mean by...? Do you think the...(researcher was biased)?	A legislator has introduced a bill mandating the use of electric cars in midwestern states to reduce acid rain. Which argument best supports passage of this new law? a. It will substantially reduce the amount of sulfur dioxides necessary for producing acid rain. b. It will reduce use of gasoline, decreasing our reliance on fossil fuel resources. c. It will result in need for fewer stack scrubbers, freeing up money for clean fuel research.

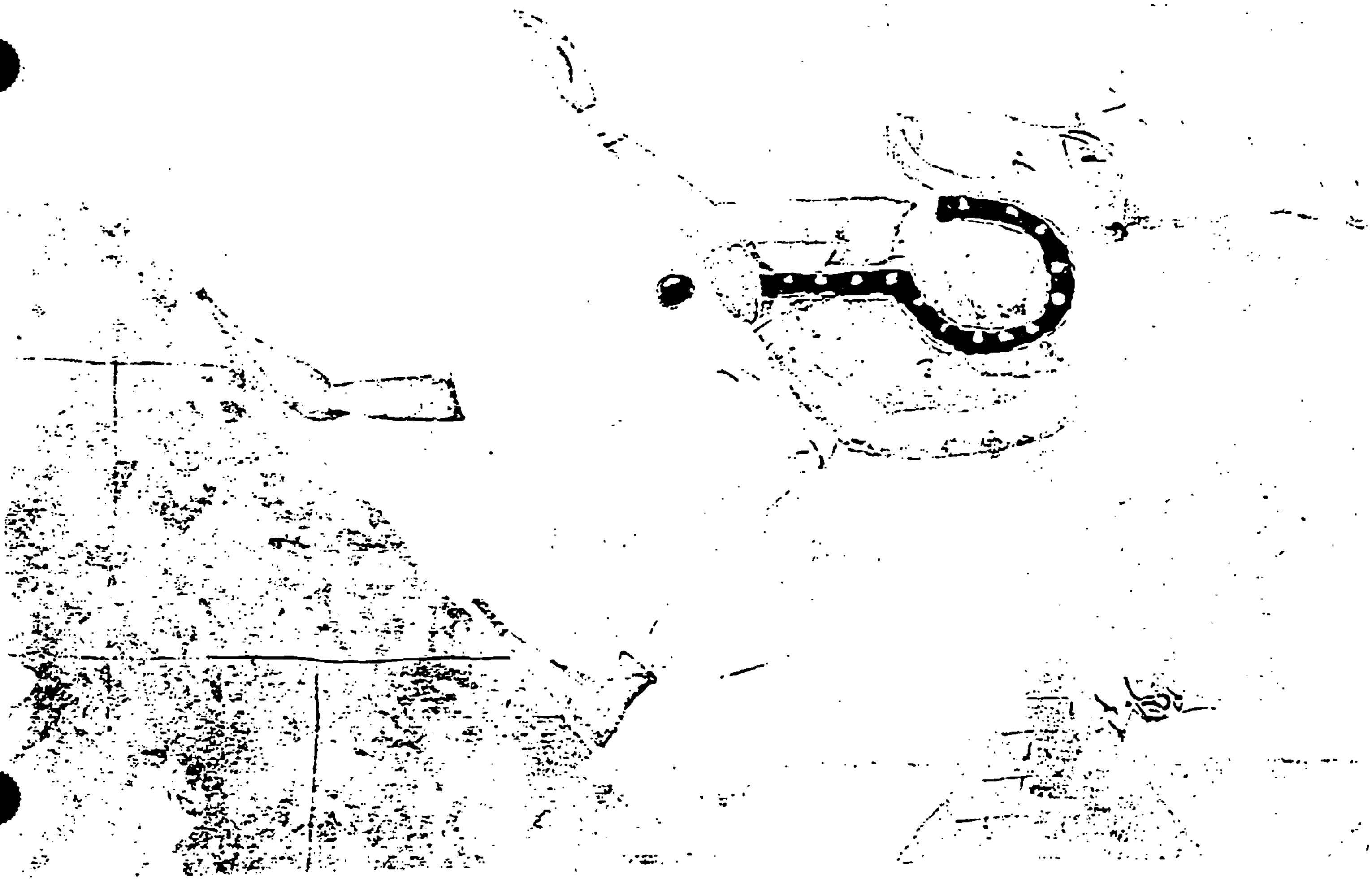
Table of Specification

Directions: For each objective, indicate how many questions (number or percentage) you will write at each level.

Forestry Objectives	Level					
	Knows	Comprehends	Applies	Analyzes	Synthesizes	Evaluates
Identify common trees without a key and identify specific or unusual species of trees or shrubs through the use of a key.						
Understand forest ecology concepts and factors affecting them including: the relationship between soil and forest types, tree communities, regeneration, competition, succession.						
Understand the cause and effect relationship of factors affecting tree growth and forest development. (climate, insects, microorganisms, wildlife, etc.)						
Understand how wildlife habitat relates to: forest communities, forest species, forest age structure, snags and den trees, availability of food and riparian zones.						
Understand how the following issues are affected by forest health and management: biological diversity, forest fragmentation, air quality, aesthetics, fire, global warming and recreation.						
Understand basic forest management concepts and tools such as: how various silvicultural practices are utilized, the use of tree measuring devices and the use of best management practices.						
Apply silviculture concepts and methods to develop general management recommendations for a particular situation and management goals.						
Identify complex factors which influence forest management decisions (economic, social and ecological).						
Understand the value of trees in urban/suburban settings and the factors affecting their health and vival.						

The Pyramid Approach

To Reading, Writing, and Asking Questions



nce Scope Vol. 17 by Hinton. Copyright © 1994 by NSTA. Reprinted by permission of NSTA via the Copyright Clearance Center.

Help students learn to be masters of their own thinking. This activity teaches students how to ask, and answer, questions at each of the levels of learning.

by Nadine K. Hinton

Asking the right questions and answering them is at the root of all scientific investigation. So before students can successfully pursue independent research projects, they must first learn the higher level or critical thinking skills necessary to ask relevant questions. Introducing critical thinking in the science classroom has long been a goal of educational reform. Using Bloom's taxonomy, I developed a lesson that teaches students the various levels of knowledge and how to form questions that address each level. After the lesson, students study a topic of their choice and produce a report that reflects their unique interests.

Devised by Benjamin Bloom, the Taxonomy of Educational Objectives is a hierarchy of learning skills divided into six levels—knowledge, comprehension, application, analysis, synthesis, and evaluation. Figure 1 briefly defines each level. Students need to master each of the lower levels before they can move on to the higher levels. Teachers are frequently criticized for relying on lower-level questions and neglecting to encourage students to go beyond basic recall. This lesson not only makes students aware of the need for higher level thinking, but also helps teachers foster these skills.

Learning to ask questions

For the first part of this lesson, I teach students how to ask questions at various levels by leading the class through the Key Words and Sample Questions sheet (Figure 1), using a sample topic such as bears. To ensure that students fully understand each level before moving on to the next, I generally cover knowledge and comprehension on the first day, then spend one day on each of the next levels.

To begin, I ask students what they would like to know about bears and list all their questions on the board. Then I ask students, "Do you think you would be able to answer *all* interesting and possible questions about bears by reading only one source of information? What are the advantages of using more than one source of information? Identify as many sources of information you can think of to find information about bears." I write all responses on the board. If students suggest sources such as books or interviews with scientists, I ask students for specific names.

Next, I hand out copies of the Key Words and Sample Questions sheet and discuss the first level—knowledge. I have students read two or three paragraphs from their textbook about bears. Then students write and answer three or four knowledge-level questions based on what they have just read and underline the key word that indicates that each is a knowledge question. To make sure everyone understands the knowledge level, I ask students to share their questions with the class.

Continuing through each level of the taxonomy, students write and answer questions about the topic of bears, continuing to read in their texts or other appropriate resources, and share them. It is important to spend enough time on

ART BY SERGEY IVANOV

Nadine K. Hinton, a former middle school science teacher, now teaches fourth-grade science in the able and talented program at Emerson Elementary School in Westerville, Ohio.

each of the levels so that students truly understand the subtle differences between the levels and the thinking processes each requires. Although some of the key words for various levels overlap, with sufficient practice over an entire class period, students learn to distinguish between the levels. If any students do have difficulty on a particular level, I give extra assistance to help them understand. In my experience over several years, most students have caught on without difficulty and I have been pleasantly surprised by the level of sophistication students achieve when writing their questions.

During the lesson, I emphasize that each level of questions builds on information gained in earlier levels. To illustrate this, I use a pyramid analogy. I draw a pyramid on the board and explain to students that a pyramid has a broad base to support its top. I tell students that the pyramid represents what they have learned about bears: In order to have a strong base for the pyramid, students had to find out lots of information about the topic before applying the knowledge and working at the higher levels. I remind students again that the more interesting and fun questions at the higher levels depend on the information learned at the earlier levels.

Independent research

Once students have a firm grasp of the levels of questions, I assign a research project. Independent research allows students great freedom in choosing topics of interest to them and pursuing those topics in depth. Students select any scientific topic they want to know more about, and using the Research Project sheet (Figure 2) as a guide, they write appropriate questions at various levels and conduct research to answer them. Students work through all six levels of Bloom's taxonomy on one topic, and then have the option to work on a second topic for extra credit. If I feel that some students are not yet able to work at the higher levels, I allow them to work on the first three levels for two or more related topics. While the project requires students to write and answer more questions at the basic levels, students earn more points for the higher level questions. This emphasizes the value of learning at the higher levels of the taxonomy.

Students work independently in class and at home for two weeks. If students have difficulty, especially at the higher levels, I help them reword their questions to address the appropriate level. However, in general students do not have difficulty because we spend so much time learning each level before beginning the independent work.

When they are finished, students organize their list of questions and answers in a notebook, report, or poster display for each topic they chose to study.

Extensions

The results of students' investigations can be shared with the rest of the class, other classes, or at a school open house. Allowing students to share what they have learned further models how scientists work—in the real world, knowledge gained is not complete until it is shared.

Sharing the information can take many forms besides the standard oral presentation, so I encourage students to think of creative and fun approaches. For example, a student who studied an animal could write each question and answer on a separate sheet of paper and construct an illustrated book; show different breeds or species with a mobile, pictures, chart, or collage; illustrate a habitat with a diorama, photographs, or a picture; compare different species with a chart; or even tell interesting facts through a puppet show, flannel board story, story, or poem.

Once students understand the different types of knowledge and questions, they can go on to apply this to science and many other academic areas throughout their lives. The ability to acquire knowledge that is objective and complete by generating questions and conducting research will ultimately enable them to become well educated citizens capable of clear and critical thinking.

Benefits

- Students are encouraged to use more than one source of information.
- Allowing students to ask their own questions focuses their learning on individual areas of interest. In my experience, student reports are more original and less likely to include the questionable use of long, direct quotes from source materials.
- The key words in the higher levels of the taxonomy are process-oriented and represent what scientists actually do. ☐

BEST COPY AVAILABLE

FIGURE 1. Key words and sample questions

1. Knowledge

Knowledge is the ability to remember information that you have learned.

Key words to use in your knowledge questions:

define
describe
identify
label
match
name
outline
reproduce
count
list
trace

Sample knowledge questions:
Make a dictionary to *define* important words about your topic.
Outline the encyclopedia article on your topic.
Trace a picture and *label* the parts.

2. Comprehension

Comprehension is the ability to understand the information. Comprehension depends on how well you have learned the information at the knowledge level.

Key words to use in your comprehension questions:

convert
explain
distinguish
give examples
estimate
paraphrase
predict
compare
describe
interpolate
rewrite
contrast
extrapolate
summarize
compute
interpret

Sample comprehension questions:
Explain how animals were used in the research and the benefits of the research for animals and humans.
Compare and contrast the anatomical structure of the forelimb of two species.
Paraphrase (summarize in your own words) what you have learned about your topic.

3. Application

Application is using the knowledge in new ways. Knowing and comprehending information about the topic are essential before you can apply the information.

Key words to use in your application questions:

change
apply
utilize
demonstrate
employ
construct
manipulate
practice

Sample application questions:
Construct a table to *demonstrate* your findings.
Construct a graph of your findings.
Apply this concept to a new situation.

4. Analysis

Analysis means to break down the knowledge into parts so that it can be understood better. After you know a lot about the topic, fully understand the information, and apply the information, then you can analyze the information.

Key words to use in your analysis questions:

break down
infer
construct
develop
diagram
arrange
create
formulate
discriminate
detect
design
generalize

Sample analysis questions:
Construct an experiment to test your hypothesis.
Discriminate between facts and inferences.
Detect unstated assumptions about your topic.

5. Synthesis

Synthesis means to put information about the topic back together in a new and creative way.

Key words to use in your synthesis questions:

categorize
compose
design
modify
rearrange
combine
create
explain
organize
reconstruct
compile
devise
generate
plan
relate
reorganize
integrate
revise
rewrite

Sample synthesis questions:
Integrate your knowledge into other topics in science, or in another subject such as social studies or math.
Explain the results of your experiment.
Categorize or combine information about your topic in a new way.
Create an original plan to investigate your topic.

6. Evaluate

Evaluation means to develop clear criteria and judge the knowledge you have gained.

Key words to use in your evaluation questions:

appraise
evaluate
measure
select
assess
grade
rank
test
critique
judge
rate
determine

Sample evaluation questions:
Select criteria and evaluate your project.
Determine the impact of the research on your topic on people.
Rank the contributions made by different researchers in the field.

FIGURE 2. Research project

Name________________________________ Research topic______________________

You must complete Part I. You may choose to earn additional points by completing Part II. *Do not fill in point values; the teacher will use this sheet to score your written work.*

Part I.

Working on a single topic, write the number of questions indicated for each of the levels below and conduct research to answer them. Underline the *key word* in each question.

Basic knowledge about your topic

Knowledge—5 questions and answers, worth 1 point each = 5 points _______/ 5

Comprehension—5 questions and answers, worth 2 points each = 10 points _______/10

Application—3 questions and answers, worth 3 points each = 9 points _______/ 9

Higher level knowledge about your topic

Analysis—2 questions and answers, worth 5 points each = 10 points _______/10

Synthesis—1 question and answer, worth 10 points = 10 points _______/10

Evaluation—1 question and answer, worth 10 points = 10 points _______/10

After you complete this part, you may choose to continue writing and answering questions to earn extra points. Additional questions and answers will be worth the given point values.

Part II. Basic knowledge about a new topic

For a topic other than the one you studied for Part I, write and answer questions at the following levels. You may write as many questions and answers as you want to earn extra credit for Part I.

Knowledge—each question and answer is worth 1 point _______

Comprehension—each question and answer is worth 2 points _______

Application—each question and answer is worth 3 points _______

TOTAL _______

Recopy your questions and answers into a notebook, a report, or a display on posterboard. You must list sources in correct bibliographic form.

Relevant Inquiry

Six questions to guide your students

by Abour Cherif

In our technological society, science teachers will increasingly be demanded to demonstrate the relevance of their subject. Society can no longer afford to produce a citizenry incapable of understanding and applying the concepts, principles, and processes of science to the environment. Young people are naturally excited when they encounter something new, and are doubly excited when they discover its relevance to daily life. It is time to re-examine an old idea, the process of inquiry, in the context of socially relevant science education.

To inquire is to seek knowledge and understanding by questioning, observing, investigating, analyzing, and evaluating.

During the 1960s, the processes of inquiry became the focal point for curriculum reform. However, by the 1970s two criticisms of inquiry-based science were frequently heard: many programs neglected the developmental levels of students, and few emphasized the social or technological context in which science develops.

But these criticisms do not reduce the value of inquiry for students. According to Suchman (1966), an inquiry-based learning cycle should present discrepant events or problematic situations, encourage observation, ask for explanations, encourage the testing of those theories, and debrief the process. These elements can be the framework for relevant science education in the 1990s.

Through the years, I have used six key questions to focus the inquiry process in classroom science experiences:

1. What do you think will happen?
2. What actually happened?
3. How did it happen?
4. Why did this happen?
5. How can we find out which of these hypotheses is the most reasonable?
6. How can you relate the investigation to your daily life?

The sixth question is specifically designed to encourage students to establish relevance. This sequence makes relevancy a natural outgrowth of the process of learning which takes place through using the inquiry approach to science. Used regularly, it encourages a habit of mind.

A student observes an insect skimming the surface of water.

Questions one through five encourage observation, analysis, and speculation. The sixth, "Can you think of something we use in our daily lives that is designed or built on the same idea, concept, or principle?" is the relevancy question. It can also be called an "idea application" or an authentic assessment to test understanding. The aim of this question is to encourage students to apply principles in their daily lives so that they can affectand be affected by science and its applications.

After students have named some objects that they think were designed using the same idea or phenomenon being observed, they will be asked how these objects work in the context of the relevant hypothesis (reasoning explanation). The objectives here are (a) to make sure that students understand the idea or the concept under investigation (assessment); (b) to make sure they master the inquiry process; (c) to help them develop the ability of applying the same reasoning pattern they use in science to other situations; (d) to see science as part of not only society, but also themselves; (e) to accept science as a way of knowing and understanding; and (f) to enrich the curriculum and teaching of science at the elementary and secondary school levels. In short, the relevancy question within the cycle of inquiry motivates students to maintain their focus on the learning activities and to search for new ideas, problems, or phenomena associated with the investigated object.

In this issue of *The Science Teacher* a familiar exercise on enzymes is redescribed from the standpoint of inquiry. Similar experiences can be made more meaningful and long-lasting by adding the relevancy question.

There is no doubt that teaching science as inquiry in a relevant context will pose a challenge to science teachers, especially

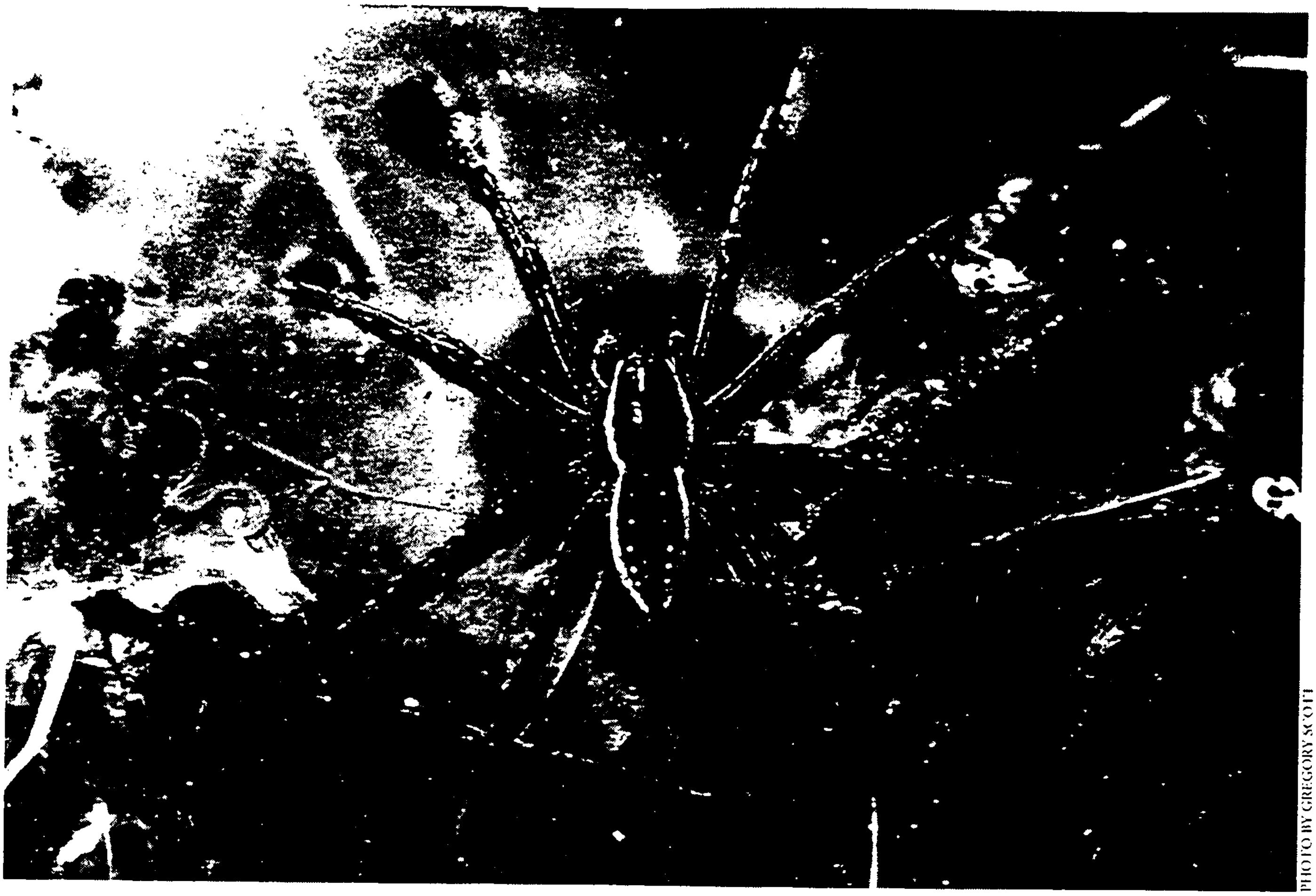


PHOTO BY GREGORY SCOTT

those who are reluctant to teach science as inquiry in the first place. But without such an approach, education might never achieve the explicit aim of scientific inquiry, and students could develop an unrealistic picture of science.

In teaching science, the teacher's role is as critical in relevancy as in the inquiry proccess. Teachers ask questions that help students observe, generate ideas, make hypotheses, test their ideas logically and empirically, and explore their meanings in daily life. As the students extend the water insect experience, they can explore surface tension through additional inquiry, including "What runs faster, soapy water or regular water?," "Why do we use soap to wash our hands?," and "What does a detergent do in the wash?" Observations may also take a completely different direction, focusing on the appearance of the water as the insect crosses it, such as "What happens to light waves on the surface of water?" and "How do rocks affect the surface of a pond?" As students work to confirm their hypotheses, the direction that the inquiry lesson will take is never predictable.

Teachers might find Carin and Sund's *Discovery Activities for Elementary Science* (1980) and the late Tik Liem's *Invitations to Science Inquiry* (1987) useful in teaching inquiry in a relevant context. Carin and Sund ask teachers to be able to answer the question, "How will children use or apply what they discover?" after every activity, and Liem provides some relevance for each pheonomenon he discusses.

This fall students across the country are studying Bernoulli's principle, many through the process of inquiry. Before the lesson is through, teachers should help their students relate the lessons to their daily lives—playing tennis, spray guns for painting, spray bottles and pressure cans, lift in air flight, supersoaker squirt guns, and so on.

In other classrooms, students are discovering the meaning of density. They can easily be encouraged to extend their understanding of this principle to an adaptive tool for life. For example, the swim bladders on the classroom aquarium fish, the hollow bones of birds, or the bladders on seashore plants, can all be related. Perhaps the students might even be encouraged to extend their inquiry to the school pool or local pond.

In the most recent progress report from the National Academy of Science on the development of science standards (July 1993), the committee writes:

> *"Inquiry represents a set of interrelated processes by which scientists pose questions about the natural world, investigate phenomena, and cultivate deeper understanding. It is at the very heart of science's historically productive and distinctive 'way of knowing.' Approaching science learning in a questioning mode, therefore, is congruent with the practice of science itself."*

But inquiry is not enough. The new science standards promise to address "Science and Human Affairs," incorporating "scientific facts, concepts, principles and theories and political decisions." The key to that standard is relevance.

Abour Cherif is a professor of science education and teaches science and mathematics at Columbia College Chicago, 600 S. Michigan Ave., Chicago, IL 60605.

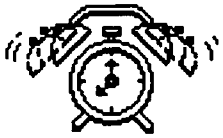
237

Wait Time: Slowing Down May Be A Way of Speeding Up

by Mary Budd Rowe

This paper describes major outcomes of a line of research that I began nearly twenty years ago on a variable called wait time. To put it briefly, when teachers ask questions of students, they typically wait one second or less for the students to start a reply; after the student stops speaking, they begin their reaction or proffer the next question in less than one second. If teachers can increase the average length of the pauses at both points, namely, after a question (wait time one) and, even more important, after a student response (wait time two) to three seconds or more, there are pronounced changes (usually regarded as improvements) in student use of language and logic as well as in student and teacher attitudes and expectations. There is a threshold value below which changes in wait time produced little effect and above which (2.7 seconds) there are marked consequences for both teachers and students.

The kinds of circumstances in which wait time one and two have been studied span elementary through college classrooms, mostly in science and literature. They range from docent programs in museums to rather diverse special education contexts (e.g., classrooms involving the mentally and physically handicapped and the gifted and talented).



An adaptation of the wait time concept for use in lectures appears to yield outcomes comparable to those mentioned above for classroom discussions, specifically, improvement in comprehension and attitude. Applications of wait time have been diverse, but the underlying patterns that make the variable so useful across such disparate contexts appear to be the same and will be discussed briefly later.

The wait time variable has an intuitive appeal. It makes sense to slow down a little and give students a chance to think. Unfortunately, it is difficult for many people to get average wait times up to three seconds or longer. The present one-second or less wait times appear to be almost immutable and are definitely not culture dependent (Chewprecha, Gardner, and Sapianchi, 1980).

Mary Budd Rowe is professor of science education at the University of Florida and president elect of the National Science Teachers Association. This article is reprinted with minor abridgement from the Journal of Teacher Education *(January-February 1986), published by the American Association of Colleges for Teacher Education, with permission of the publisher.*

Discussion of the difficulties encountered in establishing longer wait time patterns will illustrate that what appears to be a simple technique that makes a fundamental impact on the reasoning, roles, and norms in a classroom is, in fact, difficult to learn.

Effects of Wait Time on Students and Teachers

To "grow," a complex thought system requires a great deal of shared experience and conversation. It is in talking about what we have done and observed and in arguing about what we make of our experiences that ideas multiply, become refined, and finally produce new questions and further explorations. While listening to tape recordings of high school biology students discussing laboratory findings (Rowe and Hurd, 1966) and the conversations and "talk" in elementary school classes during a "hands-on" science program (Rowe, 1968; 1969a, b), I made two observations common to both sets of data. The pace of interaction between teachers and students was very rapid for both elementary and high school classes, except for three recordings in each group where the pacing seemed slower and the level as well as the quantity of student participation was greater. Wait time one, the interval between the end of a teacher question and the start of a student response, was three to five seconds on the average for the three special tapes in each set. For all the other recordings, wait time for pausing was less than one second and was too brief to measure reliably with a stopwatch.

Effects on Students

To help document the astonishing speed at which teacher and student exchanges took place, I fed the sound from the tapes into a servo-chart plotter. The servo-chart plotter made a graph of the speech patterns and pauses and revealed another pause location that might be important, wait time two. Wait time two, the accumulation of pauses between student utterances before the teacher speaks again, in most of the recordings averaged 0.9 seconds, but on the three special tapes it exceeded three seconds. Servo-chart plots showed substantial pauses in the body of student explanations. Quick reactions by teachers appeared to cut off student elaboration. At this juncture it was necessary to determine if these protracted pauses of three seconds or longer, wait times one and two, played a part in producing desirable student outcomes observed in the three tapes at each level or whether they were just interesting anomalies. To answer that question for the elementary group, teachers and staff members in the trial center and I began a series of studies that lasted a number of years and involved both small groups of students and whole classes. We manipulated wait times one and two separately and then together to observe what happens (Rowe, 1972, 1973; 1974a, b, c, d, e; 1975). In addition, I monitored the consequences of protracted exposure to longer wait time schedules in order to examine both immediate and long-term effects. I found consequences for both students and teachers, highlights of which are listed below and all of which were subsequently verified by other researchers.

1. **The length of student responses increases between 300 and 700 percent, in some cases more, depending on the study.**

Under the usual one-second average wait times, responses tend to consist of short phrases and rarely involve explanations of any complexity. Wait time two is particularly powerful for increasing the probability of elaboration.

Hanna (1977) did a study of the impact of extended wait time on the quality of primary student responses to stories. Independent judges rated the quality of student responses higher under the three-second treatment than under the control format of one second.

2. **More inferences are supported by evidence and logical argument.**

Under one-second wait times, the incidence of qualified inferences is extremely low, but it becomes quite common at the three-second wait time threshold (Anderson, 1978, Arnold, Atwood, and Rogers, 1973).

3. **The incidence of speculative thinking increases.**
4. **The number of questions asked by students increase as does the number of experiments they propose.**

As a rule, students ask questions infrequently, and when they do, the questions are usually to clarify procedures and are rarely directed to other students. This situation changes rather dramatically under the three-second regimen.

5. **Student-student exchanges increase; teacher-centered "show-and-tell" behavior decreases.**

Under very short wait times, students compete for turns to perform for the teacher. There is little indication that they listen to each other. Under the three-second regimen, however, they show more evidence of attending to each other as well as to the teacher, and as a result, the discourse begins to show more coherence. This outcome is particularly influenced by wait time two.

6. **Failures to respond decrease.**

"I don't know" or no responses are often as high as 30 percent in classrooms with mean wait times one and two of one second, which is the most common pace. Increasing wait time one to three seconds is particularly important for this outcome. During training, teachers often ask, "What if the student just doesn't know? Wait time will just be an embarrassment." The practical answer to that is to provide an "I pass" option. A student who has that option and exercises it at the end of three seconds is 70 percent more likely to be back in the discussion spontaneously before the period is over than is the case under the normal one-second regimen.

7. **Disciplinary moves decrease.**

Students maintained on a rapid recitation pattern show signs of restlessness and inattentiveness sooner than do students on the longer wait time treatment plan. At first this seems counter-intuitive to teachers. It appears that fast-paced teacher questioning is a device for maintaining control of behavior. In fact, it not only inhibits the kind of thinking teachers seek to encourage, but it can also increase the need to discipline. At this point, it may not be apparent why increased wait time should be a factor for improved classroom discipline. The explanation may lie in a remark by a fifth grader to his mother about his teacher who was experimenting with three-second wait times. "It's the first time in all my years in school that anybody cared what I really thought - not just what I am supposed to say." Protracted wait time appears to influence motivation, and that in turn may be a factor in attention and cooperation.

8. **The variety of students participating voluntarily in discussions increases. Also, the number of unsolicited, but appropriate, contributions by students increases.**

Under the short wait time pattern, a major portion of responses comes from a small number of students: Typically six or seven students capture more than half of the recitation time. Under the three-second regimen, the number of students usually rated as poor performer who become active participants increases. Interestingly, this change in verbal activity gradually influences teacher expectations for students because more students do more task-related talking. (Verbal competence appears to be a salient factor in teacher judgments concerning a student's capabilities.)

9. **Student confidence, as reflected in fewer inflected responses, increases.**

Under a short wait time schedule, student responses are often inflected as though a tacit question such as "Is that what you want?" were attached to their statements. In a series of investigations to assess growth of confidence and a shift of reliance away from unsupported declarations by a powerful source, I presented a laboratory apparatus and a controlling variables problem to individual students chosen from different science settings (Rowe, 1968, 1969b, 1971). To assess the strength of an evidence-inference linkage, when subjects discovered and stated a relationship as a result of working with the apparatus, I would say, "I disagree." I wanted to observe what they did as a consequence. Could they persist through three disagreements? Some students came from the experimental science program classes with the usual short wait time pattern; others came from classes that in addition to the experimental science program also had three-second wait time regimens. A third group of students came from classes still engaging in the city's standard science program. I found that three-fourths of the new science and long-wait-time-group persisted through three disagreements by returning to the system, demonstrating their findings, and arguing the logic of their explanations. The other groups did much less well. For those in the experimental program under a short-pause procedure, less than half lasted through three disagreements. For the standard program (largely from a book), only 2 percent met the criterion - most could not even make a start on the problem presented to them (see Honea, 1981, for consonant results in an attitude/wait time study using social studies content).

In a wait time investigation conducted with Pueblo Indian students, Winterton (1977) found that students who were previously described by teachers as nonverbal contributed spontaneously twice as often in the long wait time classes as did their counterparts in science classes operating on the short wait time regimen. Winterton also reported increased values on other verbal indicators identified by Rowe (see Rowe, 1973, 1978 for summary and training techniques).

10. Achievement improves on written measures where the items are cognitively complex.

Tobin concluded that the wait time variable makes a significant contribution to performance on cognitively more complex test times at all three levels: elementary, high school, and college (Tobin, 1984; Tobin and Capie, 1982; Tobin, 1980). In his more recent work done in Australia, Tobin (1983, 1985) reports that average wait times there are even shorter than they are in the United States. Samples from two South American sources also show a shorter baseline wait time. In both situations as well as in Thailand (Chewprecha, et al., 1980), increasing wait time to three seconds, particularly wait time two in science, improves language and logic variables and in some studies written test performance as well (see also Yeany and Porter, 1982).

Almost as soon as teachers begin the wait time procedure, there are noticeable changes in speech and attitude outcomes. In fact, the promptness of changes, often detectable in the first hour, suggests that the wait time variable must have pervasive connections to both cognitive and affective factors. In a carefully designed and controlled study at the National Gallery of Art in Washington, Marsh (1978) found that even in groups of strangers, docents who used longer wait times could increase visitor engagements with ideas. Thus, it is a variable that does not rely on long-standing prior acquaintance of students with each other to produce results.

Effects on Teachers

Once teachers stabilize longer wait time patterns, certain characteristics of their discourse change. These changes are treated as outcome variables because they are influenced by the wait time factor.

1. Teachers' responses exhibit greater flexibility. This is indicated by the occurrence of fewer discourse errors and greater continuity in the development of ideas.

Under the short wait time schedule, the discourse does not build into structural propositions. To put it another way, there are more discontinuities in the discourse between students and teachers. Instead of a well-prepared banquet of ideas, the sequence of discourse resembles a smorgasbord at which everyone goes along, commenting on what she or he picks up, but paying no attention to the doings of others. One can calculate a discontinuity index for classroom discourse in much the same way one does when evaluating a computer-assisted-instruction program (Rowe, 1978). The index is higher for short wait time regimens.

2. The number and kind of questions asked by teachers changes.

There are fewer questions, but more of them entail asking for clarification or inviting elaboration or contrary positions.

As teachers succeed in increasing their average wait times to three seconds or more, they become more adept at using student responses - possibly because they, too, are benefiting from the opportunity afforded by the increased time to listen to what students say. Boeck and Hillenmeyer (1973) reported that wait time one following a complex question tended to be longer than after a low-level question. Rice (1977), Doerr (1984), and Hassler, Fagan, and Szabo (1980) confirm the original finding that increased wait times result in a cognitively more advanced pattern of teacher questions and reactions.

3. **Expectations for the performance of certain students seem to improve.**

Under the longer wait time schedule, some previously "invisible" people become visible. Expectations change gradually, often signaled by remarks such as "He never contributed like that before. Maybe he has a special 'thing' for this topic." This effect was particularly pronounced where minority students were concerned. They did more task-relevant talking and took a more active part in discussions (Rowe, 1969b, 1974e, 1975) than they had before.

While protracted wait times were never intended for use in drill and practice, neither I nor other researchers (e.g., Jones, 19080, Arnold, Atwood, and Rogers, 1974) have found markedly different wait time one values to be related to the level of question. I reported rather that this value was more influenced by teacher expectations. I asked teachers, prior to wait time training, to list the top five and bottom five students in their classes. Teachers gave the top five an average of 1.2 seconds of wait time one and the bottom five slightly less than one second (Rowe, 1974a, b, c, d, e; 1978). Gore (1981) suggested that teachers gave more wait time to one sex than the other. However, his measurement of wait time did not conform to the definitions.

Training for Wait Time

In their eagerness to elicit responses from students, teachers often develop verbal patterns that make the achievement of wait time two unnecessarily difficult.

Chief among the inhibitors is the habit of mimicry, repeating part or all of what a student says. A high mimicry rate cuts off extended wait time and reduces the quantity and quality of student responses. An anecdote illustrates the unintended consequence of a mimicry pattern. In a classroom where the teacher was changing his pattern in order to increase wait time two, one of the students asked, "Mr. B., how come you are not repeating things any more?" Before he could reply, another student answered the question. "I know. He knows that we can tell from the tone of his voice which answers he likes and which he doesn't, and we can stop thinking."

There are other verbal signals to consider avoiding or reducing in conjunction with wait time, e.g., "Yes... but..." and "... though" constructions because they signal the student that an idea is about to be rejected without the consideration due it.

Various procedures have been tried to help teachers learn to increase wait times (e.g., Anshutz, 1975; Atwood and Stevens, 1976). So far, the procedure that gets the most people to achieve relatively stable criterion three-second wait times in classroom settings takes longer than we would like, six to twelve hours. Moreover, it is a bit aversive because it involves transcribing ten-minute segments of tape recordings from three teach-reteach cycles using groups of four students. (When teachers work with small groups, wait times are as short as when they work with a whole class, Rowe, 1973.) The procedure is further complicated by the fact that teachers have seen their servo-chart plots for each teach-reteach cycle.

With the teach-transcribe-reteach procedure, 70 to 80 percent of people achieve three-second criterion wait times (Rowe, 1973, 1974a, b, 1978; McGlathery, 1978). One must be aware, however, that in the third or fourth week after teachers start using longer wait times in their classes, they revert to the original fast pace unless they have a chance to talk about what they are experiencing. What appears to happen in this transition interval is that grounds for decision making are less clear cut than was the case under the fast schedule. For example, teachers cannot decide how long to let student-student interaction go or how they feel when the nature of student-teacher interaction changes. In short, there are role and norm transformations taking place, and until these get settled, some teachers feel uncomfortable. A little support during this transition, even some advance warning that it will happen, appears to be sufficient to reinstate the three-second wait time average and to get teachers through the transition period.

Garigliano (1973) followed a teach-reteach regimen in a wait time training experiment but dropped the transcribing procedure out of one group in favor of having teachers listen to their tapes and identify and measure both species of wait time. His best performing treatment group (transcribed) attained 2.8-second averages. He confirmed the student effects described by Rowe, provided that average wait times did not drop much below this value.

Swift and Gooding (1983) and DeTure (1981) found that written training protocols are virtually useless in helping teachers achieve three-second wait times. In Swift's study, teachers averaged 1.35 seconds for wait time one and 0.68 seconds for wait time two, values that differed little from the means of his untrained group. Similarly, DeTure reported averages of 1.47 and 0.87 seconds for wait time one and two respectively for people trained with written or oral protocols.

Swift and Hawkins (1979) and Gooding, et.al. (1982) introduced an electronic monitoring device, the basic concept for which was initially developed jointly with Rowe, as a substitute for the feedback function supplied by the servo-chart plotter. Their voice-actuated relay system flashed a green light when wait times were satisfactorily long and a red light when wait times were too short. Teachers could have immediate wait time feedback while they were interacting with students. This method did result in some improvements but did not help the group attain criterion wait times until the procedure was accompanied by supportive intervention. Swift, Swift, and Gooding (1983, 1984) report that when the wait time devices were removed, despite supportive intervention, teachers reverted to short wait times. It may be that the presence of the mechanical device, while somewhat helpful, prevented teachers from attending to the fundamental changes in student-teacher interaction that take place with longer wait times, namely; the decisions occasioned by subsequent shifts in roles and norms.

DeTure (1985) remarks at the conclusion of a review of training procedures that the quick fix for this variable may not be feasible. Transcribing tapes as part of the training procedure in teach-transcribe-reteach cycles is time consuming but remains the procedure that enables more people to achieve a three-second wait time and successfully transfer it to the classroom.

Based on research, it is clear that wait time two is more important than wait time one in many of its effects. Ironically, some training programs and teacher competency rating schemes mistakenly focus on only on wait time one (DeTure).

All the training techniques may be useless if teachers believe they will lose control of the class under the longer wait time schedule. As the Soars so aptly observed (1983), teachers confuse management of ideas with management of discipline. They need to know that behavior management is actually easier with protracted wait times (Rowe, 1974a).

Adaptation of Wait Time for Lecture Formats.

Often in high school, and particularly in college, there is a need to convey complex content, and the lecture appears to be the most commonly chosen format. For the lecture situation, I developed a ten-two procedure for college and the eight-two for high school. Based on a theory about how short-term and long-term memory interact, I identified four types of mental lapses that take place on the part of listeners in science classes (Rowe, 11967a, 1980, 1983).

Using the ten-two and eight-two formats, participating science faculty would lecture for eight to ten minutes then stop for two. In the strictly regulated two-minute intervals, students in sets of three shared their notes and helped each other clarify concepts. All unresolved questions were to be reserved for the last five minutes of the period. Experimental groups following this regimen generally show improved performance over control groups on the more complex test items, more delayed retention, and more positive attitudes toward the subject and method. The quality of student questions also improves as does the usefulness of their notes.

Rewards

Another line of research that impacts on the wait time situation deals with teacher sanctioning. The effects of protracted wait times are enhanced if the teacher sanctioning pattern (either positive or negative statements by the teacher) is reduced.

That is, a high positive or negative sanctioning pattern reduces some of the effects of protracted wait times, particularly the following: student confidence, speculation, and elaboration (Rowe, 1974b, d; also see McGraw, 1978; Soar and Soar, 1983).

Special Education

Exposure to longer wait times is as useful to talented students as it is to lesser-ability youngsters. Gifted and talented high school students participating in a summer science program found the extended wait times particularly motivating, for the same reason as did the fifth grader mentioned earlier. Bright students see many connections between ideas but they never get to talk about them. With increased wait times, the changes in their production of ideas, in the variety of moves under the game model of the classroom, and in their expressions of relief at being able to go beneath the surface ideas are evident. Servo-chart plots of their explanations show that explanations come in bursts separated by substantial pauses (often in excess of five seconds), as does the speech of most students if they are not interrupted during the process by short wait time two intrusions. Thus the protracted wait times help both fast and slow learners, but for different reasons.

Two recent studies, one with mildly handicapped subjects and one with severely handicapped, showed some desirable outcomes for a five-second interval as opposed to the usual one-second pace (Korinek, 1985; Lee, 1985). In these cases, fundamental processing just takes more time. Extended wait time one was particularly important in the study by Lee.

Shrum (1985) found that wait time two (post-response wait time) in second language classes is even shorter (.73 seconds) than the .90 seconds reported by Rowe, much too short for thoughtful cognitive processing. She reports that average wait times are longer following questions in the native language than they are in the second language (see also Rochester, 1973).

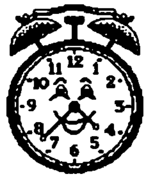
Conclusion

Under a wide variety of instructional situations and levels ranging from first grade through university level, from classrooms to museum and business settings, the quality of discourse can be markedly improved by increasing to three seconds or longer the average wait times used by teachers after a question and after a response. These pauses are ordinarily so brief, one second or less on the average, that an adequate exchange of ideas and the nurturing or new ideas cannot take place. Wait time, however, is just another technique if one does not understand why fostering more productive exchanges among us all is so important. Gwen Frostic, a poet and artist, tells us in her book Beyond Time:

> *We must create a great change*
> *in human direction -*
> *an understanding*
> *of the interdependency*
> *by which the universe evolves*
> *Know*
> *- that knowing -*
> *is the underlying foundation*
> *for the life we must develop...*
> *We cannot leave it to the scientists -*
> *nor any form of government -*
> *each individual*
> *must fuse a philosophy*
> *with a plan of action.*

Wait time provides a context in which teachers and students may dialogue together in the service of that purpose.

Article by Mary Budd Rowe transcribed by Science & Mathematics Network from "American Educator" magazine, Spring 1987 issue, pages 38-43, 47.



DRAGONFLY POND

1987, 1992 Council for Environmental Education.
Reprinted with permission from Project WILD Aquatic Education Activity Guide. The complete Activity Guide can be obtained by attending a Project WILD workshop. For more information, contact the National Project WILD Office at (301) 493-5447.

OBJECTIVES

Students will: 1) evaluate the effects of different kinds of land use on wetland habitats; and 2) discuss and evaluate lifestyle changes to minimize damaging effects on wetlands.

METHOD

Students create a collage of human land-use activities around an image of a pond.

BACKGROUND

Every human use of land affects wildlife habitat, positively or negatively. What humans do with land is a reflection of human priorities and lifestyles. The search for a modern day "good life" and all of its conveniences produces mixed results for wildlife and the natural environment. Sometimes people see undeveloped areas of natural environment as little more than raw material for human use. Others believe that the natural environment is to be preserved without regard for human needs. Still others yearn for a balance between economic growth and a healthy and vigorous natural environment. Very real differences of opinion regarding balance exist between well-meaning people.

Age: Grades 4-12
Subjects: Science, Social Studies
Skills: analysis, application, classification, communication, comparing similarities and differences, description, discussion, drawing, evaluation, generalization, inference, interpretation, invention, listening, listing, mapping, media construction, prediction, problem solving, psychomotor development, small group work, synthesis, using time and space, visualization
Duration: one to three 45 to 60-minute periods
Group Size: designed for a classroom of several small groups; can be modified to be an individual activity
Setting: indoors
Conceptual Framework Reference: VII.A., VII.A.1., VII.A.2., VII.A.3., VII.A.4., VII.B., VII.B.1., VII.B.2., VII.B.3., VII.B.4., VII.B.5., VII.B.6., VII.B.7., VI.A., VI.A.2., VI.A.3., VI.A.4., VI.A.5., VI.B., VI.B.1., VI.B.2., VI.B.3., VI.B.4., VI.B.5., VI.B.6., VI.C., VI.C.2., VI.C.12., VI.C.15., VI.C.16., VI.D., VI.D.1.
Key Vocabulary: land use planning, wetlands, trade offs, lifestyle
Appendices: Local Resources, Ecosystem, Observations and Inferences, Simulations

At the core of land use issues is the concept of growth. Growth in natural systems has inherent limits, imposed by a dynamic balance of energy between all parts of the system. Energy in natural systems is translated into food, water, shelter, space and continued survival. This means that the vitality of natural systems is expressed by their ability to be self-regulating. This capacity for self-regulation makes it possible for all natural members of an ecosystem to live in harmony. All the life forms of any ecosystem must be considered. The microbes in the soil are just as necessary to a habitat as the plants and predators. It is this natural dynamic balance, with all its inherent and essential parts, that much of human land use has tended to disturb. Human activities can often go beyond the natural limits of a setting. Humans have the ability to import energy sources that allow a system to exceed its natural limits—or to remove energy sources that are necessary for a system to stay in balance. For example, people can build dams to create power, water can be captured for irrigation, wetlands can be drained for homes and buildings. All of these activities affect wildlife habitat.

Wetlands, for example, are often seen as swampy wastelands, yet they are the nurseries for hundreds of forms of wildlife. Fish, frogs, toads, migrating birds, snakes, insects and a remarkable variety of plants all make a home of wetlands. Wetlands are highly vulnerable to development, pollution and a variety of forms of human interference with the natural flow of water. Hundreds of thousands of acres of valuable wetlands are lost each year—for example, to draining, dredging, filling and pollution.

Given the extensive impacts humans have already had and continue to have on the land, a major challenge now facing humans is how to have a more responsible impact. How can we develop the awareness, knowledge, skills and commitment that are necessary in order for humans to take responsible actions affecting the remaining areas of natural wildlife habitat? How can we develop the necessary understanding to restore a more natural dynamic balance in places where human disturbance has existed for centuries?

The major purpose of this activity is to encourage students to wrestle with these concerns. In this simulation, students use the "Dragonfly Pond" as a microcosm of environmental concerns involved in management decisions. They struggle with the arrangement of overlapping and conflicting land uses in an effort to preserve a wetlands habitat. When the students reach some kind of agreement about the local issues, the activity shifts to how what they have done affects other dragonfly ponds downstream. The activity ends with consideration of the idea that the planet is, in fact, a single "Dragonfly Pond."

MATERIALS

for each three students: scissors; masking tape; paste or glue; paper, one set of land use cutouts; one Dragonfly Pond cutout; a large piece of paper (18" x 24") upon which to fasten the cutouts

PROCEDURE

1. Prepare copies of the two cutout sheets ahead of time. Explain the activity. Tell the students that they will be responsible for arranging the pattern of land use around the Dragonfly Pond in such a way as to do the best they can to preserve the health of this beautiful aquatic area.

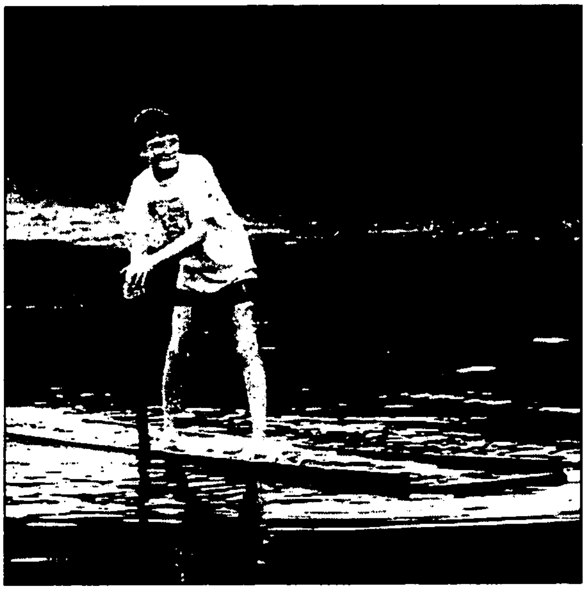
2. Divide the class into groups of three to five, with each group representing one of the interest groups. Students will stay in these groups until the end of the activity. Possible interest groups are:

- residents - want to live in the area
- farmers - want to use the land to raise food and livestock
- business interests - want to use the land for commerce and economic growth
- gas station owners - want to make a living in servicing and repairing cars
- parks department personnel - want people to have a place for recreation
- highway department personnel - want to maintain access in the area
- bleach factory representatives - want to preserve jobs and commerce

NOTE: Add others that you think may be locally important.

3. Pass out the land use materials. Pass out the 18" x 24" paper that will serve as the base for each group's pond and its associated land use activities. Have the students cut out the land use pieces and Dragonfly Pond. Tell them that all the land use cutouts must be used; park and farm land may be cut to smaller sizes, but all the pieces must be used. Parts may touch, but not overlap. The students may also create additional land uses of their choosing. When they fasten the cutouts to their large base sheet, suggest that they use small loops of tape. This will allow them to change their minds before pasting the pieces down.

4. Once the students have cut out the necessary materials and are ready to begin the process of making land use decisions, have them first create a list of pros and cons for each land use. Guide the class discussion so that they consider the consequences of each land use. Record these on the chalkboard. The following are only a few of the many possible examples:



236

BEST COPY AVAILABLE

10. Ask the students to brainstorm possible problems that could be faced within each of these aquatic systems as a result of the human activities at Dragonfly Pond. Make inferences and predictions about the potential consequences of these activities. For example, you could emphasize the effluent from the bleach factory. How will it be treated? Where? By whom? Where will it go? With what effects?

11. Ask the students to look again at all of the land uses in this activity. If they had been considering any of them as inherently bad, have them consider a different question. What could the people who are actually in charge of these various land uses do in their practices to minimize the damage to Dragonfly Pond? Have the activity end with an emphasis on solutions rather than on problems. Point out, for example, the revolution taking place in the "mining" of industrial effluents through "scrubbers" to extract wastes as profitable resources. (Perhaps the students need to make a "scrubbing filter" for the bleach factory.) Agricultural practices are changing so as to reduce the use of potentially lethal agents. Petroleum wastes are being recycled and domestic awareness regarding uses of pesticides and detergents is evolving.

12. Ask the students to create a list of things they think they personally can do to begin to reduce the potentially damaging effects of their own lifestyles on the "downstream" habitats they may never have thought about. If possible, invite them to periodically, throughout the school year, report on their progress in carrying out these new practices. Consider with them in discussion the idea that all the waters of the planet are, in fact, part of a single "Dragonfly Pond."

EXTENSIONS

1. Do the activity again up to step 6. After each interest group has presented its plan, form new groups with each of the new groups having a representative from each interest group. Have the new groups devise plans that all of the interests can agree on. Discuss how, if at all, this is a realistic experience in working to balance various community interests.

2. Set up an action team to locate a dragonfly pond in your community. Determine the overall quality of the wetlands with which it is connected.

3. Trace any stream or river system that passes through your community from its source to its final entrance into the seas. List all the sites that you can identify that lower the quality of the waters in their journey and suggest how to reverse the process.

4. Collect newspaper articles for local water-related and land use issues as a current events activity.

5. Learn more about environmental impact statements. Try to obtain actual copies of statements about wetlands in your area. See what concerns are addressed in these documents.

6. Learn about the national wildlife refuge system. Are there any wildlife refuges in your area? What animals find refuge in them? Visit a national wildlife refuge.

7. Find out about private organizations that work to protect wetlands. Two examples are The Nature Conservancy and Ducks Unlimited. Find out about what they do and how they do it.

8. Find out about zoning laws and land use regulations in your area. Would the plan your group proposed for Dragonfly Pond be allowed in your community?

EVALUATION

1. Name three things that people can do to reduce or prevent damage to wetlands. Under what conditions, if any, do you think actions to reduce damage to wetlands would be **appropriate**?

2. Under what conditions, if any, do you think actions to reduce damage to wetlands would be **inappropriate**? Select any action that you personally think would be appropriate and that you could take to reduce or prevent damage to wetlands. Describe what you would do.

BEST COPY AVAILABLE

PRO	CON
Farms:	
• produce food • economic value • provide jobs through seasonal employment	• use pesticides - (herbicides, insecticides) that may damage people and environment • source of natural soil erosion • sometimes drain wetlands for farm lands • use chemical fertilizers that may damage water supplies
Businesses:	
• produce employment • provide commerce • create economic stability	• produce wastes and sewage • may contaminate water (detergents, pesticides) • use chemical fertilizers (lawns, etc.)
Homes:	
• provide a sense of place • develop a sense of community	• generate wastes and sewage • use water • contribute to loss of wildlife habitat

5. Have the students work in their teams for a long enough period of time to begin to seriously grapple with the challenge.

6. Invite each group to volunteer to display and describe their work in progress. Encourage discussion of their choices. In the discussions emphasize that:

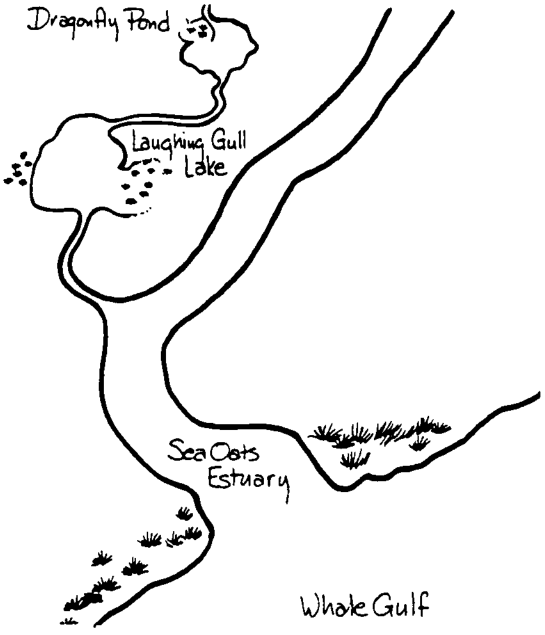
- no land use can be excluded;
- wildlife habitat must be preserved; and
- **everyone** must agree.

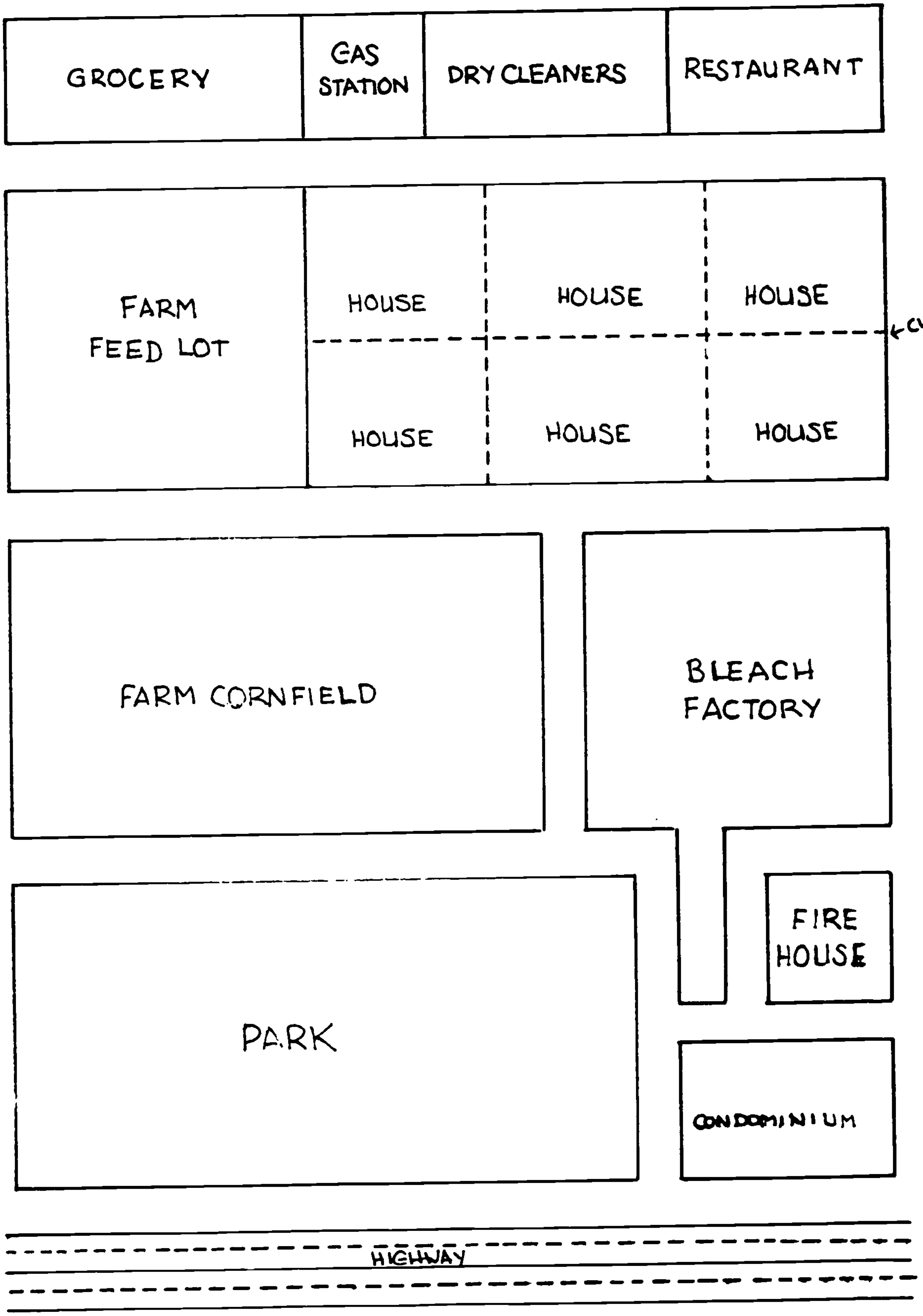
Look for the consequences of their proposed land use plan. Be firm about the issues, but fair about this being a very difficult set of choices. Ask additional groups to volunteer to show their work in progress and discuss theirs similarly. NOTE: For wildlife habitat this is a "no-win" activity in many ways. The best that can be hoped for is that the land use plans will minimize the threats to the Dragonfly Pond.

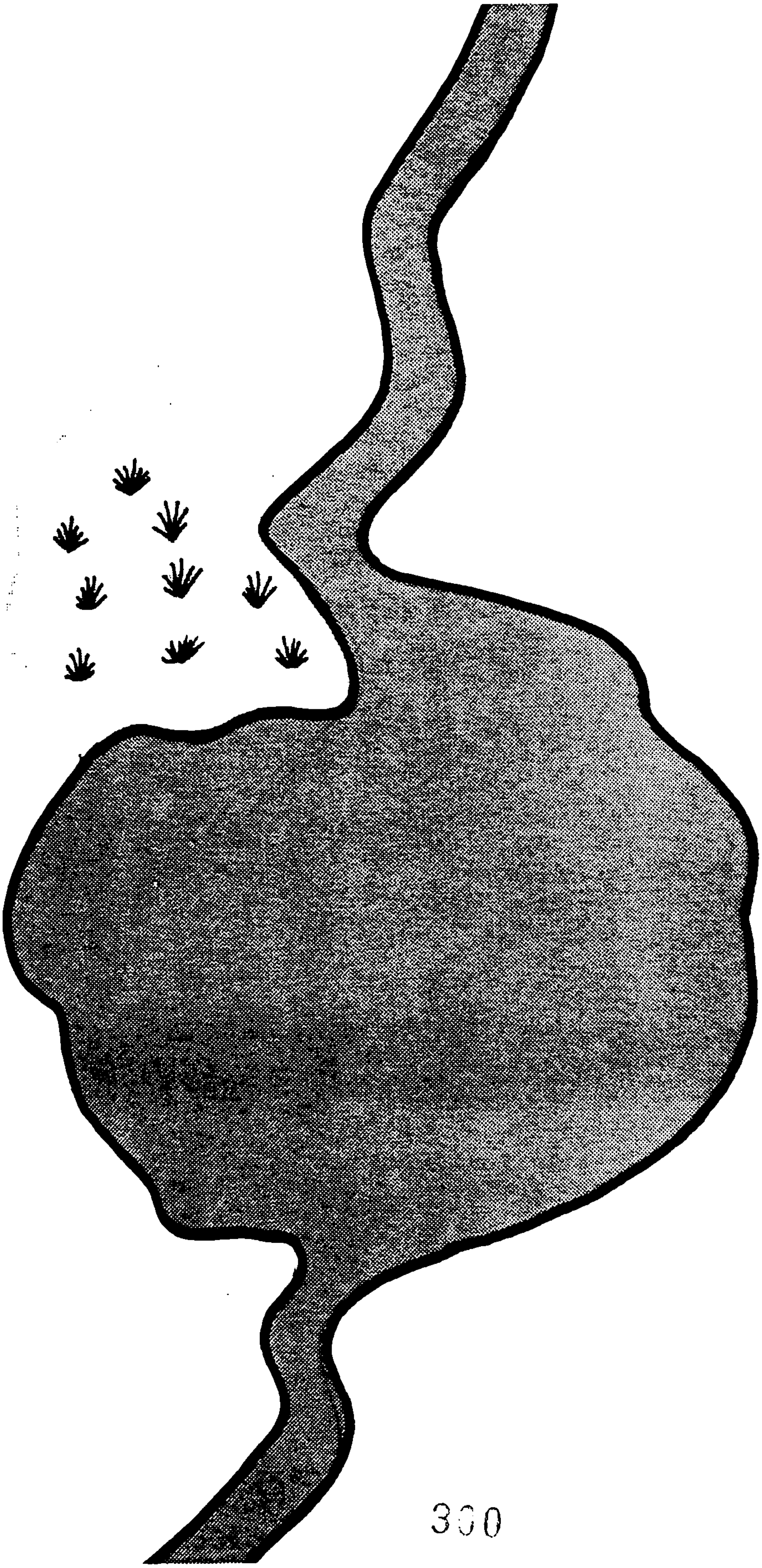
7. Continue the discussion by asking more students to share their proposed plans. Again, be firm in discussing the consequences. Point out that shutting down the factory and businesses will be likely to destroy the economic base of Dragonfly Town. Abandoning the farm affects food supplies and employment. Farmlands provide habitat for some wildlife. However, if wetlands are drained to create farm land, that results in a loss of habitat for some wildlife as well as a loss of other important values of wetlands.

8. Give the students additional time working in their groups to come up with what they believe to be the best possible land use plan under the circumstances. Being sensitive to their frustrations, display all the final land use plans above a chalkboard for all to see and discuss. Analyze and discuss the merits of each of the approaches. Point out that although their solutions may not be perfect, they can minimize the damage to Dragonfly Pond.

9. Choose one of the students' images above the chalkboard. Next, on the chalkboard, continue Dragonfly Creek downstream. Many students tend to dump effluent below Dragonfly Pond and let it flow downstream. Show the route the stream might travel. On the chalkboard drawing, have the downstream part of Dragonfly Creek become another pond and wetland and label the new area Laughing Gull Lake. Continue the drawing to Sea Oats Estuary and finally into Grey Whale Gulf.




GROCERY
GAS STATION
DRY CLEANERS
RESTAURANT
FARM FEED LOT
HOUSE
HOUSE
HOUSE
HOUSE
HOUSE
HOUSE
CUT
FARM CORNFIELD
BLEACH FACTORY
FIRE HOUSE
PARK
CONDOMINIUM
HIGHWAY



300

Assessment, Practically Speaking

How can we measure hands-on science skills?

By Lehman W. Barnes and Marianne B. Barnes

THOUSANDS OF ELEMENTARY school children busily do hands-on science activities every day. They observe and classify objects, measure length, volume, and mass, collect and record data, and manipulate materials. These students know that science involves both doing and communicating. But as they prepare for science tests, what have students come to expect? Are they being assessed on *all* that they've learned?

The Motor-and-Wires Kid

Jimmy was thrilled when we began a science unit on electricity and magnetism. I had assigned the first 11 pages of chapter four and was beginning to discuss the main ideas of the unit. Suddenly Jimmy burst out, "I have a couple of motors at home, could I bring them into class and show them to everyone? Or one of the 'electric magnets' I made last summer? I saw a picture of one in a book about science at the grocery store. All you need are some wires, a nail, and a battery."

"Sure Jimmy," I said, glad to see him excited. "Bring in your motors and wires."

DANE PENLAND SMITHSONIAN INSTITUTION

Doing a hands-on biology activity.

The next day, as I was unlocking the class door, I heard the rush of footsteps. There was Jimmy with a large paper bag containing all kinds of stuff—batteries, motors, wires, nails, pliers, and tape. "When are we having science today?" he asked me. His excitement was evident as he pored through his bag.

Teachers thrive on flexibility, especially in response to student enthusiasm, so I began science right after the morning announcements, a time usually reserved for language arts. Jimmy showed his classmates the motors, batteries, and wires, demonstrated how to build an electric magnet, and built an electric circuit. He eagerly shared the contents of his bag with the other students, most of whom were equally eager to learn what he knew about the motors.

During the next two days, with the class's interest and excitement levels staying high, I introduced the main ideas of the science unit and, thanks to Jimmy, got the whole class involved in creating series and parallel circuits. I ended the activities with a brief review for Friday's science test.

What Does My Test Test?

The comprehensive test—vocabulary, labeling, matching, multiple-choice, true-or-false, short-answer, and puzzle questions—accurately assesses students' mastery of the verbal aspects of the science unit. Jimmy did well that Friday, especially on the short-answer questions. His answers were complete, and he even included drawings of his two setups. At the bottom of his test paper he wrote, "I think I know a whole lot more, but I can't show you on this kind of test."

Jimmy's comment struck me. The test lacked an opportunity for students to demonstrate what they had learned through the manipulation of materials. How do test items assess practical performance? Paper-and-pencil tests adequately assess verbal learning, but they often neglect the equally important practical learning.

The quantity and quality of practical learning experiences in elementary classrooms has grown in recent years. Practical assessment, however, lags behind. If we believe in hands-on learning, then we must approach the assessment of this learning with practical hands-on testing. Otherwise, we convey the message that practical learning is less important than verbal learning.

JANE PENLAND, SMITHSONIAN INSTITUTION

Evaluation Potential

Practical assessment tests hold an enormous potential for elementary science teachers, because so many areas of science would be better evaluated in such a manner. For example, think about evaluating science skills in the following scenarios:

- working with basic science equipment, such as a thermometer, a triple beam balance, a meterstick, a graduated cylinder, and a stopwatch;
- performing laboratory skills and procedures, such as working with a magnifying glass or microscope, heating or filtering a substance, mixing a solution, or measuring rates;
- observing and classifying three-dimensional objects, such as shells, rocks, plants, and animals (currently, most assessment tests employ visual observation only in two-dimensional settings);
- collecting and recording data in tables, charts, and graphs that students create themselves—such graphs could reflect temperature changes over time, heartbeats per minute, or a ratio of the manipulated variable to a responding variable;
- designing experiments and performing investigations from a set of materials and a specific question (Which paper towel will hold the most water? How can you make the tablet dissolve faster? Which material would keep you warmer?);
- generating a set of investigative questions from a set of materials, such as a cart, weights, and an inclined plane; a set of paper gliders; or a set of pendulums;
- manipulating objects to demonstrate understanding of concepts and connections among concepts—for example, understanding electrical circuits, or understanding the relationships between the mass, volume, and density of an object;
- building models—physical representations that demonstrate natural phenomena—such as a cell, the solar system, or a geological structure;
- communicating in the process of investigation during small group work, individual writing, summarizing and presenting to others, or creating a display.

Verbal *and* practical learning are fundamental ingredients of a good elementary science program. Historically, verbal learning has been emphasized in schools and has, appropriately, been measured by verbal assessment. Now, with practical learning finding its rightful place in the instructional program, practical assessment should develop as well. Elementary educators must face the challenge to practically assess their increasingly creative hands-on science teaching.

Science assessment should measure hands-on skills.

LEHMAN W. BARNES is an associate professor of science education at Florida State University in Tallahassee. MARIANNE B. BARNES is a professor of science education at the University of North Florida in Jacksonville. They are coeditors of the Florida Science Teacher.

BEST COPY AVAILABLE

Student Evaluation

Name__________________________________

Topic__________________________________

Description of Project:__________________

____

____

____

The reason I chose this was______________

____

____

The help I received was _________________

____

____

Something I learned about myself or my topic was______________________________

____

____

____

Peer Responses:

Name:__________________________________

____

____

Name:__________________________________

____

____

Innovative Student Assessment in Environmental Education

Nancy Murphy, Antioch University Seattle
Peggy Cowan, Alaska Dept. of Education
Diane Cantrell, Ohio Department of Natural Resources
Bill Andrews, California Department of Education
Peggy Cowan, Alaska Dept. of Education, Div. of Educational Program Support

This paper presents a brief overview of the purposes of assessment and innovative strategies to assess for those varied purposes. Examples are drawn from national environmental education programs such as Project Learning Tree, Project WILD, Sharing Nature With Children, and Class Project.

Traditional Assessment and Recent Alternatives

Traditionally we have used assessment to measure retention, a summative process put to normative use. Formative processes of assessment (those activities that tell the teacher what the student understands and what needs to happen next in instruction) have traditionally occurred informally. This workshop addressed only those areas of assessment that are valuable for the purposes of instructional decision-making (the formative purposes), with suggestions of how to document these to satisfy some summative purposes through a strategically-designed portfolio.

Redefining Assessment in the Service of Instruction and Learning

Every individual enters an educational experience with a set of images about the topic. The theories of constructivism suggest that learning actually consists of each individual's efforts to modify these images (or schema) to accommodate or reject new information and experiences. Consequently, we are now refocusing our attention in assessment to evaluate the degree to which students construct meaning for themselves (instead of looking at the degree to which they accept information as we present it). It should value growth over mastery, and it should support lengthy periods of practice and accomplishment before expecting further growth.

Assessment should also accommodate a variety of learning styles and intelligences. Awareness, knowledge and action take many forms. We need to search for the mode in which these are being communicated, and we need to help students broaden their range of expression.

We are also searching for assessment strategies that validate unspoken issues of power in the classroom. If the purpose of the lesson is to develop or reinforce student empowerment, then the assessment should be responsive to the individual's personal sense of empowerment, either through self assessment or student input into the performance criteria. If the lesson targets concepts or behaviors identified by the instructor, then the expectations should be explicitly itemized in the assessment tool. This tool should in turn be used as a communication device, one that relieves the student from the guesswork involved in pleasing the teacher.

Murphy, N., Cowan, P., Cantrell, D., & Andrews, B. (1994). Innovative student assessment in environmental education. In R. Mrazek (Ed.), Pathways to partnerships: Coalitions for environmental education (pp. 33-51). Troy, OH: NAAEE.

Issues in Assessment from an Environmental Educator's Perspective

Considerations in Unit Design

Environmental educators have traditionally organized educational activities around a sequence of awareness, knowledge, and action. The effect of this influence is evident in the wide acceptance of a Learning Cycle Model for science instruction. Although the literature contains numerous variations, a learning cycle model approach generally contains at least three stages. It begins with an initial engagement phase which activates student interest and elucidates students' prior knowledge or schema for the concept. This is followed by an exploratory phase in which the student interacts with the objects to gain an intuitive sense of the phenomenon in question. This phase usually includes guided discoveries during which the students "invent or discover concepts" that give meaning to the experiences of the exploratory phase. Finally, the students apply their newly learned concepts and skills in additional contexts to practice them and to extend the range of their usefulness (Gallagher, 1979; Murphy, et al, 1989). The result is a somewhat flexible sequence including engage, explore/discover, and extend.

The similarities between the environmental education sequence and the learning cycle model can be roughly compared as follows:

ENVIRONMENTAL ED. SEQUENCE	LEARNING CYCLE MODEL
Awareness	Engagement and Assessing Preconceptions
Knowledge	Exploring Concepts and Communicating New Discoveries
Action	Extending/Applying Concepts in New Contexts

Note that a primary difference is that the environmental education sequence emphasizes knowledge for the purpose of action, with student action becoming the motivator for knowledge development. The Learning Cycle Model emphasizes the importance of student discovery and ownership of new conceptual schema, using application or action as a verification of the transferability of these new concepts. The two are compatible and interchangeable. We highlighted portions of both throughout this workshop.

Types of Environmental Education Teaching Strategies

Environmental educators flaunt an appealing diversity of teaching strategies, ranging from expository modes to more student-centered methods. The following list of familiar activities represents the range:

TEACHING STRATEGIES	EXAMPLES OF ACTIVITIES	SOURCE OF EXAMPLE
Exposition	Short Takes	NatureScope: Endangered Species
	The Hunters	Project WILD
	A Letter from Archy	Project Learning Tree
Computer Assisted Instruction	SimCity	Maxis
	Decisions, Decisions: The Environment	Tom Snyder
Discussion	Most Activities	most curricula
Demonstrations	Crack, Crumble and Carry	NatureScope: Pollution
	Prime Parts	NatureScope: Birds,Birds,Birds
Drill and Practice	Few Activities	
Recitation	Few Activities	
Guided Imagery	Stormy Weather	Project WILD
	Tree Imagery	Sharing the Joy of Nature
	Another Way of Seeing	Project Learning Tree
Brainstorming	Aqua Words	Aquatic WILD

	Ethi-Thinking	Project WILD
	Which Should I Buy	Project Learning Tree (S)
Sensory Awareness	Blind Walk	Sharing the Joy of Nature
	Urban Nature Search	Project WILD
	Adopt-a-Tree	Project Learning Tree (E)
	Micro Trails	Acclimatizing
Investigations and Experiments	River Cutters	GEMS (Great Explorations in Math and Science)
	Animals in Action	GEMS
	Animal Movement in Water	OBIS
	Owl Pellets	Project WILD
	A Field. a Forest and a Stream	Project Learning Tree (E)
	Water Canaries	Project WILD
	Soil Soakers I. II	AIMS: Water Precious Water
Games and Simulations	Bat & Moth	Sharing the Joy of Nature
	Build a Tree	Sharing the Joy of Nature
	Catch Me If You Can	AIMS: Critters
	Hooks and Ladders	Aquatic WILD
	How Many Bears Can Live in This Forest	Project WILD
	Population Game	OBIS
	Forest Concentration	Project Learning Tree (E)
Role Playing	Dragon Fly Pond	Aquatic WILD
	My Use of Your Use or Our Use	Project Learning Tree (E)
Individual and Group Projects	Here Today. Gone Tomorrow	Project WILD
	Fashion a Fish	Aquatic WILD
	Build a Mangrove	NatureScope: Wading Into Wetlands
Peer Teaching	Many Activities	
Debates	Pro and Con	Project WILD
Surveys and Questionnaires	Surveys and Slogans	NatureScope: Wading Into Wetlands
	Living Research: Aquatic Heroes and Heroines	Aquatic WILD
	Interview a Board Worker	Project Learning Tree (E)
	Wildlife Issues: Community Attitude Survey	Project WILD
Case Studies	Local Examples	
Issue Analysis and/or Investigation	What Did Your Lunch Cost Wildlife	Project WILD
	Forest Consequences	Project Learning Tree (E)
Moral Dilemmas	Ethi-Reasoning	Project WILD
	A Look at Lifestyles	Project Learning Tree (S)
	Values Clarification: A Handbook of Practical Strategies for Teachers and Students	Simon et al
Community Studies	Planning for People and Wildlife	Project WILD
	Keeping Score	Project WILD
	Plan Your Community's Future	Project Learning Tree (S)
	Investigating and Evaluating Environmental Issues and Actions	Hungerford et al
Problem Solving	Education in Action: A Community Problem Solving Program for Schools	Stapp et al
	Migration Barriers	Project WILD
Action Projects	Monday Group	Project WILD
	Can Do	Project WILD
	Improve Your School Site	Project Learning Tree
	Can You Help!	NatureScope: Rain Forests
	CLASS Project	National Wildlife Federation

BEST COPY AVAILABLE

Matching Assessment to the Unit Purposes

We have found that it is difficult to design an assessment tool for a particular environmental education activity or teaching strategy outside of the context of an instructional unit. It is more productive to develop assessment tools based upon the activity's role within the purposes of the unit. For example, a simulation can be used to communicate students' preconceptions, to reinforce a concept, or to apply or transfer a concept. Different assessment tools would be appropriate for the different purposes of the simulations. For this reason we have chosen to organize this workshop by presenting strategies that are categorized by the purposes of instruction.

Types of Assessment Strategies for Different Purposes of Instruction

Assessing Conceptual Change or Mastery

If you accept the premise that all of your students have unique schema about the concept you are addressing, and if you assume that in order for a student to thoroughly engage in the educational activity s/he must somehow make connections between the activity and the current image, then it follows that you might want to provide multiple entry points for engagement so that all of your students are motivated. The first step in this process is to assess those preconceptions. The following sequence is recommended:

- identify current knowledge structures
- acknowledge current understandings and support communication of reasoning
- provide an initial activity that engages all of these schema
- provide small challenges to current schema that are within the reach of each student

The next step is to assess the step-like progress that students make as their schema shift and evolve to accommodate and explain new experiences. We call this assessing conceptual change.

As mentioned above, students come with unique preconceptions. They also construct new meanings by modifying those existing preconceptions one step at a time. This means that we must manage complex classrooms in which each student is engaged in the unique task of analyzing and modifying his/her current knowledge base. This is not as difficult as it might sound.

Most environmental educators are concerned about encouraging students to become effective stewards of Planet Earth. The environmental concepts are indeed fairly straight forward and simple. The number of contexts in which they are applied are complex and varied. We are not satisfied by the knowledge that students understand a concept. *We want to be sure that they understand the concept sufficiently to comfortably and creatively transfer that information to new situations in new contexts.* As educators, we want to support this ability to transfer, and we want to assess our success at this endeavor.

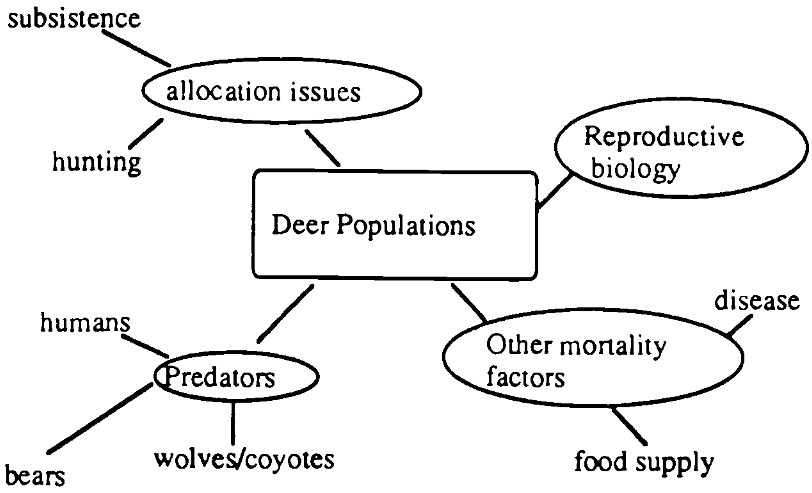
The following assessment tools can aid educators as they manage classrooms to provide for effective conceptual change and mastery. The assessment tools encourage students to successfully communicate their schema, allow the teachers to document and validate the varied communication styles of their diverse students, and either clearly articulate teacher expectations to the students or allow students to participate in the development of criteria.

Concept Mapping

Also known as webbing and bubble diagrams, concept maps are connected collection of words that represent one's understanding of the relationship between ideas. Concept maps have the following advantages:

- They permit a variety of "right" answers to surface
- They permit the comparison of student understanding to expert knowledge
- They improve everyone's understanding as we search for personal and shared meaning
- They illuminate preconceptions, and your students begin to ponder and communicate the organization of their ideas.

Sample concept map



Teachers often ask students to create concepts maps using the following phrase:

"Tell me what you know about _____________ (the concept)? As the students share their current knowledge, the teacher writes the words and phrases on chart paper. It often helps for the teacher to have in mind a visual image of the way s/he has organized the instruction around the concept (I call this an organizational template). This will help the teacher decide where to place the student ideas on the chart paper. The resulting student-created concept map provides information on how much the students know about the upcoming unit and how they organize that knowledge.

After the teacher has modeled concept mapping on chart paper for the class several times, the students will be ready to create their own individual concept maps. You can either ask them what they know about the concept or provide them with relevant terms to organize in a concept map.

Prior Knowledge Charts

Poll your students in the engagement phase on what they know and what they want to find out about your topic. Take a tally on what they learned/discovered in the explore phase.

WHAT WE ALREADY KNOW:	WHAT WE WANT TO FIND OUT:

WHAT WE LEARNED:

DISCOVERED PRINCIPLES:

Rubrics

CHECKLISTS: Checklists are easy ways to keep track of student behaviors. In this case, the teacher need only note that a behavior exists. Checklists encourage teachers to organize their thoughts about outcomes. They can also help us to review whether or not we are focusing on process skills, conceptual development, attitudinal changes, behaviors, social development or other modalities. Students appreciate a checklist because it defines our criteria and minimizes their guess work. Teachers can refer to checklists to get a sense about what percentage of the class has not attained the expected outcome and then adjust instruction accordingly. Likewise, teachers can assign grades to total number of points accumulated by total check marks.

Likert Scales

A Likert scale is really a checklist which allows the teacher to note to what degree a behavior exists.

Analytical Trait Scales

Analytical trait scales are a variation of a rubric in which the specific levels of performance expectations have been articulated. In the case of this first example, the criteria and performance expectations are identified in advance by the instructor. The advantages of the analytical trait scale include:

- students are immediately aware of the expectations of the instructor and can act upon those expectations,
- scoring is consistent for each criteria,
- expectations which are unclear for students can be identified in advance, and
- they preclude the necessity to provide lengthy comments on assignments (since most of the standard comments have been predicted and included in the rubric, these comments are provided by a check mark in the appropriate cell).

Analytical trait scales also have a few disadvantages. Some complain that they create too much consistency in the output of all students, squelching creativity. Several strategies have evolved to address those concerns:

- Attach an additional criteria at the end which is labeled Creative Approaches. Students are then assigned additional points if they extend themselves beyond the instructor's expectations or imagination.
- Add one criteria labeled Personal Criteria. Students identify and self-score one criteria that they set for themselves.
- Perhaps the most effective strategy is for the instructor to provide a blank rubric to the class followed by a discussion his/her initial expectations and the reasons behind them. Then the class can decide as a group what expectations might be reasonable for them and what behaviors/outputs might indicate various performance levels.

Holistic Scales

Holistic scoring provides one score for performance on a number of combined criteria. It does not break the performance into the task analysis categories (in contrast to analytical trait scoring). A holistic scoring rubric often lumps the individual performance indicators of an analytical trait scale together. Some teachers prefer holistic scoring because it more appropriately represents the real world (a concert pianist is judged on the effect of his/her total performance, not the breakdown of the individual skills). Other teachers prefer to give the students the specific feedback on each criteria, therefore adding more objectivity to the final score.

The following four sample rubrics illustrate the differences between Checklists, Likert Scales, Analytical Trait Scales, and Holistic Scales:

HABITAT CONCEPT CHECKLIST

Student Names

Criteria:															
Knows the four components of habitat															
Understands the interdependence of habitat components															
Can explain the impacts of human development and natural disasters on this balance															

HABITAT CONCEPT LIKERT SCALE

	No Evidence	Some Evidence	Effective Mastery
Habitat has four components: food, water, space and shelter			
Habitat systems maintain their own system of checks and balances: all of the components are interdependent			
Natural disasters and human impacts can alter this natural balance			

HABITAT CONCEPT ANALYTICAL TRAIT SCALE

	Emerging	Developing	Applying
Habitat has four components: food, water, space and shelter	Beginning to recognize the components	Can name all 4	Can name all 4 and transfer to other situations and populations
	Emerging	Developing	Applying
Habitat systems maintain their own system of checks and balances; all of the components are interdependent	Beginning to recognize that population dynamics are in response to habitat components	Knows that booms and busts occur but cannot adequately explain why	Can explain that habitat components become limiting factors before they are depleted
Natural disasters and human impacts can alter this natural balance	Beginning to associate impacts with effects on habitat	Associates disasters and human impact with habitat changes, but no specific examples	Identifies how disasters and human impacts affect specific habitat components; identifies effects on population dynamics

HABITAT CONCEPT HOLISTIC SCALE

Emerging	Developing	Applying
Beginning to recognize the components	Can name all 4 habitat components	Can name all 4 and transfer to other situations
Beginning to recognize that population dynamics are in response to habitat components	Knows that booms and busts occur but cannot adequately explain why	Can explain that habitat components become limiting factors before they are depleted
Beginning to associate impacts with effects on habitat	Associates disasters and human impact with changes, but no specific examples	Identifies how disasters and human impacts affect specific habitat components and population dynamics

Center Responses (Performance Tasks)

Many teachers create "worksheets" for students to use at centers. These guide the students through particular activities and aid them as they record their thoughts and results. Most performance tasks analyze the students' ability to apply the process skills of science (observe, classify, measure, infer, predict, experiment, communicate) to a particular situation or task.

FALLEN TASK CARD

1. LIST the animals (or evidence of animals) on your log:

2. CHOOSE ONE ANIMAL whose complete habitat could be supplied by the log:

3. LIST EVIDENCE of the components of that habitat:

Food:	Shelter:
Water:	Space:

Assessing Cooperative Groupwork and Consensus-Building Skills

Most educators agree that cooperative group strategies are important skills to develop. (Some educational theorists contend that we construct new knowledge as a result of social negotiation and consensus building.) As a result we are emphasizing activities which promote improved communication within and between groups, shared decision making strategies, and cooperative behaviors. Consequently, we want to assess our students' abilities to perform these skills. These might include assessing your students' ability to participate in a group, communicate ideas, stay on the topic, offer useful ideas, support and consider other ideas, and involve others to promote diverse contributions. The following rubrics contain ideas for assessment that can be adapted to a number of different formats and situations.

COOPERATIVE GROUPWORK SELF ASSESSMENT CHECKLIST:

A. Group Participation

Did my fair share of the work	
Did not try to dominate the group or interrupt	
Participated in group activities	

B. Staying on Topic

Paid attention, listened to what was being said and done	
Made comments aimed at getting the group back to topic	
Did not get off the topic or change the subject	

C. Offering Useful Ideas

Gave ideas and suggestions that helped the group	
Offered helpful criticism and comments	
Influenced the group's decisions and plans	

D. Consideration

Made positive, encouraging remarks about group members and their ideas	
Gave recognition and credit to others for their ideas	
Was considerate of others	

E. Involving Others

Got other involved by asking questions, requesting input, or challenging others.	
Tried to get the group working together to reach group agreements	
Seriously considered the ideas of others	

F. Communicating

Spoke clearly, was easy to hear and understand	
Expressed ideas clearly and effectively	

G. Overall Experience

This group helped me improve my understanding of the problems and the ways of solving them more than if I had worked alone	
Working with the group was an enjoyable experience	

A more complex cooperative group skill involves developing consensus among disparate interest groups. Since it can be assumed that everyone is ultimately concerned about a long and healthy life on a healthy planet, the challenge can often be redefined as recognizing common goals. Many strategies for developing this "Win-Win" philosophy are described in the book *Getting to Yes: Negotiating Agreement Without Giving In* (Fisher and Ury, 1981). One of the first steps, then, in investigating environmental and social issues involves identifying different points of view and developing a healthy awareness of factors that limit our own points of view. The following rubric identifies some of these skills and can be used with simulations, case studies and issue investigations.

POINTS OF VIEW LIKERT SCALE

Scoring Scales

Criteria	1 No Evidence	2 Some evidence presented; still working on effectiveness	3 Effective demonstration of skills/attitudes/ concepts	4 Complete mastery of skills/attitudes/ concepts and ability to apply to different contexts
How well does the student frame the issue? (Can s/he describe what the issue is about?)				
Can the student identify different points of view? (Different perspectives and reasoning supporting those perspectives?)				
How well does the student articulate his/her own point of view?				
Can identify source/basis of his/her opinions				
Can identify needs for additional info (what kind, where to find it, what info could make him/her change his/her opinion)				

BEST COPY AVAILABLE

POINTS OF VIEW LIKERT SCALE (ELEMENTARY)

	No Evidence	**Rarely**	**Often**	**Always**
The student can describe what the issue is about				
The student can state a personal opinion about the issue				
The student can suggest a solution to the issue				

ORAL CONTRIBUTIONS HOLISTIC SCALE

Points	**Range of Oral Contributions**	**Anecdotal Evidence**
0-2	Makes occasional contributions	
3-5	Makes occasional significant contributions and usually listens carefully and responds to the points made by others	
6-8	Usually effective, occasionally shows the ability to analyze previous contributions and take the discussion forward	
9-10	Pertinent contributions made on a wide variety of issues in both large and small groups without over dominating, able to lead a discussion when necessary. A good listener as well as a good talker	

(The Joint Matriculation Board Examinations Council; 1987)

Assessing Application, Action, and Empowerment

How do we as educators assess whether or not our academic concepts affect behavioral changes in our students? How do we then respond by changing our instruction to promote behavioral changes? This is not to suggest that all environmental education should promote behavior modification techniques but to encourage the promotion of critical thinking skills which transfer to critical-think-before-you-act-skills. This book suggests several strategies to assess this form of transfer, ranging from self-assessments to more covert methods. The following analytical trait scale includes criteria for taking action. They are useful for service projects, issue investigations, or STS approaches.

TAKING ACTION LIKERT SCALE

Scoring Scales

Criteria	1 No Evidence	2 Some evidence presented; still working on effectiveness	3 Effective demonstration of skills/attitudes/ concepts	4 Complete mastery of skills/attitudes/ concepts and demonstrates ability to apply to different contexts
Does new knowledge translate into ideas for meaningful action?				
Is there evidence of action taken?				
Is there evidence of consistency between personal point of view and his/her response to a salient event?				

STS LIKERT SCALE

	Always	Often	Sometimes	Rarely
The student identifies mutual influences of science, technology and society in relation to social issues				
The student strives to acknowledge many points of view and identify the sources of his/her own point of view				
The student engages effective problem solving and decision making skills				
The student engages in a societal or personal course of action after weighing the trade-off among values and effects drawn from various scenarios and alternative options				

Learning Logs/Contracts

Some teachers prefer a project approach to instruction in which students review issues, choose an action to accomplish, design a plan of action, and investigate scientific, technological, and social considerations in light of their project. Learning Logs are journals formatted to document these projects. They consist of at least three sections: 1) a contract which describes the project, timeline, and evaluation criteria; 2) a resource section that contains research information, relevant notes, diagrams, charts, bibliographies; and 3) the product which includes all working drafts and documentation of an authentic product.

Learning Contracts. Contracts are the vehicle for providing ownership and autonomy for student learners without sacrificing accountability. Through the process of contract development, students and teachers develop a means of communication and collaboration, resulting in a mutual pursuit of the learning experiences and outcomes. They are particularly helpful in field-based projects. Contracts also allow for flexibility to adjust the activities to accommodate the learner's style or particular strengths while still addressing identified objectives or outcomes. The following format encourages clear and explicit objectives (Knowles, 1991):

Learner: ____________

What are you going to learn/produce? (Objective)	How are you going to learn it? (Resources and strategies)	Target date for completion	How are you going to know that you learned it/succeeded? (Evidence)	How are you going to prove that you learned it/succeed? (Verification)

CONTRACT CHECKLIST

Students' Name										
Objective was expressed in operational terms										
Resource review of appropriate breadth and depth										
Timeline was realistic										
Effective presentation of evidence/verification of project success										

Environmental Skills Inventory

The following Environmental Skills Inventory includes a thorough list of criteria from which to pick and choose relevant criteria for your purposes. It might be more useful to use this checklist as a guideline for portfolio entries rather than a simple checklist. For example, students and teachers can decide what actions demonstrated these behaviors and determine how to document the occurrence of those behaviors in a portfolio.

Student Names

Criteria															
Identifies environmental issues															
Seeks historical background of issue															
Investigates environmental issues															
Separates opinion from fact															
Evaluates sources of information															
Analyzes environmental issues from various perspectives															
Applies ecological concepts to predicting probable ecological consequences															
Determines roles played by differing human beliefs and values in environmental issues															
Identifies alternative solutions															
Evaluates alternative solutions															
Conducts risk analysis															
Identifies and clarifies personal value positions															
Examines issues from local, national, regional and international points of view															
Demonstrates ability to forecast, to think ahead, plan															
Works cooperatively with other people															
Uses effective decision-making skills															

(modified from the Draft ASTM Standards, Alaska State Department of Education, 1993)

Authentic Products. When students engage in these meaningful activities, the most effective form of feedback is the public perception of the usefulness of their products. Therefore, any instructional strategy which encourages students to produce outcomes for public consumption also provides high incentives for the students to carefully edit and revise their products prior to completion. These activities are self-assessing in the most meaningful sense.

Scoring Scales

Criteria	1 No Evidence	2 Some evidence presented; still working on effectiveness	3 Effective demonstration of value to society	4 Exceptionally effective; still receiving applause
Did the project result in responsible action that was of value to society?				

Assessing Attitudes and Values

Much of the literature on environmental education refers to three domains: knowledge, attitude, and behavior. Many of the environmental education curriculum options include activities that promote an affective link to the environment ("Hug a Tree", "Adopt an Endangered Species", etc.). Do our students have a positive attitude towards ecological issues? Do they believe that they can be effective change agents? Do they value their relationship with the natural world? These attitudinal indicators provide important information to teachers as we plan instruction.

The following list of affective indicators of attitude and value development can be used in a variety of ways to document attitude change in students. These criteria reflect a student's sense of responsibility for the resolution of environmental issues, a respect for both nature and society, and a sense of efficacy in resolution skills. Teachers would probably only use a few of these criteria in a checklist, or they might use these criteria as guidelines for choosing items to include in a portfolio.

ENVIRONMENTAL ATTITUDE INVENTORY

Criteria															
Motivation to actively participate in environmental improvement programs															
Takes into account historical perspectives while focusing on current and potential environmental situation															
Strong internal locus of control															
Recognition of impacts of personal behavior, acceptance of personal responsibility for the impacts and willingness to help correct or avoid negative impacts															
Balancing love of nature with love of humanity															
Willingness to curtail some individual short term privileges for long range public good															
Respecting diversity of human perception, learning styles and value systems															

(modified from the Draft ASTM Standards, Alaska State Department of Education, 1993)

Strategic Documentation for Summative Purposes

The above assessment issues serve the purpose of informing instruction. They keep the teacher updated on the immediate schema and skill level of each student so that the teacher may continuously modify and manage the learning environment for best results. However, in the real world we need to provide additional information to administrators, program developers, parents and students about a number of norms. How do the outcomes of my instruction compare to the outcomes of other teachers? How does this student compare to the norm? How effective is this curriculum program compared to others? These summative and normative questions are a major purpose of assessment. They fall outside of the definition of authentic assessment in the service of instruction. However, educators are often called upon to provide documentation that answers these questions. How can we document some of the above authentic indicators of student ability in the course of instruction so that we don't need to dedicate our valuable time to non-instructional assessment? How do we decide which assessments to document and save? Finally, how do we contribute to more authentic forms of normative or standardized assessment procedures in environmental education?

Portfolios

A portfolio is a purposeful collection of student work that exhibits to the student and others the student's efforts, progress or achievement in a given area. Portfolios show what students know, not what they don't know. This collection should include:

- student participation in selection of portfolio content
- the criteria for selection
- the criteria for judging merit (if appropriate)
- evidence of student self-reflection

As teachers, we need to identify the purpose of the portfolio. It provides an opportunity to document and display student conceptual development for the summative and normative needs of administrators. If your district has a list of competencies and outcomes required of students, then it might be best to organize your portfolio around those criteria. Think about collecting material that documents individual growth in addition to comparing end results between students.

When designing portfolios, keep in mind their value at providing students the opportunity to display their own particular strengths in terms of learning styles or dominant intelligences. Think about how particular competencies might be demonstrated through musical, linguistic, mathematical, spatial, kinesthetic, or interpersonal models. Also strive to help students broaden their preferences and styles.

Putting it All Together: A Sample Unit on Habitat

Unit Abstract: Activities and Assessments

A simple example of a learning cycle model approach to an environmental education lesson follows. Assume that the teacher wants to address the concept of habitat, focusing on three sub-concepts: 1) habitat has four components (food, water, shelter, space), 2) habitat systems maintain their own system of checks and balances (all of the components are interdependent), and 3) natural disasters and human impacts can alter this natural balance. The following chart suggests an instructional sequence and some assessment considerations for each stage of instruction.

LCM Stage	Assessment Purpose The teacher wants to:	Assessment Tools Possible strategies
Engage The teacher will present the sensory awareness activity "Micro-Hike" from *Sharing Nature with Children*. In this activity the students carefully investigate 200 linear centimeters of ground and list their observations. This initial activity is followed by a concept mapping session on preconceptions about habitat ("What can you tell me about habitats?") or the construction of a "What We Know" Chart	Determine each student's preconceptions in order to provide effective multiple entry points for exploration. If necessary these documents can serve as baseline information from which to assess growth. Facilitate engagement (as each student needs to find some way of activating his/her current schema with the upcoming experiences).	The students list their observations and the teacher reviews these lists for initial observations of relationships between habitat components. Environmental Attitude Self-Assessment Concept maps about habitat preconceptions Prior Knowledge Charts
Explore and Discover The students experience three activities that reinforce the sub-concepts of habitat 1) "Oh Deer" from *Project Wild* is a simulation that results in a graph of deer population dynamics that boom and bust but recover as habitat components become limiting factors to population growth 2) "The Fallen Log" from *Project Learning Tree* is an investigation of a rotten log in which the students look for an animal and its necessary habitat components on that log 3) "Forest Consequences" from *Project Learning Tree* is a group project in which the students draw a forest on a mural and represent the effects of various developments on the habitats within that forest After each activity the students engage in either a discussion, journal session, or performance task card completion during which they verbalize their discoveries about habitat concepts	Determine the degree of conceptual change in the students (students illustrate this by creating concrete and verbal models of their schema). Determine if more explorations are necessary. Identify student-generated testable questions for inquiry-based experiments. Reinforce behaviors that elicit and respect alternative explanations and ways of knowing	Conceptual Change Rubrics Journals Discovered Principles Lists Prior Knowledge Charts Performance Tasks
Extend (Application and Empowerment) The students next engage in a role-play activity "To Zone or Not to Zone" from *Project Wild*. In this activity they assume a role of a particular interest group and represent that point of view in a mock trial about a proposed development This is followed by a moral dilemma activity "Ethi-Reasoning" from *Aquatic Wild* in which the students must decide how to respond to a proposed stream diversion that would affect the value of their property Finally, the students are challenged to design and complete an action project "Can Do" from *Project Wild* is an example of a lead in for such a project	Determine if the student can transfer the new understandings (either in a new context or in ways which benefit society). Facilitate new interests in students as they extend their original schema. (serves as "opener" instead of lesson "closure")	Points of View Scales Authentic Projects Rubric Taking Action Rubrics Learning Logs Contract Rubrics

The right hand column lists the possible assessment documents available for the activities. Most teachers collect this information informally for instructional purposes, and it is not necessary to document it all. Strategic choices on just what to document for summative purposes will result in a useful and efficient portfolio.

Samples for the Portfolio

HABITAT UNIT PORTFOLIO SELECTION GRID

Types of Assessments to Document and Display in a Portfolio	Specific Documents to Include (selected by student)
Evidence of conceptual change (preconceptions, postconceptions; details of conceptual mastery)	Prior Knowledge Chart on Habitat Analytical Trait Rubric on Habitat Concepts
Evidence of Cooperative Group and Consensus Building Skills	Points of View Likert Rubric
Evidence of concept application and personal empowerment	Taking Action Likert
	Reflection Questions on each of above

Summary

In summary, as educators we are under great pressure to maximize our effective use of instructional time. We are placing greater emphasis on acquiring continuous updates on our students' individual conceptual schemas. To be effective, we must collect this information informally and act upon it immediately in the classroom, but we should also consider ways to document it for other purposes. We need to be innovative in this endeavor, maximizing our data collection while minimizing our paperwork and the time we commit to it.

References

American Forest Foundation. (1987). Project learning tree. Washington DC: American Forest Foundation.

Cornell, J. B. (1979). Sharing nature with children. Nevada City, CA: Ananda Publications.

Fisher, R. and Ury, W. (1981). Getting to yes: Negotiating agreement without giving In. New York: Houghton Mifflin.

Gallagher, J. (1979). Basic skills common to science and mathematics. School Science and Mathematics, 79, 555-565.

Hungerford, H.R., Litherland, R.A., Peyton, R.B., Ramsey, J.M, and Volk, T. L. (1988). Investigating and evaluating environmental issues and actions: Skill development modules. Stipes Publishing Company.

Joint Matriculation Board Examinations Council. (1987). Science, technology and society (AS) specimen questions. Manchester, UK: author.

Knowles, M. (1991). Using learning contracts. San Francisco: Jossey-Bass.

Lawrence Hall of Science. (1989). Great explorations in math and science. Berkeley CA: University of California.

Lawrence Hall of Science. (1978). Outdoor Biology Instructional Strategy. Nashua, NH: Delta Education, Inc.

Murphy, N., Stephens, S. and Randles, P. (1989). The Alaska science consortium's learning cycle model. Alaska Science Consortium Journal (1) School of Education, University of Alaska Fairbanks. Fairbanks, Alaska.

National Wildlife Federation. (1982). The class project. Washington DC: National Wildlife Federation.

National Wildlife Federation. (1986). Naturescope. Washington DC: National Wildlife Federation.

Project AIMS. (1988). Activities integrating math and science. Fresno, CA: AIMS Education Foundation.

Project WILD. (1983). Project WILD. Boulder, CO.

Simon, S., Howe, L., Kirschenbaum, H. (1972). Values clarification: A handbook of practical strategies for teachers and students. NY: Hart Publishing Company Inc.

Stapp, W.B. et al. (1988). Education in action: A community problem-solving program for schools. Ann Arbor, MI: University of Michigan, School of Natural Resources.

Van Matre, S. (1974). Acclimatizing. Warrenville, IL: Earth Education.

Western Regional Environmental Education Council. (1986). Project WILD, elementary activity guide.

Western Regional Environmental Education Council. (1987). Aquatic Project WILD, aquatic education activity guide.

Zoller, U. (1990). The Individualized Eclectic Examination (IEE): An innovative strategic model for science and STES (science-technology-environment-society)teaching for all. Journal of College Science Teaching, 19, 289-291.

BEST COPY AVAILABLE

A Portfolio of Learning

By Lloyd H. Barrow

At the end of science methods classes, students are often asked to document what they have learned. Because learning is a gradual process, some individuals have difficulty answering this important question. Now there is a way to overcome this problem—have your science methods students make portfolios.

Portfolios are common components of job-search strategies in such fields as art, modeling, and finance, yet they are new to much of education. Discussing educational applications, Collins (1991) defined a portfolio as a collection of work that demonstrates evidence of knowledge, skill, and disposition. Bonnstetter (1991) described a portfolio as a systematic, well-organized collection of a student's knowledge, process skills, and attitudes.

Because portfolios will likely play a significant role in the future of science education, science methods students should experience the process themselves and feel comfortable before having their future students create portfolios for self-evaluation, teacher evaluation, and parent conferences. In addition, you will have an excellent tool with which to assess what your methods students have learned in your class.

Portfolio Factors

Before using portfolios in your methods class, you must decide how to handle content selection, portfolio appearance and production, and evaluation measures.

Content. To establish your portfolio assignment, you must choose between summative representation versus the collection of work at specific time intervals; students' best work versus all their work; growth from the beginning to the end of the course versus single selections; and new documents prepared just for the portfolios versus samples of previous work. You must also decide how to select evidence that promotes reflection, and whether to accept elective additional evidence of importance to the student.

Students' portfolios should include items that document

- competence in basic or integrated science processes;
- attributes of successful elementary science teaching;
- competence in designing hands-on, minds-on science instruction;
- and attributes of a K–6 science curriculum that promotes learning.

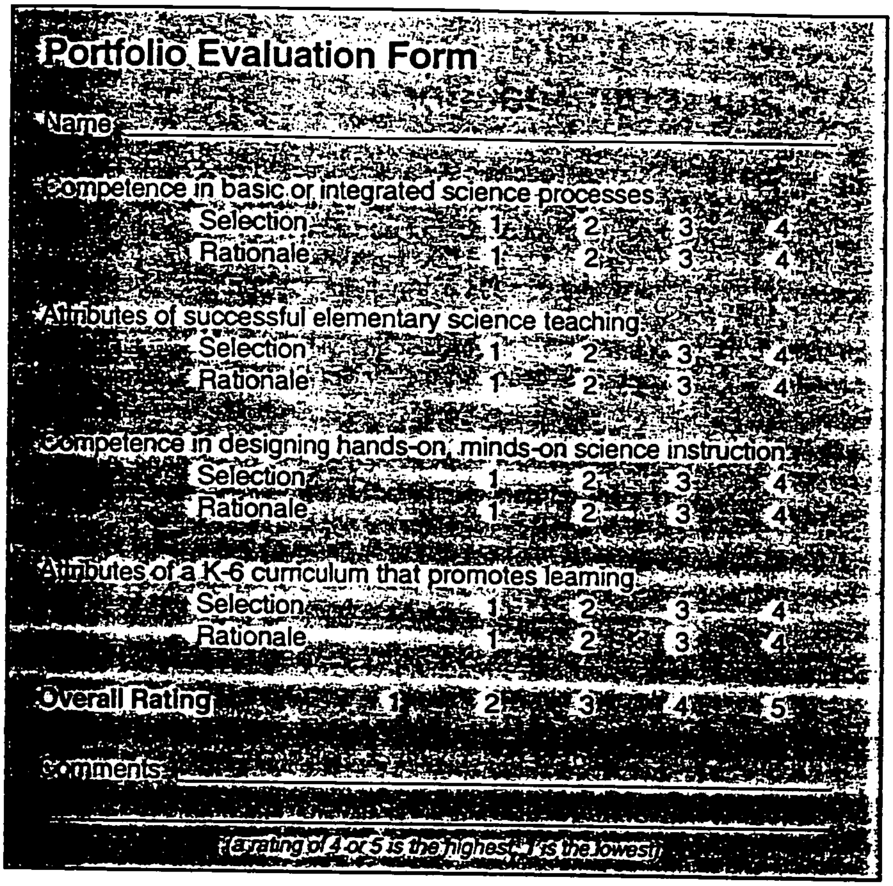
Allow individual methods students to select evidence that shows their competence in each area and provide a rationale for the selection of evidence.

For novice portfolio designers, the most common question is "What do you want?" A response such as, "Evidence that you have achieved each of these competencies and reasons that support this assertion," doesn't always help. Encourage methods students to use creatively the open-ended nature of portfolios. Having students select their best effort requires them to examine carefully all the components of the methods course. Requiring a rationale prevents the portfolio designer from selecting only assignments with the highest scores. For example, one of my students submitted a document that had a low score, but in her rationale she explained how she applied the formative evaluation comments to subsequent assignments. Here was evidence of learning.

Appearance. Consider establishing guidelines as to the portfolios' appearance. The finished products may be creative, traditional, "sizzling," or serious displays; freedom cultivates diversity. For example, one of my students submitted her portfolio as a time capsule for future elementary science methods students. Another submitted her portfolio as a legal brief of evidence with a summation. Yet another student addressed each category from the perspective of a student, a future teacher, and a community member.

Production. You'll also have to decide whether portfolios should be designed by individual students or teams of students, how much information

Science & Children Vol. 31 by Barrow. Copyright © 1993 by NSTA. Reprinted by permission of NSTA via the Copyright Clearance Center.



Portfolio Evaluation Form

Name ____________________

Competence in basic or integrated science processes
Selection 1 2 3 4
Rationale 1 2 3 4

Attributes of successful elementary science teaching
Selection 1 2 3 4
Rationale 1 2 3 4

Competence in designing hands-on, minds-on science instruction
Selection 1 2 3 4
Rationale 1 2 3 4

Attributes of a K-6 curriculum that promotes learning
Selection 1 2 3 4
Rationale 1 2 3 4

Overall Rating 1 2 3 4 5

Comments ____________________

(a rating of 4 or 5 is the highest; 1 is the lowest)

you want about the documents, and what the portfolio demonstrates. In making these decisions, bear in mind whether students are experienced portfolio designers or novices.

Finally, determine the amount of time students have to complete the assignment. For the past year, I have been using portfolios as a component of the course final in elementary science methods. To ensure that the portfolio assignment is a reflective look at what has been learned, I set the due date at two weeks before the end of the semester. This provides students with an adequate amount of time to design and construct their portfolios.

Evaluation. To evaluate the portfolios, select a clear set of scoring criteria. You might base the score on an average of all the graded work included. Let students know whether you will retain the completed portfolios or return them.

An evaluation form (see figure) provides feedback to the science methods student. Evaluating portfolios is very subjective, and the form helps you focus on the content rather than the display. After evaluation, the form and the instructor's comments are returned to the students. Besides providing valuable feedback, detailed comments give science methods students a model they can use in their future teaching.

Get Your Feet Wet

Once you have decided to use portfolios, learn more about them by developing a personal portfolio of your own. You might consider sharing this evidence of your work in science education with your department chair.

Having carefully considered the portfolio's purpose, organization, and assessment, you'll feel confident in asking your methods students to answer the question, "What did you learn in science methods this semester?"

Resources

Bonnstetter, R. (1991). Science portfolios: Communicating student progress. *ICASE Journal, 2*(4), 27–28.

Collins, A. (1991). *Performance-based assessment of biology teachers: Promises and pitfalls.* A paper presented at the Annual Meeting of the National Association for Research in Science Teaching, Fontana, WI.

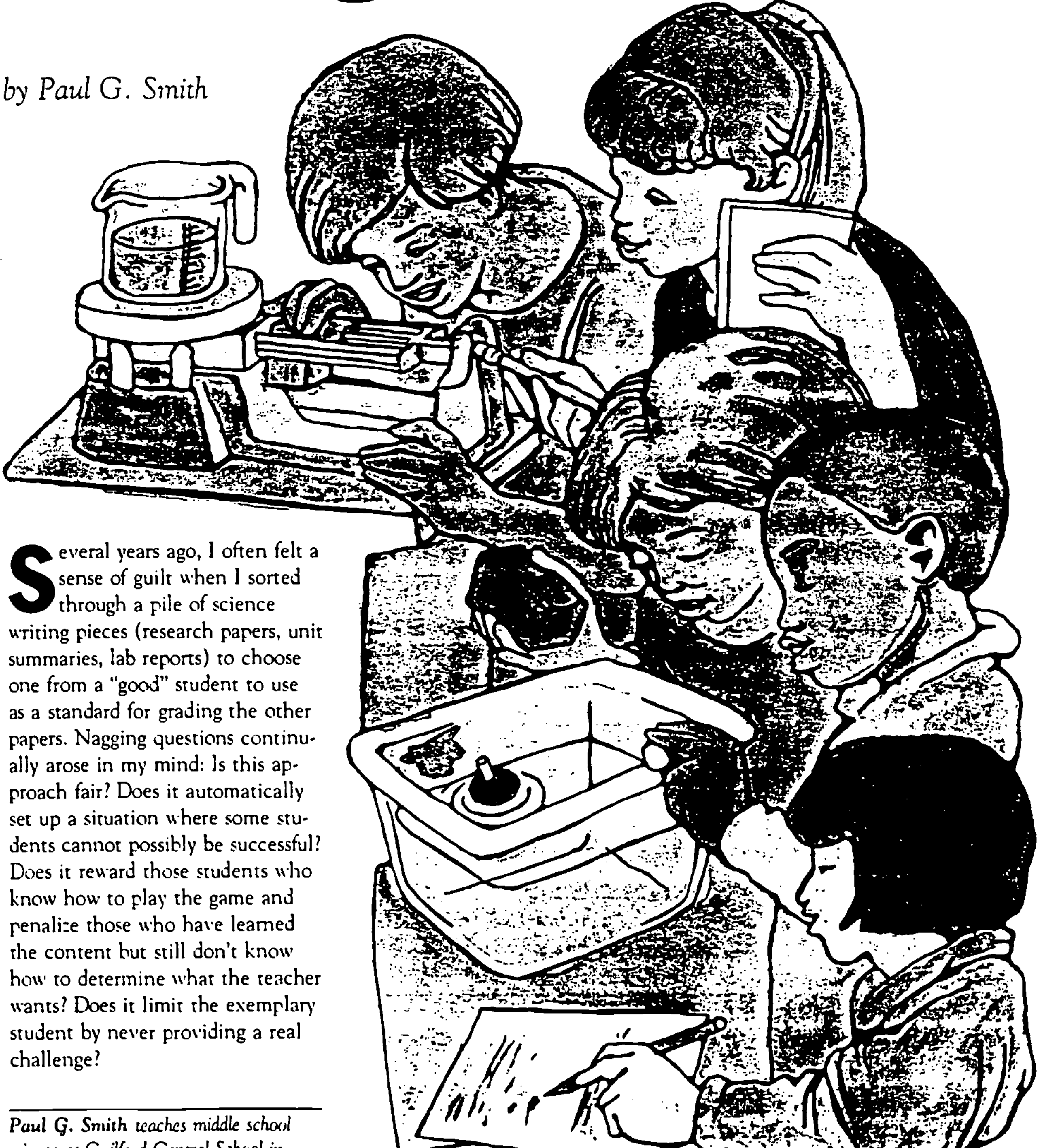
_____. (1990). *Portfolios—They capture context.* Washington, DC: American Association for the Advancement of Science Forum presentation.

TEACHING TEACHERS presents practical teaching methods for preservice and inservice teachers. If you have an idea that you think could benefit your fellow teachers in their understanding of science and/or teaching, send your manuscripts to column editor Michael Kotar, Department of Education, California State University, Chico, CA 95929.

LLOYD H. BARROW is a professor of science education and director of the Southwestern Bell Science Education Center, at the University of Missouri, in Columbia.

Reveling in Rubrics

by Paul G. Smith



MAX-KARL WINKLER

Several years ago, I often felt a sense of guilt when I sorted through a pile of science writing pieces (research papers, unit summaries, lab reports) to choose one from a "good" student to use as a standard for grading the other papers. Nagging questions continually arose in my mind: Is this approach fair? Does it automatically set up a situation where some students cannot possibly be successful? Does it reward those students who know how to play the game and penalize those who have learned the content but still don't know how to determine what the teacher wants? Does it limit the exemplary student by never providing a real challenge?

Paul G. Smith teaches middle school science at Guilford Central School in Guilford, Vermont.

As a result of my participation in two National Science Foundation–sponsored workshops during the summer of 1993, I decided to change my approach to assessing student writing. My new approach—scoring rubrics—has been very successful in my middle school science program at Guilford Central School, a small K–8 school located in southeastern Vermont. The twist, though, in my program is that the rubrics are created not by me, but by the students themselves. In this way, students clearly understand what is expected of them, because they have played a role in determining those expectations.

A scoring rubric can be loosely defined as a device (checklist, scale, description) that identifies the criteria by which a particular project will be evaluated. Rubrics can be used to evaluate a wide variety of projects, including written work, oral presentations, videos, and science projects. In a broad sense, scoring rubrics are already an integral part of most teaching. Teachers have always used informal rubrics, usually in the form of a set of basic criteria stored in their heads. There is an important difference, however, between teachers having a general idea of what "should" be in a writing piece and the kind of rubric discussed here. Specifically, rubrics provide all parties—teachers, parents, and students—with an unequivocal, common understanding of these criteria.

Developing the rubrics

Guilford's middle school science program consists of a series of units based on a yearlong theme. Each unit of study develops understanding of one of the central concepts of science (such as cell theory, evolution, plate tectonics, atomic theory). Each unit includes a wide variety of hands-on activities, including open-ended, inquiry-based experimentation and laboratory investigations. At the end of a unit, all students prepare a written summary of the concepts presented during the unit. Before writing the summaries, the class itself develops the scoring rubric by which the assignment will be graded.

To develop the rubric, the class discusses two questions: "What information should go into the unit summary?" and "How should the information be presented?" Answers to these two questions are incorporated into two scales—content and style—by which students will be evaluated. In developing the content scale, students discuss what was important in the unit and what concepts should be included in the summary. Through this discussion, students must reflect on their recent learning and identify important concepts.

I choose to use a range of zero to four points for the content and style scales, but other point ranges will work just as well. To assign the point values, we start by identifying those concepts all students should include in the summary. These are listed in the rubric as requirements for a score of three. To earn a score of four, a student must meet all of the requirements and go beyond, by including new information, providing a new perspective, or making connections with other units.

To determine how the work should be presented (the style scale), students focus on the mechanics of good writing—limiting misspellings, using complete sentences and appropriate grammar—and on stylistic concerns such as clarity and conciseness. Again we use a range of zero to four points, with three as meeting all the expectations and four going a step beyond.

Figure 1 shows an example of a rubric for a summary of a unit on the physical and chemical properties of water. The rubric contains criteria (such as "clear organization") that may seem too general or too terse when viewed outside of the context of the classroom discussion. However, the discussion that occurs while creating the rubric clarifies and sharpens students' understanding of the criteria. Rubrics for lab reports and any other science writing assignments can be developed in a similar fashion.

While the actual rubric produced through this discussion is important, even more important and exciting is the learning that takes place during the discussion. Just what is clear organization? When my students and I share our answers to this question, we are getting to the heart of what makes good writing and clear understanding. Not surprisingly, my students appreciate the opportunity to have a voice in how they are evaluated and what is expected of them. As they learn to develop rubrics throughout the year, students become more practiced at identifying important concepts and more articulate about what *they* think makes a good writing piece. The value of discussions at this metacognitive level is incalculable.

Using the rubric

Once a rubric has been developed, students receive a copy to use as they write a first draft of the unit summary. I schedule writing time during class to allow students to clarify concepts and correct misconceptions. This is a critical and often exciting teaching time. At this point in their learning, students are forced to wrestle with their understanding of critical concepts. By attempting to make sense of the information in order to explain it clearly, students are truly constructing meaning for themselves.

On the day that first drafts are due, students exchange papers and evaluate their peers' work using the rubric. That is, they score each other's work using the criteria that they themselves have established. It is a wonderfully empowering moment. The students have had a say in what *should* be in the writing, they have struggled to include that information and present it clearly in their own papers, and they are now in a position where they can effectively evaluate their peers' work and help them improve. In the past, I have witnessed many a "peer conference" in which the only feedback on a piece of writing was "This is nice. I like it." With rubrics, the difference is palpable—"You haven't explained . . ." or "This paper is well organized." Also, many students ask their parents to "peer" conference their work, so the parents appreciate having a rubric to use as a guideline for evaluating their child's work.

After a second draft and peer conference, students prepare a final draft. This draft is handed in with the previous drafts and the scoring rubrics from each peer conference. In my experience, the feedback from the two peer conferences has been accurate and to the point.

FIGURE 1.

Sample scoring rubric for a unit on the physical and chemical properties of water. A score of three indicates what the class felt all students should include in the summary.

Content Scale

0------------------------1------------------------2------------------------3------------------------4

• No work completed	• Few concepts • Models not used in explanation	• Some concepts explained	• Uses atomic model to explain changes in states of water, surface tension • Explains shape of "Ice to Vapor" melting curve • Describes how pattern was used to determine relative density of layered liquids •Describes process and explains solution to "Water Purification" problem

Style Scale

0------------------------1------------------------2------------------------3------------------------4

• No work completed	• Poor organization • Many misspellings • Punctuation missing or inappropriate	• Clear organization • Very few misspellings	• Appropriate punctuation	• Extremely clear, concise writing

First Reviewer's Name:

Score for Style: **Score for Content:**

Comments:

Second Reviewer's Name:

Score for Style: **Score for Content:**

Comments:

When they understand the expectations, students seem to have a good sense of the quality of their work. I have noticed a marked decrease in students asking me "How did I do on my paper?" They already know how they did.

The benefits of change

The end result of switching to scoring rubrics has been a significant increase in the quality of students' writing and in their level of understanding of science concepts. On several occasions, students have expressed that they learned more through the process of writing than through the science activities themselves. If "learning more" can be interpreted as "making more sense of" (as perhaps it should), then this comment is not as unreasonable as it seems. Teachers often make the mistake of thinking that if a student has successfully completed an activity, then learning has taken place. Students, and all of us, need to have opportunities to assimilate our experiences to make learning meaningful.

Rubrics are simple tools to develop and use. There is not a lot of preparation time involved; and rubrics do not require cleanup after use. They simply require a commitment to give students a stake in how they will be evaluated and to allow them time to ponder and discuss what they have learned. The benefits of more successful, engaged students with clearer understanding are well worth the effort. ❑

How can an oil spill be cleaned up?

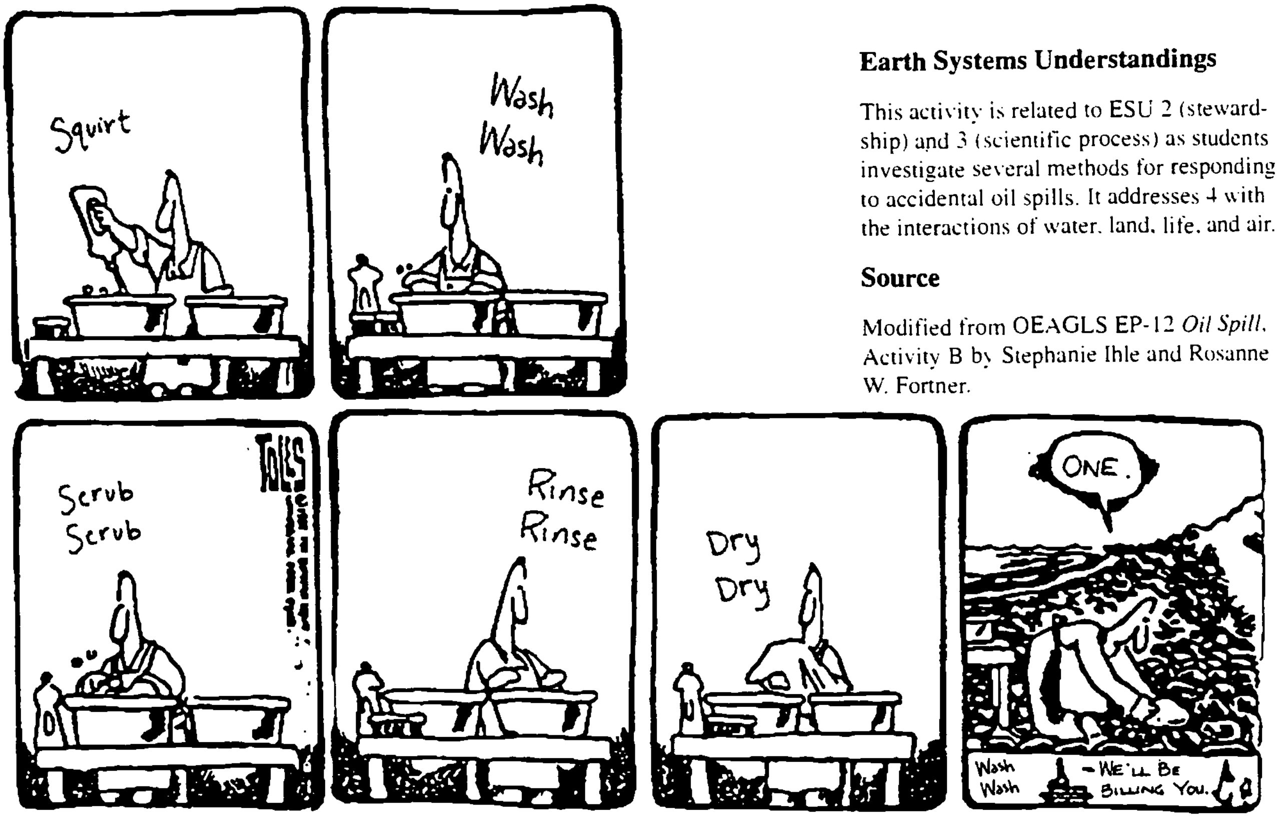
The moment a spill occurs, nature begins cleaning up. The oil separates into heavier and lighter parts and is spread by wind and currents. Some of it evaporates, like gasoline spilled from the gas pump. Certain types of bacteria called petrophiles consume some of the oil. According to marine affairs specialist E. W. Seabrook Hull, "Within a couple of years no sign of the disaster remains. The oil is gone, and the birds and other marine life are back, as though nothing had happened. This has been shown in the case of *Torrey Canyon*, the *Wafra*, the *Arrow*, the *Argo Merchant*, Santa Barbara and numerous other events."

Success in cleaning up an oil spill depends upon preparedness and rapid action by the spiller and by Federal. state, and local agencies. When a spill occurs, in U.S. waters it is reported to the nearest U.S. Coast Guard station. The spiller. by law, is supposed to clean up the oil. If the spiller does not clean up the pollution, the Coast Guard takes over. and the spiller pays the clean-up costs. In this activity your team will create an oil spill and try various methods of cleaning it up.

OBJECTIVES

When you have completed this investigation, you should be able to compare the effectiveness and impact of three ways in which oil may be removed from water.

Eugene, Oregon, Sunday, April 16, 1989



©Tribune Media Services, Inc. All Rights Reserved. Reprinted with Permission.

Materials:

For each team of students:

- Paper bowl or butter tub.
- Water.
- 10 ml of motor oil.
- 25-cm pieces of twine.
- Handful of straw.
- Handful of sand.
- Newspapers to cover working surfaces.
- Matches.
- Wooden splints.
- Paper towels.
- Liquid detergent.
- Dropper.
- Safety glasses.
- Alcohol burner.

Earth Systems Understandings

This activity is related to ESU 2 (stewardship) and 3 (scientific process) as students investigate several methods for responding to accidental oil spills. It addresses 4 with the interactions of water, land, life, and air.

Source

Modified from OEAGLS EP-12 *Oil Spill*, Activity B by Stephanie Ihle and Rosanne W. Fortner.

Grant. (1997). Great Lakes Environmental Issue (Earth Systems – Education Activities for Great Lakes Schools). Columbus, OH: The
o State University.

PROCEDURE

I. CONTAINMENT

If an oil spill is quickly contained in one area, cleanup is easier, and less environmental damage is likely to occur.

1. Add about 2 cm of water to your butter tub or bowl to serve as a lake. An oil tanker has sprung a leak in the middle of your "lake." Add two drops of oil to the water's surface.
2. Tie the ends of a piece of string together and gently place the circle of string on top of the water, with the oil inside. Slowly add 2 ml more oil inside the circle. Pull the oil to one side of the pan using the string.
3. Does the string keep the oil from spreading over the entire lake? This is how a "boom" operates to contain a spill.
4. Some contained oil can be reclaimed (collected for further use). Use a dropper to try to reclaim some of your oil. About how much oil were you able to reclaim?

Containment

3. The string should contain the oil. If too much oil is added, however, it will overflow the boom. You may want to adjust the amount of oil students add. For lighter oils, spreading is greater, and you should decrease the amount used.
4. Answers will depend on how thorough the students are. Most of the oil can probably be removed, but it will be mixed with water. Further treatment would be necessary before the oil could be reused.

II. REMOVAL OF OIL FROM WATER

Whether the oil is contained or free, it still must be cleaned up to prevent further environmental damage. Although there are many elaborate techniques for oil removal, some simple and non-technical methods are still widely used.

A. *Removal by burning*

1. Remove the string from your lake. Pour 5 ml of oil on the water surface.
2. Put on safety glasses and light your alcohol burner. Set fire to the tip of a wooden splint. Try to ignite the oil spill with the splint.
3. Does the oil burn? If so, how long did it burn? Was there any oil left when the flames went out? If the oil did not burn, try to explain why.
4. If the oil could be burned, what other damage to the environment might occur?
5. Is the burning of the oil an effective way to clean up an oil spill? Explain.

Removal by burning

3. The oil should not burn. In trying to explain why, students may explain that "it is wet." In reality, the oil will not burn, because it is a type that does not contain flammable substances. Petroleum fractions are separated with their uses in mind. Some contain volatile mixtures, while others (like this oil) are mostly inert.
4. If the oil burned, damage might occur in the form of air pollution.
5. No. Not all types of oil will burn, and if they do burn they could cause other environmental damage.

B. Removal by sinking

Ordinarily, oil floats on water because it is not as <u>dense</u> as water. Increasing the oil's density will make it sink to the bottom.

1. If your oil was cleaned up in Procedure A, add 5 ml of new oil to your lake.
2. Sprinkle enough sand on the oil spill to cause it to sink. Does this method remove all (or most) of the oil from the surface?
3. When this method is used, what other effects will it have on the environment?
4. What should you know about the water environment before using this method to clean up a real oil spill?
5. Is sinking a good way to clean up an oil spill? Explain.

Removal by sinking

2. Most of the oil will sink when sand is added. However, if left standing the oil may escape and bubble to the surface again.
3. Bottom organisms could be smothered. Contaminants could be trapped in the bottom sediments so that future burrowing animals would be poisoned.
4. You should know what bottom organisms you would damage and whether the oil is light enough to surface again.
5. No. There is too much potential for damaging bottom organisms (such as shellfish) and no promise of permanent oil removal.

C. Removal by adsorption

Certain materials will attract oil to their own surfaces. This is called **adsorption.** You have probably seen pictures of this type of clean up method.

1. Pour 5 ml of new oil into your lake. (You do not need to dump the oily sand from B unless it is piled high enough to break the water surface.)
2. Place a small amount of straw on top of the oil. What happens?
3. How can you remove the oil from the lake now? Check your idea with your teacher, and try the idea if the teacher approves. Did your idea work?
4. Is adsorption a good way to clean up an oil spill?

Removal by adsorption

2. Oil sticks to all the surfaces of the straw.
3. Picking up the straw or burning the straw are the most frequent suggestions. Both work fairly well, especially if clean straw is added and removed several times.

   NOTE: If students wish to burn the oily straw, this activity should be supervised outdoors. Black greasy smoke may result. If clean motor oil has been used, however, it will not ignite.
4. This is a better way than most, especially if the oily straw is mechanically removed instead of burned. In reality, the oily straw would probably be hauled to a land fill, where it will again be a contaminant.

D. Removal by detergents

Household detergents are used to remove oil from laundry or grease from dishes. They do this by breaking up oil drops and dispersing them in the water to form an emulsion.

1. Dump the contents of your lake in the container provided by your teacher. Wipe the lake basin out and add fresh water.
2. Add one drop of oil and one drop of liquid detergent to the lake. Stir the two together vigorously with a wooden splint. What happens?
3. Does dispersion by detergents let you clean up the oil easier? Explain.
4. How could the environment be damaged by use of detergents?

In actual use, detergents are designed to allow natural clean-up to take place more easily. Clean water would not be noticeable until later, as compared to the other clean-up methods.

Removal by detergents

2. A milky suspension is formed. Neither drop is visible any more.
3. This method does not clean up oil. It only breaks it up into tiny droplets that are not as noticeable. Detergents are sometimes used in this way to speed up natural dispersal.
4. The detergents could harm water animals and reduce the "waterproof" characteristics of ducks and other water birds.

RESOURCES

National Response Center: 1-800-424-8802. See http://www.glc.org/docs/advisor/95/oil/report.html – a list of phone numbers for states.

The Internet has many valuable resources for learning more about oil spills in the Great Lakes and other areas. Several organizations help respond to oil spills including the U.S.E.P.A., Great Lakes Commission and Great Lakes Information Management Resource (GLIMR. Government of Canada). For example:

http://www.glc.org/docs/advisor/95/oil/spills.html – the Great Lakes Commission. Advisor – March/April 1995. Oil spills in the Great Lakes Basin: Response and prevention.

See also http://www.glc.org/projects/conting/conting.html – the Great Lakes Commission compiles data on sensitive areas and assists with area contingency planning.

http://www.epa.gov/superfnd/oerr/er/oilspill/response.htm – U.S.E.P.A. Oil Spill Prevention. Preparedness and Response: Responding to Spills: see also http://www.epa.gov/superfnd/oerr/er/oilspill/freshwat.htm – Sensitivity of Freshwater Habitats.

http://www.great-lakes.net/pollution/emerg.html – Oil and Hazardous Materials Spills in the Great Lakes: Emergency, Planning and Response – lists agencies, area contingency plans and other sites.

SE062036

ERIC

U.S. Department of Education
Office of Educational Research and Improvement (OERI)
National Library of Education (NLE)
Educational Resources Information Center (ERIC)

REPRODUCTION RELEASE

(Specific Document)

I. DOCUMENT IDENTIFICATION:

Title: SWEEP: Sciencing with Watersheds, Environmental Education, and Partnerships. Instructor's guide to Implementation.

Author(s): Bainer, D., Barron, P., and Cantrell, D.

Corporate Source: The Ohio State University, Mansfield

Publication Date: Summer 1998

II. REPRODUCTION RELEASE:

In order to disseminate as widely as possible timely and significant materials of interest to the educational community, documents announced in the monthly abstract journal of the ERIC system, *Resources in Education* (RIE), are usually made available to users in microfiche, reproduced paper copy, and electronic media, and sold through the ERIC Document Reproduction Service (EDRS). Credit is given to the source of each document, and, if reproduction release is granted, one of the following notices is affixed to the document.

If permission is granted to reproduce and disseminate the identified document, please CHECK ONE of the following three options and sign at the bottom of the page.

The sample sticker shown below will be affixed to all Level 1 documents	The sample sticker shown below will be affixed to all Level 2A documents	The sample sticker shown below will be affixed to all Level 2B documents
PERMISSION TO REPRODUCE AND DISSEMINATE THIS MATERIAL HAS BEEN GRANTED BY Sample TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC) 1	PERMISSION TO REPRODUCE AND DISSEMINATE THIS MATERIAL IN MICROFICHE AND IN ELECTRONIC MEDIA FOR ERIC COLLECTION SUBSCRIBERS ONLY, HAS BEEN GRANTED BY Sample TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC) 2A	PERMISSION TO REPRODUCE AND DISSEMINATE THIS MATERIAL IN MICROFICHE ONLY HAS BEEN GRANTED BY Sample TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC) 2B
Level 1	Level 2A	Level 2B
☑	☐	☐
Check here for Level 1 release, permitting reproduction and dissemination in microfiche or other ERIC archival media (e.g., electronic) and paper copy.	Check here for Level 2A release, permitting reproduction and dissemination in microfiche and in electronic media for ERIC archival collection subscribers only	Check here for Level 2B release, permitting reproduction and dissemination in microfiche only

Documents will be processed as indicated provided reproduction quality permits.
If permission to reproduce is granted, but no box is checked, documents will be processed at Level 1.

I hereby grant to the Educational Resources Information Center (ERIC) nonexclusive permission to reproduce and disseminate this document as indicated above. Reproduction from the ERIC microfiche or electronic media by persons other than ERIC employees and its system contractors requires permission from the copyright holder. Exception is made for non-profit reproduction by libraries and other service agencies to satisfy information needs of educators in response to discrete inquiries.

Sign here, → please

Signature: Deborah Bainer

Printed Name/Position/Title: Deborah L. Bainer

Organization/Address: Ohio State University, Mansfield
1680 University Drive Mansfield, OH 44906

Telephone: 419-755-4287

FAX: 419-755-4367

E-Mail Address: bainer.1@osu.edu

Date: Jan 29, 1999

(over)

SE062037

U.S. Department of Education
Office of Educational Research and Improvement (OERI)
National Library of Education (NLE)
Educational Resources Information Center (ERIC)

REPRODUCTION RELEASE

(Specific Document)

I. DOCUMENT IDENTIFICATION:

Title: SWEEP: Sciencing with Watersheds, Environmental Education and Partnerships. Summer Institute Participant Notebook

Author(s): Bainer, D., Barron, P., and Cantrell, P.

Corporate Source: The Ohio State University, Mansfield

Publication Date: Spring 1998

II. REPRODUCTION RELEASE:

In order to disseminate as widely as possible timely and significant materials of interest to the educational community, documents announced in the monthly abstract journal of the ERIC system, *Resources in Education* (RIE), are usually made available to users in microfiche, reproduced paper copy, and electronic media, and sold through the ERIC Document Reproduction Service (EDRS). Credit is given to the source of each document, and, if reproduction release is granted, one of the following notices is affixed to the document.

If permission is granted to reproduce and disseminate the identified document, please CHECK ONE of the following three options and sign at the bottom of the page.

The sample sticker shown below will be affixed to all Level 1 documents	The sample sticker shown below will be affixed to all Level 2A documents	The sample sticker shown below will be affixed to all Level 2B documents
PERMISSION TO REPRODUCE AND DISSEMINATE THIS MATERIAL HAS BEEN GRANTED BY Sample TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC) 1	PERMISSION TO REPRODUCE AND DISSEMINATE THIS MATERIAL IN MICROFICHE, AND IN ELECTRONIC MEDIA FOR ERIC COLLECTION SUBSCRIBERS ONLY, HAS BEEN GRANTED BY Sample TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC) 2A	PERMISSION TO REPRODUCE AND DISSEMINATE THIS MATERIAL IN MICROFICHE ONLY HAS BEEN GRANTED BY Sample TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC) 2B
Level 1	Level 2A	Level 2B
☑	☐	☐
Check here for Level 1 release, permitting reproduction and dissemination in microfiche or other ERIC archival media (e.g., electronic) and paper copy.	Check here for Level 2A release, permitting reproduction and dissemination in microfiche and in electronic media for ERIC archival collection subscribers only	Check here for Level 2B release, permitting reproduction and dissemination in microfiche only

Documents will be processed as indicated provided reproduction quality permits.
If permission to reproduce is granted, but no box is checked, documents will be processed at Level 1.

I hereby grant to the Educational Resources Information Center (ERIC) nonexclusive permission to reproduce and disseminate this document as indicated above. Reproduction from the ERIC microfiche or electronic media by persons other than ERIC employees and its system contractors requires permission from the copyright holder. Exception is made for non-profit reproduction by libraries and other service agencies to satisfy information needs of educators in response to discrete inquiries.

Sign here,→ please

Signature: Deborah Bainer

Printed Name/Position/Title: Deborah L. Bainer

Organization/Address: Ohio State University, Mansfield
1680 University Drive
Mansfield, OH 44906

Telephone: 419-755-4287

FAX: 419/755-4367

E-Mail Address: bainer.1@osu.edu

Date: Jan.29,1999

(over)