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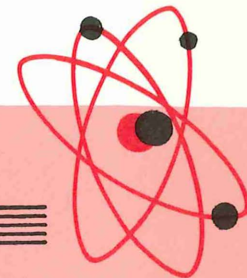
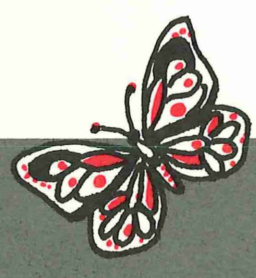


SCIENCE

LEARNER OUTCOMES



DEPARTMENT OF EDUCATION 1988

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CHAPTER 1

Minnesota State Board of Education Values, Philosophy, Mission and Goals

School districts nationwide, and certainly in Minnesota, are constantly striving to improve the learning experiences they provide students. The last two or three decades have seen heightened interest in improving all parts of the education process, including appropriate involvement of students, parents, and the community at large.

The documents that constitute the *Minnesota Department of Education's Coordinated Model for Education Improvement* incorporate many of the concerns expressed and issues addressed by the public, Legislature, and reports published on the state of public education. One of these documents titled, **Goal and Outcome Specification Process,** suggests a set of procedures for appropriate involvement of the public. These procedures include public participation on the development of statements of values, philosophy, mission, and learner goals. These sets of statements are a hierarchy of increasingly specific concepts ranging from values, the most general, to learner goals, the most specific, that give form and direction to public education. Given this hierarchy, staff, skilled in subject matter and the profession of teaching, can develop very specific learner outcomes for each subject area.

The following sets of statements were adopted by either the Minnesota State Board of Education or the Minnesota State Legislature for two purposes. First, they provide a model for use by communities and school staff as they strive to improve the learning experiences they provide for residents. Second, they are the hierarchy used by Department staff and teams of educators as they develop model learner outcomes for each subject area. Only the **Mission Statement for Public Education** adopted by the Legislature gives explicit direction to public schools. All other parts of this document are models, suggestions for the consideration of residents and professionals in each school district.

LEARNER VALUES

THE MINNESOTA STATE BOARD OF EDUCATION VALUES THE FOLLOWING HUMAN ATTRIBUTES AS PREEMINENT FOR THE CITIZENS OF THE STATE OF MINNESOTA.

COMPASSION—a condition in individuals whereby each is sensitive to the conditions affecting the lives of others and each has the commitment to assist others when appropriate and possible.

COMPETENCE—a condition in individuals whereby each attains levels of knowledge, skill, and affect commensurate with his or her potential.

COOPERATIVENESS—a condition in individuals whereby each interacts with others in a manner that mutually benefits all participants in the interaction.

CREATIVITY—a condition in individuals whereby each acts or expresses self in new, improved, or unique ways.

CRITICAL THINKING—a condition in individuals whereby each is able to judge the potential for a proposal or activity to achieve its stated purpose.

HONESTY—a condition in individuals whereby each is fair and straightforward in the conduct of human interactions.

LEARNING—a condition in individuals whereby each continually strives to increase personal levels of fulfillment and competence in an expanding array of human endeavors.

PROBLEM SOLVING—a condition in individuals whereby each has the ability to identify, frame, and propose new, improved, or unique solutions to existing and emerging problems.

RESPONSIBILITY—a condition in individuals whereby each strives to fulfill the obligations of self-sufficiency and active commitment to the common good.

SELF-ACCEPTANCE—a condition in individuals whereby each has a positive self-image, through assertion of rights, holding personal physical and emotional well-being as an ideal, accepting personal talents with humility and personal limitations with the resolve to improve where possible and accept where necessary.

EDUCATION SYSTEM VALUES

THE MINNESOTA STATE BOARD OF EDUCATION VALUES THE FOLLOWING SYSTEMIC ATTRIBUTES AS PREEMINENT FOR ALL SCHOOLS IN THE PUBLIC EDUCATION SYSTEM.

ACCOUNTABILITY—a condition in every school whereby each is able to justify its use of public resources by effectively fulfilling its mission of student learning.

EFFECTIVENESS—a condition in every school whereby each accomplishes its mission in a time frame and at a performance level defined by students, parents, citizens of the community, and their representatives.

EFFICIENCY—a condition in every school whereby each accomplishes the highest possible level of excellence with available resources.

EQUITABILITY—a condition in each school whereby every student attending the school is provided with appropriately designed and individually determined opportunities to achieve the highest level of excellence his or her potential allows.

EXCELLENCE—a condition in every school whereby the highest possible standards are accepted as the norm for performance for all students.

RESPONSIBILITY—a condition in each school whereby each accepts and acts on the belief that: the parent(s) has primary responsibility for raising and educating the child; the community is responsible for assisting parents in areas of needs; and the school, as a part of the community, is responsible for providing learning experiences.

RESPONSIVENESS—a condition in every school whereby diversity of personal and group needs and aspirations are expected, accepted, encouraged, and routinely addressed.

WHOLENESS—a condition in every school whereby each gives necessary and appropriate consideration to the potential career needs and social, emotional, and physical growth of each student as it designs and implements educational programs.

MINNESOTA STATE BOARD OF EDUCATION

PHILOSOPHY
FOR
LEARNING IN THE PUBLIC SCHOOLS

THE STATE BOARD OF EDUCATION BELIEVES THAT:

...Human beings are becoming globally interdependent while maintaining extremes in diversity of behaviors, sophistication, and values. Advancement requires people who are at the same time honest, responsible, compassionate, and cooperative. Schools must model those characteristics as they provide opportunities for individuals to develop those traits.

...Each human being must understand and accept self before there can be any expectation that he or she will become a self-sufficient contributing member of society. Schools must implement systems and procedures and must conduct human interactions in a manner that encourages, enhances, and assists in the development of a positive self-image by every individual. Schools must ensure that their systems and procedures and their conduct of human interactions do not inhibit the development of a positive self-image by every individual.

...Life in our world today is becoming increasingly complex. Population growth, diminution of natural resources, pollution of the environment, and technological advances in communications and travel have brought the human race closer together, increased the amount of human interaction, and brought on problems never before faced by humankind. Individuals living within this situation must be increasingly competent in an ever-widening range of activities and must be progressively creative in solving technological and human problems. Schools must ensure ongoing opportunities for individuals to develop and improve competence in all areas of human endeavor, model and enhance creativity, and provide experiences in creative problem solving for students. Schools must ensure that every student is provided an appropriately designed opportunity to develop the basic learning tools of communications and computation.

MINNESOTA STATE BOARD OF EDUCATION

PHILOSOPHY FOR THE PUBLIC EDUCATION SYSTEM

THE STATE BOARD OF EDUCATION BELIEVES THAT:

...A democratic society has a need for an educated citizenry and a responsibility to meet that need. The public schools are entrusted with fulfilling that need. To carry out its mission, schools expend a significant portion of the state's public resources. This public trust assumes a self-evident responsibility for utilizing resources efficiently, performing as effectively as contemporary wisdom allows, and accounting for the excellence of its results.

...The citizens of Minnesota are extremely diverse in terms of heritage and dreams for the future. Concurrent with this diversity is the democratic societal need to have a total citizenry educated to a level that provides the means for communication, productivity, and assuring the maintenance of a free society. To meet the public need, the public schools must assure high standards for responsiveness and equity of access. To meet the diverse needs of individuals, responsibility for planning, implementing, and maintaining specific learning opportunities must be vested as close to the individual as efficient use of public funds allows.

...All humans can learn and each exists and enters school as a whole person, indivisable into such conceptual components as intellectual, social, emotional, physical, and future career aspirations. Each is more than the sum of the parts. These are expedients, oversimplified arbitrary divisions of human attributes that are interrelated and interreactive within each person. Each community has a shared responsibility with the parents for meeting the needs of each child. Each school must implement programs that stress the intellectual development of each student, and give full consideration and necessary attention to other attributes essential to learning and adulthood in a free democratic society.

MISSION FOR PUBLIC EDUCATION

As adopted by the Minnesota Legislative Commission on Public Education
and enacted into law, Chapter 40, Laws of 1985

The purpose of public education is to help individuals acquire knowledge, skills, and positive attitudes toward self and others that will enable them to solve problems, think creatively, continue learning, and develop maximum potential for leading productive, fulfilling lives in a complex and changing society.

MINNESOTA STATE BOARD OF EDUCATION MISSION

The purpose of Minnesota State Board of Education is to provide the vision and leadership essential to an increasingly equitable and effective system of public education as defined by the Minnesota State Legislature.

MISSION STATEMENT FOR THE MINNESOTA DEPARTMENT OF EDUCATION

The Minnesota Department of Education provides leadership, service, and regulation to maintain and improve an equitable, uniform and quality system of public education for all learners.

The Department provides leadership as an advocate for education by defining quality education and by seeking the resources necessary to meet the needs of all learners.

The Department provides service through informational and technical assistance that will improve the productivity and performance of students and staff, and provide opportunities for the development of the potential of all learners.

The Department regulates education by maintaining, interpreting, and enforcing Minnesota State Board of Education rules and state and federal laws.

MINNESOTA STATE BOARD OF EDUCATION

LEARNER GOALS

A. In order to effectively participate in formal learning experiences, each student will develop the skills of:

1. reading to gather data, information, perspective, understanding, and to utilize reading as a leisure time activity;
2. writing to explain, describe, and express a point of view and feelings;
3. listening to gather data, information, perspective, and understanding;
4. speaking to explain, describe, express a point of view and feelings, and to debate an issue;
5. computing to apply arithmetic functions to situations;
6. using technological tools to enhance learning opportunities.

B. In order to lead a productive and fulfilling life, each student will accumulate knowledge and develop the understanding, application skills, and affect essential to:

1. participation in lifelong learning to gain additional information and skills;
2. living within local, state, national, and world political and social structures;
3. examining personal beliefs and values and the relationship between those and behavior;
4. making informed ethical and moral decisions;
5. citizenship;
6. stewardship of the land, natural resources, and environment;
7. acting on the impact of natural phenomena on human life;
8. acting on the impact of technological advances on human life;
9. expression of self and understanding of others through creative and aesthetic endeavors;
10. developing an understanding of career options and general education requirements for each;

11. developing an understanding of world and national economic conditions as a base for making informed decisions on consumer products, occupations, and career needs and resources;

12. selecting or preparing for a series of occupations that will be personally satisfying and suitable to one's skills and interests;

13. management of personal affairs.

C. In order to resolve issues and meet needs creatively, each student will develop the thinking and decision-making skills of:

1. comparing, differentiating, and relating information and facts about which each has the ability to understand and apply knowledge;

2. combining various facts, situations, and theories to formulate new and original hypotheses or to develop new solutions;

3. critiquing and making judgments about materials, conditions, theories, and solutions;

4. generating and valuing creative alternatives.

D. In order to value, understand, and act based on an acceptance of the interdependence of humankind, each student will develop the knowledge, skills, and affect essential to:

1. seeking interactions and feeling comfortable with others who are different in race, religion, social level, or personal attributes, as well as those who are similar in these characteristics;

2. acting with an understanding of the basic interdependence of the biological and physical resources of the environment;

3. acting with an understanding of the interrelationships among complex organizations and agencies in modern society;

4. assuming responsibility for dependent persons of all ages in a manner consistent with both their growth and development needs and the needs of society.

E. In order to value, understand, and act based on knowledge of the diversity of humankind, each student will develop the knowledge, skills, and affect essential to:

1. basing actions and decisions on the knowledge that individuals differ and are similar in many ways;

2. basing actions and decisions on the knowledge that values and behaviors are learned and differ from one social group to another;

3. basing actions and decisions on the understanding of life styles or behaviors within the context of the value system of the societies in which they were learned;

4. withholding judgment of another's actions until after trying to understand the personal and social context of that action.

F. In order to address the problems of humankind through group effort, each student will develop the knowledge, skills, and affect essential to:

1. basing actions and decisions on the understanding that as individuals move from one society to another, they can learn life styles and can learn to behave appropriately in different societal contexts;

2. acting on the belief that human behavior is influenced by many factors and is best understood in terms of the relevant person context in which it occurred;

3. acting in accordance with a basic ethical framework incorporating those values contributing to group living, such as honesty, fairness, compassion, and integrity;

4. working in groups to achieve mutual goals;

5. providing leadership in resolving personal and societal issues.

G. In order to effectively resolve conflicts with and among others, each student will develop the knowledge, skills, and affect essential to:

1. assuming responsibility to form productive and satisfying relations with others based on respect, trust, cooperation, consideration, and caring;

2. acting on the belief that each individual has value as a human being and should be respected as a worthwhile person in one's own right;

3. dealing with conflict in a constructive manner.

H. In order to act on contemporary events and issues with a perspective of their historical origins, each student will develop the knowledge, skills, and affect essential to:

1. understanding the origins, interrelationships, and effects of beliefs, values, and behavior patterns in world cultures;

2. understanding one's culture and historical heritages, the literary, aesthetic, and scientific traditions of the past, and familiarity with the ideas that have inspired and influenced humankind;

3. understanding the manner in which heritages and traditions of the past influence the direction and values of society;

4. exploring one or more world language and culture.

I. In order to develop a positive attitude toward self, each student will develop the knowledge, skills, and affect essential to:

1. developing the self-confidence needed for confronting one's self;

2. developing feelings of positive self-worth, security, and self-assurance;

3. living with one's strengths and weaknesses;

4. acquiring knowledge of one's own body and a positive attitude toward one's own physical appearance;

5. adopting the idea of self-realization based on the concept that there is more than one way of being human and that efforts to develop a better self contribute to the development of a better society;

6. understanding that self-concept is acquired in interaction with other people.

7. developing habits, such as pride in good workmanship;

8. adopting a positive attitude toward work, including an acceptance of the necessity of making a living and an appreciation of the social value and dignity of work.

J. In order to set personal goals, each student will develop the knowledge, skills, and affect essential to:

1. selecting personal learning goals;

2. making decisions with purpose;

3. planning and organizing the environment? one's goals;

4. accepting responsibility for, and the consequences of, one's own decisions;

5. controlling or releasing emotions according to one's values;

6. working now for goals to be realized in the future;

7. selecting viable alternatives for actions in changing circumstances.

K. In order to cope with change, each student will develop the knowledge, skills, and affect essential to:

1. initiating appropriate change while recognizing the value of existing structure and concepts:

2. tolerating ambiguity;

3. basing actions on an understanding that coping with change is a continuous process throughout life;

4. developing an understanding and acceptance of the changing world of work and the potential need to change careers several times throughout one's life;

5. using career information and ongoing counseling services for making informed and satisfying vocational choices.

L. In order to lead a healthy, fulfilling life, each student will develop the knowledge, skills, and affect essential to:

1. assuming responsibility for one's own health and safety by establishing a daily regime of health behaviors that will contribute to a positive life style and an improved quality of life;

2. making informed decisions in regard to the selection and utilization of health products and services;

3. making decisions regarding life styles that promote healthful family living;

4. being an advocate for adequate and effective public health measures that will protect the individual, family, community, and the environment;

5. an appreciation of physical and motor fitness and understanding of its relationship to health maintenance;

6. function in the continuum of play-skill activities which include understanding, cooperation, accepting rules, controlling emotions, following group process, and acquiring self-satisfaction;

7. maintenance of the physical conditioning to participate in a variety of individual, dual, and group sports/activities and to participate in outdoor activities.

CHAPTER 2

A SUGGESTED PLAN FOR PLANNING

Overview

It takes energy and considerable commitment to embark on an assessment of one's science education curriculum with an eye to improving it. It is also a time-consuming process. Yet, it is likely to be an enormously satisfying task for everyone involved. After all, the improvement of the science education curriculum is a problem-solving process and the search for solutions to problems is close to the heart of all science educators. Furthermore, the process is infused with the expectation of both immediate and long-term benefits.

The work is *evaluative:* Do we have objectives? How close are we to achieving them? How desirable are they? What is the impact of our practices on students? The work is *stimulative:* How can we improve the science education programs? What kinds of outcomes are acceptable? How does one level of the system articulate with another level? How will the new science education program be managed and maintained? What will students be able to do better?

It is clear that the first step in any planning process is an assessment of where one is now—what the present program is like. It is also clear that the planning process is not absolutely linear; there may not be a clean place to start the process, nor may there be an obvious end point. No single sequence of activities will fit all science assessment and curriculum implementation efforts. Such efforts are influenced by many variables, such as the extent of curriculum implementation; district commitment of time, materials, and formal resources; the ability, willingness, and opportunity of those involved to participate fully; what is known about the students; faculty experience with and attitudes toward children, education, and the assignment itself; and the cultural attitudes and rules of the school and community, either explicit or implicit, that determine the science education curriculum.

However, one has to start somewhere. And we start with steps or stages. The order will more than likely vary. We expect you to modify the sequence and develop your own process for redefining and redesigning the science education curriculum in your school district/school. Good luck!

In the scheme that follows, we have arranged a series of steps in flowchart or computer program-like sequence. It is not a program! There are no recursive, self-correcting loops. When decision points are reached and the choices are yes and no, your options will vary. At each decision point, there is a space for writing the completion date.

In the chapters and pages that follow, you will find a variety of information ranging from a rationale for science education that might make writing a philosophy statement easier, to recommended essential course components and examples of teaching to given objectives.

We suggest that you look over this guide and use what is useful. Feel free to discard what is not. Teachers, during the trial phase workshops, felt that Chapter's Two and Five were the most useful. Chapter Three, Rationale was especially good for reference.

START
date: ______________________

Form a school/school district science education improvement task force. The team should be relatively small yet representative. Its leader can be internal, e.g., the science department chair, or external, e.g., a science educator from another district. The task force should be "representative" although the membership of these committees will vary considerably from district to district. Potential task force members include: science teachers (K-12; all buildings); administration (curriculum coordinator, building/district level); outside curriculum specialists (MDE, college, university); parents, students, board members, and interested community members. You will want to think about the makeup of the task force in terms of the assignment. Can they understand it well enough to be useful? Are there individual axes to be ground? Are they interested in and good at problem solving? Are they open-minded? How well are they likely to work together? Do they have the sensitivity to view the science education program in the context of the rest of the school curriculum? Are they likely to "know" what needs to be done? Are they active, dependable people who will work to accomplish something?

The task force should be clear on its role. The work it has set out to do will almost inevitably lead to calls for change and innovation. This implies decisions. These are the kinds of decisions that involve a variety of resources, especially time and money. How and who will make decisions internally is quite different from the external decision making process. Is this group advisory? To whom will it make recommendations? Science department? Principal? Superintendent? School board? Or is the task force involved in a first step, using the process as a way of seeking clarification and agreement on the science education program? You may be interested only (no small step) in developing a framework for learner outcomes, matching units of instruction to them, and specifying what students will learn and do in those units. Does/should the work of the task force have to be coordinated with other department or ongoing assessment, evaluation, and planning initiatives? Does the PER Curriculum Advisory Committee play a role? If so, what is it?

Have you identified your team?
date: ______________

NO

YES

Task definition. This could be written as goals and objectives or you could set a research or work agenda. What are the problems or issues (perspectives of committee members; consensus on the purpose of science ed?problem, e.g., curriculum balance; continuity; direction; who is affected; etc.)? What are the facts (analysis of science program content, instruction, support, perceptions, etc.)? Where do we go from here (curriculum redesign, staff development, elicit administration/board action, etc.)?

As you collect data, the problems or issues may change, and you should be prepared to modify your beginning ideas, *or* they may become more clearly defined. Remember, too, that you can collect too much data in terms of both will and time to analyze it!

Have you identified the task?
date: ______________

NO

YES

Resources. These include *time* (release time, staff meetings, evaluation, task force meetings), *money* (task force budget, substitutes, materials, travel), and *support services* (typing minutes and reports, photocopying).

Have resources been negotiated?
date: ______________

NO

YES

Assessment and elaboration of learner outcomes for science. The assessment instruments are divided into four main areas. They are subdivided as indicated below. The self-assessment items are divided into K-6, 7-12, and K-12.

1. What is Science, What are Scientists?

2. Self-Assessment Elements
   a. The Science Education Curriculum
   b. Facilities and Laboratory Safety
   c. Support for Science Education
   d. Perceptions
   e. Science Education and Me

3. Increasing Options to Play the Scientific-Mathematical Game: Toward a Multicultural, Non-sexist Science Education Curriculum

4. Learner Outcomes for Science: What Should be Learned?
   a. Elementary
   b. Life Science
   c. Earth Science
   d. Physical Science
   e. Biology
   f. Chemistry
   g. Physics
   h. Science, Technology, and Society
   i. Science for Personal Needs
   j. Processes of Science Education
   k. Science Attitudes and Values

Each of these areas is discussed separately in the following four steps. Directions for using the assessment instruments are found with the instruments.

The assessment instruments should be carefully reviewed before they are distributed. It is recommended that all of the assessment instruments be completed. However, it is recognized that assessment needs will vary. Furthermore, the assessment assignment and process the task force decides on may influence choices. Finally, you may want to shorten some of the assessment lists before you use them. These kinds of decisions depend on the local situation.

Do you understand the possibilities and have you reached agreement on them?
date: ____________________

NO

YES

What is Science, What are Scientists? The major purpose of this section is to seek some general agreement on what science is. This is not an easy task and we know that. Science and sciencing are slippery concepts to define. However, by reflecting on what science is, it is hoped that you will reach some common ground. That common ground is important for K-12 curriculum design. It tells you a little about the territory.

Agreement reached in the nature of science.
date: ____________________

NO

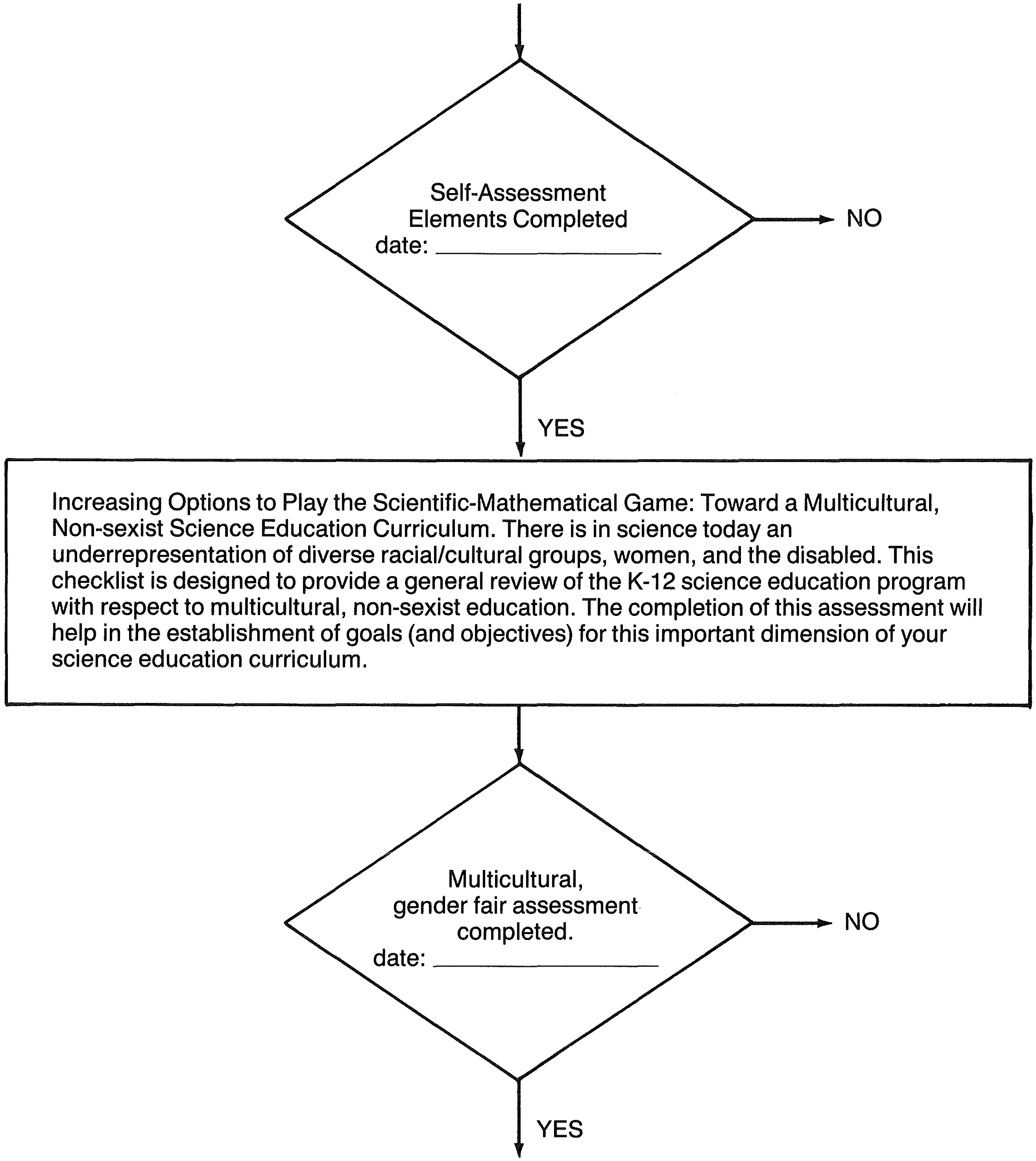
YES

Self-Assessment Elements. In "Science Education and Me," you examine your own personal perceptions about dimensions of science education by indicating whether you agree, are undecided, or disagree about each of the items. This is an exercise for private reflection and self-insight. This assessment is a task force assignment.

The remaining self-assessment items focus on facilities and laboratory safety, the curriculum, support, and student and parent perceptions. These are to be completed by internal (task force) and external (all science teachers, a sample of parents and students) participants.

Evaluation of the variables for each of these elements is based on a discrepancy model. Two questions are addressed for each variable: what IS (perceived achievement) and what OUGHT (perceived desirability) to be. This is done through the utilization of a five-point rating scale or by placing the responses directly onto a matrix.

There are separate items for K-6, 7-12, and K-12.


Self-Assessment
Elements Completed
date: ____________
NO
YES
Increasing Options to Play the Scientific-Mathematical Game: Toward a Multicultural, Non-sexist Science Education Curriculum. There is in science today an underrepresentation of diverse racial/cultural groups, women, and the disabled. This checklist is designed to provide a general review of the K-12 science education program with respect to multicultural, non-sexist education. The completion of this assessment will help in the establishment of goals (and objectives) for this important dimension of your science education curriculum.
Multicultural,
gender fair assessment
completed.
date: ____________
NO
YES

Learner Outcomes: What Should Be Learned? Basically, we need to know why we teach something and when. The objectives provided are considered by the committee as essential, realistic, and desirable—the important outcomes of a K-12 education in science by grade level, course, process skills, topic areas, and affective outcomes. They are purposely limited in scope, usually around twenty for each.

These outcome variables are evaluated in four ways. These are: 1) learner outcome evaluated by a discrepancy model: what IS (perceived achievement) and what OUGHT (perceived desirability) to be; 2) whether the learner outcome should be adopted; 3) grade-level placement; and 4) degree of emphasis in the curriculum, i.e., whether the outcome is to be introduced, maintained, emphasized, or whether it is not covered or applicable at a particular level of instruction or in a particular science course.

The topics and the outcomes provided in this document represent a place for the task force to start. Both topics and outcomes can and should be modified—additions, deletions, corrections—based on the variables of your local situation.

There are 11 areas of "clusters" of science education represented. They are: 1) Elementary; 2) Life Science; 3) Earth Science; 4) Physical Science; 5) Biology; 6) Chemistry; 7) Physics: 8) Science, Technology, and Society; 9) Science for Personal Needs; 10) Processes of Science Education; and 11) Science Attitudes and Values. Areas should be deleted or added as appropriate.

Duplicate the learner outcomes and send them to the entire science staff for their reactions, changes, additions, and deletions. Encourage written comments about the learner outcomes from teachers. Casual comments made over lunch, in the hall, or over coffee in the faculty lounge are all too easily forgotten or, occasionally, misrepresented!

The task can be made more manageable by asking teachers to react to only those topics which are specific to their teaching assignment. However, there is a danger in doing this, e.g., the teaching of science process skills does not stop at sixth grade; STS—science-technology-society—objectives range across most of the science curriculum; science for personal needs and concerns can add new dimensions to the teaching of science at almost any level or in any course.

Final decisions about adoption, placement, and curriculum emphasis are a task force assignment and responsibility. Summarizing the data obtained from the science faculty is not a small assignment, particularly when you take into account written comments, additions, deletions, and modifications. Placing the data on large summary matrices may be useful. It will provide a quick visual summary of the distribution of responses. If most of the responses are in the upper areas of the matrix, the science faculty has both high expectations and agreement on desirability. The science faculty may be apathetic or unaware of the importance of outcomes or disinterested in a particular curriculum emphasis.

The selection of outcomes is both a large *and* satisfying task. It is the big *what* of science education. Its completion will help you make decisions about curriculum organization, provide you information useful in the selection of curriculum programs, and indicate instructional directions and alternatives.

Learner Outcomes
Adopted According
to Agreed Upon
Criteria
date: ____________________

→ NO

↓ YES

Time devoted to science...time in science devoted to emphases within science. This is primarily a matter of setting clear expectations and standards. There are some standards and general guidelines provided in the Rules of the Minnesota State Board of Education. The rules are concerned with required curriculum offerings and the distribution of instructional time. The rules should be reviewed and any special application to the school/school district noted.

Time allocation for science instruction. A useful rule of thumb for the amount of time allocated in kindergarten is 10 percent of the time per day. For grades one to two, 20-25 minutes per day. For grade three, approximately 35 minutes per day and for grades four, five, and six, the time is approximately 45 minutes per day.

Beyond sixth grade, courses and clocks play a more determinant role in scheduling. Certainly, as a minimum for all science classes, one full class period every school day should be considered.

Curriculum emphases. In 1982, the National Science Teachers' Association published its position statement, "Science-Technology-Society: Science Education for the 1980s." The following minimums of time directed toward science-related societal issues during science instruction were recommended. For the elementary school level, 5 percent; middle/junior high school level, 15 percent; and senior high school level, 20 percent. Such decisions will have to be made about emphasis you choose to promote within your program.

Agreement Reached
On Time Devoted to
Science Education
date: ____________________

→ NO

↓ YES

A Checkpoint: "Is the Thing Broke?" "Can You See the Forest For The Trees?" To this point, you have spent a lot of time on assessment—collecting data. Fortunately, some of that time has been spent in completing an assessment task: choosing the learner outcomes which will form your program.

At this point, it may be appropriate for you to present the results of your assessment to appropriate people in the school or district. This can be in the form of a written or oral report.

You are looking for reactions, suggestions, general comments, and opinions. Make this report as concise as you can. It could include sections such as: the process, findings, recommendations, and implications. You should make it clear that this is an interim or preliminary report. It is not a final plan. You will need to consider all reactions carefully before you prepare a final report or plan.

A tool to help you in the summarization is included for your consideration. It is in the form of a report card and is found on pp. 86 to 88.

Results of assessment analyzed, completed and reported

date: ________________

NO

YES

Elements of a Plan for Science Education. It is expected that most schools/school districts will develop their own schemes for organizing a plan and this is the way it should be. Some elements that you should consider include:

- Introductory statement. This statement makes clear why science education is a part of the general education curriculum. This is a "we believe" statement about what the school or district is committed to helping students achieve. Chapter One lists the goals of the Minnesota Department of Education for public education. Science goals (subgoals) are included in this listing. There statements may be useful to the development of this section as well as the section dealing with science literacy in Chapter Two.

  From a philosophical point of view, you may want to say something, for example, right at the outset, about the relationship between concepts and experience...content and process. "Scientists use tools, instruments, and methods (or processes) to explore the objects and events of the natural world. Formal concepts are invented and refined to represent and explain the natural world. Scientists connect their words (concepts) by experience (process) to the parts of the natural world they represent. This is a very powerful way of knowing and scientists have to learn how to explore the natural world.

"Science education is, therefore, not a matter of instruction in content alone because this is not what science is. Science is a process of socialization, of becoming a member of a community. It involves the development of *shared* understanding and meaning through discussion and agreement; learning *how* to observe, measure, record and represent data, experiment, interpret, etc.; learning the *territory* of science; and learning appropriate *standards* of exploration.

"Science is a functional activity and its set of tools is to be made available to students so that they can explore events and figure out how things work. As they work, always connecting experience with meaning, the words will become their own and will not remain a mystifying and poorly understood foreign language."

- **Assessment results.** This can include information assessment procedures used and a description of the current state of affairs.

- **Definition of goals for science education.** Goal setting should flow from the assessment. Goals should be reasonably specific and attainable. They are a reflection of what a successful redesign of the science curriculum looks like. They might be categorized so that they focus on population characteristics (K-6, 7-12) or the curriculum, etc.

- **Solution (Implementation Plan).** This section addresses how you have decided to achieve the goals set. There are many possible solutions. Yours has to be the ideal one for your situation. Obviously, this includes clearly recognizing and taking into account what is good about your current school/school district program.

  As you search for the ideal solution, you will soon bump into resources. These include both costs (Are budgets available?), time (Is in-service/release time available?), and support (Do proposed tasks require secretarial help or copying services?). Your solution must be consistent with the school/school district goals and educational philosophy...its cultural norms and mores.

  There will be decisions, too, on the level and nature of the curriculum redesign as well as the priority for such changes. Is it the physical science program that requires a major revamping or the entire K-6 program or only parts of courses that are weak with respect to learner outcomes and other curriculum emphases you have selected?

  Your implementation plan should pay some attention to a realistic time line. Curriculum redesign takes time. Your preparatory steps are testimony to the time required in assessing the state of the science education program. The time required will vary depending on the thoroughness of the examination. It is one thing to select key concepts and quite another to focus attention on appropriate teaching strategies. Time will be required for staff development, changing and revising course content, maintaining the support system for sustaining the effort, deciding on evaluation procedures, institutionalizing procedures, and so on.

The consensus in the literature and from the experience of those involved in significant changes is that the process takes three to five years, if substantive improvement are to accrue.

Review and evaluation. Sooner or later you will want to know: "How are we doing?" When are you going to conduct periodic assessments and what will you monitor? Do you intend that the science education curriculum, K-12, be revised by an external audit team every five years?

How much time is devoted to science, K-6? Are the science process skills being integrated into the curriculum? Are "hands-on" activities being used as recommended? What are the concerns of the teachers involved? What do parents and students say about science? When will you begin to use achievement measures to evaluate student outcomes? Will you use items from the Minnesota science assessment data bank? Improvement in student learning is not likely to improve overnight, although there is an overwhelming tendency to want to use achievement as the sole evaluation measure.

Have you completed the plan, presented it, and gotten authorization to proceed?
date: ______________

NO

YES

END
date: ______________
START
date: ______________

A PLAN FOR SELF ASSESSMENT

You have just completed your **Plan to Plan.** The first step in any curriculum evaluative process is self-assessment. The material that follows is designed to help individuals and committees work through all of the factors that impinge on curriculum development: finances, equity, prejudices, and attitudes concerning science, status of the present curriculum, etc.

We have included, with their permission, the process developed by the National Science Teachers' Association. This process involves a two-axis grid system that is rather cumbersome to put together, but when complete, gives the committee a very clear idea of what is and ought to be. We have also included two questionnaires relating to basic attitudes toward science education in your school/class and personal attitudes toward science as an enterprise. Since these two factors color any product you will develop, it is important to surface these issues immediately. Finally, we have included in this section a process for evaluating learner outcomes. Our rationale is: learner outcomes, whether yours, ours, or a combination of both, are often honored more as tokens than in fact. People will spend time putting long lists together, only to forget them when the project is over. We are suggesting that the committee decide which outcomes are proposed and at what level the outcomes should be introduced, emphasized, and maintained. When that task is complete, your committee will have a profile that indicates the relative importance of each outcome as well as the level at which it might be assessed. All that remains is for the committee and the teachers to review their curriculum area and indicate how they specifically address each of the outcomes they said were important at their particular course or grade level. If an outcome you have indicated as important is not addressed, additional activities or units will need to be added to the curriculum that will emphasize the outcome or else a decision to eliminate the outcome must be made. Having reviewed the curriculum, all that remains to be done is to consider the cost impact to the district and strategies of assessment.

The authors realize that curriculum development is a difficult and a lengthy process. It is not a process that can be successfully completed in a couple of hours after school. It is an ongoing process that evolves quality curriculum over a rather long period of time, only after a series of assessments and reevaluations. Simply adopting a new text will not do the job. Successful science programs are composed of three parts: content, skills (processes), and inquiry. If one leaves any of these components out of the goal or learner outcome structure, even if one says they are assumed in the course content, that person is really saying that the missing outcomes are not important, and experience shows that the outcomes will be lost in the shuffle, will not be evaluated and will be forgotten. This is particularly true of the process skills of science.

WHAT IS SCIENCE, WHAT ARE SCIENTISTS?

Some Points of Common Agreement

Science is one of those enterprises that everyone talks about but, as long as nobody tries to define it, we all think we can communicate. What we teach and the values students infer from their experience with us speak more loudly than any lesson or lecture we might give. In order to reflect those unspoken values more honestly in the curriculum, the authors are asking each committee of K-12 teachers to go through this activity and discuss their perceptions according to the directions below.

Directions

A. Each person should read the statements listed below. In the spaces provided, indicate whether you can accept it or not by putting an A(gree) or D(isagree) in the space provided.

B. Once each person has had a chance to review the statements about what science is, the whole group should break up into sub-groups of four or five people. Try to have at least one elementary teacher and one secondary science teacher in each subgroup. Starting at the top of the list, review each person's reaction to the statements. Can your group rewrite the statements so that they are more acceptable? If you cannot, throw it out and go on to the next statement. Can your subgroup come up with a short list of characteristics that describe what science is and what scientists are? Keep the list fairly short, but as descriptive as possible.

C. When all of the subgroups are finished, get together in one large group and review the process to come up with one set of characteristics that best describes the feelings of the entire committee.

Agree or Disagree
A or D

______ 1. Scientific knowledge may originate from observations, experiments, spiritual insights, or imagination.

______ 2. Scientists believe that everything in the universe is knowable.

______ 3. Science is neither moral nor immoral, however, scientists are. Therefore they should speak out only on issues for which they are scientifically and technically trained.

______ 4. Scientists believe that all events have explainable causes.

______ 5. Science is a search for common patterns in what appear like quite unlike events.

______ 6. Understanding in science is expressed in scientific laws or principles.

______ 7. In science, theories are structures of ideas that are used to explain and interpret facts.

8. There is very little privacy in science. Research reports are often greeted skeptically. They are routinely questioned, challenged, and subjected to criticism by other members of the scientific community.

______ 9. The major characteristic of scientific knowledge is its tentativeness.

______10. Science may never make moral judgments; the law must.

______11. For any theory, there are many hypotheses that can be formulated using that theory.

______12. In hypothesis testing, scientists make a prediction from a set of assumptions and then test that prediction through experiments, collecting data, or making observations.

______13. The only kind of evidence that scientists consider when making scientific judgments is empirical evidence.

______14. The beliefs of scientists are tentative rather than dogmatic. They are based on evidence rather than authority.

______15. Science is concerned with developing technology to benefit humankind.

______16. The methods of science are both quite stable and universally used; what changes constantly is science as a body of knowledge.

______17. A hypothesis is basically a guess.

______18. Scientists believe that all things are caused by natural events.

______19. The social implications of science are of concern to both scientists and other citizens.

______20. What a scientist sees (observes) is influenced by her or his past experiences and by the conceptual structures that she or he has developed.

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This list of attributes owes a lot to the work of others. It is hardly original. Included are ideas suggested by the following resources.

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SCIENCE EDUCATION AND ME

Overview

The following statements provide an opportunity for you to examine some of your perceptions about science education. The list of statements makes no claims about coverage. It minimally covers some of the more obvious dimensions of science education: students, science and technology knowledge, teaching, purpose, profession, and teacher.

The results of this self-assessment need not be shared. The purpose of the exercise is primarily self-knowledge and to encourage introspection. There is a separate set of questions for elementary and secondary teachers.

Directions

1. Read each statement and decide whether you (A)gree, are (U)ndecided, or (D)isagree; then place the appropriate letter in the space provided.

2. When you are finished, complete the sheet labeled "Science Education: A Personal Viewpoint," which follows the exercises.

ELEMENTARY, K-6

"Summer makes you 'spire. (A moment's pause).
No, that's not right. The sun makes you 'spire."

M. Pitts, Editor, Texas Day Care
1971, No. 30, p. 13

______ 1. Science is for everyone—not just future scientists and engineers.

______ 2. I am excited about the subject matter of science and technology.

______ 3. The major purpose of science study in elementary school is to lay the foundation for students to take more science in secondary school.

______ 4. For the most part, I regard myself as comfortable, confident, and capable enough to do a good job teaching science.

______ 5. Children have firmly held views about many science topics prior to being taught science at school.

______ 6. Elementary science education should help children begin to discover relationships and to figure out how things work.

______ 7. Among the most beautiful words a teacher can say are "I don't know. Let's find out."

______ 8. I assume that both boys and girls are interested and ready for science activities.

______ 9. There are many kinds of science. There is "children's science," "scientist's science," "teacher's science," "curriculum science," "textbook science," "historian's science," etc.

______ 10. I have an adequate understanding of science and technology.

______ 11. The most important fact about teaching science in elementary school is that those who take science are children.

______ 12. I have attended at least one regional, state, or national meeting of science teachers in the past five years.

______ 13. I think children need the time to express science concepts in their own way before we insist upon the proper use of science terms.

______ 14. There is more to science literacy than the ability to read and write about it.

______ 15. An important emphasis in elementary school is the science-technology- self-society connection.

______ 16. I generally wait a few seconds after I ask a question of my students.

______ 17. I seek out new ideas and view in-service programs/college courses about science/ science education as an opportunity to grow professionally.

______ 18. I make considerable use of plants and animals in both my science classes and my classroom.

______ 19. When children learn science, they need a vast array of direct experiences and plenty of opportunity to talk over what went on, to wonder and suggest why "this" probably happened and not "that."

______ 20. I think that elementary science is being adequately taught in my school.

SECONDARY

1. I regularly read at least one science-related publication.

______ 2. My purpose as a science teacher is to help students learn fundamental principles and concepts of science and to have the ability to use the science process skills.

______ 3. I have read one of the recent books or studies issued about the status of American education.

______ 4. I enjoy teaching the concepts and processes of science with each new group of students.

______ 5. Learning about science and technology is a basic component of citizenship education.

______ 6. I would like to know more about adapting science to the needs, interests, and abilities of students, including special and gifted students.

______ 7. I know what I am doing and why, have clear goals and plans for my course(s), make clear to students why they are learning this "stuff," and come to each class meeting well prepared.

______ 8. The common thread of education, including science education, is the development of the ability to think.

______ 9. The proliferation of scientific information has changed the nature of science and science education.

______ 10. During a class discussion, I try to wait at least 3-5 seconds after asking a question to give students time to think carefully about the answer.

______ 11. I keep up-to-date on new methods and practices in science education.

______ 12. I have taken science/science education courses beyond the requirements for licensure and changes on the salary schedule.

______ 13. The major purpose of science study is to lay the foundation for students to take more science courses in college.

______ 14. I seek to extend my knowledge and understanding of students and their world through conferences, seminars, or discussions with other persons who work with adolescents.

______ 15. When I begin a unit of study, I ask my students to tell me what is going on in some natural situation, e.g., what are the forces on a book to keep it at rest; where does the moisture come from that collects on the inside of windows on a cold day; what causes the light and dark parts of the phases of the moon, etc.

______ 16. I have a commitment to learning more about the history of science, including the contributions of women and of scientists representing minority groups.

______ 17. Learning relationships among science concepts facilitates the application of knowledge and enhances future learning.

______ 18. I have participated in curriculum development and/or curriculum trial activities designed to try out, develop, or evaluate new ideas for the advancement of science teaching.

______ 19. I have made a presentation in one or more programs for teachers and/or have served as an officer in an organization for teachers.

______ 20. Science helps students use knowledge of science in decision making relative to personal needs, interests, desires and goals, and in solving problems of people, technology, and society.

______ 21. I show an interest in students by attending extracurricular activities.

______ 22. I provide adequate opportunity for active work by students.

______ 23. I attend at least one regional/state/national conference or seminar related to science education each year.

______ 24. I engage in self-examination regarding my own individual teaching practices, e.g., What kinds of questions do I ask? In what ways do students determine the pace of instruction in my class? Do I prepare students adequately for laboratory work? What is my role in laboratory activities? To what degree am I governed by the need to cover material?

______ 25. I hold membership in a regional, state, and/or national organization for science teachers.

SCIENCE EDUCATION: A PERSONAL VIEWPOINT

Major characteristics of a good teacher are:

The major purpose for which I teach science is:

My major strengths in teaching science are:

The area of science/science education in which I would most like to improve is:

The major reforms needed in the science education program in our school/district are:

INCREASING OPTIONS TO PLAY THE SCIENTIFIC-MATHEMATICAL GAME: TOWARD A MULTICULTURAL, NON-SEXIST SCIENCE EDUCATION CURRICULUM

Overview

In the past few years, there has been increasing concern about the underrepresentation of diverse racial/cultural groups, women, and the disabled in quantitatively based disciplines such as engineering, mathematics, computer science, the physical sciences, and the biological sciences. The destructive pathways that have led to such underrepresentation among those who do science are both direct and indirect and include sociological, cultural, and educational factors. Some researchers claim that intrinsic biological differences between the sexes determine intellectual ability in science. In "Sex Differences in Intellectual Ability," Dr. Meredith M. Kimball, Simon Fraser University, British Columbia, points out that:

> "(t)he exact origin of any sex differences inability might be unimportant were it not for the tendency of educators, governments, and the public in general to accept the absence of girls from science and mathematics as "natural," suggesting that "nature" is somewhat responsible for this lack of interest and achievement, and that we should not interfere... We see this point of view reflected in comments such as that made by a Newsweek journalist in an article on sex differences in mathematical ability, "if they (the sex differences) are genetic we must learn to accept them."

From: *Who Turns the Wheel.* Proceedings of a Workshop on the Science Education of Women in Canada, 1982 Science Council of Canada.

More impressive is literature on the effects of elementary and secondary institutions indicating the importance of the early years of education in increasing the representation of women and minorities in the quantitative disciplines. The task before science educators and, in a wider and more pervasive sense, schools, is to enlarge such restricted horizons and to provide compensating resources and encouragement for these students (girls and minorities) who do not have them outside school.

The environment for science and mathematics education in grades K-12 very much lies in the word "supportive." A criterion that should be used in investigating the science curriculum is how supportive it is for young women, minority students and the disabled (as well as young men). This includes but is not limited to:

- Encouraging all students to acquire the academic skills they need to major in science at a college or university.
- Promoting career awareness so that all students may learn of opportunities in mathematics and science-related professions early enough so that they may prepare for them;
- Providing educational enrichment activities that can contribute to preparation, development and commitment of students for science-related careers;

- Helping students to pursue the options of entering a college science major, e.g., actively encouraging an early orientation toward science careers and training.

It is clear that the K-12 science education program should be multicultural and nonsexist. Such perspectives should quite literally influence and infuse all classroom work. In 1981, the Educational Equity Section, Department of Public Instruction, State of Iowa, prepared a checklist to be used in the review of science curriculum programs. The purpose of *Multicultural Nonsexist Education in Iowa Schools—Math and Science* is "to determine the degree to which they are consistent with the basic concepts of multicultural, nonsexist education." The checklist is a general guide and a profound consciousness-raiser. Many of the questions in the survey which follows are taken from it. Some items have been modified.

In *Multicultural Nonsexist Education in Iowa Schools,* multicultural education and nonsexist education are defined as follows:

> *Multicultural Education:* the educational processes which promote the understanding and appreciation of the cultural diversity of our pluralistic society. Within the total multicultural educational process, special emphasis shall be placed on the following groups: Asian American, Black American, Hispanic American, Native American, and the handicapped. The educational program shall be characterized by practices which provide equal opportunity for all participants regardless of race, color, age, national origin, religion, or handicap.
>
> *Non-sexist Education:* the educational processes which foster the knowledge of, and respect and appreciation for, the historical and contemporary contributions of men and women to society, as well as those educational processes that reflect the wide variety of roles open to both men and women. The educational program shall be characterized by practices which provide equal opportunity to both sexes.

Directions

1. In the spaces provided, each person should indicate whether he or she agrees (yes) or disagrees (no) with the statement.

2. When you are finished, tally the responses, either item by item or by clusters of ideas. Use this opportunity to review and discuss the items. What are some of the concerns?

3. After each cluster of items, space is provided for adding your own questions.

4. In Subsection E, you will find some questions that ask for honest self-assessment. Your answers do not need to be discussed directly with the group although it is likely they will influence group discussion.

5. After you have rated and discussed the items, use the matrix format provided to develop an overall rating for the status of multicultural, non-sexist education in science for your school/school district. For this analysis, the item reads "An adequate multicultural, non-sexist science education program is provided for all of our students."

6. The matrix can be used to focus on the extent to which instruction in science is meeting the needs of all students in your school. There are many questions that can be and need to be considered when incorporating multicultural, non-sexist concerns into teaching and learning. An abbreviated list designed to help you summarize your discussion is found in the sheet titled "Multicultural Non-sexist Education and Science Education: Considerations."

A. The School

1. Are there diverse role models (male-female, diverse cultures/races) teaching science at both the elementary and secondary levels?

   ______ Yes ______ No

a. If the answer is no, what has caused this to happen? Are there any strategies for changing this pattern? If no, what are some appropriate strategies?
b. If the answer is no, what impact does this have on the strategies that will be used to achieve multicultural, non-sexist science objectives?

2. Are there disabled employees on the school district staff who may serve as role models for students?

   ______ Yes ______ No

3. Are there diverse student enrollments (male-female balance and ethnic and racial diversity similar to that found in the district) in all elementary and secondary science courses?

   ______ Yes ______ No

a. If the answer is no, what has caused this to happen? Are there long-range strategies for changing this pattern? If no, what are some appropriate strategies?
b. If the answer is no, what impact does this have on the strategies that will be used to achieve multicultural, non-sexist science objectives?

4. Are scheduling practices used which may result in sex-typed enrollments (80 percent or more of one sex) or the relative isolation of racial/cultural groups and the disabled?

   ______ Yes ______ No

5. Do girls who wish to pursue advanced science courses find their fears that "girls don't become scientists" reinforced clearly by the ratio of boys and girls in the classroom?

   ______ Yes ______ No

6. Are science courses given titles which are more meaningful to one sex or cultural group?

   ______ Yes ______ No

7. Are course descriptions free of bias or stereotyping?

   ______ Yes ______ No

8. Has there been meaningful interaction between science teachers and the personnel within the district who are responsible for the implementation of multicultural, non-sexist education?

   ______ Yes ______ No

9. Has in-service on multicultural, non-sexist approaches to the science curriculum been provided for all elementary and secondary science teachers?

   ______ Yes ______ No

10. Have the district administrators incorporated multicultural, non-sexist education concepts into staff evaluation procedures?

   ______ Yes ______ No

11. Have you interviewed students, say, in ninth and twelfth grade, for example, about course preferences and personal reasons for preferences; important things that need to be discussed in science; areas where the school has different expectations for boys than it has for girls and what those different expectations are; and their rating of the usefulness of mathematics and science?

   ______ Yes ______ No

12. Is there an organized effort to prepare minority, female, and handicapped students for science based fields of study? This may include tutoring; independent study groups, peer support systems; academies, university and career counseling; special field trips; and summer employment/internship programs.

   ______ Yes ______ No

13. Are there present education programs which help parents to become aware of the possibilities of science in their children's future?

   ______ Yes ______ No

14. Do such programs offer suggestions and activities for parents to use in nurturing children's interest in mathematics and science?

   ______ Yes ______ No

B. Curriculum Content

1. Does the science curriculum include units/activities which explore the importance of basic scientific skills in broadening career options and enhancing future earning capacity?

   ______ Yes ______ No

2. Does the science curriculum include units/activities which cause students to become aware of their attitudes toward science and which may lessen the science anxiety that many students, especially female and minority students might be experiencing?

   ______ Yes ______ No

3. Does the science curriculum include units/activities which explore related careers in non-stereotypic ways?

   ______ Yes ______ No

4. Does the science curriculum include content on the contribution of diverse racial/cultural groups, both women and men, and the disabled to the field of science?

   ______ Yes ______ No

5. Do life science and biology curricula include content and experiences which provide students with a basic awareness of:

   - the common characteristic of all human beings?

     _______ Yes _______ No

   - human adaptation in a biosocial context?

     _______ Yes _______ No

   - the role science can potentially play in preventing racism or racial equality and respect?

     _______ Yes _______ No

   - sex determination and sex differentiation in humans?

     _______ Yes _______ No

   - attitudes toward people who may look or act differently from most other people?

     _______ Yes _______ No

   - view and implications of sexual stereotyping, gender identity and gender role, and how science comes to be perceived as a male domain?

     _______ Yes _______ No

   - the role science can play in promoting sexual equality and how it may also be misused as a basis for promoting sexism?

     _______ Yes _______ No

C. Instructional Materials

1a. Are illustrations in science textbooks, supplementary materials, audiovisual aids, and on bulletin boards representative of the cultural/racial diversity in the United States as well as the roles open to both men and women in today's society?

_______ Yes _______ No

1b. Are disabled persons represented?

_______ Yes _______ No

2a. Are both women and men, diverse cultural/racial groups and the disabled shown in both active and passive roles in doing science?

_______ Yes _______ No

2b. Traditional and non-traditional roles?

_______ Yes _______ No

2c. Domestic and non-domestic roles?

_______ Yes _______ No

3. Are instructional materials free of ethnocentric or sexist language patterns which may make implications about persons or groups solely based upon their culture, race, sex, or disability?

_______ Yes _______ No

4. Are the content areas, mentioned in Section B, included in science instructional materials?

   ______ Yes ______ No

5. Do the materials tend to reinforce stereotypes about cultural/racial groups, men and women, or the disabled?

   ______ Yes ______ No

6. Do examples and word problems use both Anglo origin names such as Mary Jones, Bob Smith, and James Baker, as well as names of non-Anglo origin such as Juanita Ramos, Mitsue Yashima, or Jonathan Youngbear?

   ______ Yes ______ No

7. Have multicultural, non-sexist criteria been integrated into the science instructional materials selection process at a district level?

   ______ Yes ______ No

8. Are problems of combining career and family explicitly addressed, and are clear models of women who are successful at both career and marriage provided?

   ______ Yes ______ No

D. The Classroom

1. Do classroom teachers avoid using language patterns which may be sexist or ethnocentric?

   ______ Yes ______ No

2. Do teacher expectations affect the performance and enrollment patterns of women, minorities, and the handicapped in science?

   ______ Yes ______ No

3. Are classroom management strategies and role assignments used which reinforce multicultural, non-sexist student behavior?

   ______ Yes ______ No

4. Do all students have equal experience with the instruments, materials, and techniques of science?

   ______ Yes ______ No

5. Are students alerted to stereotyping when it occurs in instructional materials?

   ______ Yes ______ No

6. Do all students have equal opportunities in taking a variety of science related field trips and other extracurricular science experiences?

   ______ Yes ______ No

7. Are persons of diverse cultural/racial groups, men and women in both traditional and non-traditional roles, and disabled individuals used as resource persons in the classroom?

   ______ Yes ______ No

8. Is there a balance between large group, small group, and individual activities in the classroom schedule so that all students, regardless of sex, race/culture, and disability are encouraged to become integrally involved?

______ Yes ______ No

9. Are the bulletin boards and teacher-made displays in the classroom representative of the cultural/racial diversity in the United States and roles open to both men and women?

______ Yes ______ No

10. Have classroom teachers alerted the counseling staff to possible multicultural, non-sexist guidance techniques which are relevant to course work and career preparation in science?

______ Yes ______ No

11. Are students exposed to people who use mathematics and science in the workplace?

______ Yes ______ No

12. Are tests culturally fair, i.e., do they assess the skills and content actually taught?

______ Yes ______ No

13. Are all children encouraged through teacher feedback and guidance to persevere as they work their way through appropriately challenging problems and situations?

______ Yes ______ No

14. Are minority and women students actively encouraged to take the more challenging educational path?

______ Yes ______ No

15. Is there a list of resource materials designed to help you implement multicultural, non-sexist science education? Such a list might include information about newsletters/periodicals ("Women Chemists," "Women in Forestry," "CML Newsletter"); associations and committees of or for women, minorities, and the handicapped in science, engineering, mathematics, and medicine (e.g., Native American Science Education Association, American Indian Science and Engineering Society, Association of Handicapped Student Services Providers in Postsecondary Education, AAAS Project on the Handicapped in Science, Minority Participation in the Earth Sciences; NABT Section on the Role and Status of Women in Science Education); audiovisual materials; biographies of minorities, women and the handicapped; and curriculum programs.

______ Yes ______ No

16. Are there discussions of male/female stereotypes in classrooms?

______ Yes ______ No

17. Is it expected that every youngster be fully involved in all of the science procedures of a science learning activity?

______ Yes ______ No

E. Teacher Expectations

1. Is there an overrepresentation of minority students and/or girls among your low achievers?
   ______ Yes ______ No

2. If so, do you:

   a. Interact more with high achievers and ignore and interrupt low achievers more frequently?
      ______ Yes ______ No

   b. Ask more and higher level questions of high achievers and provide low achievers with questions that require only simple recall?
      ______ Yes ______ No

   c. Follow up with probing questions for high achievers and call on someone else if a low achiever is unable to provide a prompt, accurate response?
      ______ Yes ______ No

   d. Provide a longer wait time for high achievers to respond to a question and cut off response time for low achievers who hesitate?
      ______ Yes ______ No

   e. Seat high achievers closer to the teacher's usual position and cluster low achievers further away?
      ______ Yes ______ No

   f. Praise high achievers more often and criticize low achievers more frequently?
      ______ Yes ______ No

   g. Provide supportive communications for high achievers and engage in dominating behaviors with low achievers?
      ______ Yes ______ No

   h. Provide high achievers with detailed feedback and give less frequent, less accurate, and less precise feedback to low achievers?
      ______ Yes ______ No

   i. Demand more work and effort from high achievers and accept less from low achievers?
      ______ Yes ______ No

3. Do you interact more with high-achieving boys that with high-achieving girls?
   ______ Yes ______ No

4. If you wish to, please answer the following situation items.

   What do you do when:

   - A girl begins a thoughtful explanation and a boy interrupts?

4. (continued)

- Students organize themselves into laboratory groups, and a girl reaches for a paper and pencil to take notes?
- Students assign themselves tasks and responsibilities during laboratory work with regard to race/cultural commitments and sex (boy/girl) differences?
- A young woman tells you that her mother has attempted to dissuade her from choosing a career in science?
- A disabled and non-disabled student are working together. The disabled student is overshadowed and/or patronized by the well-intending non-disabled student?

MULTICULTURAL NONSEXIST EDUCATION AND SCIENCE EDUCATION: CONSIDERATIONS

What do we mean by multicultural non-sexist education in science?

What are we already doing?

What do we do that inhibits or restricts the achievement of multicultural non-sexist education?

What elements/areas are we going to include as goals for the K-12 science education program?

What are the implications for training, curriculum development efforts, long-term commitment, and support requirements (human and financial)?

USER'S GUIDE TO A MATRIX ASSESSMENT

In the preceding section, you have seen a step-by-step process for analyzing the science curriculum. Without additional tools, you will find the job odious and, likely, haphazard. Consequently, we have provided you with an assessment instrument for each section that we have suggested you evaluate: nature of science, the curriculum, physical facilities, laboratory safety, support for science education within your district, preceptions of science education from students, parents, and teachers, equity, and finally learner outcomes.

The method of evaluation is simple. We suggest that you assess your program in terms of **OUGHT** and **IS,** both for your teaching situation and your school. The rating scales to be used are as follows:

OUGHT *to be achieved in the Science Education Program*

4—of utmost value
3—of significant value
2—of medium value
1—of insignificant value
– 1—of negative value

IS *achieved in the Science Education Program*

4—extremely high level
3—above average
2—on the average
1—less than average
– 1—avoided or non-existent

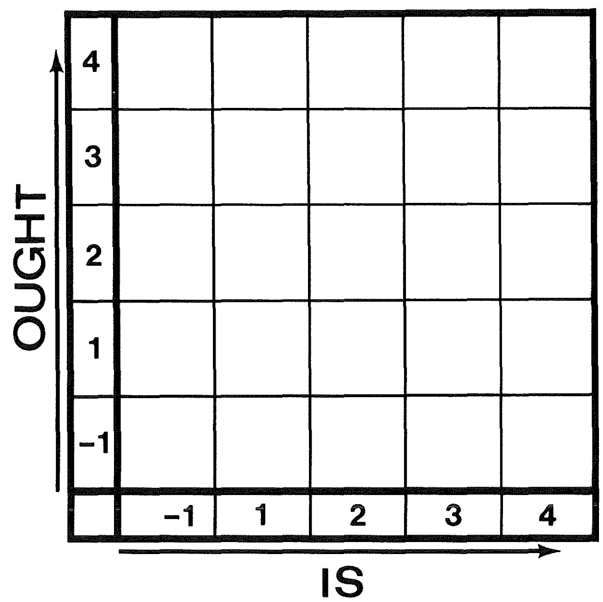
Two matrix formats, one large and one smaller version, are reproduced for your convenience.

Directions

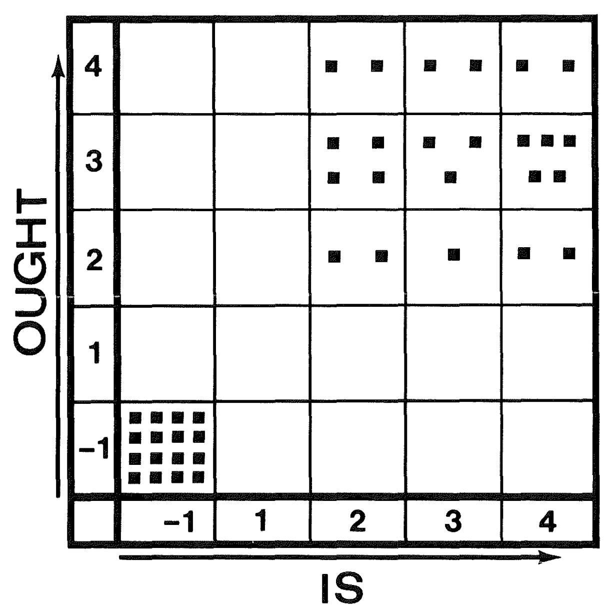
It is recommended that each individual on the task force or committee attempt to answer each questionnaire that relates to her or his level. Fill out one of the small matrixes for each assessment item that applies. Note that some items are yes/no only and do not need a matrix. As individual matrixes are completed for each assessment section, combine the committee results on to the large matrix you will find at the end of this section (Note: You will have to reproduce sufficient copies of the large matrix). Once group results have been pooled, patterns should emerge as illustrated below. The large matrix can be made into a transparency that is suitable for visually displaying the work of a group. The matrix has the following form:

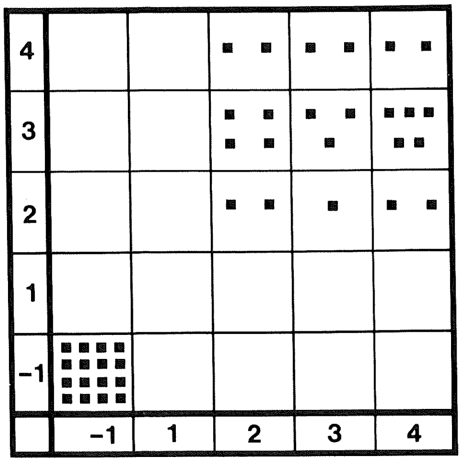
You will note that **OUGHT** is on the vertical and that **IS** is on the horizontal axis.

For each statement, circle the rating you wish to assign to **OUGHT**. Do the same for **IS**. To score this item, place an "X" in the box where the two ratings intersect. Two examples follow. In Matrix "A" an important goal is being achieved: it is one that ought to be achieved and is achieved, but only moderately. Matrix "B" raises significant questions about the achievement of a goal; it is one that is achieved but ought not to be achieved.

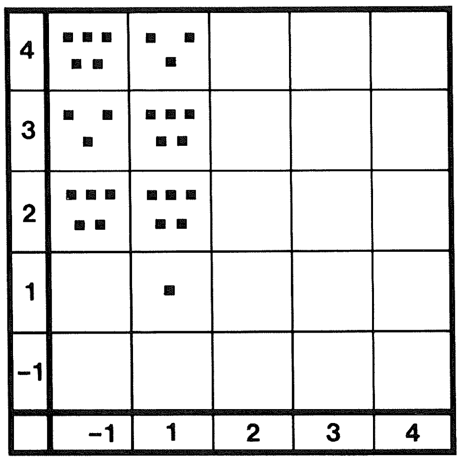


Occasionally, you may be uncertain about the meaning of an item or how it applies to your school or teaching situation.

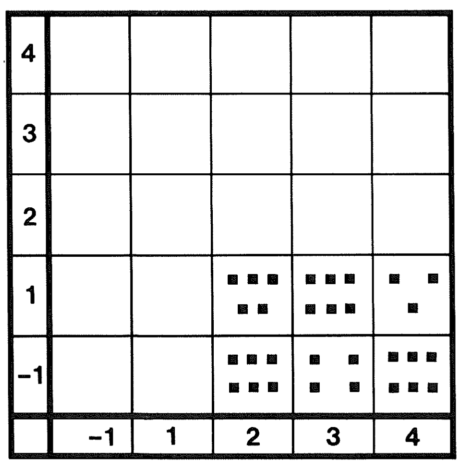




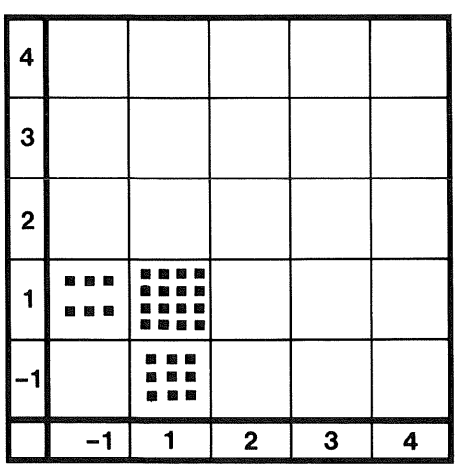
Responses in this area indicate important goals being achieved and in matrix box -1, -1, undesirable goals being achieved.



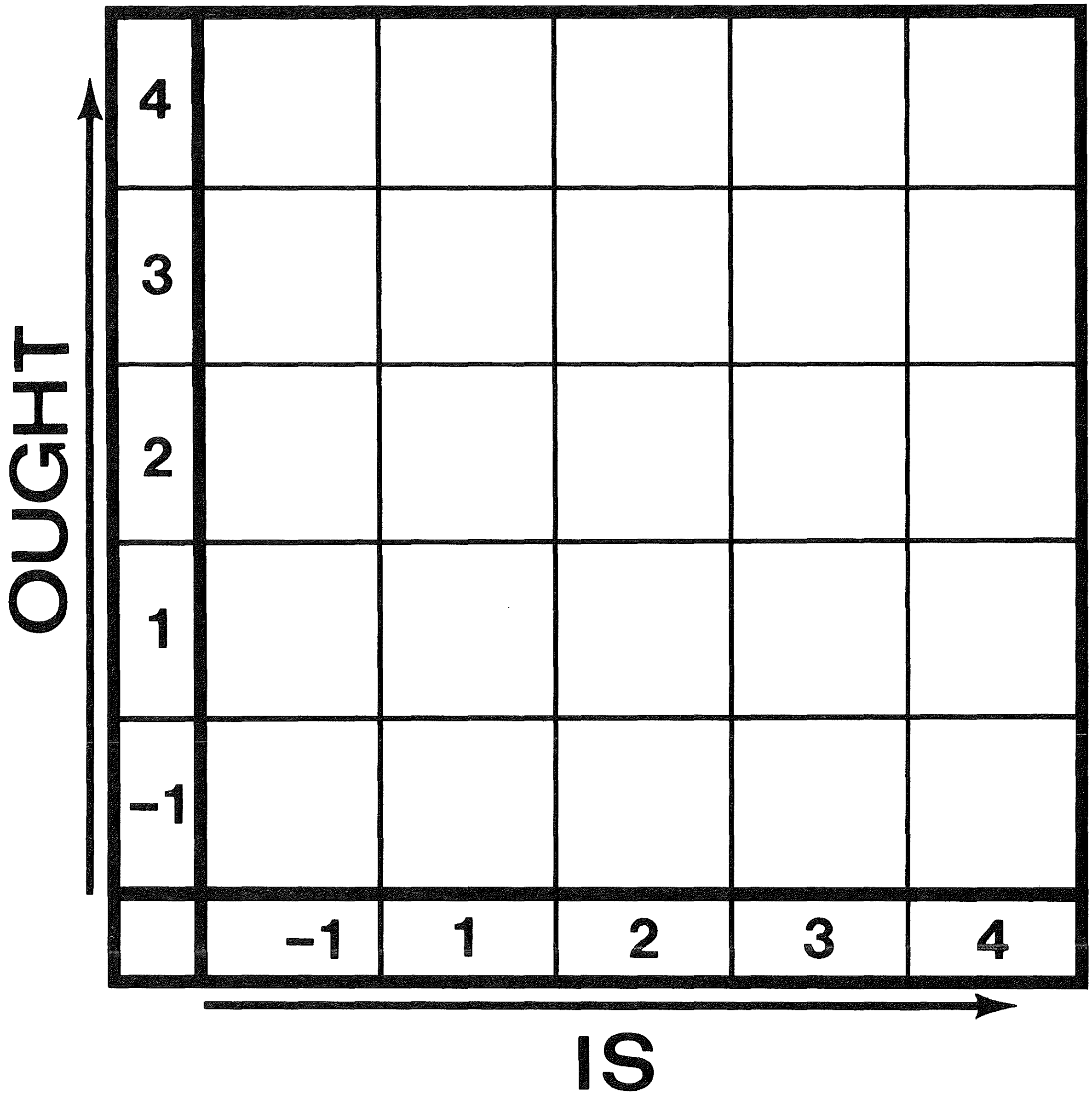
Responses in this area indicate achievement is short of expectations.



Responses in this area indicate that more time, energy, or resources may be spent than is justified.



Responses in this area indicate items that probably deserve little or no future attention.



Use this matrix to make a transparency to use during your in-service instruction. You may also use this matrix as a summary matrix for an entire module.

THE SCIENCE EDUCATION CURRICULUM

Overview

This section is divided into three parts: 1) Elementary, K-6, 2) Secondary, 7-12, and 3) Elementary and Secondary, K-12. The first part is to be completed by the elementary curriculum committee, the second part by the secondary curriculum committee, and the third part by both committees. The elementary and secondary checklists are further subdivided into three parts: A) Curriculum Planning; B) Classroom; and C) Evaluation.

Directions

1. In the blanks provided in front of each item *or* on the matrix sheet provided, indicate whether the item OUGHT (O) to be achieved and whether it IS (I) achieved in your school/district. Use the rating scales described in "A User's Guide to a Matrix Assessment" (p. 43). If you use the matrix, be sure to label and number the items.

2. Review and discuss your individual responses with another person, then in groups of four, eight, and so on until the entire group has reached agreement on the statements. At each step, you can add to the list of statements and combine, modify, or omit statements. The large matrix provided may be especially useful as the group becomes larger.

3. The space under the comments heading is to be used to describe additional information needed, to clarify or amplify items in the checklist, to explain judgments and ratings, questions raised, and most importantly, evaluative comments and implications for the science education curriculum/program in your school.

ELEMENTARY, K-6

A. Curriculum Planning

O	I	
____	____	1. Our school has a grade K-6 curriculum document which specifies long-range goals and short-term objectives for each grade level.
____	____	2. The grade K-6 curriculum document specifies and describes the science experiences for all grade levels. It includes both required and optional units of instruction.
____	____	3. One of the curriculum goals in the plan is to stimulate enthusiasm for the study of science.
____	____	4. Another curriculum goal in the plan is to help students gain an understanding appropriate for their age of a *few* basic science concepts.
____	____	5. The curriculum plan clearly lists concepts, skills, scientific attitudes, and attitudes toward science to be developed by students.

O I

____ ____ 6. The curriculum plan clearly lists concepts and skills that should be fostered in students. About attitudes, it says that students should develop their own personal preferences and attitudes toward science.

____ ____ 7. The development of the curriculum plan included a full range of stakeholders: teachers, parents, students, administrators, and others who are accountable for its implementation, maintenance, and evaluation.

____ ____ 8. Local curriculum guidelines have been developed. Elementary teachers were involved in the development of these guidelines.

____ ____ 9. The science curriculum plan is consistent with the Minnesota Department of Education goals and subgoals of public education in the State of Minnesota. (The learner outcomes in science are subgoals).

____ ____ 10. The science curriculum plan specifies the amount of time that should be spent on science on a daily or weekly basis. The weekly amount of time for science means for students in grades 4-6.

Comments:

B. Classroom

O I

____ ____ 1. The curriculum encourages children to think like scientists rather than memorize a lot of facts.

____ ____ 2. Learning activities in science are arranged in order of increasing complexity and abstraction.

____ ____ 3. The science curriculum deliberately and profusely makes use of art, writing, mathematics, social studies, and reading.

____ ____ 4. Our curriculum values human creativity and originality. These values are promoted by including inventing/invention fairs in which students are invited and challenged to become inventors.

____ ____ 5. The curriculum accords the student the right to be wrong, to learn from mistakes by retracing or repeating procedures.

O I

____ ____ 6. The science program emphasizes direct firsthand experiences with science materials and equipment (hands-on science), inquiry strategies, and student decision making.

____ ____ 7. Instructional materials which teach science process skills— observing, classifying, measuring, communicating, defining operationally, predicting, inferring, controlling variables—are used with all students.

____ ____ 8. Content is balanced among the life sciences, earth sciences, and physical sciences.

____ ____ 9. The science content and processes used with students are suited to their cognitive developmental abilities and physical capacities.

____ ____ 10. The science program is determined by the textbooks and activity manuals adopted for use.

____ ____ 11. The curriculum provides enrichment opportunities for students such as cooperative learning experiences with secondary schools, businesses, other institutions, and the community.

____ ____ 12. The instructional materials direct students to work using the processes of science rather than the "cookbook" approach to laboratory investigations.

____ ____ 13. The curriculum is designed to inform students about careers in science and technology.

____ ____ 14. The curriculum is designed to be taught in cooperative small groups.

____ ____ 15. Scientific information about the participation of women and minority members in science and technology is provided to students.

____ ____ 16. The actual science curriculum taught reflects the concepts, processes, and values defined in the K-6 curriculum plan.

____ ____ 17. The curriculum ties classroom science to real world issues, e.g., is personally relevant and applicable—contributes to the individual's survival and well being and, e.g., consumers and health issues *and* explores science related societal issues—contributes to the quality of life, e.g., custodians of the environment and ways science and technology change the way we live.

____ ____ 18. Ideas and/or activities from the exemplary major national curriculum materials, particularly the National Science Foundation sponsored programs during the 1960s, have been incorporated into the curriculum.

____ ____ 19. Science is used as a vehicle for bringing mathematics into the "real" world, e.g., using mathematical techniques to display and extract information from data.

O I

____ ____ 20. Science is used as a vehicle for showing uses of computers, e.g., the use of databases, recording temperature changes over a long period of time, and collecting data and making graphs.

____ ____ 21. Computers are used to teach specific science skills or concepts.

____ ____ 22. Information about science careers is included as part of each unit.

Comments:

C. Curriculum Evaluation

O I

____ ____ 1. The science education curriculum plan in our school is evaluated and modifications are made in it by a science curriculum committee periodically.

____ ____ 2. When modifications are made in the science education curriculum plan, the educational advantages to be gained by the changes are specified.

____ ____ 3. Students are asked their opinion of the effectiveness of instructional materials and activities used in science.

____ ____ 4. Teachers keep records of activities in science that both work and don't work and their reasons.

____ ____ 5. The assessment framework includes performance measures in science (appropriate to age, grade, and experience levels), e.g., using scientific equipment and measuring instruments, making and interpreting observations, classifying objects, recording information from graphs and charts, placing information in graphs and charts, estimating, predicting, and interpreting information.

____ ____ 6. Evaluation procedures are consistent with science objectives.

____ ____ 7. A locally developed, multiple choice, criterion-referenced test is administered late in the school year to sixth-grade students. It covers the processes and content that students have covered in grades 3-6. The test is used to improve the quality of the program.

O I

____ ____ 8. At the end of instructional units in science, students exhibit proficiency on measures that are consistent with the objectives.

____ ____ 9. Each year, parents are asked for their comments about the science education program.

____ ____ 10. Students suggest ways in which their work in science is to be evaluated.

____ ____ 11. Students and parents know how they are being evaluated in science.

____ ____ 12. Attempts are made to assess student attitudes about science.

____ ____ 13. An alternative grading system has been developed for science that is consistent with an activity-centered program. Teachers, parents, and students understand it.

____ ____ 14. Valid means, e.g., standardized tests, are used to identify students with special talent and interest in science.

____ ____ 15. Students who do well in science are encouraged to participate in extracurricular science activities if available.

____ ____ 16. Periodically, the elementary science education program is evaluated by someone outside the school/school system, e.g., by the state science consultant, the science coordinator from another district, or by a college faculty member.

____ ____ 17. Periodic reports about the science education program are made to the Board of Education.

Comments:

SECONDARY, 7-12

A. Curriculum Planning

O I

____ ____ 1. Our school has a grade 7-12 curriculum document which specifies long-range goals and short-term objectives for each course of study.

O | I

____ ____ 2. The grade 7-12 curriculum document specifies and describes the science experiences for each course of study. The plan clearly specifies science requirements and electives.

____ ____ 3. The curriculum plan clearly lists concepts, skills, scientific attitudes, and attitudes toward science to be developed by students.

____ ____ 4. The curriculum plan clearly lists concepts and skills that should be fostered in students. About attitudes, it says that students should develop their own personal preferences and attitudes toward science.

____ ____ 5. The development of the curriculum plan included a full range of stakeholders: teachers, parents, students, administrators, and others who are accountable for its implementation, maintenance, and evaluation.

____ ____ 6. Local curriculum guidelines have been developed. Secondary teachers were involved in the development of these guidelines.

____ ____ 7. The science curriculum plan is consistent with the Minnesota Department of Education goals and subgoals of public education in the State of Minnesota. (The learner outcomes in science are subgoals.)

____ ____ 8. The science curriculum plan specifies the amount of time that should be spent on science on a daily or weekly basis. The weekly amount of time for science means for students in grades 7-12.

____ ____ 9. The science plan states reasons why students take science in this school/school district.

____ ____ 10. The plan includes a laboratory requirement for all science courses.

____ ____ 11. The curriculum plan clearly specifies what students need to know in science, how science should be taught, and how the curriculum is to be structured.

Comments:

B. Classroom

O I

____ ____ 1. Materials for general classes are different from, rather than "watered-down" versions of, the objectives for academic classes.

____ ____ 2. Ideas and activities from major national science curriculum materials, e.g., National Science Foundation-sponsored materials or reports, e.g., Project Synthesis, are used to plan instruction.

____ ____ 3. The curriculum is designed to help students organize isolated concepts into meaningful relationships.

____ ____ 4. Curriculum experiences help students identify and cope with the influence of science and technology on their lives.

____ ____ 5. The curriculum helps students learn how to cope with expository texts and develop skills to understand dense prose in order that they may become independent learners.

____ ____ 6. Science curriculum learning experiences take into account the intellectual, emotional, and social development of students.

____ ____ 7. The science program helps students develop the ability to act as responsible, informed decision makers who can deal with science- related issues.

____ ____ 8. The science courses are organized to help students learn and understand concepts and skills for future science instruction beyond high school.

____ ____ 9. The curriculum is designed to help all students acquire a sense of the scientific and technological aspects of many kinds of work.

____ ____ 10. The textbook is the curriculum, i.e., the dominant science experiences are a text-and-lecture approach and reliance on text materials.

____ ____ 11. The curriculum provides opportunities for students to design their own experiments.

____ ____ 12. Curriculum experiences promote the development of greater skills in observing, classifying, communicating, reasoning, hypothesizing, inferring, designing investigations and experiments, collecting and analyzing data, drawing conclusions, and making generalizations.

____ ____ 13. The curriculum provides opportunities to extend learning experiences beyond the school walls and school hours.

____ ____ 14. Students become familiar with the usefulness of integrating technologies (calculators, computers, television) with experiences in science.

O I

____ ____ 15. The curriculum emphasizes growth in problem solving and decision making abilities.

____ ____ 16. For each course, the curriculum offers at least two different levels of science to meet the needs of students of different abilities.

____ ____ 17. The curriculum has a double emphasis—the development of reasoning and the proper formation of concepts.

____ ____ 18. In science courses, a conscious effort is made to cite women and minority persons as exemplars when discussing careers in science and technology.

____ ____ 19. Special learning activities have been designed that provide background, the learning of basic concepts and necessary laboratory skills are provided so that students can conduct meaningful inquiries in science.

____ ____ 20. Primary program materials emphasize the concepts/processes and values of science.

____ ____ 21. Instructional materials for laboratory work require students to use the processes in inquiry rather than a "cookbook" approach.

____ ____ 22. Homework is designed to give students an opportunity to review materials they have learned in class and to apply newly acquired concepts and reasoning skills to different situations.

____ ____ 23. Students are asked to make predictions and then are asked how they arrived at those predictions.

Comments:

C. Curriculum Evaluation

O I

____ ____ 1. The science education curriculum plan in our school is evaluated and modifications made in it periodically by a science curriculum committee.

____ ____ 2. When modifications are made in the science education curriculum plan, the educational advantages to be gained by the changes are specified.

O I

____ ____ 3. Students are asked their opinion of the effectiveness of instructional materials and activities used in science.

____ ____ 4. Each year, parents are asked for their comments about the science education program.

____ ____ 5. Students know how they are being evaluated in science.

____ ____ 6. Attempts are made to assess student attitudes about science.

____ ____ 7. Periodically, the secondary science education program is evaluated by someone outside the school/school system, e.g., by the state science consultant, the science coordinator from another district, or by a college faculty member.

____ ____ 8. Periodic reports about the science education program are made to the Board of Education.

____ ____ 9. Evaluation of students includes essay questions, lab reports, lab practicals (tests of students' ability to use lab equipment and process skills), library research projects, lab or field research projects.

____ ____ 10. Evaluation procedures are consistent with science objectives.

____ ____ 11. Standardized tests are used to measure student achievement in science.

____ ____ 12. Our tests require only a small amount of memorized factual material. Emphasis is on the correct use and interpretation of information.

____ ____ 13. Students who demonstrate talent and interest in science are encouraged to take more than the required number of science courses.

____ ____ 14. Both the standardized tests and teacher-constructed tests evaluate the processes and values of science as well as the content.

____ ____ 15. Students are asked to demonstrate the following abilities: using measuring instruments; estimating physical quantities; reading information from graphs, tables, and charts; representing information as graphs, tables, and charts; observing in a scientific way; interpreting presented information; planning investigations; and performing investigations.

____ ____ 16. Test taking skills are integrated through the ongoing science curriculum.

____ ____ 17. Periodically, a representative sample of high school graduates are surveyed to learn how the science program has served them and to ask for their suggestions and criticisms.

O I

____ ____ 18. End-of-course testing using instruments constructed by individual teachers.

____ ____ 19. End-of-course testing makes use of instruments developed by all teachers in a particular discipline.

____ ____ 20. Students are asked about their attitudes and values toward science, e.g., are science classes useful and enjoyable? Are they interested in pursuing a career in science? Do science related societal problems affect them, and if so, what can they do about them? Is what they learn in science class applicable to out-of- school activities? Has science improved our lives? At what level should controversial research topics be funded or pursued?

Comments:

ELEMENTARY AND SECONDARY, K-12

O I

____ ____ 1. There is a K-12 curriculum document, designed by a K-12 curriculum committee, that clearly defines what is to be taught at each grade level. It is developmentally based, identifies learner outcomes, and provides for periodic evaluation and updating.

____ ____ 2. The Board of Education receives periodic briefings on the status of the science program.

____ ____ 3. The development of the science program is influenced by research findings, current trends in science education, assessment of progress in science education (state and national), outside specialists in science education, national curriculum development projects, etc.

____ ____ 4. Periodically, e.g., every five years, the curriculum for each content area and/or grade level K-12 is reviewed by an external audit team. The observations and recommendations of this team are used by the K-12 curriculum committee to make decisions about the science education program.

____ ____ 5. The results of this external evaluation are communicated to the science faculty and are used in considering and making program changes.

O I

____ ____ 6. The science curriculum is coordinated from grade to grade.

____ ____ 7. Enrichment activities, e.g., individualized learning materials, are available for students of all abilities.

____ ____ 8. The science program consists of four interdependent parts: knowledge or knowing (e.g., What do I Know? What is the evidence?), implications for action (e.g., What do I infer? What can I do with what I know? What are other possible interpretations?), prediction of consequences (e.g., What would happen if...?), and the analysis of values (Do I care? Does anyone care?).

____ ____ 9. There are opportunities for students and teachers to have a voice in the science program and classroom activities.

____ ____ 10. The science program has been adapted to take advantage of particular local needs, conditions, and resources.

____ ____ 11. Concepts are encountered repeatedly throughout and across the curriculum.

____ ____ 12. Our school offers different levels of science instruction to meet the needs of students of different abilities.

____ ____ 13. The instructional materials teach concepts through the use of the learning cycle, i.e., *concept exploration,* in which students explore a concept, discuss observations and ask questions using preselected science objectives or systems; *concept explanation,* in which students are introduced to the concept used to explain what they have explored; and *concept application,* in which students may discover new uses for the concept and application in other situations.

____ ____ 14. Special education students are mainstreamed into regular science classes.

____ ____ 15. Suitable curriculum activities, materials, and instructional strategies have been developed for mainstreamed special education students.

____ ____ 16. Gifted students are provided with challenging materials and independent activities above and beyond the regular class materials.

____ ____ 17. The curriculum contributes to an understanding of the nature, potential and limitations of science, e.g., the natural world (or universe) in intelligible, causal, and not capricious in nature.

____ ____ 18. The curriculum chosen for study through school contributes substantially to understanding the nature of the subject area of science.

O I

____ ____ 19. The curriculum is personally relevant and applicable to the individual's well being, understanding of self, and quality of life.

____ ____ 20. The curriculum is useful in potential cause perception.

____ ____ 21. The curriculum contributes to social decision making with particular emphasis on science-technology-society-based issues.

____ ____ 22. Girls and minority students are encouraged to continue with science throughout their schooling.

____ ____ 23. The curriculum plan clearly describes the education beliefs and assumptions of those responsible for science instruction.

____ ____ 24. The curriculum plan describes why students should study science.

____ ____ 25. The instructional objectives in science are communicated to students and parents.

____ ____ 26. In our science program, we have decided what kind of science education is most appropriate for all our students and for what reasons.

Comments:

Overview

This section is divided into three parts: 1) Elementary, K-6, 2) Secondary, 7-12, and 3) Elementary and Secondary, K-12. The first part is to be completed by the elementary curriculum committee, the second part by the secondary curriculum committee, and the third part by both committees. There are two subsections in each part: A) Facilities; and B) Laboratory Safety.

Directions

1. In the blanks provided in front of each item *or* on the matrix provided, indicate whether the item OUGHT (O) to be achieved and whether it IS (I) achieved in your school/district. Use the rating scales described in "A User's Guide to a Matrix Assessment" (p.____). If you use the matrix, be sure to label and number the items.

2. Review and discuss your individual responses with another person, then in groups of four, eight, and so on until the entire group has reached agreement on the statements. At each step, you can add to the list of statements, combine, modify, or omit statements. The large matrix provided may be especially useful as the group becomes larger.

3. The space under the Comments heading is to be used to describe additional information needed, to clarify or amplify items in the checklist, to explain judgments and ratings, questions raised, and most importantly, evaluative comments and implications for the science education curriculum/program in your school.

ELEMENTARY, K-6

A. Facilities

O I

____ ____ 1. Our classrooms are equipped with running water, sinks, and sufficient electrical outlets.

____ ____ 2. Our classrooms have adequate storage areas for science equipment and materials.

____ ____ 3. There is an "outdoor classroom," an environmental education area on the school grounds that can be used for nature study, environmental science investigations, garden projects, etc.

Comments:

B. Laboratory (Classroom) Safety

O	I	
____	____	1. Teachers instruct the students in safety procedures at the beginning and throughout the year.
____	____	2. All safety equipment is checked each year and replaced as necessary.
____	____	3. Students are tested about safety apparatus and procedures from the beginning of the year.
____	____	4. Provision is made for children to have washing materials available when chemicals are used.
____	____	5. Plastics are substituted for glassware in all of our laboratory work.
____	____	6. Children are instructed not to taste anything during a science activity.
____	____	7. When using a heat source, students are instructed to maintain a clear working area, to button and/or roll up loose sleeves, and to tie back long hair.
____	____	8. When students are involved in activities which use a heat source, a bucket marked "FIRE" is placed in an accessible place in the classroom. It is filled with water or sand.
____	____	9. When students are involved in activities which use a heat source and chemicals, students and teachers wear safety goggles.
____	____	10. Strong acids and alkalies are not used in our program.

Comments:

SECONDARY, 7-12

A. Facilities

O	I	
____	____	1. Science classrooms and laboratories are adequately equipped and maintained for the conduct of our program.

O I

____ ____ 2. There is sufficient space and laboratory accommodations so that the entire class can participate in laboratory work.

____ ____ 3. There is sufficient space so that students involved in research projects, e.g., for science fairs, have a safe, secure, and undisturbed place to work.

____ ____ 4. Separate storage areas for science equipment and supplies are available.

____ ____ 5. There is an "outdoor classroom," an environmental education area on the school grounds that can be used for ecology investigations.

____ ____ 6. Science classrooms and laboratories are not used by other classes or as study halls.

____ ____ 7. A greenhouse is available.

____ ____ 8. There are adequate and appropriate facilities for housing animals that pay attention to the environmental, space, and behavioral needs of animals.

Comments:

B. Laboratory Safety

O I

____ ____ 1. A complete, up-to-date inventory of all chemicals is maintained. It includes quantity and date of purchase, as well as other pertinent information, e.g., excess or unused chemicals, substances that are hazardous, and chemicals requiring special storage procedures.

____ ____ 2. When working with chemicals, safety goggles are mandatory for students, teachers, and classroom visitors.

____ ____ 3. Any poisonous substances are stored in a secure (locked) area or a poisons cabinet.

____ ____ 4. All reagents are clearly labeled by formula and name. In addition, appropriate warnings are included on the label: flammable, allergen, volatile, acid, base, irritant, toxic, etc.

O	I	
____	____	5. Students are routinely instructed on how to "turn-off" an experiment safely at any stage, e.g., during a fire drill in the middle of a laboratory session.
____	____	6. Shielding for both teacher and students is provided for demonstrations involving the possible explosion or implosion of apparatus or the possibility of injury due to chemical splattering.
____	____	7. Adequate supervision of the laboratory is provided at all times.
____	____	8. Chemicals are purchased in quantities such that they will be used in a reasonable and safe period of time. Chemicals are dated when received.
____	____	9. Smoke detectors have been installed in the chemical stores area.
____	____	10. Laboratory rules are prominently posted in all laboratories.
____	____	11. Electrical outlets in the science laboratories are properly grounded.
____	____	12. Chemicals are not stored in classrooms.
____	____	13. Master cut-off controls for water, gas, and electricity are available in a central area.
____	____	14. Chemicals are stored in compatible families, *not* alphabetically.
____	____	15. Science teachers have completed appropriate first aid training.
____	____	16. There are clearly labeled fire extinguishers for all classes of fires.
____	____	17. Science teachers have received training in how to use a hand-held fire extinguisher.
____	____	18. The science department has up-to-date resource books on school science safety and manuals listing potentially hazardous substances.
____	____	19. No food is allowed or stored in the laboratory, including especially the laboratory refrigerator.
____	____	20. A student safety contract that details the safety requirements and expectations of the school and the relationship of these policies to the students is required. Students are expected to read and sign the contract which signifies that they have been instructed in the requirements for safety in the school laboratory.
____	____	21. Students are required to take and pass a safety test before they can participate in laboratory work.
____	____	22. Safety-related questions are included on quizzes.

O I

____ ____ 23. Chemistry laboratories are adequately ventilated and equipped with fume hoods.

____ ____ 24. Fume hoods are not used to store chemicals.

____ ____ 25. Safer alternatives that will accomplish the same purpose have been substituted for laboratory experiments involving toxic or otherwise hazardous or potentially hazardous substances.

____ ____ 26. Some experiments for which there is not a safe alternative have been eliminated from our program.

____ ____ 27. Films or videotapes of dangerous chemical reactions are shown as a substitute for certain chemical reactions.

____ ____ 28. Mercury thermometers have been replaced with non-mercury types.

____ ____ 29. Safety equipment is available in sufficient quantities for students.

____ ____ 30. Safety equipment is provided in the science laboratory, e.g., eye wash solutions, safety shower, fire blanket, fire extinguishers, broken glass container, sand bucket on the floor.

____ ____ 31. When experiments are introduced, students review any necessary safety training related to the work.

____ ____ 32. Whenever new equipment is introduced to students, appropriate safety rules are discussed and reviewed.

____ ____ 33. The science teachers have participated in a workshop on chemical and laboratory safety.

____ ____ 34. The use of contact lenses in the laboratory is actively discouraged.

____ ____ 35. The science department has developed a letter to parents informing them of potential hazards, safety training and procedures, and the need for their children to obey rules.

____ ____ 36. Each year (or periodically), a knowledgeable member of the science staff is designated as the manager of chemical storage areas.

____ ____ 37. Acids are stored away from other items in a dedicated storage area, preferably a locked cabinet. Nitric acid is stored separately unless there is a special compartment in the cabinet.

____ ____ 38. Flammables are stored in a dedicated locked and vented cabinet.

____ ____ 39. The gas/air/water outlets are both labeled *and* distinguishable one from another.

Comments:

ELEMENTARY AND SECONDARY, K-12

A. Facilities

O I

____ ____ 1. Overall, the science facilities—classrooms, laboratories, and special spaces/places—are well suited for our science program. They have adequate storage areas, are appropriately equipped, and are maintained on a routine basis.

Comments:

B. Laboratory Safety

O I

____ ____ 1. The science department and science program is in compliance with Minnesota's Employee Right-to-Know Law. This includes: 1) setting up an initial, pre-assignment, and annual training and information program; 2) an inventory of hazardous substances and agents in the workplace; 3) identification of employees who may be exposed; 4) establishing a written information system; and 5) maintaining material safety data sheets (MSDS) and information systems on harmful physical agents, and infectious agents; a labeling system for hazardous substances.

O	I	
____	____	2. A list of national, state, and local emergency telephone numbers is posted near the teacher's desk or work area. Key numbers include: fire department, physicians or hospital emergency room, poison control center, police, and rescue squad.
____	____	3. The school/school district has a safety policy which is approved by the department, principal, and the central administration.
____	____	4. The school/school district has an accident procedure and a process for recording and reporting an accident.
____	____	5. A safety audit of all science facilities is conducted each year.
____	____	6. All safety hazards are reported to the principal in writing.
____	____	7. A plan has been developed and is followed for the safe removal of excess and/or old and/or hazardous chemicals.
____	____	8. *General* safety procedures and guidelines have been developed for the science laboratory.
____	____	9. *Specific* safety procedures and guidelines have been developed for working with microorganisms, plants and animals, chemicals, electricity, and lasers.
____	____	10. Teachers are familiar with the code of practice on using animals in, the classroom published by the National Science Teachers Association.
____	____	11. Alcohol burners are not used in our school.
____	____	12. The risk of all experiments and demonstrations have been taken into account. The written assessment includes: ability level of students, general safety features of the laboratory/classroom, hazards involved with the experiment, provisions for disposal of substances produced, toxicity level of products and reactants, documentation, and whether a safer alternative is available.
____	____	13. First aid kits are available in all science classrooms and laboratories.

Comments:

SUPPORT FOR SCIENCE EDUCATION

Overview

This section is divided into three parts: 1) Elementary, K-6, 2) Secondary, 7-12, and 3) Elementary and Secondary, K-12. The first part is to be completed by the elementary curriculum committee, the second part by the secondary curriculum committee, and the third part by both committees. There are two subsections in each part: A) Budget, and B) Administrative Support.

Directions

1. In the blanks provided in front of each item *or* on the matrix provided, indicate whether the item OUGHT (O) to be achieved and whether it IS (I) achieved in your school/district. Use the rating scales described in "A User's Guide to a Matrix Assessment" (p.____). If you use the matrix, be sure to label and number the items.

2. Review and discuss your individual responses with another person, then in groups of four, eight, and so on until the entire group has reached agreement on the statements. At each step you can add to the list of statements, combine, modify, or omit statements. The large matrix provided may be especially useful as the group becomes larger.

3. The space under the Comments heading is to be used to describe additional information needed, to clarify or amplify items in the checklist, to explain judgment and ratings, questions raised, and most importantly, evaluative comments and implications for the science education curriculum/program in your school.

ELEMENTARY, K-6

A. Budget

O	I	
____	____	1. Our budget is sufficient to allow the purchase of enough supplies, materials, and equipment needed for an activity-based science program.
____	____	2. Teachers in our school are involved in the development of the science budget.
____	____	3. There are petty cash funds or teachers are reimbursed when it is necessary to purchase special materials for science throughout the school year.
____	____	4. There is a budget sufficient for at least one science-related field trip each year at each grade level.
____	____	5. The staff knows how much it costs to educate a child currently in science.
____	____	6. There is a budget for support of extracurricular activities, e.g., participation in science fairs.

Comments:

B. Administrative Support

O	I	
____	____	1. The procedure for ordering materials and equipment is efficient and sufficiently flexible.
____	____	2. Authorization to purchase supplies and materials locally is easily obtained when there is a justifiable reason for the request.
____	____	3. The school/school district employs an elementary science supervisor/consultant.
____	____	4. The school/school district employs a science resource teacher.

Comments:

SECONDARY, 7-12

A. Budget

O	I	
____	____	1. The science budget is sufficient to allow the purchase of all supplies and materials that are needed for a laboratory, inquiry- based program.
____	____	2. The science department is involved in the development of the budget.
____	____	3. The science department has developed a mutually agreed upon list of major purchases indicating their priorities.
____	____	4. There are petty cash funds or teachers are reimbursed when it is necessary to purchase special materials for science throughout the school year.

O I

____ ____ 5. There is a budget for maintaining equipment on a regular basis.

____ ____ 6. The staff knows how much it costs to educate a child currently in science.

____ ____ 7. There is a budget sufficient for at least one science-related field trip each year in each science course.

____ ____ 8. There is a budget for support of extracurricular activities, e.g., participation in the Science Olympics, science clubs, and science fairs.

____ ____ 9. The science department is current and active in seeking available local, state, and federal sources of funds.

Comments:

B. Administrative Support

O I

____ ____ 1. The procedure for ordering materials and equipment is efficient and sufficiently flexible.

____ ____ 2. Authorization to purchase supplies and materials locally is easily obtained when there is a justifiable reason for the request.

____ ____ 3. There is a science department chair.

____ ____ 4. The school/school district employs a full-time secondary science supervisor.

Comments:

ELEMENTARY AND SECONDARY, K-12

A. Budget

O	I	
____	____	1. The budget for science is a line item in the total school budget.
____	____	2. During period of financial stress, teachers in the science program are asked to make recommendations for plans to make immediate cuts.
____	____	3. If a protracted period of financial stress is projected, teachers in the science program are asked for their recommendations and their implications.
____	____	4. In establishing the budget for science, K-12, a committee of elementary and high school teachers use a weighted formula to prioritize the needs and decide how the money will be spent.

Comments:

B. Administrative Support

O	I	
____	____	1. There is administration support in terms of time, money, and inservice for the development of a science program that meets the needs of all students, e.g., gifted, special needs and, in high school, so-called academic and non-academic students.
____	____	2. Teachers are involved in the development of inservice programs.
____	____	3. Release time is provided for teachers to attend local, regional, state, or national conferences or seminars or to visit outstanding science programs in other schools.
____	____	4. There is a fair and reasonable rotating schedule for staff members who want to attend local, regional, state, or national science education activities.
____	____	5. The school covers all or a significant portion of a teacher's expenses to attend professional activities.
____	____	6. The school/school district employs a K-12 science supervisor/ consultant.

O	I	
____	____	7. The school/school district employs a K-12 curriculum supervisor/ consultant who spends 25 percent of her or his time on science.
____	____	8. The school/school district employs a K-12 science resource teacher.
____	____	9. The administration actively supports the development of grant proposals from local, state, and national sources for the development of curriculum and science program innovations and improvements.
____	____	10. The administration actively supports the formation of "local alliances" — new partnerships and action groups of scientists, engineers, and science educators joined with representatives from business, labor, and community service groups in support of science and technology education.
____	____	11. There is a broad-based community supported equipment loan and repair program which is used to support the science program that includes temporary as well as long-term loan arrangements. It includes, where necessary, instruction on how to use the equipment (and sometimes, equipment that may already be in the school stockroom).
____	____	12. The administration regularly provides time and opportunity for K-12 planning and curriculum development which involves a variety of teachers and others throughout the school district.
____	____	13. The K-12 budget for science is realistic and adequate for the science program.
____	____	14. There is a budget for honoraria to defer some of the expenses for consultants, workshop leaders, and others.
____	____	15. There is an active ongoing sabbatic leave program that pays teachers either their full salary or partial salary.
____	____	16. Help and support—money, time, and services-is given teachers *after* planning and initial training over a fairly long time.
____	____	17. There are stipends for teachers to pay for work beyond the school day or in the summer.

Comments:

PERCEPTIONS

Overview

To broaden your view of the assessment of the science education program, you may need to sample the opinion of students and parents about selected dimensions. You will find potential items for consideration listed below. The Student and Parent Categories are divided into two subsections: Elementary; K-6 and Secondary, 7-12. Some practical considerations are listed below.

- Review these lists carefully before you use them. You may want to add, delete, modify items, and to further tailor the assessment to your needs. The suggested items are neither complete or appropriate for all situations. You may further find it useful to differentiate the items, e.g., junior high school and senior high school. When you have reached agreement on the items, teachers should answer the items. This will provide you with useful comparative information on perceptions of characteristics of the science education program.

- Use representative committees of students and parents to make the assessments. For elementary programs, the assessment items, as written, are most appropriate for sixth-grade students. Their responses should be based on and reflect their experiences for the entire K-6 science education program.

- Remember, this is a twofold assessment process. The first category is perceived desirability — **OUGHT** — and the perceived achievement — **IS** — for each variable. You can have students place numbers next to the items or give them numbered small matrix sheets and have students and parents place their responses directly on the matrices.

- When you are finished with both assessments—the teacher assessments and the student/ parent assessments of the variables—prepare a summary matrix or overlays.

- In addition to preparing a master matrix of the data, you may find it very valuable to have a serious discussion with respondents about the responses and the science education program.

Directions

1. In the blanks provided in front of each item *or* on the matrix sheet provided, indicate whether the item OUGHT (O) to be achieved and whether it IS (I) achieved in your school/district. The rating scales to be used are as follows:

__OUGHT__ to be achieved in the Science Education Program

4—of utmost value
3—of significant value
2—of medium value
1—of insignificant value
– 1—of negative value

IS achieved in the Science Education Program

4—extremely high level
3—above average
2—on the average
1—less than average
– 1—avoided or non-existent

2. At the end of the questionnaire, you will find a space for comments. Please use it to make additional observations about the science education program, describe additional characteristics of a quality science education program, or to explain judgments and ratings.

STUDENTS

A. Elementary, K-6

O I

____ ____ 1. Teachers appear to enjoy teaching science.

____ ____ 2. As a part of the science program, I have to show that I know how to use scientific equipment and instruments.

____ ____ 3. We are regularly asked to make hypotheses.

____ ____ 4. We identify the variables in the experiments we do.

____ ____ 5. We collect, organize, and record data in tables.

____ ____ 6. We use histograms (or graphs) to show results.

____ ____ 7. We draw tentative conclusions (make inferences) from histograms (or graphs).

____ ____ 8. We work in pairs or small groups in science classes.

____ ____ 9. Teachers frequently ask us to support our answers with evidence.

____ ____ 10. There are enough supplies and pieces of science equipment to go around.

____ ____ 11. There are enough textbooks or required reading materials for each student to have a copy.

____ ____ 12. We take at least one science field trip each year.

____ ____ 13. In science classes we become familiar with science-related careers.

____ ____ 14. In science, at least once a week, we do a laboratory activity.

____ ____ 15. We are given opportunities in science classes to handle the materials of science, e.g., equipment and apparatus.

O I

____ ____ 16. Teachers ask us what we think about what we study and which kinds of science activity we prefer.

____ ____ 17. At least once per year, we are given an opportunity to pursue our own investigations in science.

____ ____ 18. Most of the time in science is spent in discussion, reading the textbook, and doing worksheets.

Comments:

B. Secondary, 7-12

O	I	
____	____	1. As part of our science courses we are taught safety procedures both at the beginning and throughout the school year.
____	____	2. Students are encouraged to take more than the minimum number of science courses.
____	____	3. The science rooms are organized so that when I need single pieces of equipment I know where to find them.
____	____	4. As part of our grade, we must demonstrate the ability to use the equipment and instruments of science.
____	____	5. We are required to make hypotheses in our science class.
____	____	6. We are required to be able to put information into tables and graphs.
____	____	7. We are required to be able to read information from tables and graphs.
____	____	8. We are required to observe similarities and differences between two or more events.
____	____	9. We are required to collect information we observe and to find patterns in or explain our observations.
____	____	10. Our tests and quizzes include not only questions about factual information but also questions that ask us to interpret information.
____	____	11. At least once a year (or once per course), under the supervision of our teacher, we design our own experiment.
____	____	12. We are routinely asked to make predictions about events.
____	____	13. At least once in each science course we are asked to design an investigation.
____	____	14. Occasionally, when we are asked what we would do to obtain better data from an experiment, we repeat the experiment.
____	____	15. Teachers place a lot of emphasis on ideas and how they are related to each other.
____	____	16. There are opportunities to use computers in science class, e.g., construction of graphs and databases; monitoring measurements; storing, retrieving, and organizing date; as a tool for modeling and simulation; and games.
____	____	17. The science teachers enjoy teaching science.

O I

____ ____ 18. In our science classes, information and activities are related to science in our personal lives, careers in science and technology, and societal problems related to science and technology.

____ ____ 19. We take at least one science-related field trip in each science course.

____ ____ 20. Teachers ask students to justify and explain their ideas.

____ ____ 21. Teachers allow time after asking a question so that students have a chance to think about the answer.

____ ____ 22. Our science teachers encourage cooperation, e.g., students work in pairs/small groups, students respond to comments and questions of other students, students help each other analyze and solve problems.

____ ____ 23. Most of the time, science teachers ask both single-answer questions as frequently as open-ended, thought provoking questions.

Comments:

PARENTS

A. Elementary, K-6

O I

____ ____ 1. The science instruction offered by the school is appropriate.

____ ____ 2. Throughout elementary school, the science topics studied appear to be well balanced among the life sciences, earth sciences, and physical sciences.

____ ____ 3. Children's science experiences are consistent with the experimental nature of science, i.e., the science program provides hands-on experiences with real objects.

____ ____ 4. In the elementary science program, children are introduced to fundamental concepts of science and given time to discover and understand their meaning.

____ ____ 5. Children are given sufficient direct experiences to become confident in making their own observations and raising their own questions.

O I

____ ____ 6. Children engage in discussions of their ideas and observations.

____ ____ 7. Children apply what they learn in science class to everyday, familiar objects and events.

____ ____ 8. Students are evaluated in science on both knowledge and skills (observing, classifying, measuring, predicting, inferring, recording and analyzing data, developing and testing hypotheses, designing and conducting experiments).

____ ____ 9. The school holds programs to assist parents with helping their children in science.

____ ____ 10. The science program has been modified to be of maximum benefit to the academically gifted and to children with learning difficulties.

____ ____ 11. Parents or other community members are asked to assist teachers as laboratory aides during science lessons, or for extracurricular activities, e.g., science fair projects, after school science programs.

____ ____ 12. The science learned by children — knowledge and activities — is appropriate to the age, mental ability, and skills of the students.

____ ____ 13. My child comments about how much he or she enjoys science class.

____ ____ 14. Teachers provide opportunities for students to ask questions about science and then to find answers to these questions.

Comments:

B. Secondary, 7-12

O I

____ ____ 1. The science program encourages students to *think* like scientists rather than memorize a lot of unrelated facts.

____ ____ 2. There is an emphasis in science on understanding concepts and in learning how they are related to one another.

____ ____ 3. The science program has been modified to be of maximum benefit to the academically gifted and to children with learning difficulties.

O	I	
_____	_____	4. In general, my child is satisfied with what she or he learns and does in science class.
_____	_____	5. The science education program provides students with information about careers in technology and science-related fields.
_____	_____	6. The science teachers are both enthusiastic and knowledgeable.
_____	_____	7. The science teachers place a great deal of emphasis on scientific reasoning.
_____	_____	8. In science, students explore some of the science and technology problems related to society.
_____	_____	9. Science courses are related to practical, personal concerns of students.
_____	_____	10. Students who do well in science are encouraged to take more than the required number of science courses.
_____	_____	11. Laboratory experiences are an important part of science instruction.
_____	_____	12. Our school has established a science advisory committee which includes scientists, community leaders, parents, and teachers.
_____	_____	13. Community members, students, and parents are all involved in major decisions affecting the science program such as textbook adoptions, course modifications, and graduation requirements.
_____	_____	14. My child's school holds programs to assist parents with helping their children in science.
_____	_____	15. Students are evaluated in science on what they know as well as their ability to use the skills and instruments of science.
_____	_____	16. Parents are informed about the science program, e.g., special activities, contemplated changes, textbook adoption, innovative programs.
_____	_____	17. I have a clear understanding of what is expected of my children in science classes.
_____	_____	18. I have been informed about acceptable laboratory safety practices and training my children have received to prepare them for work in the laboratory.
_____	_____	19. I have examined a student laboratory safety contract.
_____	_____	20. The science program integrates intellectual skills and practical hands-on experiences with the materials and instruments of science.

O	I	
____	____	21. Courses in high school science emphasize learning concepts and skills for academic study beyond high school.
____	____	22. In science classes, students are expected to back up claims by evidence.
____	____	23. Science teachers give adequate reasons for accepting or rejecting a student's statement or response.
____	____	24. In discussions, suggestions, questions, and statements by students are honored.
____	____	25. The science program actively encourages all students to pursue careers in science, e.g., learning units and activities explore science-related careers in ways that show the contributions of females, minorities, and the disabled.

Comments:

Overview

Learner outcomes are carefully selected samples of knowledge statements considered as some essential learning outcomes for students.Learner outcomes are statements of expectations for science education. The outcomes stated below were developed and categorized by a team of Minnesota science teachers and curriculum specialists. They are intended as a guide to aid in assessment and evaluation—a status check on where the science program is, review, and local school district curriculum planning. This includes selection of goals/objectives, determination of the scope and sequence of the science program, implementation considerations—the means to achieve science education goals and objectives, evaluation strategies, and a written plan.

The list of learner outcome examples is neither exhaustive nor prescriptive. It is understood that the scope of expectations for science is plentiful. We have selectively focused on a few important ideas that encompass elementary and secondary school science. The focus and debate of our group has been on the fundamental rather than what is nice but secondary. Users of this guide will no doubt have valid modifications, preferences, and priorities of their own.

This de-emphasis, if you will, of factual knowledge in science to that knowledge which is considered essential, is consistent with other themes in this guide. We live today in a society that is overloaded with information. It is provided, if not always effectively, then consistently. Furthermore, the expansion of scholarly knowledge in science has changed the nature of the field. For example, it has been reported by Fensham and Kornhauser (1982 Sixth International Conference on Chemical Education, M. Gardner (Ed), University of Maryland), that the first million entries in chemical abstracts took 32 years to accummulate while the second million occurred in only two years. After choosing content, a major task in science education today is in helping young, inexperienced learners to learn to use it. We believe this is best done when, to use the words of Arnold Arons, the science curriculum "is experientially rooted and not too rapidly paced." In other words, it takes time to use science content in order to know it.

The translation of goals and objectives for science education into specific grade level and subject matter or curriculum content is a local school district affair. It should include broad representation from the science educators in that school or system as well as, where appropriate, other "stakeholders" who have views about the school curriculum and who desire to influence decisions about it. "Stakes" in the science curriculum are held not only by science teachers but also by parents, school administrators, as well as other groups and institutions in the community.

It is suggested that, as a part of a local planning process, the science learner outcomes be very carefully examined. Local schools/school systems are encouraged to select what is good and consistent with their previously stated goals and reject any learner outcome material that is not congruent or to substitute/develop their own science learner outcomes.

Once learner outcomes have been carefully evaluated locally and/or supplemented in a way that is consistent with local broad-range goals, *then* the science education curriculum can be selected, implemented, and evaluated. Evaluation is a process for determining if expectations are being met. This includes, of course, testing students for grading purposes, i.e., focusing on the achievement of student learning outcomes. It also includes program effectiveness, i.e., focusing on the quality of the entire science education program. These kinds of evaluation can be conducted using local criteria, something that is difficult, if not impossible, using commercial standardized materials.

It is obvious that no single sequence of activities will fit all curriculum implementation efforts. On the contrary, a particular sequence of implementation activities will depend on many variables. These include: the level at which the curriculum is to be implemented; the school district's commitment in time and money; assignment of personnel, material resources, and facilities; the ability, willingness, and opportunity of those involved to fully participate; the students to be served and what is known about them; staff experiences and attitudes toward children, education, and science—in fact, all attitudes and rules, explicit or implied, that govern the schools and communities regarding curriculum.

The general purpose of science curriculum improvement is to benefit students. Achievement of this goal will not occur by mandate nor quick action. Since worldview, both individual and collective, determines, or at least influences, the nature of every transaction which takes place during a human activity such as curriculum implementation, the participating staff and others should be aware of the various world views that will influence the identification of issues. What are the problems? Data collection—What are the facts? and the development of options — where do we go from here? It is to be expected that the educational priorities of the individuals and groups involved in the work will be very diverse, and correspondingly, it can be expected that a dogmatic approach to curriculum development will result in a lack of commitment of everyone involved. Ownership and commitment will not be immediate. Like the development of trust, they develop over time and through the work associated with improving the effectiveness of a science education program.

High on any agenda for improving science education programs is the reaching of agreement on the basic outcomes, or expectations or the terminal goals of science education—the list of skills, knowledges, and attitudes to be learned by the student, all finely tuned and interrelated. This is the *what* of science education. What content is important and where, level and/or subject matter area, should it be taught? These considerations lead to the organization of the science curriculum, e.g., the relationship between laboratory and content, a unified approach, a special curriculum, or a strict scope and sequence.

Every course, unit, daily lesson plan, or individual learning experience should be related to the terminal goals of science education. The work is difficult but not an impossible task. Because of differences between individuals, making decisions in the early stages will involve negotiation. You will have to decide whether there will be a vote with a plurality decision, or whether consensus is desired. The overall goal is the establishment and/or maintenance of a new science education curriculum program or a permanent course of study. It is important to reach a decision that is as widely supported as possible, or, at least, not actively opposed.

From the perspective of the discipline, learner outcomes for science education have been subdivided into: 1) Elementary, 2) life science, 3) earth science, 4) physical science, 5) biology, 6) chemistry, and 7) physics. In addition, learner outcomes are also included for these components of science education: 8) Science, Technology, and Society, 9) Science for Personal Needs, 10) Processes of Science Education, and 11) Science Attitudes and Values.

LEARNER OUTCOMES: Instructions

1. A matrix sheet has been provided in order to help you rate each learner outcome from the perspective of your level or science discipline. Initially, you will be asked to look at each outcome, and from the point of view of your level/ discipline assign a number from -1 to 4 in both the **IS** and **OUGHT** columns:

__OUGHT__ to be achieved in the Science Education Program

4—of utmost value
3—of significant value
2—of medium value
1—of insignificant value
– 1—of negative value

__IS__ achieved in the Science Education Program

4—extremely high level
3—above average
2—on the average
1—less than average
– 1—avoided or non-existent

2. The assessment you have just made is based on a discrepancy model: what IS and OUGHT to be. The degree of agreement or discrepancy between IS and OUGHT provides information about the following items, e.g.,

When the ratings for IS are: and ought are:	-1, 2, 3 ,4 1, 2, 3, 4	Agreement. Outcomes being achieved avoiding undesirable outcomes, no changes.
When the ratings for IS are: and OUGHT are:	-1, 1 2, 1	Discrepancy. Outcomes fall short of expectations. You want this to change.
When the ratings for IS are: and OUGHT are:	2, 3, 4 -1, 1	Discrepancy. Too much time and resources spent on outcomes. You want this to change.
When the ratings for IS are: and OUGHT are:	-1, 1 1	Agreement. These are neutral outcomes. Few or no changes.

If you used a matrix to record your evaluations, use the graphical interpretation of the data to assist you in making the following decisions.

a. Grade level/subject. In the row of cells (following pages), use one of the following symbols to indicate the degree a learner outcome should be stressed:

I — *Introduce*	This represents the first time a topic will be presented as a part of a classroom activity.
M — *Maintain*	Review and reinforcement of learner outcomes previously introduced at an earlier level.

E — *Emphasize* This is a learner outcome that is to be stressed in a unit of instruction. It is an outcome of concern and importance in teaching science at a given level or in a particular course of study.

N — Not covered or applicable at this level of instruction or science course.

b. Adoption. In the space that says: ADOPTION YES NO, indicate whether the learner outcome should be adopted. Obviously, this should be done for those outcomes that are not currently a part of the curriculum.

c. For each cluster of outcomes, there is space provided under the heading, Comments, to be used to add learner outcomes or to describe additional information needed, to clarify or amplify items in the checklist, to explain judgments and ratings, questions raised, for any evaluative comments, and implications for the science education curriculum/program in your school. The task force will appreciate and use this information in making final decisions about the selection of outcomes.

LEARNER OUTCOMES
A CHECKLIST

KEY CONCEPTS

O	I		K-3	4-6	Life Science	Earth Science	Physical Science	Biology	Chemistry	Physics
____	____	1. Cause and Effect Adopted: YES NO								
____	____	2. Change Adopted: YES NO								
____	____	3. Cycle Adopted: YES NO								
____	____	4. Energy—Matter Adopted: YES NO								
____	____	5. Equilibrium-Homeostasis Adopted: YES NO								
____	____	6. Fundamental Entities Adopted: YES NO								
____	____	7. Interaction Adopted: YES NO								
____	____	8. Organism Adopted: YES NO								
____	____	9. Probability Adopted: YES NO								
____	____	10. Patterns and Symmetry Adopted: YES NO								
____	____	11. System Adopted: YES NO								

KEY PROCESS SKILLS (THINKING SKILLS)

O	I		K-3	4-6	Life Science	Earth Science	Physical Science	Biology	Chemistry	Physics
____	____	1. Observing Adopted: YES NO								
____	____	2. Inferring Adopted: YES NO								
____	____	3. Classifying Adopted: YES NO								
____	____	4. Measuring Adopted: YES NO								
____	____	5. Using Science and Math Symbols Adopted: YES NO								
____	____	6. Predicting Adopted: YES NO								
____	____	7. Communicating Adopted: YES NO								
____	____	8. Formulating Hypotheses Adopted: YES NO								
____	____	9. Controlling Variables Adopted: YES NO								
____	____	10. Interpreting Data Adopted: YES NO								
____	____	11. Defining Operationally Adopted: YES NO								
____	____	12. Building Scientific Models Adopted: YES NO								

KEY PROCESS SKILLS (THINKING SKILLS)

O	I		K-3	4-6	Life Science	Earth Science	Physical Science	Biology	Chemistry	Physics
____	____	13. Experimenting Adopted: YES NO								
PERSONAL NEEDS										
____	____	1. Personal Needs Adopted: YES NO								
SCIENCE—SOCIETY—TECHNOLOGY										
____	____	1. S/T/S Adopted: YES NO								

GRADING YOUR SCHOOL DISTRICT'S/SCHOOL'S SCIENCE EDUCATION PROGRAM

You have now rated each of the areas you and your task force thought were important. You have not only rated each section individually, but you have combined your group results on one master matrix for each section. As promised, you will by now have noted patterns that emerge as all of the data are gathered. What does that mean? While there is no right way to rate a section, perhaps the method of choice is the simplest.

For each area indicated, assign a letter grade, A, B, C, D, or F, based on your assessment of the science education program in your school. Further grade differentiation can be achieved by adding a plus or minus to the letter grades. The comments should be written in the form of a note to the Committee Chair and/or the Science Department Head and/or the Science Curriculum Consultant.

WHAT IS SCIENCE, WHAT ARE SCIENTISTS?	GRADE
Elementary, K-6	
Secondary, 7-12	

Comments:

SELF-ASSESSMENT ELEMENTS	GRADE
THE SCIENCE EDUCATION CURRICULUM Elementary, K-6	
Curriculum Planning	
Classroom	
Curriculum Evaluation	
Secondary, 7-12	
Curriculum Planning	
Classroom	
Curriculum Evaluation	
Elementary and Secondary, K-12	

SELF-ASSESSMENT ELEMENTS (cont.)

	GRADE
FACILITIES AND LABORATORY SAFETY	
Elementary, K-6	
Facilities	
Laboratory Safety	
Secondary, 7-12	
Facilities	
Laboratory Safety	
Elementary and Secondary, K-12	
Facilities	
Laboratory Safety	
SUPPORT FOR SCIENCE EDUCATION	
Elementary, K-6	
Budget	
Administrative Support	
Secondary, 7-12	
Budget	
Administrative Support	
Elementary and Secondary, K-12	
Budget	
Administrative Support	
PERCEPTIONS	
Students	
Elementary, K-6	
Secondary, 7-12	
Parents	
Elementary, K-6	
Secondary, 7-12	

SELF-ASSESSMENT ELEMENTS (cont.)

	GRADE
SCIENCE EDUCATION AND ME Elementary, K-6	
Secondary, 7-12	

Comments:

INFERENCES BASED ON THE REPORT CARD

SECTION I—It is clear that the strengths of our science program are:

SECTION II—How adequately do classroom procedures reflect the learner outcomes of science education for courses or grade levels? (What do we need to do?)

Section III—In what respect is the science program most in need of improvement?

Section IV—In order of priority, the following steps are recommended to convert these weaknesses into strengths.

Section V—Some implications of these recommendations include:

Section VI—When these recommendations are completely implemented, what would the science program in the school/school district look like, i.e., what are the indicators of quality that a visitor might easily identify?

CHAPTER 3

RATIONALE AND GOALS OF THE DISCIPLINE

Curriculum Issues

A. Introduction

In the opening chapter to *Education in the 80s: Science* (NEA, 1982), Drew Christianson writes that, "What we want most of all in terms of science literacy is an educated public that shows a sense of proportion about the scientific endeavor...What we are looking for, then, is a situation in which lay people demonstrate knowledge of both the potentialities and the limitations of science—what people in less scientific times called wisdom."

The development and achievement of competency is scientific wisdom—scientific laboratory—is at the core of science education in the schools. In many ways, this document is the beginning of one model. It attempts throughout to answer and provide direction for the basic questions of science literacy:

What is science?

What are some concepts in science?

How should students learn science?

What competency and willingness should students have to use scientific or technological information to fully and effectively realize citizenship in a democratic society?

What kinds of science will meet the personal and career needs of students? What can science education contribute to the enlargement of understanding and values?

After all these years, it would seem that the territory of science education should have yielded to exploration and revealed all of its secrets. This is not the case. The territory is complex, its boundaries still unclear, and there are still areas that require detailed mappng. There are disagreements about its geography many interesting trails are left for exploration. Each explorer who has made forays into the interior has shed a different, but useful, light on the nature of science education. The map of tree science education territory still does not specify into one landscape, theory and actual teaching practice.

In this chapter, the forces that should shape the current school science curriculum (that is, content) and instruction (that is, teaching approach) are discussed. It is our hope that you do not find what has been done here detached from "the real world," and that it provides a useful base of operations for your expeditions into the territory of science education.

In the next chapter, the outcomes of science education are listed. While the basis or rationale for science education, helping students become effective thinkers in science, and the goals of science education can, to some extent, be considered separately from the outcomes of science education as they are in this chapter, these materials must be viewed and reviewed separately, together, and from a variety of perspectives. The Learner Outcome Study Group made distinctions, drew boundaries, extracted meaning, and imposed order. Although this was one of the charges, we remained reminded of a profound insight of Kenneth Boulding: "All important distinctions are unclear."

B. What Does It Mean To Talk Of People As If They Are Scientists? What Is Science?

The level of debate concerning the nature of science, its guiding philosophies, history, practices, sociology, limits, and the role that concepts and conceptual schemes play, has dramatically increased, particularly in the last two decades. This large and growing body of work cannot be meaningfully summarized in a way that is short, accurate, or accepted among those who discuss such matters.

In spite of this caveat, and it is an important one, the question is a vital one to ponder. It is a question most science educators have probably been asked. The answer is...well, try it. Ask yourself, your colleagues, and your students what is meant by the term scientific or unscientific or what it means to talk of people as if they are scientists. You will find multiple meanings associated with these notions.

When about 60 ninth graders were asked: "What is science?" they responded:

1. Cold, objective facts that are somehow out there, external of humans, waiting to be discovered (there are lots of facts, too many according to students!)

2. Science has a special way of arriving at the truth, a stepwise method and only this scientific method is used to establish truth (there are considerable arguments about the steps and their number.)

3. Scientific truth is value free, essentially changeless, and infallible ("cool, unemotional, and impersonal").

Human Judgement and Ingenuity

In contrast to the image of science of the ninth-grade students is the actual experience of scientist Stephen Stanley. In 1973, Stanley provided an explanation for one of the great puzzles of paleontology: the proliferation of species at the beginning of what geologists call the Cambrian period, what is known as the Cambrian "explosion" of life. Using data from many contemporary field studies in ecology, Stanley assumed the appearance of new life forms that fed on the grassy set of abundant and dominant forms of life. These grazers or croppers allowed ever new forms to survive the competition from the previously dominant ones, which in time resulted in new grazers. The reasons Stanley offered in support of his theory are in stark contrast to many ideas of what science is. Stephen Jay Gould notes that they:

> "do not correspond to the simplistic notions about scientific progress that are taught in most high schools and advanced by most media. Stanley does not invoke proof by new information obtained from rigorous experiment. His second criterion is a methodological presumption, the third a philosophical preference, the fourth an application of prior theory. Only Stanley's first reason makes any reference to Precambrian facts... Science, at its best, interposes human judgement and ingenuity upon all its proceedings. It is, after all (although we sometimes forget it), practiced by human beings."

Ever Since Darwin,
W.W. Norton and Co., 1977,
page 125.

This particular ''practice'' of human beings is deep-seated and is one of many ways that men and women use to understand themselves as well as their universe. Up to this point little has been said about the discipline itself.

More Than Facts

In the NOVA television program, ''The Pleasure of Finding Things Out,'' physicist Richard Feynman described the difference between knowing the name of something or facts, and knowing something or understanding the source of the facts. While he was growing up, Feynman learned a great deal about science from his father and recounted the results of one weekend walk.

> ''Then next Monday when they were all back to work once more, all the kids were playing in the field and one kid said to me, ''See that bird, what kind of bird is that?'' And I said ''I haven't the slightest idea what kind of bird it is.'' He says, ''It's a brown throated thrush,'' or something, ''your father doesn't tell you anything.'' But it was the opposite; my father had taught me, looking at a bird he says, ''Do you know what that bird is?'' ''It's a brown throated thrush—but in Portugese it's a —, in Italian it's a —. He says, ''In Chinese It's a —, in Japanese a —, etc. Now, he says, ''you'll know absolutely nothing whatever about the bird. You only know about humans in different places and what they call the bird.'' ''Now,'' he says, *Let's look at the bird and what it's doing.''* (emphasis added)

Science has its facts, e.g., that the earth revolves around the sun. But it is much more than this; it is the finding out, too, e.g., how do we know that the earth revolves around the sun? What are the reasons that we accept it? After all, appearances suggest the opposite. In the words of John W. Renner (Science Education 66:709-716, 1982), ''Science is the process of extracting meaning...''

Science is not a set body of knowledge or restricted as it once was to the ''natural sciences,'' the science of nature—the traditional and narrow disciplines of physics, chemistry, geology, and biology. This particular way of looking at the universe has led to the development of many sciences. The result for every science is an established body of knowledge, the development of tactics (processes) for doing science, an identifiable community of men and women who do science and the organization of knowledge into coherent frameworks known as theories.

C. Components of Science Education

The domain of science for educational purposes include six components that are the basis for the dimension of literacy known as scientific literacy.

Nature of Science. There are multiple meanings associated with the term "science." Not all chemists or biologists, for example, have the same notion of what "science" is. There are some necessary criteria that make it possible to characterize science. Science is first and foremost a human enterprise. Its methods and concepts evolve as the scientific community evolves and grows.

Key Concepts of Science. A relatively small number of certain concepts are pervasive throughout most if not all of the various specialized sciences. They comprise the building blocks from which the conceptual structures of science—law, principle, etc.—are built. The overall number of concepts can be kept to a workable number by subsuming certain concepts in others.

Processes of Science. It was in the 1960's that the intellectual processes of science were recognized as legitimate content for science learning. These are very persuasive arguments that favor an emphasis on process. They are less likely to change in time than is content. They have generalizability to life problems. The processes of science that are listed here are essentially those identified by the Commission on Science Education of the American Association for the Advancement of Science (1964).

Science-Technology-Society. One of the major purposes of science education in the 1980's is citizenship, the development of informed citizens who can deal with social problems rooted in science and technology.

Science for Personal Needs. Science and technology influence all of us. School programs should contribute to understanding how science can be used in everyday decision making.

Attitudes About Science. Two important outcomes in science programs are the fostering of scientific attitudes *and* attitudes toward science. Scientific attitudes are comprised of traits such as perseverance, willingness to consider evidence, questioning of all things, etc. Attitudes to science include willingness and intent to use science skills and concepts, liking to take part in various science-related activities, etc.

Nature of Science

We live in a scientific culture, but that does not mean that we understand much of the science that underpins it. But why should students know the scientific basis for our culture? In a provocative essay in Daedalus (Spring 1983), Kenneth Prewitt suggested a reason. It is found in the term savvy. "A savvy person," according to Prewitt, "has those skills and insights that make for survival and success in what would otherwise be bewildering and intimidating situations." Literacy about science reduces some of the blooming, buzzing confusion about our culture. It is empowering to know the rules, see the patterns, understand the hierarchies, and speak the language, if not like a native, then well enough to be able to "get by."

In this spirit, a scientifically literate person understands the nature of scientific knowledge is such that:

a. ALL SCIENTIFIC KNOWLEDGE IS TENTATIVE

— Judgment in science can never be final or absolute.
— The data of science must be regarded as provisional and subject.

b. THE KNOWLEDGE OF SCIENCE IS PUBLIC

— Science is not a private matter.
— The work of science is open to and thrives on scrutiny.
— The status of scientific knowledge is earned through convincing others of its nature.

c. SCIENTIFIC KNOWLEDGE IS REPLICABLE

— When an experiment is repeated, there is a reasonable expectation that similar results will be obtained.
— Every tenet, principle, method, or explanation is open to investigation or it may not be associated with science.

d. SCIENCE IS PROBABILISTIC

— Statements in science have only probabilistic, not exact information.
— The probabilistic nature of science imposes certain qualities on the conclusions drawn in the process of interpreting data, embodied in the notion of "on the average."

e. SCIENCE IS THE PRODUCT OF HUMAN ENDEAVOR AND CULTURE

— The construction of scientific knowledge is active, creative, rational, emotional, and pragmatic.
— Science is a knowledge-making process.
— Science cannot segregate itself from society; science and society are interrelated.
— Science continues to exist for a variety of non-scientific reasons—commercial, strategic, bureaucratic, political, and social.
— Human prejudice may retard or block insightful new knowledge because it may run contrary to established norms, conventions, or protocols.

f. SCIENCE IS HISTORIC

— Scientific knowledge if the past has provided the basis for today's knowledge which in turn will provide the basis for tomorrow's knowledge.
— Science knowledge of the past should be viewed in its historical context and not be degraded on the basis of our present knowledge.

g. AMONG THE WAYS OF KNOWING, SCIENCE IS DIFFERENT

— Natural events are determined or caused.
— Science investigates what is knowable.
— Scientific knowledge is based on consensus, i.e., by publication of results, debate, and criticism by peers, the reported experiments must be reproducible by others. Then it is accepted.

Key Concepts of Science

The term "concept" is used here in much the same way that learning theorists use the term. "We define concepts as a regularity in events or objects designated by some label. "Chair" is the label we use (in English) to designate an object with legs, a seat, and a back that is used for sitting on." (Joseph D. Novak and D. Bob Gowin, Learning How to Learn, Cambridge, 1984).

The scientifically literate person understands and accurately uses basic science concepts. There are at least two ways to identify and think about such concepts. One is idiosyncratically, i.e., the unifying concepts within each particular discipline of science which undergird it. Another, and the one we have chosen, is to identify the key concepts of science which represent a minimal conceptual core of science knowledge.

In the former, the result is an intractable array of concepts. Furthermore, and more to the point, the student is left without a sense of how the parts of science fit together. In the latter, an attempt is made to cut across the discipline of the sciences to identify the key content dimension—the minimal usable core—of science literacy.

Identifying a minimal content or conceptual core of science knowledge has been and will continue to be a persistent problem in science education. Those opposed to such approaches argue that there are few common denominators across disciplines. Concern is also expressed that science is a more variable enterprise than a unitary scheme can express. Finally, there is concern about the level of generality of such unifying concepts, i.e., they are too abstract to be meaningful or relevant to elementary and secondary students.

There are several powerful counterarguments. One is that while in practice many concepts can be identified, the key concepts represent a general class of related concepts. It has also been observed that groups undertaking the task of identifying key concepts came up with quite similar lists independently. A final argument for focusing curriculum on key concepts has been presented by the Center for Unified Science. In Prism II, a newsletter of the Center published in the Spring of 1974, Victor Showalter wrote that "each key concept can be viewed as a continuum along which the individual progresses as (she/he) learns more complex relationships (i.e., principles or laws) involving the concept." This implies:

1) a hierarchy of concepts;
2) a framework within which to understand the content of science knowledge;
3) that learners construct understanding based on a knowledge of relationships and prior knowledge; and
4) levels of development regarding understanding of particular concepts.

A WORKING LIST OF KEY SCIENCE CONCEPTS	SOME WAYS OF THINKING ABOUT THE CONCEPT
CAUSE-EFFECT	A relationship of events that substantiates the belief that "nature is not capricious." Once established, it enables predictions to be made. Predictions rest on a belief that events are not totally capricious, that what I do to the system makes a difference in how the parts act. A particular situation or series of events *always* results in a unique effect. The effects are not capricious but have their source in a definable situation, which causes them.
CHANGE	Everything is in the process of becoming different or something else. The rate at which it happens varies from very fast to very slow so that it may be unnoticed in these extreme cases. Many involve several stages or mechanisms. Change is described by comparing the final state of the system to the initial state of the system.
CYCLE	The apparent pattern in which certain events or conditions seem to be repeated at regular intervals or periods. A clock in the sense that it measures time under a given set of environmental conditions. Cycles often work together as a dynamic, integrated and interacting whole, for example, the fundamental biogeochemical cycles—the rock cycle, the water cycle, the nutrient cycle, and the CO2/02 cycle.
ENERGY/MATTER	Interchangeable manifestations of substance and that which enables something to be moved or changed. Energy is a quantity having the dimensions of a force times a distance which is conserved in all interactions in a cloud system. It exists in many forms and can be converted from one form to another. Matter is the stuff of which all things are composed. "Energy has mass and mass represents energy." Albert Einstein The story of energy-matter is one of flow and change, governed by strict rules.

A WORKING LIST OF KEY SCIENCE CONCEPTS	SOME WAYS OF THINKING ABOUT THE CONCEPT
EQUILIBRIUM AND HOMEOSTASIS	A state of affairs in which changes or tendencies to change occur in opposite directions, exist, or happen at equal rates or are of the same magnitude. The process of adjustment, of control that results in a steady state, a teetering sort of balance. When observable changes no longer occur in a reacting system.
INTERACTION	A situation in which two or more things influence or affect each other. The relation among objects that do something to one another.
SCIENTIFIC MODEL	A more or less tentative scheme or structure which seems to correspond to a real structure, event, or class of events and which has explanatory value. A mental image of a system, having unobserved parts or properties, that is helpful in explaining how the system functions. A representation of something, usually somewhat simplified and in a different scale of time or space. A model is an abstract description of the real world; it is a simple representation of complex forms, processes, cause-effect relationships and functions or combinations of these; it may be verbal, graphic, three-dimensional, analogocal, mathematical, or a combination of these. Because relationships change as scale changes, a physical model often does not look like physical reality, e.g., a thermal model of a building and an architectural model.
ORGANISM	An open, dynamic system which is characterized by the processes of life. May be used as an analog to explain certain non-life events or things. An individual living thing, either plant or animal. The biotic components of the ecosystem.

A WORKING LIST OF KEY SCIENCE CONCEPTS	SOME WAYS OF THINKING ABOUT THE CONCEPT
PROBABILITY	The relative certainty (or lack of it) that can be assigned to certain events happening in a specified time or sequence of other events. A mathematical basis for prediction that for an exhaustive set of outcomes is the ratio, the outcomes that would produce a given event to the total number of possible outcomes. That relative frequency with which an event occurs in an indefinitely large number of trials. No probability can ever be exactly known, because no action can be performed an indefinite number of times. Science can reach general conclusions only in the form of a "bet" about what should be there in the long run. Probability is measured on a scale marked zero at one end—absolute impossibility—and one at the other—absolute certainty.
PATTERNS AND SYMMETRY	The belief that most, if not all, patterns in nature are structurally or functionally independent of direction. Balanced proportions...a sense of rest and order. Our aesthetic appreciation of symmetry may stem from its vital role in nature.
SYSTEM	A group of things or events which can be defined, at least in part, by boundaries that one person can communicate to another and which enable it to be discussed and studied more effectively. A group of related objects that form a whole. Systems are often selected because the objects interact or have the ability to do so. Any set of objects or variables among which a relationship is believed to exist.
UNITS	Units come into two distinct types. Fundamental SI units of measurement, from which others are derivable, include kilogram, meter, second, and mole. Descriptive units include units of structure and function, e.g., atom, molecule, cell, ecosystem.

Processes of Science

In learning to do what scientists do, one thing that students should do is become highly involved in using the processes of science. Such activities reflect the nature of science and the typical activity of scientists. Process skills provide students with ways to find things out about the world. Students do this by observing, by classifying, by collecting, and interpreting data, drawing conclusions from the data and (sometimes) using what has been learned as the basis for new investigations.

The process skills of science are not independent of content. It is not merely "activity" in the name of "hands-on" science. The process skills are, in fact, interdependent with content and are used relationally, i.e., with objects or events.

For the purposes of this document the process skills are divided into basic processes and integrated processes. The basic processes provide the foundations for more complex integrated processes.

There are many reasons for including the process skills in science education programs. Some of these have already been discussed. Others include developmental considerations, e.g., emotional, psychological, physical, and intellectual. Process-oriented science gives students an opportunity to manipulate objects and can, therefore, increase enthusiasm for science. It gives students another opportunity to be successful and provides a more variegated approach to learning science than a reliance on reading, lectures, and discussion.

One of the strongest arguments for process skill activities is their generalizability beyond science and science education to everyday problems of living. The process skills can be used to determine which brand provides the best value or to help make an energy-related decision or when is the best time to trade an automobile.

Basic Processes

OBSERVING

This is the most basic process of science. Observing is using the five senses to obtain information about objects and events. This includes using scientific equipment and instruments for extending the range of human senses as well as the ability to distinguish relevant from irrelevant observations.

INFERRING

An inference is an interpretation explanation of an observation or observations and relies on careful thinking. It involves using the available data and information to choose the most likely explanation or hypothesis. Such a judgment is never final or absolute. It is what is most probable, given the observations and the state of what we know.

CLASSIFYING

This is the process used to impose order on collections of objects or events. Classification schemes are used to identify objects or events, to show similarities, differences, and interrelationships.

USING NUMBERS

The technique of using number systems to express ideas, observations, relationships, etc., often as a complement to the use of words.

MEASURING

A procedure by which one uses an instrument to estimate a quantitative value associated with some characteristic of an object or an event. It requires the ability to use instruments properly and the ability to carry out calculations with the measurements made.

USING SPACE TIME/RELATIONSHIPS

The description of spatial relationships and their change(s) with time.

PREDICTING

The ability to make a specific forecast of what a future observation will be is an important process skill in science. Predictions are not random guesses; they are based on previous observations, measurements, and inferences.

COMMUNICATING

This is a process not only of science but of all human endeavors. Scientists communicate with oral and written words, diagrams, maps, graphs, pictures, mathematical equations, and various kinds of visual demonstrations.

FORMULATING HYPOTHESIS

A hypothesis is any tentative explanation from something observed or inferred.

Testing a hypothesis that is a generalization from observations consists of making more and more observations of whatever class of objects or events is covered by the hypothesis.

Testing a hypothesis that is a generalization from an inference also involves conducting a test which will provide data that will support or not support the hypothesis.

USING COMMON SCIENTIFIC AND MATHEMATICAL SYMBOLS

These include the skills of reading information in symbolic form from graphs, tables and charts, and using scientific symbols and conventions.

Integrated Processes

INTERPRETING DATA

Data are the pieces of information collected to answer questions. Interpreting data is concerned with using data to make inferences, predictions, and hypotheses. It is also concerned with developing skills in making statistical statements about collections of data, e.g., mode, mean, median, range, and average deviation.

IDENTIFYING AND CONTROLLING VARIABLES

Each property that can appear in different objects, in distinctively different values, is referred to as a variable. A variable is anything that can change. It may influence the outcome of an experiment or a series of observations.

The process of controlling variables is pervasive in scientific investigations. The most definitive and reliable results are obtained when the variables can be identified, controlled, and when one of them can be measured operationally.

DEFINING OPERATIONALLY

Definition of a term by giving a set of directions for what should be done experientially to test the statement. Describes the specific operations needed to perform in order to measure a variable. For physical scientists it is a "what you do or what operation you perform" and "what you observe" definition. For example, an operational definition of an acid might be:

> An acid is a substance that changes the color of plant dyes (for example, litmus) from blue to red.

For biologists, operational definitions are descriptive and describe what to observe. The "what you do" is not specified. For example, a definition of the amnion,

> Inner, fluid-filled sac composed of a thin double membrane that surrounds the embryo in reptiles, birds, and mammals.

SCIENTIFIC MODEL BUILDING

Scientific models provide a possible explanation of how a system of interest functions, although it may not give an accurate description of what really happens in the system. In order to properly use scientific models, the scientist or student must be able to evaluate the factors that contribute to the system of interest, Model building can satisfy the student's need for thinking in concrete and abstract terms about a system. By bringing ideas to an accessible, testable scale, models facilitate understanding and enhance prediction. After they are compared to the "real world," or system of interest, models must often be revised.

EXPERIMENTING

This process encompasses all of the basis and integrated processes. Experimenting often begins with observations that suggest questions to be answered. It may include a hypothesis to be tested. The succeeding steps in an experiment involve identifying and controlling variables, making operational definitions, constructing a test, carrying out the test, collecting and interpreting data, and sometimes modifying the hypothesis that was being tested.

In *Science: A Process Approach* (AAA, Xerox, 1963), the authors said the following about the best kind of investigation: Change (manipulate) one variable in a systematic way, and watch for and measure corresponding changes in another (the responding) variable; hold constant (keep the same) all the other variables you can think of while you are manipulating one variable and observing the response of another.

Science-Technology-Society

The effects of science and technology on society are truly pervasive. They extend from the way our federal taxes are allocated for research and development—in 1983 about 80 percent of the expenditures were in applied research and development; the remaining 20 percent being in basic research—to the way we live—food production, shelter, clothing, health care, information, genetic engineering, transportation, and energy.

And yet the relationship between science and especially technological advance and quality of life is disputed territory. It is all too easy to characterize the disputes as being about the goods (not goods) that parallel the goods of such advances. In "Ethics and the Problems of Hazardous Waste Management: An Inquiry into Methods and Approaches" (1984), Peter Timmerman, Institute for Environmental Studies, University of Toronto, points out that what makes many of our current dilemmas so difficult is that "the various value system at odds are rooted in full-scale views of the world which penetrate very deeply into such complexities as people's essential definitions of what constitutes well-being. Their clashes are versions of what the philosopher Hagel defined as true tragedy: not the clash of good vs. evil, but the clase of good vs. good. Battle here is joined over such things as "rights," "obligations," "the good of society," the "destruction of a community," "sharing of risks," "compensation of assumed burdens," and a host of others."

This guide is being written during a period of perceived educational crisis and it is not surprising, given the fact that we are an advanced scientific and technological society, that considerable attention focused on the purposes and content of science education.

The societal has forced many as well as personal and day-to-day dominance of science-related social issues has forced many science educators to question the countenance of the current school science curriculum. Should there be any linkage between school science and current concerns, technology, and values?

In 1982, the National Science Teachers' Association published a position statement on science, technology, and society. It minces no words in stating that the primary focus of school science for the 1980s should be on the relationship between science and society:

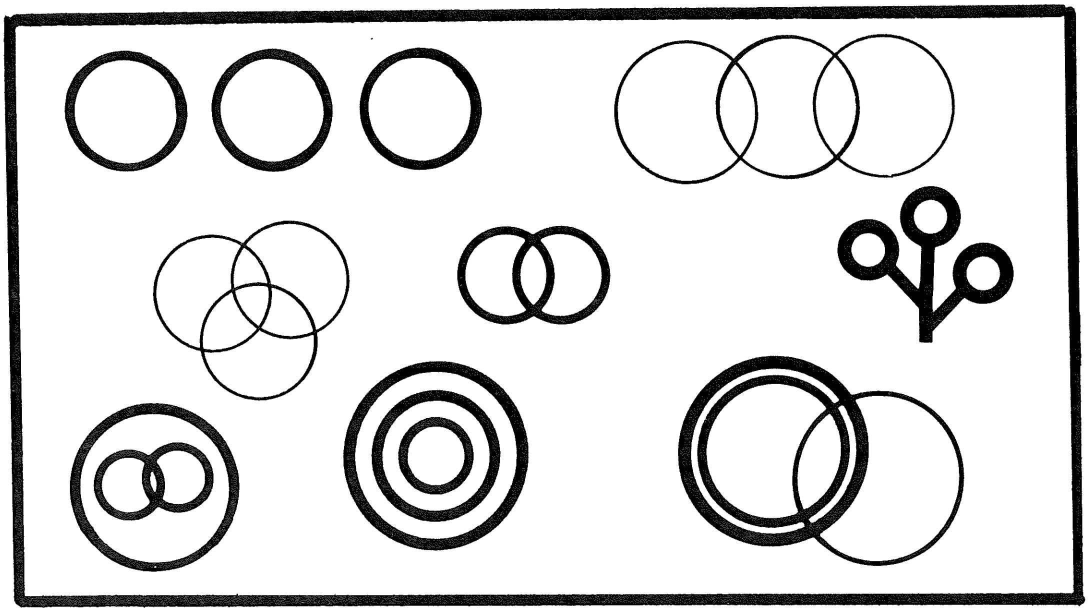
> The goal of science education during the 1980s is to develop scientific literate individuals who understand how science, technology, and society influence one another and who are able to use this knowledge in their everyday decision-making. The scientifically literate person has a substantial knowledge base of facts, concepts, conceptual networks, and process skills which enable the individual to continue to learn and think logically. This individual both appreciates the value of science and technology in society and understands their limitations.

The science/technology/society perspective was also identified as a major new organizer for school science in Project Synthesis (1981), a National Science Foundation supported effort at identifying the ideal state of science education and contrasting it with the actual state of affairs. Project Synthesis identified eight areas of concern within the STS interface. They included energy, population, human engineering, environmental quality, use of natural resources, national defense and space, sociology of science, and the effects of technological development.

According to Project Synthesis, there are some new shoulds for science education programs. These include preparing individuals to use science for improving their own lives and coping with an increasing technological world and preparing citizens to use science to deal responsibly with science-related societal issues. Such science education programs should provide students with:

- An understanding of energy problems from a personal perspective
- An understanding of their role in population growth/regulation
- An understanding of the emerging problems in the field of human engineering
- An understanding of the various aspects of environmental quality and that those aspects may differ in priority from person to person
- An understanding of the various aspects of environmental quality and
- An understanding of the various aspects of using the earth's natural resources
- An understanding of the various accomplishments of space research and national defense programs
- An understanding of the sociology of science
- An understanding of the effects of hard and soft technology on individuals and society in general
- The background necessary for taking responsible action on energy-related issues confronting society
- The background necessary to understand and react to problems associated with population dynamics
- The background necessary to develop insight into the emerging work field of human engineering and its impact on society
- The background necessary to recognize the variations in acceptable environmental quality in their communities, states, and nation, as well as to maintain or improve them
- The background necessary to recognize the societal problems involved in finding, using, and conserving natural resources
- The background necessary to react to the problems and potential benefits to society of the national defense and space programs
- An understanding of the sociological effects of science and technology
- An understanding of the impact of technological developments on society, in order to make reasonable and responsible decisions.

Some ways of thinking about the interaction and the relationship of science, technology, and society are found in the following graphic. *The* relationship is not represented; there are many ways to represent the relationship. Think about each of the three major categories of the STS perspective and write each in the circle where you think it belongs (or devise a representation of your own).



Science for Personal Needs

Whatever the career after high school — butcher, baker, candlestick-maker, or farmer, factory/office worker—high school graduates should feel at home with the ideas of science and technology. How do things work? How did I work? What are some of the effects of specific technologies on me and how did I relate to them? What are the scientific principles underlying technology? What are the facts that bear on the issues affecting my life?

Should I believe the work of Von Daniken or Velikovsky? How can it be evaluated? What do I make of it? What are some plausible consequences of changes imposed on some situation or system? What are the facts and the influences in a given situation?

Students need the confidence that they can understand the personal dimensions of science and technology and how to use what has been learned in science in everyday life as they make decisions and solve problems. This will help them to lead satisfying lives and make informed decisions about their personal well-being. Science is always embedded in moral questions. Therefore, a personally oriented science also asks questions about the human implications of what we have learned.

Attitudes About Science

There are two major categories of attitudes in science education: scientific attitudes and attitudes toward science. Traditionally, the notion of scientific attitudes includes commitment to the use of a particular approach to problem solving, projectivity, rationality, open-mindedness, tentativeness, etc. In the broad category of attitudes toward science is included attitude toward scientist, scientific interests, satisfaction, enjoyment, etc.

In 1984, the ERIC Clearinghouse for Science, Mathematics, and Environmental Education published "Attitude Research in Science Education," an information bulletin designed to provide an overview of studies in attitude research. Both the "attitude to science" (a predominantly affective orientation) categories are in need of careful reconceptualization, re-examination and, interestingly, a much clearer justification.

The purpose of this section is not to argue that attitudinal objectives be abandoned. It is rather to alert science educators to the current status of this domain in science education — unclear, chaotic, and confused. Given this state of affairs, what should science teachers do?

First of all, science educators have some things going for them. Science can engage students. There is much in science that is fun (this is not to deny the pain in learning science, too), of absorbing interest, and of surpassing importance in the modern world of affairs. Much of its content can be connected to the world of the student. Because of the way science is constructed, students are offered many opportunities to be successful. It may be helpful if students know why they are taking science.

Do scientists really possess the affective characteristics such as objectivity, open-mindedness, skepticism, detachment, ascribed to them? The evidence from several studies is that they do not. The picture is more multidimensional. They are both objective and emotional (e.g., when defending a position), open-minded and close-minded (e.g., depending on theoretical orientation and personal biases). It depends on the situation. Scientists are often selfish and secretive (s.f. James Watson, The Double Helix). This is not the public image of science or scientist.

So, another thing that science educators can do is present from time-to-time more accurate pictures of scientists. These characteristics, intertwined as they are in scientists (and in all of us), are suitable for students' examination and evaluation. They will learn that it is not easy to separate "good" from "bad."

It is worth quoting Colin Gauld "Science Education 66:109-121, 1982) on still another point related to science teaching. "(V)ery few writers explain what they mean by open-mindedness, objectivity, or skepticism, and little indication is given of how evidence is weighed or of how one decides when there is sufficient evidence to make a decision." When studying science-technology-society and science for personal needs, there are rich and ample opportunities to raise questions related to these items. "What do we know...? How do we know...? Why do we accept or believe...? How do we make a decision when the best minds, or when the best data, are ambiguous and provisional? How do we analyze changing problems? What conclusion does an objective assessment of...lead to?"

In 1966, the Educational Policies Commission published a document titled "Education and the Spirit of Science." The discussion about a set of basic values thought to underlie science has application to any consideration of science attitudes.

> ...like other sets of values, they have the defect that neither individually nor jointly do they provide a fully adequate guide to action; in many concrete human situations, viewers values, all cherished, are invoked, and the choice of the choice of action involves an ethical consequence. The value of the spirit of science expresses the belief that the compromise is likely to be better if based on thoughtful choice; in this respect they differ from those value systems which hesitate to submit all problems to reason...
>
> By their very nature, these values cannot be acquired through indoctrination...(1966:16)

What is important to students in their everyday life would seem to be the idea of "thoughtful choice." The study of science is rich in opportunities and the promise of challenges to think. Assuming that students and teachers have reached some agreement about the worth of the study of science, it would seem that students should develop their own informed preferences and attitudes.

Why Science?

As can be seen in the preceding, science is a critical component of the school curriculum for many intertwined and interlocked reasons. There are many reasons for teaching science. They include the very basic motivation to understand the universe. The reach is impressive. There are personal reasons, too, such as the know how to understand and not be bewildered by commonplace events in nature, new technologies, and knowing how to make the scientific-technological system work.

As a still more inclusive level, sociocultural and even the relationships between nations, are a variety of social problems whose roots are in science and technology. These include chemical fertilizers, nuclear energy, genetic engineers, population growth, and concerns about the natural systems that undergird the economy. These problems are not so much ever solved; more often they change form. In a democratic society, such problems require all of our active involvement if we are to successfully cope with them. Science also has contributions to make to basic education and even to success in the workplace for those high school graduates who do not go on to a four-year college — the largest segment of the American workforce. There are many reasons for teaching and learning science that include:

a. Science is a way of knowing. There are a variety of ways of knowing about the world—ways by which we satisfy our curiosity about it. Today, science is one of the preeminent ways to experience and know the world. Viktor Weisskopf, Massachusetts Institute of Technology, has observed that "About 500 years ago (our) curiosity took a special turn toward detailed experimentation with nature. It was the beginning of science as we know it today. Instead-its creation and present form—it tried to acquire partial truths in a small measure about some definable and reasonable separable group of phenomena. Science developed only when (we) began to refrain from asking general questions such as: What is matter made of? How was the universe created? What is the essence of life? Instead, (scientists) asked limited questions, such as How does an object fall? How does water flow in a tube? Thus, in place of asking general questions and receiving limited answers, they asked limited questions and found general answers. It remains a great miracle that this process succeeded, and that the answerable questions became gradually more and more universal." (Science 176:138-146, 1972).

b. In Science Teaches Basic Skills (NSTA), 1983), Kenneth R. Mechling and Donna L. Oliver point out that "Science content is basic because it is part of kids' everyday lives. Children are surrounded by technology that they must utilize and an environment with which they must interact effectively. Project Synthesis identified four areas in which science touches children's lives in significant ways: besides helping them learn scientific ideas and processes, it meets personal needs, it helps them become informed citizens, and it assists them in making career decisions.

"One of the reasons why science content is so basic is that children like it. Recent surveys show that science-related topics are often chosen by children for individual projects, and a high percentage choose science as their favorite subject."

c. Recruitment of the young. In the last several hundred years, there has been an increase in numbers of scientists and scientific specializations. If science is to continue to prosper, attention must be paid to developing and nurturing an interest among the young.

d. Welfare of society. We have a crucial dependence upon science, e.g., in agriculture, medicine, industry, government, and with the military. "Our aim in teaching basic science," according to David Hawkins, "should be to prepare all youngsters for eventual participation in the democratic discussion and reordering of ends; the narrowing, even the failure to broaden basic science education, creates scientific and technological oligarchies, while the rest of us tend to become incompetent for democratic rule, to become—in the language of Toynbee—a cultural proletariat." (Daedalus, Spring 1983).

e. Science complements other curriculum areas. The research findings, particularly for elementary and middle school, are impressive. Science education contributes to the development of basic skills of language, reading, arithmetic, perception, logic, and creativity. The effect of science on language and logic development is particularly well documented for disadvantaged students (of Science Teaches Basic Skills, NSTA, 1983).

f. We are surrounded by the status and pervasive influence of science and technology to our welfare as individuals and to the welfare of our society. A scientific literacy is basic for living, working, and decision making in the 1980s and beyond.

g. Regaining contact with our world of experience. Richard D. Logan and George T. O'Hara (Science Education 66:515-530, 1982) and others have called attention to the influence of recent life style changes that "have led to an orientation away from before-after/cause-effect reasoning" both short-term and long-term and analytical observations of events of the world. "(S)cience instruction encourages students to inquire, to hypothesize, to ask questions, to describe the phenomena they observe, and to list the possible factors involved."

h. Lifelong learning skills. According to Michael J. Padilla (School Science and Mathematics LXXX:601, 608, 1980), "(T)here are several strong arguments for inclusion of process skill activities. One is the generalizability of these skills to life. Many life problems can be analyzed and solution proposed by applying process skills. Which brand of soap or corn flakes provides the best value? Are frozen, canned, or fresh green beans more economical? Should a hydroelectric, coal burning, or nuclear plant be built in the local community? Which candidate better reflects an individual's viewpoint? All these questions can be simplified by collecting and organizing data and drawing conclusions from it. The skills of identifying and controlling appropriate variables, designing experiments and defining operationally are all important parts in this process.

i. Development of thinking skills. In an extensive literature review, W.K. Esler (Teaching Elementary Schools Science, Wadsworth, 1977) notes that science helps children develop thinking skills. This goal, the full development of the intellect, of helping students become effective thinkers, is of increasing interest in this age of information.

j. The workplace and understanding how things work. In *High Schools and the Changing Workplace: The Employer's View* (National Academy of Sciences; National Academy of Engineering; Institute of Medicine; Committee on Science, Engineering, and Public Policy, 1984) it is stated that "Competency in science and technology includes the ability to apply the scientific method, whether or not it is labeled as such; that is, the ability to formulate and state hypotheses, and then to evaluate them by experimentation or observation. That competency will serve all graduates, whether they work in technical occupations or not. It serves, for instance, in localizing a problem in a word processing system, in repairing mechanical systems, or in identifying the source of a recurring error in computation.

   "Further, the well-educated high school graduate will be able to apply the basic principles of the physical, chemical, and biological sciences to work. Thus, high school graduates competent in the basic sciences will be able to evaluate risks better, understand the rationale for industrial processes, and even suggest how they might be improved. The particulars are less important than the generality: that knowledge of science and technology dissipates unknowns and enhances confidence in one's ability to analyze and solve a problem."

k. The critical consumer of information. We are bombarded with information of all sorts. Some of it passes as science. "Genetically Identical Replica Made of Aging Millionaire," "Earth Visited by Intelligent Aliens," "Loch Ness Monster: A Scientific Study," "Chariots of the Gods." Our newspapers and media regularly report the results of some new scientific study, for example, on the benefits (or hazards) of exercise, the dangers of the depletion of the ozone layer, or whether there is really an energy/ resource crisis.

   A large segment of the general public is naive about scientific reasoning. What does it mean that a claim is supported by the "facts?" When is a fact a fact? Why is it that scientists pay attention only to certain kinds of evidence? What is the difference between a casual connection and a statistical correlation? Is the fact that substance x causes cancer in mice, relevant to humans?

Science education contributes to comprehension of what science does, how it operates, and the validity of conclusions reached by the methods of science.

"Science" means different things to different people. The snapshot of science taken here is clearly a sociological (and ecological) one, i.e., science consists of identifiable communities of scientists, an idea shared by many scientists, historians of science and, of course, sociologists. These are not communities, necessarily, of physical proximity; they are communities of shared values and beliefs. According to historian of science Thomas Kuhn (The Structure of Scientific Revolutions, University of Chicago Press, 1962), "The most global is the community of all natural scientists. At an only slightly lower level the main scientific groups are communities: physicists, chemists, astronomers, zoologists, and the like...A scientific community consists, in this view, of the practitioners of a scientific specialty."

Like communities, there is a set of rules by which its members are expected to live. The literature of each science community has certain safeguards of quality, e.g., articles are published only after review by other members according to accepted conceptual, methodological, theoretical, and equipment standards. These define the problems that scientists work on. The literature is a public one. Entry into the community occurs through a process of learning very similar to socialization, i.e., novices attain professional status through research, training, instruction in a degree program, again according to well established scientific procedures, knowledge, and theory. Scientific communities are recognized in the wider community, i.e., they have status. Such status is the bases for expert testimony and funding and other kinds of recognition.

Science education is about understanding this science as a basic enterprise of the human species. Through their experiences in science, students become fam iliar with what is most important to know about a discipline, its methods, how concepts are related to each other and to the key concepts, and with the use of scientific instruments for extending the range of human senses. Like scientists, students explore, explain, and apply or test their explanations. The addition of science-technology-society and science for personal understanding to the science curriculum provides students places to apply and use science in relevant societal and personal contexts.

This view of science education connects concepts of knowing with those of citizenship—the scientifically literate citizen. Consider the 1867 Inaugural Address at the University of St. Andrew, at which John Stuart Mill uttered the following visionary words.

> We are born into a world which we have not made, a world whose phenomena take place according to fixed laws, of which we do not bring any knowledge into the world with us. In such a world we are appointed to live, and in it all our work is to be done. Our whole working power depends on knowing the laws of the world—in other words, the properties of the things which we have to work with and to work among and to work upon all may and do rely for the greater part of this knowledge on the few who in each department make its acquisition their main business in life. But unless an elementary knowledge of scientific truths is diffused among the public, they never know what is certain and what is not, or who are entitled to speak with authority and who are not; and they either have no faith at all in the teaching of science or are the ready supes of charlatans and imposters. They alternate between ignorant distrust and blind, often misplaced confidence.

Concern about the scientifically literate citizen is hardly news. What has changed is that science and technology affect us today, directly and indirectly, individually and societally, in ways that could not be imagined when Mill wrote these words. To use Kenneth Prewitt's insightful metaphor, participation in today's society requires "scientific savvy."

INSTRUCTIONAL STRATEGIES

A. Science Education: The Unfolding of Thinking

One of the most familiar metaphors in science education is the teacher-student- subject triangle. (of. David Hawkins, the ess reader. 1970, pp. 45-51). This is familiar true to science teachers; it is the classroom. While the overall emphasis of this document which contains guidelines for local decision making is on the subject corner of the triangle, so much so that the triangle is greatly truncated, we are very much aware that it is in the relationships between the three that science education is ultimately won or lost. We recognize, too, that this triangle is embedded in a much larger social, cultural, and economic context.

The focus of this short section is on another corner of the triangle: the student. It is about how this corner, namely the thinking abilities of children, affects the relations between the other two corners.

> Compared to other living organisms that we know about, humans enter this world quite emptyheaded. Many species of birds, fish, and other animals are preprogrammed with information that enables them to survive, gather food, and reproduce their own kind. Some can travel to locations they never experienced directly. Others behave in ways that are independent of learning. But the human baby is quite helpless. It must *construct* a view of the world itself.
>
> Lawrence F. Lowry
> in Developing Minds, Association for
> Supervision and Curriculum Development
> 1985, pp. 72-80 (emphasis added)

How we think and learn to think is not something we often think about. Our view is that knowledge is personally constructed; the myth is that it is discovered (and some of it may be) and then transmitted to learners.

The sequential development of thinking capabilities and the idea that we construct knowledge is supported by a novel and diverse research base. Science educators are probably most familiar with the work of cognitive psychologists. These include Jean Piaget, Jerome Bruner, Robert Gagne, and Erik Erickson. Two other cognitive psychologists deserve mention. The research of Joseph Novak and David Ausubel, who, while repudiating the Piagetian notion of stages of cognitive development, also provides convincing evidence that we construct what we come to know.

The neuroscience research base about the nature of human thinking is less well known to most science educators. This work is *briefly* summarized by Lawrence Lowery (of. Developing Minds, Association for Supervision and Curriculum Development, 1985). It includes growth spurts of the brain, patterns of cellular growth, and electrical activity. Neuron development and myelination of the brain progress in stages. It takes about eleven years for the myelination of the corpus callosum which results in regular communication between both sides of the brain. All of this is not to say that the answers are in. Much more research is necessary to determine the relationship of learning tasks and the timing of their presentation to the development of cognitive abilities.

B. Piagetian Education

The discussion that follows is based on the work of the Swiss psychologist Jean Piaget (1896-1980). It is often referred to in the science education literature. The overall goal of Piaget's research was to develop a general theory of knowledge. The approach he took was developmental—how and why does knowledge of a thing develop as it does? How do individuals come to know what they know? How does the ability to reason mature over time? Piaget's research was based on naturalistic observations, interviews, and the involvement of children in tasks.

In seeking explanations for the development of children's cognitive abilities, Piaget identified four major cognitive developmental stages of reasoning that are spaced and occur in intervals. These stages are: 1) sensorimotor—information is organized into mental structures by sensory experiences; 2) preoperational—thinking is centered on self and is often intuitive; 3) concrete—meaning is primarily in physical terms; and 4) formal though — thinking in terms of the possible or hypothetical these stages respectively: 1) the active child; 2) the intuitive student; 3) the practical student; and 4) the reflective student.

While it has been well documented that children pass through these stages in the same order, including across cultures, it is important to understand that the rate varies between individuals and that the developmental stages are not age determined (the stages are statistical averages). Piaget did not view the stages as a series of limitations although they are often described in this way. Joseph Pearce puts the development of thinking this way:

> Although at any stage of development nature is preparing us for the next stage, the beauty of the system is that we are conscious of none of this. Ideally, we must fully accept and exist within our developmental stage and respond fully to its content and possibilities. This means that every stage is complete and perfect within itself. The three-year-old is not an incomplete five-year-old; the child is not an incomplete adult. Never are we simply on our way; always we have arrived. Everything is preparatory to something else that is in formation.
>
> The Magical Child
> E.P. Dutton, 1977

Each stage represents both new thinking capabilities and also a new period for integration and consolidation of cognitive content. In each stage, experience, information, and knowledge are uniquely organized into a different view of the world. In the sensorimotor period, it is a highly sensory world view; in the period of formal thought, it is the ability to identify and isolate the possible combinations of variables (and establish their relationships) involved in complex problems.

Characteristics of each of the four Piagetian stages are summarized in the following table. What is not clear in the table is that the characteristics have a beginning and an ending. In the sensorimotor period, for example, the child begins with no concept of space and ends up with a concept of immediate space. Furthermore, the development of reasoning is both richer and a more differentiated process than is shown here. Interested readers should refer to the literature, e.g., *Piaget for Educators* by Rodger W. Bybee and Robert B. Sund (Merrill, 1982).

In many discussions of the significance of Piaget's work for science education, cognitive stage theory—ages and stages—is regarded as the most distinctive feature. This is a very limiting interpretation of Piaget's overall framework and of children. Most children are in transition and demonstrate varied reasoning patterns. This is perhaps most noticeable in the state between concrete operational and formal thought, i.e., in students in upper elementary, middle, and junior and senior high school. During this period, students use concrete operational thought consistently; formal thought inconsistently.

Piaget did not view the stages of thinking development as his most important contribution to a theory of knowledge development. What we should learn from Piaget is that learning and reasoning are active processes. In other words, humans construct what they know. They do this by modifying ideas, not simply by receiving new ones. A person's current construction of experience is the basis for processing new information and for organizing it into new mental structures. For science educators, this means that children come to school with neither blank minds to be filled *by* school science experiences nor that they are without strong theoretical views about how the world works. That they bring sundry ideas to science, often in the form of misconceptions, is well known to science educators.

Selected examples of such pre/misconceptions or, more broadly speaking, "alternative frameworks," include:

1. Elementary School—I can see because light shines on things and brightens them or food for plants is whatever material is needed and taken in by the plants or the attribution of life to inanimate objects (About rain: "Clouds think it's too hot...I guess they start sweating and then the sweat falls on us.")

2. Middle/Junior High School—Water tables are underground lakes or the shadow of the earth causes the phases of the moon or a large ice cube takes longer to melt than a small ice cube because the large ice cube has a colder temperature than the small ice cube.

3. Senior High School—Heavier objects fall faster than lighter objects dropped from a moving carrier will fall straight down or plant food should have a place in a food chain or all mutations are harmful to the organism.

Table

As Thinking Unfolds, Understanding Develops

Stage	Approximate Age Range	Approximate Grade Level	Thinking Characteristics
SENSORIMOTOR (ACTIVE CHILD)	0-2	Preschool	Interacts through sensory and motoric activities Developing concept of self, space, time, cause/effect, play and object permanence (objects exist even when out of sight) Actions imposed on objects one at a time
PREOPERATIONAL (INTUITIVE STUDENT)	2-7	Preschool 2	Intuitive answers ("Because") Egocentric (child center of reality) Aware of past, present, and future Make believe play Animistic explanations of cause/effect Reasons in one direction (A causes B, B causes A) Groups two objects (attribute) Links two events (relationship) Can imitate actions
CONCRETE OPERATIONAL (PRACTICAL STUDENT)	7-11	3-6	Restricted to direct experience (requires objects) Classifying/Grouping with a rational logic Reversing though processes (A B, B A) Mathematical operations Combine more than one idea at a time Unaware of inconsistencies and mistakes in reasoning Clear, sequential directions for projects
IN TRANSITION (IN-BETWEEN STUDENT)	11-15	Middle/Jr. High School	Rational but unsystematic approach to problem solving Uses concrete procedures to solve abstract problems Inadequate observations and procedures used for difficult problems

Table–As Thinking Unfolds, Understanding Develops (Cont.)

Stage	Approximate Age Range	Approximate Grade Level	Thinking Characteristics
FORMAL OPERATIONAL (REFLECTIVE STUDENT)	14–Adulthood	Senior High School	Abstract reasoning Hypothetical-deductive reasoning (can manipulate and control variables) Proportional reasoning Combinatorial reasoning (organize and reorganize)

Facilitating Cognitive Development: Where Do We Go From Here?

> It is important for curriculum and instruction to reflect the biological basis for thinking. A horizontal curriculum is one in which students are challenged to use a particular stage of thinking with different materials at various levels of abstraction without the progressive requirement of having to be at a more and more advanced developmental stage. The model allows students at an identified stage of development to explore many experiences within and near that stage... The essence of the approach is derived from the biological basis for thinking — the thinking capability is independent of the objects involved in a given task. Students experience small, sequential steps of equilibration through an inexhaustible set of possible experiences.
>
> Lawrence F. Lowery
> p. 77 in Developing Minds
> Association for Supervision
> and Curriculum Development
> 1985

What interested Piaget throughout his life was the relationship between thinking and things. While his work has shown us many things, one of Piaget's most significant findings may be that the way children organize knowledge throughout life and the way adults organize knowledge is different; not wrong, but different.

While Piaget's writings are voluminous, he wrote only two books, relatively late in his career, about education. Specific suggestions for instruction in science based on Piaget's theory were first developed by Robert Karplus and his colleagues at Lawrence Hall of Science, University of California, in the 1960s. This application of Piaget's ideas for science educators is known as the teaching/learning cycle. The design is the basis for the elementary school science materials developed for the Science Curriculum Improvement Study (SCIS). The teaching/learning scheme is divided into three stages: **CONCEPT EXPLORATION, CONCEPT EXPLANATION,** and **CONCEPT EXTENSION:** Robert Karplus called these stages, respectively, exploration, invention, and discovery.

Piaget has stated, "There is no learning without experience." This is the basis of the teaching/learning cycle. the emphasis in activities using the teaching/learning cycle is an experience...in helping learners create their own knowledge of and about a particular idea.

Concept Exploration

In exploration activities, minimal directions are given by the teacher. This is a period of gathering data usually using the materials of the discipline.

In elementary school, children would be encouraged to discuss what they observe and to ask questions about preselected science materials. An example is introducing a unit on sound, e.g., whistles. Plastic tubes of different length and caps to cover their ends would be provided to students and they would be asked: "What can you find out about the sounds made by these tubes?" In high school, the activity might be a laboratory experiment or field trip that produces observable data. However, these are not the only possibilities for exploration experiences. Films, discussions, demonstrations, thought puzzles, etc., can be used as effectively. The criteria for an exploration activity include active engagement, an appropriate level of puzzlement (i.e., the student is not bored with the activity or paralyzed by it), and an active search for an explanation on the part of the student. Students may observe patterns, identify variables, or attempt to answer questions.

Concept Explanation

This is a period of organization in which students look for patterns and seek to make sense of the data collected. The teacher introduces the appropriate concept or sometimes concepts for what is occurring. The concept explanation part of the cycle is teacher directed. It is often in the form of a teacher led explanation. However, diagrams, tables, graphs, pictures, films, and even additional activities are also used equally effectively. The purpose of the concept is to help students explain and understand their experience in a simple, clear, and direct manner.

Concept Extension

In this phase of the learning cycle, the already introduced and partially (to fully) developed concept is used to apply, expand, modify, limit, or broaden the concept. This is a period of consolidation, providing both time and experience(s) for this to occur. The set of possible experiences is somewhat inexhaustible. The use of multiple activities are very similar to concept exploration activities. They can include the same diverse array of activities: hands-on, active laboratory investigations; reading; problem sets; puzzles; and so on.

The 4th E, Concept Evaluation

As they learn, students need to know how well they are learning and understanding concepts. Teachers also want to know how well students are doing. Such information is useful to teachers in assessing instruction and in evaluating appropriateness of concepts and designing experiences to help students learn them.

Evaluation is very much a part of the learning cycle. However, it must go beyond standardized achievement tests that are based almost exclusively on course content and often consist of a multiple-choice format consisting mostly of recall items. After labeling the concept "insect, ...the learning sequence would be completed by having students respond to:

According to this information, what are some of the characteristics of these invertebrates that make them like insects? What was true of the insects that is not true of any of these other insect-like animals is ________________.

Based on what you've said here, finish the statement "What makes insects different from other insect-like animals is ________________."

Identify the animals shown here which you think are insects and the ones you think are not. For each, be ready to tell what about the animal made you decide it was or was not an insect." (Sydelle Steiger-Ehrenberg, "Concept Learning: How to Make it Happen in the Classroom," Educational Leadership, October:36-43, 1981)

Evaluation must reflect the full range of learning experiences a student has in a science course, too. Can students read information from graphs and tables; express information in graphs and tables; use measuring instruments and other scientific equipment; estimate quantities; observe similarities and differences; interpret diagrammatic, tabular, or written information; use scientific symbols, etc.? What this means is that some of the evaluation used in science must include practical items, e.g., measuring or using scientific equipment, as well as written items.

Attitudes are, of course, extremely difficult to assess. However, few deny the importance of assessing attitudes and attitudes toward science. Some of these can be assessed by simple paper and pencil tests; others will be based on teacher observations and discussions with students.

The teaching/learning cycle is summarized in the following table.

The Teaching/Learning Cycle*

Concept Exploration

Students learn through their own activities.
Learning is "directed" by the objects, events, or situations.
Teacher guidance is minimal.
Activities should leave students with unanswered questions.

Concept Explanation

A concept or principle is presented.
The concept should be related to the exploration activity.
Different instructional materials and approaches can be used.
Instruction is teacher directed. Instruction should help students answer their questions.

Concept Extension

Students are given different activities in which they must apply new concepts and reasoning patterns.
Additional time and experiences are used to extend student understanding.
Different instructional approaches can be used during this phase.

Concept Evaluation

Student learning is evaluated in a variety of ways.
Feedback is used by the teacher to recycle students through appropriate teaching/learning phases.

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*Figure 9.1, p. 210, from *Piaget for Educators,* Second Edition, by Rodger W. Bybee and Robert B. Sund, 1982. Charles E. Merrill Publishing Company, Columbus.

The teaching/learning cycle is an activity-oriented approach to learning science. In many respects, its central purpose is to help students develop the ability to think autonomously. It is designed to help students make decisions for themselves. In such an approach, science includes not only traditional science content but also a variety of scientific process skills and attitudes. It suggests, too, that these parts of thinking interact, e.g., when one makes observations they are not independent of experience, we learn what is relevant to observe, etc.

Piaget's work shows us that instruction should be based on an understanding of the developmental process. All children pass through four main stages of cognitive development. The curriculum design must be appropriate to this developmental process. Students construct what they know as a result of both mental *and* physical activity on what is being investigated. Science lends itself well to this because this action on things — mental and physical action on things. Students should have extensive experience with objects as they learn.

Implications of Piaget's Theory for Elementary Students

The science of elementary school is *not* specific preparation for the junior and senior high school science to follow. The idea of treating specific topics should not be one of a "science readiness" for secondary school. Elementary school is a place to gather and widen a child's experience. In *What Research Says to the Science Teacher* (1981, NSTA), members of an elementary school focus group wrote that the study of science "is the place to excite students' curiosity, build their interest in their world and themselves, and provide them with opportunities by introducing exciting and important phenomena to be observed and analyzed, but it should not reflect a need to cover a syllabus of content in all science disciplines."

Elementary school science should broadly sample the major content areas of science. There should be some balance between the physical sciences and the life sciences. Children should not be stuffed with words or asked to consider concepts too abstract to be well understood. Most of all, concepts should not be selected just because they are "in the book."

Finally, the curriculum should facilitate development of the intellect. This requires action-oriented science activities — "hands-on and brains-on." The teaching/learning cycle of concept explanation, concept extension, and concept evaluation can be used to facilitate active inquiry, decision making, thinking, and learning the content and processes of science.

Implications of Piaget's Theory for Secondary Students

There is considerable evidence that the progress from concrete to formal though processes does not automatically happen at the end of elementary school, i.e., with the biological changes of puberty. But science at both the junior and senior high school level is characterized by formal concepts. "The safest estimate," according to Rodger W. Bybee and Robert B. Sund (*Piaget for Educators,* Charles E. Merrill, 1982) "is probably about 25 percent of students will display formal thinking during secondary school years." This means that the majority of junior and senior high school students still need physical, hands-on experience as they reason and grow in their ability to think about science.

Like elementary students learning science, secondary students are likely too, to learn science best by *first* experiencing a concept or phenomena of science through the materials of the discipline (earth science, physical science, biology, chemistry, physics), *then* to label the new idea through the introduction of appropriate language and *finally,* to expand the new idea by applying, modifying, limiting, or broadening it. Experience...Language...New Experience(s). The science education cycle begins at the concrete and progresses toward the abstract.

This cycle of learning implies a variety of learning modes and strategies. However, laboratory work becomes imperative, because it is a common, concrete experience. In the Science Teacher (May 1983), Jerry E. Ivins, a teacher in Cincinnati, described five different kinds of laboratory experiences. Each laboratory experience has a legitimate place in high school science and each is summarized in the chart on the following page.

One of the special difficulties of secondary school is content. However, many of the concepts students encounter require the development and use of formal operational thought. This section is a plea for the facilitation of cognitive development. The basis for that, even in secondary school, is still "action on things" using concrete experiences. Reasoning is not memorizing. Your methods should actively involve students. You can help students by your awareness that most of them are either at the concrete level or in transition to the formal level of thinking. Use questions during laboratory work to engage them, too. "How did you get your answer?" "What are some sources of error in your work?" "How could you improve the experiment next time?" "What if you did...?"

Today, in spite of the imperative of textbook size, everything cannot nor should not be "covered." The emphasis in this document, as biologist John Moore reminds us, is "on the ubiquitous and important and not the rare and important or ubiquitous and unimportant." A science education curriculum that focuses on the science technology that is essential for students to know, that helps them know why they know, that supports the students' learning of skills, and that leads them somewhere that is important, useful, interesting, and is personally connected to the world of the learner, is a powerful receipe for change. It is a case where less is, indeed, more.

THE SCIENCE LABORATORY*

Activity	Description
TYPE I	Does not require formal reasoning. Teaches important skills such as measurement and observation or how to use laboratory and scientific equipment.
TYPE II	In these laboratories, students verify concepts or principles. The problems and procedures are specified. Students can be asked about how they verified principles or concepts and data can be probed, analyzed, and discussed. However, if the majority of your laboratory activities are of this type, students will end up with the distorted view that someone knows the right answer. It is unlikely that science will be seen as a basic enterprise of human beings. It will be regarded as a given.
TYPE III	Students continue to get instruction from you (or written materials), but they do not know what results or conclusions to expect. The experiences are guided and students gain practice in finding relationships in their data.
TYPE IV	Students are still presented with a problem but you let them develop their own methodology for collecting data. These laboratories provide experience in data collecting skills such as measuring, identifying, and controlling variables, collecting and recording, and making interpretations.
TYPE V	In these investigations, the student formulates the problem, methods of data collection, makes interpretations, and draws conclusions. This is a true research project and can be an extension of a class discussion or an idea a student wants to pursue based on the student's own experience(s). It is sometimes difficult for a student to limit the problem to one she or he can handle. Students must be both knowledgeable and have process skills; teachers must be resource persons, facilitators and research advisors.

*Adapted from Jerry E. Ivins, The Science Teacher, May 1983.

CHAPTER 4
MODEL LEARNER OUTCOMES FOR SCIENCE EDUCATION

This chapter is concerned with expected learner outcomes. Several persons who reviewed this document before publication indicated that we are really dealing with **terminal outcomes** in that these are the outcomes that are expected from all students when they leave school. The authors have resisted that term because the word terminal sounds so final.

Numerous research studies have, over the years, shown that K-12 science teachers, seldom teach to objectives or goals. Projects that sought to establish objectives in science education that could be measured have been notably unsuccessful. What has happened is that either they are ignored by users or they become so loaded down with content objectives that nobody pays attention to them. What we have developed is a kind of middle-of-the-road approach in that we have identified only 26 learner outcomes. Many of these outcomes would be difficult to assess by conventional paper and pencil tests, but all lend themselves to assessing by some means. The outcomes chosen represent ideas that are generally recognized within the profession as concepts that overarch all disciplines, and they all comprise the essential outcomes that the average literate citizen ought to master.

Two issues that have not received the attention they deserve in the learner outcome chapter, mostly because to do so would be to focus on the teaching aspect rather than on the outcome aspect of science education, are global education and multicultural and gender fair issues. Although science is neither moral or immoral, science is, by its very nature, multicultural. There has never been a discovery that was not preceded by a series of precurser discoveries all over the planet. Knowledge can either explode as it is doing now, or it can accumulate very slowly, depending on the climate for learning that exists in society. These facts should be integrated into the curriculum at all levels wherever possible. Also, science is never the sole property of one gender or class of people. Science instruction should and must reflect that fact as well.

The reader is encouraged to review the learner outcomes, to consider where his or her subject, level, school, etc., fits in, especially in light of the program assessment he or she conducted from chapter one. If the outcomes seem rational and logical, then we would suggest that the reader move on to the last chapter where some attempt has been made to illustrate how those outcomes would be incorporated into the standard science curriculum.

State Board of Education Learner Goals	Learner Outcomes	Classification	Assessment
A.B. 1, 7, 8 C.D. 2	I: KEY CONCEPTS		
	A. Cause and Effect	APPLICATION/INTEGRATION	
	In a variety of contexts, learners will be able to cite examples where a particular situation or series of events always results in a unique effect. In science, all effects are caused.		
A.B. 7, 8 C. 1, 2, 3	B. Change	APPLICATION/INTEGRATION	
	Learners will demonstrate in a variety of contexts, using a variety of examples, that everything is in the process of becoming different or something else. They describe change by comparing the final state of a system to its initial state.		
A.B. 7 C. 1, 2, 3	C. Cycle	APPLICATION/INTEGRATION	
	Citing examples drawn from the various disciplines of science, learners can recognize patterns where certain events or conditions seem to be repeated at regular intervals or periods.		
	Learners will recognize that cycles work together as a dynamic, integrated, and interacting whole. Examples: water cycle, oxygen/carbon dioxide cycle.		

A.C.	D. Energy-Matter Learners will know that energy is the ability to do work; they will be able to distinguish between potential and kinetic energy. They will be able to demonstrate that they know the relationship between energy and matter and that matter is the stuff of which all things are composed.	APPLICATION/INTEGRATION
A. C. 1, 2, 3	E. Equilibrium and Homeostasis Within an appropriate discipline of science, learners will demonstrate an understanding of equilibrium and homeostasis in terms or a system or systems in balance—a state of affairs in which changes or tendencies to change occur in opposite directions, exist or happen at equal rates, or are of the same magnitude.	APPLICATION/INTEGRATION
A.C.	F. Fundamental Entities Learners will be able to do problems and cite examples drawn both from physical and life science concerning basic units such as cells, molecules, and atoms.	APPLICATION/INTEGRATION
A.B. 6, 7, 8. C.	G. Interaction Learners will be able to cite examples where two or more things influence or affect one another. For instance, they should be able to relate and quantify laws of motion.	APPLICATION/INTEGRATION

A.C. 1, 2, 3	J. Probability Learners can understand and calculate the relative frequency with which an event occurs in an indefinitely large number of trials. Also, they must realize that no probability can ever be exactly known, no action can be performed an indefinite number of times.	APPLICATION
A.C. 1	K. Patterns and Symmetry Learners demonstrate that most events in nature are balanced and predictable.	APPLICATION/INTEGRATION
A.C. 1, 3 D.2	L. System Learners when examining a set of objects or variables can distinguish relationships. Also, when dealing with a group of related objects, the learner can determine how they interact to form a whole.	APPLICATION/INTEGRATION
	II: PROCESS SKILLS (Thinking Skills)	
A.B.C. 1, 7	A. Observing The learner can employ her or his five senses to collect information concerning objects or events.	APPLICATION/INTEGRATION
A.C	B. Inferring Learners, after carefully examining observational data, can select the most likely judgment. Furthermore, learners recognize that judgement is never final or absolute; it is what is most probable given the observations and the state of what we know.	APPLICATION/INTEGRATION

A.C.	C. Classifying Learners can impose order on collections of objects or events. They can use classification schemes to identify objects or events to show similarities, differences, and inter-relationships.	APPLICATION
A.C.	D. Measuring Learners will use conventional and international units to measure a variety of scientific phenomena and/or events.	APPLICATION
A.C.	E. Using Science and Mathematical Symbols Learners will be able to construct, read, and interpret information in symbolic form (graphs, tables, and charts) using scientific symbols and conventions.	APPLICATION
A.C.	F. Predicting Learners can demonstrate the ability to make a specific forecast of what a future observation will be. They recognize that predictions are not random guesses, but based on previous observations, measurements, and inferences.	APPLICATION/INTEGRATION
A.C.	G. Communicating Learners are able to transmit and report information and data that they collect. They can inform others about what they are doing.	APPLICATION

A.C.	H. Formulating Hypotheses Learners can demonstrate the ability to make a logical explanation for something observed or inferred. They understand that their hypothesis is subject to a test which they are able to construct.	APPLICATION/INTEGRATION
A.C.	I. Controlling Variables Learners can demonstrate that they can isolate variables. They know that a variable is anything that can change, and may influence the outcome of an investigation. They understand the necessity of manipulating one variable at a time.	APPLICATION
A.C. 1, 2, 3	J. Interpreting Data Learners can demonstrate that they can use data to make inferences, predictions, and hypotheses. Also, learners are able to make statistical statements about collections of data such as mode, mean, median, range, and average deviation.	APPLICATION
A.C. 1, 2, 3	K. Defining Operationally Learners are able to define a term by giving a set of directions for what should be done experimentally to test the statement. Learners are able to describe the specific operations needed to be performed in order to measure a variable.	APPLICATION/INTEGRATION

A.C.	L. Building Scientific Models Learners are able to cite and employ models drawn from a variety of scientific disciplines. Furthermore, learners can demonstrate their understanding of how scientific models differ from other types of models—namely, that scientific models may not reflect what is actually occuring, but do offer tentative explanations for a phenomenon. They are always subject to revision as new knowledge is gathered.	APPLICATION/INTEGRATION
A.C.	M. Experimenting Learners are able to employ all of the process skills to solve an open-ended problem.	APPLICATION
A.B.C.D. K.L.	III. Personal Needs Learners are able to integrate science into their daily lives; they can use science skills to solve problems: Which is cheap? Which is best? How do things work?	INTEGRATION/VALUING
A.B.C.D.	IV. Science-Technology-Society Learners understand that science can not be separated from society, nor from persons who comprise that society. Likewise, society will always be affected by the technologies of science: hazardous waste disposal; Star Wars; pollution; medical technology. Learners will demonstrate their ability to react to STS in a variety of intelligent ways.	APPLICATION/INTEGRATION/ VALUING

CHAPTER 5

In the previous chapters, you have assessed your program, looked over a rationale for science, and probably discussed the chapter on overarching learner outcomes. The question still remains, "What does that all mean for me?" Chapter five is intended to show, in a very simple and straight-forward manner, how these learner outcomes apply to the various science subjects and grade levels. The pages that follow are arranged as follows: Elementary (primary/intermediate), life science, earth science, physical science, biology, chemistry, and physics. Each section is divided into two parts, **essential course elements** and examples drawn from the curriculum that indicate what students might be doing if you were teaching to the concept or learner outcome. These are simply illustrations; they are not intended to be course objectives. The essential course components are just that. Together they comprise a very simple course outline that contains what the steering committee felt is the content backbone of the course or grade range. Remove a piece of that backbone and you damage the course. Readers may say that in a semester course, it is impossible to teach to all of the content in the outline, or content assumed in the illustrations. To that, one can only reply that where there is not enough time provided to adequately teach the content and process skills, it must be made clear that the course taught is not to be compared with the standard school offerings (especially in the junior high school).

Also implicit in the outlines and illustrations that follow, is the fact that to be effective, science education must contain more than mere content. Science must be more than just telling the world about what science teaches. Instead, a science course should be the vehicle for promoting activities that lead students toward integrating their higher order thinking skills into their everyday lives. Science must not be divorced from the everyday experience of children. Children, large and small, learn best when they are taught within the context of their own experiences. If application and generalization are anticipated outcomes, then it is clear that students will need to have concrete examples of how concepts learned apply to the real world.

Where then does one go next? The authors suggest that persons in each discipline and in each level of science examine their response to chapter one's section titled: **LEARNER OUTCOMES: WHAT SHOULD BE LEARNED.** In that section, you have indicated which outcomes should be adopted and which could be ignored at your particular level or subject. You have also indicated where a particular concept or outcome should be introduced, emphasized, or maintained in the curriculum. Using the **Essential Course Elements** and the examples provided in the various sections, review your course of study to ensure that all of your priorities are represented to the degree you have indicated in chapter one. When this process is complete, you should have a scope and sequence that is goal-referenced and assessible. Good luck!

Essential Course Elements

1. Activities that encourage students to identify physical properties of things: color, texture, shape, smell, and size.

2. Activities that encourage students to compare objects that are similar for differences in size, shape, larger, smaller, and to quantify those observations using numbers.

3. Activities that encourage students to observe things and events over time: ice melting, relative positions, plants growing, seasons.

4. Activities that encourage students to answer the question, "What will happen if?"

5. Activities that encourage students to share information regarding how they solved/approached a problem.

6. Activities that demand that students venture a guess as to why an event occurred, or that something happened. Students, then, are encouraged to test their guess.

7. Activities that promote the identification of strategies to solve a problem.

8. Students define an event in terms of how it operates—a lever in terms of how it functions.

YOU KNOW YOU ARE TEACHING TO GOAL IF:

Cause and Effect

Primary Grades

a. Students understand that moving a switch on the wall causes the light in the ceiling to go on or off.

b. Students understand that blowing on a blackboard causes the water marks to go away faster than if one does not blow on them.

c. Students can demonstrate that watering plants at different rates causes them to grow at different rates.

d. Students understand that the rays of the sun feel warmer when the sun is higher in the sky.

Intermediate Grades

a. As one stretches a rubber band tighter, it makes a higher sound when plucked.

b. Students understand that as the sun moves higher in the sky, shadows cast by objects seem smaller.

c. Students know that lightning and thunder can be produced from electrical charges between clouds in the sky.

d. Students understand and can demonstrate that increasing the voltage to an electromagnet will cause one to pick up more paper clips.

Change

Primary Grades

a. Students understand that day changes into night and then to day again. They understand why.

b. Students can observe changes in the weather-that some days are cloudy and some days are sunny.

c. Students understand that the human body changes as it grows-from looking like a baby to looking like an adult.

d. Students know that plants change in appearance from seedlings to mature plants.

Intermediate Grades

a. Students observe that water changes in state as it is heated, and changes back when cooled.

b. Students observe that the appearance of the moon changes as we view it during different times during the lunar month.

c. Students observe that some chemicals change as they are heated.

d. Students demonstrate that things can be changed physically or chemically, and can test for the difference.

Cycle

Primary Students

a. Students observe and list the stages in the life cycle of a butterfly.

b. Students can predict what stages will come next in the life cycle of a frog.

c. Students can describe the steps in recycling aluminum cans.

Intermediate Students

a. Students can describe the steps in the water cycle.

Equilibrium and Homeostasis

Primary Grades

a. Students can predict what one would have to do to balance a teeter-totter.

b. Students can make predictions when they use balance boards or equal arm balances.

Intermediate Grades

a. Students can predict what will happen to one's heart rate when one exercises.

b. Students can predict the effect and increase in the number of rabbits (prey) will have on a predator population.

c. Students can describe what is happening in a balanced aquarium.

d. Students can describe a simple food web.

Units

Intermediate Grades

a. Students are acquainted with molecules in terms of their response to heat and cold: heat causes motion in liquids and causes solids to expand.

b. Students know that living things are composed of cells.

c. Students know that some cells are capable of living independently.

d. Students know, but may not understand completely, that all matter is made of atoms.

Interaction

Primary Grades

a. Students are able to describe the relationship between water and a seed sprouting.

b. Students are able to observe and describe the relationship between parents and their young.

c. Students describe the relationship between animals and plants, squirrels and oak trees, cows and hay, good soil and plant growth, magnets and metal objects.

Intermediate Grades

a. Students can explain how the circulation system and the respiration system relate to one another.

b. Students can demonstrate the relationship that exists between the amount of current and the strength of its magnetic field.

c. Students understand predator/prey relationships in a simple ecosystem.

d. Students begin to understand the relationships of pressure to temperature and temperature to humidity.

e. Students understand how the amount of rain affects erosion.

Organism

Intermediate Grades

a. Students can distinguish living things from those that are not alive.

b. Students can describe different types of organisms.

c. Students describe organisms in terms of their life functions: reproduction, movement, growth, respiration, nutrition, etc.

Patterns and Symmetry

Intermediate Grades

a. Students will be able to demonstrate a spectrum from white light.

b. Students will be able to categorize objects based upon characteristics they identify.

c. Students notice patterns in plants: petals, leaves, flowers.

System

Intermediate Grades

a. Students can give examples of systems (two or more interacting units).

b. Students can recognize simple environmental systems such as a pond, and describe how some part of that system interacts with another.

c. Students can visualize the human body as a system of interacting parts.

d. Students can describe how a beehive is a kind of a system, and how the specialized functions contribute to the system.

Observing

Primary Grades

a. Students describe the color, texture, and shape of a ball.

b. Students note the parts of a plant that are used for food.

c. Students can describe what happens when sugar is mixed with water.

d. Students can describe the location of the teacher's desk in the classroom.

Intermediate Grades

a. Students can describe how fish behavior in an aquarium changes when different kinds of fish are added.

b. Students can describe common features of several kinds of organisms.

c. Students can define an observation.

Inferring

Primary Grades

a. Students observe the fossil imprints of several objects and infer the identity of each.

b. By watching the flag on the school's flagpole, students infer how the leaves will fall down from the tree.

c. The identity of an object can be inferred by students using only the sense of touch and past experiences.

Intermediate Grades

a. After observing a cork floating in samples of saltwater and freshwater, students infer reasons for the difference in buoyancy.

b. Students infer from observation that vibrations cause sound.

c. After establishing ways to test foods for starch, students use the tests to infer the presence of starch in other food samples.

d. After recording observations concerning several look-alike substances, students infer what they are.

e. Given an operable flashlight, students make an inference about the parts and connections found inside.

Classifying

Primary Grades

a. Students can sort leaves into two piles according to the way they look.

b. Students can classify simple objects such as building blocks by shape and color.

c. Students can group objects according to their attraction or lack of attraction to a magnet.

d. Students can classify sounds as loud or soft, pleasant or unpleasant.

Intermediate Grades

a. Students can classify bones in a disarticulated skeleton.

b. Students can use a simple plant key to identify trees.

c. A student can classify rocks/leaves and using his or her criteria, another person can draw identical conclusions.

d. Given several types of matter, students can classify each as a solid, liquid, or a gas.

Using Science and Mathematics Symbols

Intermediate Grades

a. Students know the symbols for larger than, smaller than, add, subtract, multiply, and divide.

b. Students can compare objects serially from a graph.

c. Students can obtain some idea of the age of a tree by counting the rings.

Measuring

Primary Grades

a. Students are able to observe and compare the flow of liquids such as water, mineral oil, and detergent.

b. Students are able to use a thermometer to find the temperatures of various samples of water, air, or earth.

c. Students can compare the length of three different pencils.

Intermediate Grades

a. Students can compare the volume of two containers to see which will contain the most liquid.

b. Students can compare the widths of two or more common objects using a balance beam scale and paper clips as standard weights.

c. Students can use numbers to show the observed changes in plants.

d. Students compare the hardness of minerals by using the scratch test and a simple hardness scale.

Communication

Primary Grades

a. After finding objects that can be magnetized, students organize and/or label the objects so others will understand the results.

b. Students can imitate animal movements.

c. Students can describe what they have done to another person.

Intermediate Grades

a. Students can make a chart of the variety of clouds observed over a five-day period, and interpret that chart to someone else.

b. Students can write a report concerning an investigation they conducted.

c. Students can develop a simple identification key to a small rock, plant, or seed collection.

d. Students can construct a bar graph showing the growth of peas or bean plants over a twenty-day period.

e. Students can record the characteristics of non-living and living things.

Life Science

Essential Course Elements

1. Activities relating to proper laboratory and safety procedures included in each unit of study.
2. Criteria for classifying organisms into the five kingdoms.
3. Characteristics of life.
4. Cell Theory—cells as the basic units of structure and function of all living things.
5. Characteristics, structures, and functions of animals and plants, organs, and systems.
6. Processes of photosynthesis, respiration, and transpiration.
7. Understanding the concept of a food web and basic energy cycles.
8. The cause and effect relationship of living and non-living parts of the environment. Application of these relationships to environmental issues: acid rain, waste energy, resource management.
9. The human body systems, their structure and function.
10. Basic nature of DNA, the genetic code, and replication.
11. Basic principles of genetics: how traits are inherited and basic principles of probability.

YOU KNOW YOU ARE TEACHING TO GOAL IF:

Cause and Effect

a. Students understand the effect different light intensities have on the pupil of the eye.

b. Students can test the effect that exercise has on the heart rate.

c. Students can observe the response of organisms to changes in heat and light.

d. Students understand the body's reflex system.

e. Students can demonstrate an organism's response to stimuli.

Change

a. Students observe the life cycle of the Monarch butterfly.

b. Students observe and record the germination and growth of a plant.

c. Students can explain what would happen to a food chain if one food link were omitted.

d. Students can explain the events that take place as a forest grows ages.

e. Students understand the implications of pollution to an ecosystem.

Cycle

a. Students are able to define metamorphosis using the life cycle of the mealworm.

b. Students can observe and illustrate the life cycle of a common house plant.

c. Students can identify and show the importance of members within a food pyramid.

d. Students understand the basic elements of the human circulatory system.

e. Students understand the oxygen and carbon dioxide cycles.

Energy-Matter

a. Students are able to construct an experiment to show the importance of light to plant growth.

b. Students understand that for life to exist, energy must be produced.

c. Students understand that everything in the universe can be classified as either matter or energy.

d. Students can explain how matter in the form of food can be transformed to energy.

e. Students can explain the process of photosynthesis.

Equilibrium and Homeostasis

a. Students understand the balance within a common food pyramid.

b. Students know the interrelationship of organisms within a biotic community.

c. Students know the predator/prey relationship in a closed system.

d. Students are able to explain how hormones regulate body functions.

e. Students are able to explain the interdependence of decomposers, producers, and consumers.

Units

a. Students can explain the importance of food producers in a common food chain.

b. Students understand the common elements and compounds found in living things.

c. Students can explain how cells are used as the body's building blocks.

d. Students explain the importance of plankton to the ocean's food chains.

e. Students understand how individual traits can be used to identify a complex organism.

f. Students understand that one-half of each pair of chromosomes are donated by each parent.

Interaction

a. Students show the interrelationship between producers, consumers, and decomposers.

b. Students show the importance of each organism in a simple food chain.

c. Students are able to examine the interrelationship of the organisms within a garden plot.

d. Students can explain the interaction of body systems.

e. Students can show how one animal's physical characteristics have evolved so it can survive in a particular environment.

f. Students can recognize the importance of plants in maintaining the earth's oxygen supply.

Scientific Models

a. Students can diagram a common food chain.

b. Students can explain the five kingdom classification system.

c. Students can use tables or charts to explain possible gene combinations dealing with sex-linked traits.

d. Students can explain and cite examples of how models can be used to organize and explain complex ideas.

e. Students explain how a leaf identification guide is used.

Organism

a. Students can identify the activities that must take place for life to exist.

b. Students understand that an organism must take in food and in turn, release energy.

c. Students can explain why DNA are the molecules which form the basis of life.

d. Students are able to compare and contrast living and non-living things.

Probability

a. Students can describe the importance of probability to genetics.

b. Students can use pea plants to show dominant and recessive traits.

c. Students can show, in chart form, how color blindness can "skip" generations.

d. Students can make reasonable predictions regarding the results of simple genetic problems.

Patterns and Symmetry

a. Students can show the symmetry within a food pyramid.

b. Students can explain how elements in an ecosystem are interconnected.

c. Students understand how organisms' symmetry becomes more and more similar as one moves from kingdom to species.

d. Students can recognize symmetry in different plant leaves.

e. Students can distinguish between appropriate and inappropriate criteria for classification.

System

a. Students can distinguish between an open and a closed system.

b. Students are able to explain how body systems function.

c. Students can describe how a cell functions as an interaction system.

d. Students explain the interdependencies within a biotic community.

e. Students understand and explain how cells, tissues, and organs are organized to comprise body systems.

f. Students are able to show the dependency of organisms within a garden plot.

g. Students identify and describe the distinctive characteristics of the biomes of North America.

Observing

a. Students are able to distinguish between a seed and a non-seed.

b. Students are able to make a distinction between an observation and an inference.

c. Students are able to choose appropriate observations with which to classify animals or plants.

Inferring

a. Given certain key characteristics, students can infer if an object is an animal or plant.

b. Given a cross section of a tree trunk, students can infer growing conditions over the tree's life.

c. Students can draw conclusions from data displayed on a graph.

d. Students can draw inferences concerning what plants would be like if grown in the dark.

Classifying

a. Students can classify plants if given an appropriate key.

b. Students can place objects in sets, using appropriate characteristics.

c. Students are familiar with the principles of biological binomial classification systems.

d. Given sets of pictures where all of the items but one belong, students can select that item.

Using Scientific Numbers and Mathematical Symbols

a. Students can construct a graph showing how color blindness can skip several generations.

b. Students can construct and use a data table and graph to state the relationship between two phenomena.

Measuring

a. Students can use the common tools of life science: thermometer, balance, meterstick, clock and calendar.

b. Students can estimate large numbers such as a population of yeast.

	c. Students are precise enough so that another person could replicate their laboratory results.
Time/Space Relationships	a. Students can describe events over time: seeds germinating, eggs hatching.
	b. Students can make observations concerning fossils and the environment they must have lived in.
Predicting	a. Students can predict the probability of an offspring being either male or female.
	b. Students can make predictions from a graph (extrapolation).
	c. Given a sequence of events, students can predict the next step.
Communicating	a. Students can write a report concerning the results of a laboratory demonstration.
	b. Students can construct a key that others can use to obtain identical results.
	c. Students can use proper terms to describe a biological event or procedure.
Hypothesizing	a. Students can offer an explanation for what is happening in a balanced aquarium.
	b. Students do not attribute rational behavior to pets, invertebrates, etc.
	c. Students are willing to change their explanations when confronted with new evidence.
Controlling Variables	a. Students can identify the components of a classroom laboratory that are subject to change.
	b. Students demonstrate they realize that to obtain standard results, variables must be identified and controlled when performing an experiment.
Interpreting Data	a. Students can collect and display data from a laboratory demonstration.
	b. Students can collect data and use it to write a report.
	c. Students can find patterns in data they collect.
	d. Students can choose relevant data to collect in a laboratory demonstration.
Building Models	a. Students can explain how traits can be passed from one generation to another using the gene theory.
	b. Students can explain how DNA replicates itself.
	c. Students can explain how a cell functions.

Earth Science

Essential Course Elements

General

1. Scientific process and problem solving skills appropriate for the developmental level of the student.

2. Activities that promote an appreciation for the interrelationship of the earth sciences with all sciences, math and other content areas.

3. Activities that show the relationships between human activity and the earth sciences—energy use, pollution, resource use.

4. Components that include current earth science ideas and research.

Astronomy

1. Activities that illustrate the evolving nature of the universe and its components.

2. An analysis of the relationships among the members of our solar system.

3. An evaluation and projection of man's role in space exploration.

4. Use of astronomical techniques and instruments.

Physical Geology

1. Knowledge and classification of materials composing the earth's crust.

2. The formation and evolution of rock types.

Earth Dynamics

1. Mechanics of folding, faulting, earthquakes, and volcanoes.

2. Geologic features and their relationship to the theories of continental drift and plate tectonics.

Mapping

1. Topographic maps

2. Orienteering exercises

Weathering and Erosion

1. The dynamics of weathering and erosion correlated with surficial features.

2. Interpretations of local glacial history from geologic evidence.

Soils

1. Processes of soil formation.

2. Issues related to soil conservation.

Weather

1. Use of weather instruments to collect data.

2. Activities for transferring data to weather maps.

3. Activities for interpreting weather maps to predict future weather.

Hydrology

1. Analysis of basic physical and chemical properties of water.

2. Evaluation of water quality in natural systems.

3. The dynamics of surficial water bodies and groundwater.

YOU KNOW YOU ARE TEACHING TO GOAL IF:

Cause—Effect

a. Students can discuss the human influences on ground water quality.

b. Students are able to relate the gravitational effects of celestial bodies to the development of tides.

c. Students can associate home energy conservation with a decrease in energy costs.

d. Students can relate solar wind to the creation of auroras and disruptions in radio communications.

e. Students associate the burning of fossil fuels with the environmental concerns of acid rain and climatic warming.

f. Students can interpret the effects of differential solar heating at different latitudes on weather and climate.

Change

a. Students can discuss the evolution of a star.

b. Students can predict changes in the weather based upon atmospheric data.

c. Students associate moon phases with the changing relative positions of the earth, sun, and moon.

d. Students are able to analyze the alteration of the earth's surface caused by weathering and erosion.

e. Students know that substances in the earth's crust are continually undergoing compositional and textural change.

f. Students can identify landforms created by the movement of glaciers.

Cycle

a. Students examine the relationship between the sunspot cycle and weather patterns on the earth.

b. Students can describe the circulation of water from the surface of the earth, into the atmosphere, and back to the earth.

c. Students understand how rock samples are positioned in the rock cycle.

d. Students can describe the dynamics of orbiting bodies.

e. Students examine evidence for cyclical patterns of climatic change.

Equilibrium and Homeostasis

a. Students understand and appreciate the factors involved in creating a water budget for a lake basin.

b. Students can predict the relative positions of two orbiting bodies.

c. Students understand the relationship between oceans and carbon dioxide concentrations in the atmosphere.

d. Students understand how geologic and biologic factors interact to produce a climax ecosystem.

Units

a. Students use the basic units of the metric system in measuring temperature, mass, volume, etc.

b. Students to employ legend symbols and contour lines to extract information from a topographic map.

c. Students can discuss crystal form as a visible result of a crystal lattice.

d. Students can collect and analyze weather data. (Using standard units of weather measurement.)

Interaction

a. Students can determine how lake pH and lake basin bedrock interact.

b. Students see relationships between the earth's rotation/revoluti on and the changing appearance of the night sky.

c. Students see interactions between the ocean, atmosphere, and land to produce large-scale weather changes such as the phenomenon of El Nino.

d. Students understand how a warm and a cold air mass interact to produce a front.

e. Students deduce the relationships between bedrock, climate, and types of weathering/erosion.

f. Students can relate upwelling and general ocean circulation to nutrient availability for ocean life.

Probability

a. Students can analyze long- and short-range weather predictions for accuracy.

b. Students compare the relative degrees of hazard from lightning, thunderstorms, and tornadoes.

c. Students can discuss the likelihood of an organism becoming a fossil in a variety of depositional environments.

d. Students evaluate the relative probability of earthquake occurrence at different locations on the earth's tectonic plates.

e. Students can predict the value of a given geologic material as a barrier to ground water pollution.

Symmetry	a. Students are able to classify crystals based on their symmetry.
	b. Students can predict patterns of deposition from the structure of sand dunes.
	c. Students can identify groups of shelled fossils based on the symmetry of their shells.
	d. Students can analyze repeating cloud groups for patterns of atmospheric circulation.
	e. Students can explain the behavior of light waves in reflecting and refracting telescopes.
	f. Students can suggest reasons for symmetrical patterns in the atmostphere and the rings of Jupiter, Saturn, and Uranus.
System	a. Students analyze levels of organization in astronomical systems: solar system, galaxy.
	b. Students are able to relate major classes of rocks to their environments of formation.
	c. Students can classify minerals by their physical properties.
	d. Students can contrast air circulation in high and low pressure systems.
	e. Students can group soils according to their composition.
	f. Students can predict weather after mapping atmospheric conditions to locate frontal systems.
Energy-Matter	a. Students can discuss the changing composition of a star as fusion reactions occur to produce energy.
	b. Students relate internal dynamics of lake circulation with seasonal changes in temperature profiles.
	c. Students are familiar with the gravitational effects of the moon on the earth's surface.
	d. Students can analyze lunar evidence for impact of meteorites of different sizes.
	e. Students can compare the waste products generated in the use of solar, geothermal, fossil fuel, wind, and nuclear energy sources.
	f. Students examine patterns of heat circulation in the earth's atmosphere and oceans.
Scale	a. Students comprehend magnitudes of difference in the size of the solar system and the size of a galaxy.
	b. Students are able to model the relative distances between planets or stars.

c. Students compare the size of geographic features on the earth with those on other bodies in the solar system.

d. Students can place the activities of people on a timeline of earth history.

e. Students relate the size of details on a topographic map to their actual physical dimensions.

f. Students can compare distances covered by sound waves and light waves in a given period of time.

Observation

a. Students can distinguish observation from inference in classifying rocks or minerals.

b. Students can record atmospheric data that determine weather.

c. Students can sort soils according to their compositions.

Inferring

a. Students can infer the environmental forces that have had the greatest effect on the evolution of landforms.

b. Students will be able to describe a possible ancient ecosystem after looking at a fossil deposit.

c. Students can deduce the formational environments of rocks from their compositions and textures.

d. Students can describe specific terrains on topographic maps and relate details to their actual physical dimensions.

Classifying

a. Students can classify crystals based on their symmetry.

b. Students can sort minerals based upon their physical or chemical characteristics.

c. Students can sort cloud types into sets that conform to specific criteria.

d. Students can classify fossils according to the strata where they are found.

Using Numbers

a. Students can interpret a weather chart.

b. Students can make some generalizations from a geologic time table.

c. Students can read and interpret simple graphs.

d. Students can collect and display data.

Measuring

a. Students can use simple weather instruments to make measurements.

b. Students can use geologic table to estimate approximate ages of fossils.

c. Students can read the utility meters in their homes and make estimates of their energy consumption.

Time/Space Relationships

a. Students can make generalizations concerning bodies in the solar system.

b. Students can compare the size of geographic features on the earth with those on other bodies in the solar system.

c. Students can describe the life cycles of stars, black holes and neutron stars.

d. Students can describe the implications of traveling near the speed of light.

e. Students can describe an object in reference to another object.

Predicting

a. Students are able to predict changes in the weather based upon atmospheric data.

b. Students can predict the likelihood of earthquakes or volcanic eruptions from geographic locations on tectonic plates.

c. Students can predict the value of a given geologic material as a barrier to groundwater pollution.

d. Students can predict weather after mapping atmospheric conditions to locate frontal systems.

Communicating

a. Students use their own criteria to develop a classification scheme that would permit other students to obtain consistent conclusions.

b. Students can collect data and display that data in a way others can understand.

c. If asked to test an idea, students can write and interpret their collected information in a form that is appropriate.

Forming Hypothesises

a. Students can suggest possible reasons for events or phenomena based upon observations, data, and/or inferences.

b. Students are willing to modify ideas based upon new evidence.

c. Students can explain the difference between the scientific way of knowing and other ways of knowing.

Models

a. Students can determine the configuration of geographic features on topographic maps.

b. Students can use a stream table to examine causes of dam failures.

c. Students can construct a velocity profile for a river.

Physical Science

Essential Course Elements

1. Particulate nature of all matter; characteristic properties of matter.
2. Chemical and physical change; states of matter.
3. Elements and compounds; chemical reactions.
4. Acids, bases, and salts.
5. Chemical shorthand: symbols and physical descriptions of common elements and compounds.
6. Conservation of matter and energy.
7. Nature of energy and energy conversion.
8. Structure of the atom; the atomic nucleus.
9. Newton's laws.
10. Simple machines, mechanical advantage.
11. Properties of wave motion; sound and light as waves.
12. Electrical charges and interaction of charges.
13. Circuits, and electrical current.
14. Magnetism.
15. Applications of electricity and magnetism to daily life.
16. Proper lab/safety procedures.

YOU KNOW YOU ARE TEACHING TO GOAL IF:

Cause and Effect

a. Given a simple machine, students determine the possible causes of inefficiency and outcomes of changing the situation.

b. Students describe the effect of temperature variation on particle motion.

c. Students observe the effect of the addition of salt on the melting and boiling of water.

Change

a. Students can identify physical and chemical changes.

b. Students are able to use the particle model of matter to explain observable phenomena such as diffusion, solubility, and change of state.

c. Students can describe how and why the model for the structure of matter has changed in the last 200 years.

Cycle

a. Students can compare properties of elements within a given family or period of the period table.

b. Students can describe how harmonics and resonance are produced by sound waves.

c. Students can trace energy conversions in common phenomena.

Energy-Matter

a. Students are able to cite evidence that mass and energy are neither created or destroyed.

b. Students can cite evidence that matter is made of particles.

c. Students are able to give examples of different forms of energy.

d. Students can describe the relationship between matter and energy.

Equilibrium and Homeostasis

a. Students can use Newton's Third Law to explain common phenomena.

b. Students can cite evidence that matter and energy are neither created or destroyed.

c. Students can neutralize an acid with a base.

Units

a. Students cite evidence that all matter is made of particles.

b. Students use the particle model of matter to explain the characteristic properties of matter.

c. Students can classify a substance as an element, compound, or mixture.

	d. Students use properties to differentiate between electromagnetic and mechanical motion.
Interaction	a. Students are able to describe how static electrical charges are formed and interact.
	b. Students are able to state relationships among current, potential difference, and resistance.
	c. Students demonstrate the neutralization of an acid by a base.
	d. Students observe direct evidence for the existence of magnetic field lines and of field interactions between magnets.
	e. Students determine the conditions necessary for the interference of waves.
System	a. Students describe various forms of energy and identify conversions of energy in common phenomena.
	b. Students are able to describe how forces act in a simple machine.
	c. Students can describe how atoms combine to form molecules.
Patterns and Symmetry	a. Students use a spectroscope to identify the presence of elements.
	b. Students can demonstrate the law of reflection using a light source and mirrors.
	c. Effort force vs. resistant force.
Observing	a. Students can list observations concerning the physical properties of a given substance.
	b. Given one series and one parallel circuit, students can cite similarities and differences.
	c. Students can separate substances by properties, physical or chemical.
Inferring	a. Students can make reasonable guesses concerning the physical properties of contents of a black box.
	b. Students can guess probable reactants from the products of a chemical reaction.
Classifying	a. Students can locate elements on a periodic table.
	b. Students can classify various white powders according to their physical and chemical properties.
	c. Students can make a key from observations that can be used by someone else.

Using Numbers	a. Students can collect and display data. b. Students estimate large numbers. c. Students know the common symbols of science.
Measuring	a. Students can use the instrumentation of science: thermometers, balances, meters. b. Students calculate the average of several measurements in order to reduce error. c. Students measure using direct computer interfaces.
Predicting	a. Students make predictions using simple electrical circuits. b. Students indicate a willingness to change a prediction based on new facts. c. Knowing the PH of a substance, students can make a reasonable prediction concerning its conductivity. d. Students can make reasonable predictions concerning a substance based on its place in a periodic table.
Communicating	a. Students can write a laboratory report in its proper format. b. Students can develop a key that another person can use. c. Students can explain an event or phenomenon to another person or to the class. d. Students can set up a demonstration to illustrate an event or phenomenon.
Hypothesizing	a. Students can offer reasonable explanations for events. b. Students can distinguish a scientific hypothesis from other ways of knowing. c. Students can cite evidence as the basis of their guess.
Identifying Variables	a. When confronted with a problem, students can locate those parts that can change. b. Students can discover the factors that influence the rate of a chemical reaction such as Iodine Clock Reaction.
Interpreting Data	a. Students can read and interpret a graph. b. Students can collect and display data from a laboratory demonstration. c. Students can separate significant data from extraneous data.

Models

a. Students can cite evidence for the current model of the structure of the atom.

b. Students recognize various models of the atom and give reasons for each model.

c. Students use a Slinky as a model for sound waves.

d. Students can demonstrate the properties of waves using a tuning fork and a ripple tank.

Biology

Essential Course Elements

1. The tools and methods of science appropriate to biology.
2. The concept of life and how life differs from non-life.
3. Common characteristics of living things.
4. Cellular theory.
5. Cell structures vs. cell function.
6. Specialization: cells, tissues, organisms.
7. Energy transfer: photosynthesis and respiration.
8. Dynamic equilibrium in living things.
9. Mitosis and meiosis.
10. Relationship of RNA and DNA to genetics.
11. Genetics.
12. Evolution through time in response to a changing environment.
13. Relationships between and among biotic and abiotic factors in an ecosystem.
14. Development of multicellular organisms into specialized and interdependent systems.

YOU KNOW YOU ARE TEACHING TO GOAL IF:

Cause and Effect	a. Students can describe a reflex in the human nervous system.
	b. Students can discuss how environmental factors affect the rate of photosynthesis.
	c. Students can identify the abiotic factors that affect an ecosystem.
	d. Students can identify population determiners and their affect on any population.
Change	a. Students can predict the consequences of environmental stress on the evolution of a species.
	b. Students can describe energy changes from one tropic level to another.
	c. Students can summarize the concept of ecological succession.
	d. Students can describe the process of eutrophication.
Cycle	a. Students understand energy transfer within a living system (ADP-ATP cycle).
	b. Students can discuss the stages in the life cycle of an organism.
	c. Students can explain how respiration and photosynthesis are vehicles for cycling of materials.
	d. Students demonstrate knowledge of the carbon, nitrogen, and water cycles.
Equilibrium and Homeostasis	a. Students can cite examples of homeostasis.
	b. Students define population in terms of time, place, species, and density.
	c. Students can illustrate the ramifications of a preditor-prey relationship in a community.
	d. Students can apply the laws of thermodynamics to living systems.
	e. Students distinguish between hypo-, hyper- and isotonic solutions.
Units	a. Students distinguish between prokaryotic and eukaryotic cells.
	b. Students can describe the common elements and compounds found in living things.

c. Students are able to describe a typical cell.

d. Students can describe the stages of mitosis and meiosis.

e. Students can describe characteristics common to all living organisms.

Interaction

a. Students know the major relationships between species in a community, such as predation, parasitism, and/or symbiosis.

b. Students describe the concepts of a food chain and food web.

c. Students define and distinguish among, and give examples of population, communities, and ecosystems.

d. Students define metabolism in terms of anabolism and catabolism.

e. Students distinguish between messenger, transfer, and ribosomal RNA.

Scientific Models

a. Students can extract information from a given hereditary pedigree.

b. Students, when given a list of organisms in a community, can construct a food chain or a food web.

c. Students can describe the Watson-Crick model of DNA.

d. Students describe how an enzyme interacts with its substrate.

e. Students describe the makeup of a typical cell.

f. Students can use a Punnett Square to predict heredity.

Organism

a. Students can illustrate relationships between organisms and their surroundings.

b. Students can describe a community of organisms.

c. Students can distinguish between advanced and primitive characteristics in organisms.

d. Students can visualize the continuum of simple organisms to more complex organisms.

e. Students can describe the characteristics of an organism.

Probability

a. Students are able to solve genetic problems such as monohybrid and dihybrid crosses, test crosses.

b. Students are able to use Punnett Square, and product rule.

c. Students are able to predict a plant community given abiotic factors such as temperature, rainfall, altitude.

Patterns and Symmetry

a. Students know types of symmetry in body plans.

b. Students can explain the structure of the DNA molecule as a replicable form.

System

a. Students know the systems of plant and animal bodies and the interrelationships of these systems.

b. Students are able to describe the organizational pattern of multicellular organisms.

c. Students can compare cells, tissues, organs, and systems in an organism.

d. Students can identify typical plants and animals found in different biomes.

Observing

a. Students can distinguish major parts of a living cell, using a microscope.

b. Students can describe an organism in terms of its physical characteristics.

Inferring

a. After observing the pattern of animal tracks in the snow, students can infer the animals behavior at the time.

b. Students, when given a list of plants and animals in a given rock layer, can infer the previous environment and climate.

c. Observing the annual rings in a tree, students can reconstruct growing conditions during the life of the tree.

d. In an experiment involving a snail, anacharis, and brom thymol blue, stu- dents are able to state reasons for the observed color of the solution.

Classifying

a. Students are able to use a dichotomous key to group organisms in sets.

b. Students are able to place plants and animals into taxonomic groups based upon certain identifiable characteristics.

c. Students, given a group of simple organic molecules, are able to determine if they are carbohydrates, liquids, proteins, or nucleic acids.

d. Students are able to place plants or animals into their trophic levels (producers, consumers, decomposers) based upon certain identifiable feeding characteristics.

Using Numbers and Symbols

a. Students are able to use symbols to represent specific genotypes in genetic problems.

b. Students use letter symbols to represent chemical elements.

Measuring

a. Students are able to determine the age of a tree by counting the annual rings or the age of a fish by observing the growth lines on a scale.

b. Students are able to determine the field of view of the microscope in different magnifications.

c. Students can employ estimating strategies to count large numbers of objects such as individuals in a population.

Time/Space Relationships

a. Students can define populations in terms of location, space, and period of time.

b. Students are able to describe the changes in the observable shape and size of a plant over time.

Predicting

a. Students can predict the genotypes and ratios of the offspring expected from a given genetic cross.

b. Students can predict the effect of antibiotics on a certain bacteria based on evidence from experiments and culture plates.

c. Students can predict the possible effect on a water ecosystem of a specific new industry.

Communications

a. Students are able to take notes and summarize ideas into reports.

b. Students are able to read and interpret graphs and charts for another person.

c. Students can prepare a chart or graph from collected data.

Hypothesizing

a. Students can formulate, for example, a hypothesis explaining the loss of fish in a fish tank.

b. Students can formulate, for example, a hypothesis explaining the circular growth patterns of mushrooms often seen on lawns.

c. Students can formulate, for example, a hypothesis explaining the browning of evergreen trees on the side facing the road.

Controlling Variables

a. In a given experiment, students are able to list the variables that can affect the experiment and make sure the experiment tests for only one variable.

b. Given two test tubes, each containing a snail, anacharis and brom thymbol blue solution, students will be able to test for the effect of light on these systems.

Defining Operationally

a. Students are able to define a cell in terms of its functions.

b. Students are able to define photosynthesis in terms of its raw materials and products.

Experimenting

a. Students can design an experiment testing a hypothesis that the browning of trees along the road is due to road salt.

b. Students are able to design an experiment which will test factors that affect the growth rate of seeds.

c. Students are able to design an experiment of their own choosing.

Personal Needs

a. Students are able to evaluate data and regard sources of information with skepticism.

b. Students can understand and appreciate the effect of chemicals on the human body.

c. Students appreciate and recognize a well-designed experiment and are able to make proper inferences from the data.

d. Students avoid common science stereotypes, and view science as neither a male nor a female occupation.

e. Students understand what a scientist does.

f. Students are aware of career opportunities in various fields of science.

g. Students have a respect for common chemicals and the safety procedures that must be exercised when using them.

h. Student respect, but are not fearful of technology.

i. Students are able to look at scientific issues such as creation/evolution objectively, from several different perspectives, and distinguish the scientific way of knowing from other ways of knowing.

Science-Technology-Society

a. Students can demonstrate that there is a direct connection between scientific knowledge and economic growth.

b. Students know that in any society, scientific progress can only proceed as quickly as the political enterprise will permit. The direction and thrust of scientific research is also dependent upon the political environment.

c. Students recognize that national energy problems affect them, their families, their community.

d. Students have an understanding of the problems in the fields of human engineering and biotechnology.

e. Students have an understanding of the various aspects of environmental quality and that those aspects may differ in priority from person to person.

f. Students can demonstrate an understanding of the accomplishments and problems associated with space research and national defense programs.

g. Students can recognize the tradeoff's with respect to scientific and/or technologically related problems—a problem to one person may be an economic asset to another.

Chemistry

Essential Course Elements

1. Basic calculations including scientific notation and significant figures.
2. Classification and changes in matter, including physical and chemical changes.
3. The Periodic Table, including "families" and uses:
   a. Determine numbers of protons, neutrons, electrons.
   b. Write formulas for molecules.
4. Atomic theory, including models of the atom, shapes of orbitals.
5. Bonding and structure, including ions, complexions, bond types, formula writing (molecules, naming compounds).
6. The mole, its definition, and calculations.
7. Solids, liquids, gases, including kineticmolecular theory, phase changes, sublimation, definition of boiling, fractional distillation, properties of certain gases, distillation, vapor pressure equilibrium.
8. Solutions, including polar molecules, heat of solution, problems involving molarity, saturated solutions, solution equilibrium, ionic equations, ionization, qualitative analysis, precipitates, photography, net ionic equations.
9. Energy, including heat of reactions-exothermic and endothermic Hess's additivity law, ΔH.
10. Rate of reaction, including factors such as catalyst, activation energy, activated complex, reaction mechanism.
11. Equilibrium, including definition, LeChatelier's principle, common ion affect, equilibrium expressions and constants, solubility product constants (predicting precipitates).
12. Acids, bases, salts, (including definition, calculation and Kw), hydronium ion, titration, quantitative analysis.
13. Oxidation-Reduction, including half-cell reactions, oxidation numbers, definition, balancing redox reactions.
14. Electrochemistry, including electrical nature of matter, replacement reactions, cells and batteries, EMF series, half-cell reactions, electroplating, electrolysis, fuel cell, volts, amps.
15. Nuclear chemistry, including balancing nuclear reactions.
16. Chemistry of carbon compounds, including sp3 hybrid orbitals, hydrocarbons, isomers, esters, acids, alcohols, amines, polymers, benzene ring, aldehydes, ethers, ketones.

YOU KNOW YOU ARE TEACHING TO GOAL IF:

Cause and Effect

a. Students predict the formation of a precipitate, knowing the concentration of the ions and the Ksp.

b. Students can determine if a chemical reaction occurs on the basis of evidence of a precipitate forming, a gas evolved, or color change.

c. Students are able to predict the affect of changing pH on the color of an indicator.

d. Students can predict how temperature affects the rate of chemical reactions.

e. Students can explain the effect of temperature, pressure, concentration, and catalyst on a chemical reaction at equilibrium.

f. Students are able to predict the change in boiling temperature when the pressure is changed.

Change

a. Students recognize that adding energy to a liquid causes a change in phase.

b. Students can measure the amount of heat involved in a chemical reaction through the use of a calorimeter.

c. Students can explain the corrosion processes in a rusting automobile.

d. Students can differentiate between chemical and physical changes.

e. Students explain the color change of an indicator with a change in pH.

Cycle

a. Students can compare the properties of the halogen family in the periodic table.

b. Students can measure the vapor pressure of a liquid in a closed container.

c. Students explain how a catalyst is not consumed in a chemical reaction.

d. Students calculate the total energy of a system from the sum of the kinetic and potential energy with the formula $TE = KE + PE$.

e. Students discuss how industries should reclaim their wastes to avoid problems of pollution.

Energy and Matter

a. Students are able to use potential energy diagrams to describe a reaction mechanism.

b. Students can describe the nature of energy changes in chemical reactions using H notation.

c. Students are able to measure the heat of a reaction in energy units of calories and joules.

d. Students can determine the rate of a chemical reaction by changing either the temperature, the concentration, or a catalyst.

Equilibrium and Homeostasis

a. Students can calculate the equilibrium constant of a chemical reaction from knowing the equilibrium ion concentration.

b. Using LeChatelier's principle, students can determine whether reactants or products are favored in a system at equilibrium when a stress is added.

c. Students can measure the vapor pressure of a confined liquid.

d. Students can calculate the affects of temperature on a chemical system at equilibrium.

e. Students can state examples of systems at equilibrium such as population, solubility, and pressure.

f. Students are able to experiment with increasing the amount of precipitate by increasing the concentration of the reactants.

Units

a. Students describe the atomic structure model in terms of electrons, protons, and neutrons.

b. Students are able to balance chemical equations by conserving atoms.

c. Students can perform experiments to calculate Avogadro's number.

d. Students explain macroscopic phenomena such as diffusion and phase changes in terms of microscopic particle interactions.

e. Students explain chemical bonding in terms of exchanging or sharing of electrons.

f. Students can explain the conductivity of aqueous solutions in terms of positive and negative ions.

Interaction

a. Students are able to investigate the factors that increase the rate of a chemical reaction.

b. Students can titrate an acid with a standard base.

c. Students can explain that in an equilibrium, there is a balance between the factors of minimum energy and maximum randomness.

d. Students are able to use an element's properties to determine its position on the periodic table, or knowing its position, being able to predict its properties.

e. Students can determine the boiling point of a liquid by knowing the internal temperature and the external pressure.

f. Students can determine energy changes whenever chemical reactions occur.

Scientific Models

a. Students can construct models of molecules using ball and stick materials.

b. Students can use crystalline structures to predict the properties of solids.

c. Students can apply the collision theory to describe reaction rate mechanisms.

d. Students are able to use Arrenhius, Bronstad-Lowry, and Lewis models to classify acids and bases.

e. Students can arrange the elements in a variety of ways to describe the period- icity of groups and families.

f. Students use the kinetic molecular theory to describe gas law relationships.

Probability

a. Students are able to use the electron cloud theory to describe the probability position of an electron of a specific atom.

b. Students can use half-life relationships to explain radioactive decay.

c. Students understand that chemists cannot predict the exact behavior of two specific atoms in a chemical reaction, but can predict what will happen.

d. Students can explain that before a reaction can take place, the molecules of the reactants must first collide.

Patterns and Symmetry

a. Students employ concepts of electrical symmetry to explain the repulsion between ions.

b. Students can describe isomerism in organic compounds in terms of molecular symmetry.

c. Students can explain polar molecules and non-polar molecules in terms of charge symmetry.

d. Students describe crystals and can classify them on the basis of their structural symmetry.

e. Students can identify and describe properties of families in a periodic table.

System

a. Students know the factors that influence a shift in chemical equilibrium.

b. Students can describe a boiling process in terms of vapor pressure and atmospheric pressure.

c. Students can describe how changing the concentration of an aqueous solution affects the rate of a chemical reaction.

d. Students can prepare an aqueous solution of varying concentrations by diluting a solution of known concentration.

e. Students can describe a chemical system in terms of its being open or closed.

Observing

a. Students can observe a burning candle and distinguish between an observation and an inference.

b. Students can use a spectrometer, pH meter, thermometer to collect data.

c. Students can observe changes that occur during a chemical reaction. They can distinguish between relevant and irrelevant observations.

Inferring

a. Students can explain why equal volumes of gases under the same conditions have different weights.

b. Students can construct a model of an atom from data.

c. Students can state what ions are present after experimental analysis using a qualitative scheme.

d. Students can state the effect of antacids on the pH of stomach acid using experimental data.

Classifying

a. Students are able to recognize systems as being heterogenous or homogeneous.

b. Students are able to separate metals and non-metals according to chemical or physical properties.

c. Students can separate materials into bases and acids according to tests.

d. Students are able to distinguish if a change is physical, chemical, or nuclear.

Using Science and Mathematics Symbols

a. Students can write a balanced chemical equation from an observed reaction.

b. Students can calculate moles using scientific notation.

c. Students can explain the meaning of pH.

Measuring

a. Students can weigh an object using a balance.

b. Students are able to read a burette, or count drops during titration.

c. Students can read a thermometer two significant figures.

d. Students can determine the pH of a solution using indicator paper.

e. Students can use measuring devices connected to a computer.

Time/Space Relationships

a. Students are able to determine the rate of a chemical reaction in amount of product/time.

b. Students can observe the growth rate of crystals.

c. Students can observe and measure phase changes in melting and distillation demonstrations.

Predicting

a. Students are able to predict the affect of changing the pH on the color of an indicator.

b. Students can predict the change in boiling temperature when the external pressure is changed.

c. Students can predict the formation of a precipitate, knowing the concentration of the ions and the Ksp.

Communicating

a. Students are able to take notes and to collect data on an experiment. They are able to write a report about what was found.

b. Students can prepare a chart, graph, or diagram from collected data and explain it to someone else.

Formulating Hypothesis

a. Students are able to explain how a catalyst will affect the rate of a reaction.

b. Students can offer an explanation of what happens when a candle burns.

c. Students can describe the mechanisms of chemical reactions.

Controlling Variables

a. Students can define the variables of an experiment.

b. Students can recognize dependent and independent variables.

c. Students can relate temperature and concentration to reaction rates.

d. Students can discuss the variables that are held constant when doing a pressure, volume, temperature experiment with gases.

Interpreting Data

a. Students can construct an activity chart from a series of reactions with metals.

b. Students can distinguish qualitative data (information) from quantitative data.

c. Students can use experimental data to establish algebraic relationships between variables in the gas laws.

d. Students can interpret a heating, cooling curve involving a phase change.

Building Models

a. Students use the ''collision theory'' to explain a reaction mechanism.

b. Students are able to draw a series of progressively more complex pictures of the atom.

c. Students are able to build models of molecules.

d. Students can perform a ''Black Box'' experiment.

e. Students can explain phase changes using the ''particle theory.''

Experimenting

a. Students are able to establish a procedure to determine the factors that affect the rate of a chemical reaction.

b. Students are able to establish a procedure to determine the activity series of the metals.

c. Students can establish a procedure to determine the concentration of a salt solution.

d. Students can design a qualitative analysis scheme using knowledge of the ions obtained from previous experiments.

Personal Needs

a. Students are able to evaluate data and regard sources of information with skepticism.

b. Students can understand and appreciate the effect of chemicals on the human body.

c. Students appreciate and recognize a well-designed experiment and are able to make proper inferences from the data.

d. Students understand that both males and females can become scientists.

e. Students understand what a scientist does.

f. Students are aware of career opportunities in various fields of science.

g. Students have a respect for common chemicals and the safety procedures that must be exercised when using them.

h. Students respect, but are not fearful, of technology.

i. Students are able to look at scientific issues such as creation/evolution objectively, from several different perspectives, and distinguish the scientific way of knowing from other ways of knowing.

Science-Technology-Society

a. Students can demonstrate that there is a direct connection between scientific knowledge and economic growth.

b. Students know that in any society, scientific progress can only proceed as quickly as the political enterprise will permit. The direction and thrust of scientific research is also dependent upon the political environment.

c. Students recognize that national energy problems affect them, their families, their community.

d. Students have an understanding of the problems in the fields of human engineering and biotechnology.

e. Students have an understanding of the various aspects of environmental quality and that those aspects may differ in priority from person to person.

f. Students can demonstrate an understanding of the accomplishments and problems associated with space research and national defense programs.

g. Students can recognize the tradeoffs with respect to scientific and/or technologically related problems—a problem to one person may be an economic asset to another.

Physics

Essential Course Elements

1. Use of appropriate symbols in the discussion of physics topics.
2. Use of graphs to analyze physical relationships.
3. Manipulation of mathematical formulas to solve problems.
4. Differentiate between uniform motion and accelerated motion.
5. Use of vectors to describe and explain motion.
6. Use of Newton's laws to explain motion.
7. Describe and apply the law of universal gravitation.
8. Use of conservation laws such as momentum and energy.
9. Analysis of wave behavior including electromagnetic waves.
10. Demonstration and explanation of how to charge an object by either induction or conduction.
11. Analysis of series and parallel circuits.
12. Description of the changes that take place during artificial and natural nuclear interactions.
13. Use of geometric optics to explain images formed by mirrors and lenses.
14. Description of the forces on moving charges in electric and magnetic fields.
15. Description of and use of the field concept.
16. Use of equipment such as electrical meters, spring scales, stopwatches, meter sticks, thermometers, and equalarm balances.
17. Designing and conducting an experiment by isolating the problem, gathering data, suggesting a hypothesis, testing the hypothesis, drawing conclusions, and making predictions.
18. Describing and applying the kinetic molecular theory.

YOU KNOW YOU ARE TEACHING TO GOAL IF:

Cause and Effect

a. Students can predict the force on an object if its mass and acceleration are known.

b. Students can determine the speed of light in a medium if the angles of inci- dence and refraction are known.

c. Students are able to predict what conditions are necessary for lightning to occur.

d. Students can predict what will happen in an electric circuit as the resistance is varied.

e. Students are able to describe the color of the sky in terms of scattered light.

Change

a. Students can use graphs to analyze physical relationships.

b. Students can predict the end products in a nuclear reaction.

c. Students can calculate light intensity as the distance from a source is varied.

d. Students can calculate the percent of a sample of a radioisotope that undergoes decay during three half-lives.

e. Students are able to describe motion as a rate of change of position.

Cycle

a. Students can describe the kinetic energy of a swinging pendulum.

b. Students understand and can discuss circular motion.

c. Students are able to compare two different types of waves.

d. Students can calculate orbital parameters using Kepler's laws.

Energy-Matter

a. Students can use potential energy diagrams to describe a reaction mechanism.

b. Students can describe the nature of energy changes.

c. Students can discuss energy conservation in building design.

d. Students relate phase and temperature changes to energy content.

Equilibrium and Homeostasis

a. Students can investigate three forces in equilibrium and learn that the vector sum (resultant) of any two of the three forces must be equal and opposite in direction to the third force.

b. Students can predict the vapor pressure of a liquid at a given temperature.

c. Students are able to state what factors are needed to keep a nuclear reactor at constant temperature.

d. Students can compare the forces on an object in constant motion.

Units

a. Students can describe the difference between mass and weight.

b. Students can differentiate between derived and fundamental measurements.

c. Students compare uniform motion and accelerated motion.

d. Students are able to use SI units in measurements.

Interaction

a. Students are able to investigate the magnetic field around a current carrying wire.

b. Students can use Newton's laws to explain motion.

c. Students are able to describe and apply the law of universal gravitation.

d. Students can predict the angle of incidence and the index of refraction.

e. Students describe the operation of television picture tube.

Scientific Models

a. Students describe the assumptions of the kinetic molecular model of the atom.

b. Students predict the direction and magnitude of a force at a point using a field model.

c. Students can use Kepler's laws to predict orbital parameters.

d. Students describe the changes that take place during artificial and natural interactions.

Probability

a. Students can explain why one can predict certain experimental regularities on the half-life of a sample containing a very large number of radioactive nuclei.

b. Students can determine the size of a molecule based upon collision probability.

Patterns and Symmetry

a. Students can describe action-reaction of forces from a symmetrical point of view.

b. Students can describe the image formation of mirrors and lenses.

c. Students use the hand rules for describing magnetic fields around current carrying conductors.

d. Students can demonstrate the symmetrical nature of electrostatic charges.

System

a. Students are able to solve series-parallel circuit problems from a system approach.

b. Students use a variable incline to learn about the effect of gravitational force on a rolling ball.

c. Students determine how a stronger or weaker magnet affects a current carrying wire.

d. Students use a magnetic compass to plot the shape of a field around a bar magnet.

Observing

a. Students are able to read a meter or other measuring device.

b. Students can observe radioactive decay via a Geiger counter.

c. Students can observe motion for purposes of classification.

d. Students can utilize non-occular observation such as listening or sensing.

Inferring

a. Students can determine the charge of an object based on interaction with other charged objects.

b. Students can use emmision spectra to determine gases present in a sample of gas.

c. Students can use a mass spectrograph to determine relative abundance of isotopes.

Classifying

a. Students can distinguish uniform motion from accelerated motion.

b. Students can offer reasons why a collision is elastic or inelastic.

c. Students can offer reasons why a change is physical, chemical, or nuclear.

Using Numbers

a. Students can manipulate mathematical expressions to solve problems.

b. Students can graph numbers to show a relationship.

c. Students can use scientific notation to handle large numbers.

Measuring

a. Students can use electrical meters, spring scales, stopwatches, meter sticks, thermometers, and equal arm balances to make appropriate measurements.

b. Students can measure the direction and strength of a field using test objects.

Time-Space Relationships	a. Students can use time-space relationships when studying motion.
	b. Students understand time-space relationship when describing the motion of the solor system.
Predicting	a. Students are able to use a graph to interpolate and extrapolate data.
	b. Students can determine the angle of refraction given angle one and the index of refraction.
	c. Students can predict volumes of a gas at different temperatures and pressures.
Communicating	a. Students can write a clear laboratory report.
	b. Students can graph pertinent data and analyze the result.
	c. Students can make an oral presentation of the results of an investigation.
Hypothesizing	a. Students can offer an explanation that accounts why the radiation count is inversely related to the distance from a source.
	b. Students use a graphical representation to propose possible mathematical relationships between data.
Controlling Variables	a. Students can isolate the relationships between electrical resistance and the parameters of a wire.
	b. Students can design experimental procedures that will determine Newton's first law.
	c. Students determine the factors involved in radiation shield materials.
Interpreting Data	a. Students can use a graph to show a relationship.
	b. Students can compare ticker tapes to determine how fast an object is moving.
Defining Operationally	a. Students can define a force in terms of its effect.
	b. Students can define a field in terms of its unique property. For example, an electric field is able to exert forces on charged particles within it.
	c. Students are able to use the concept of half-life to describe radioactive decay.
Formulating Models	a. Students can use the mechanical gas model to explain phenomena.
	b. Students can use a particle model to explain light.

c. Students can describe the kinetic molecular theory.

Experimenting

a. Students can plan an experiment that would verify Ohm's law.

b. Students are able to verify Snell's law experimentally.

c. Students can devise and carry out an experiment that will test Newton's second law.

Personal Needs

a. Students can employ scientific problem solving skills to their daily lives.

b. Students are encouraged to develop enough background information to consider a career choice in physics.

c. Students demonstrate an increased appreciation of the aesthetics of the world around them using the concepts and skills of physics.

d. Students are less fearful of natural phenomena such as thunderstorms, sunspots, nuclear radiation, northern lights, etc.

Science-Technology-Society

a. Students can give specific examples of how to decrease energy use in a home.

b. Students can evaluate tradeoffs involved in personal energy conservation plans.

c. Students describe some of the effects of global nuclear technology.

d. Students can evaluate the consequences on the environment of increased energy use.

e. Students are aware of alternative energy sources.

f. Students can describe the role physics has played in space technology.

g. Students can delineate technological advances such as the effect that the vacuum pump has had on technology.