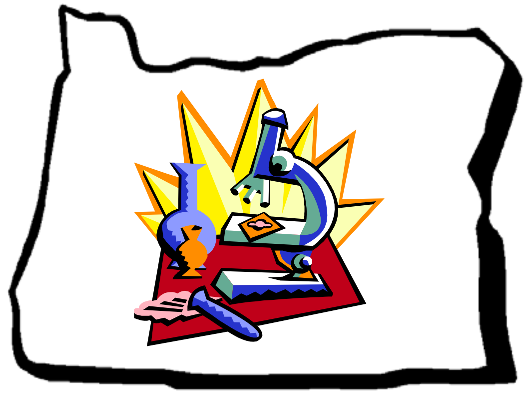

Science Teaching & Learning to Standards

Early Release for the Oregon Science Teacher Leader Institute
July 26 – 28, 2005

Oregon Teacher Resources

2005-2007

This document is on the web at www.ode.state.or.us/search/results/?id=246

People Resources

The Oregon Department of Education is ready to help teachers, classified staff, and administrators as you further develop your standards-based curriculum and instructional methods. We also can answer questions from parents, students, and the general public. Please let us know what you need.

Send Us Your Comments

Please let us know how we could change this publication to better meet your needs. Contact **Cheryl Kleckner** at:

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WHAT'S NEW

This 2005-07 edition of Science Teaching and Learning to Standards incorporates revision recommendations from the May 2005 work sessions of the Advisory Committee.

Additions to this version include:

- A summary of two new science-education-related measures that have been approved by the 73rd Oregon Legislative Assembly in the 2005 Regular Session (pages 7-8).
    - Senate Bill 383 directs that any school district that includes dissection as part of its coursework shall permit students to demonstrate competency in the coursework through alternative materials or methods of learning that do not include the dissection of animals.
    - House Joint Resolution 3 designates that the Metasequoia is the Oregon State Fossil.
- More information on the Claims/Evidence approach to teaching scientific inquiry (pages 54-62).
- Formative Assessment Tools for teachers at Benchmarks 2 and 3 as well as CIM (pages 73-90).
- A Professional Development section (pages 105-106).
- Information on Professional Learning Teams and Communities (pages 107-119).

INTRODUCTION

Foundation for Improvement

As Oregon continues to develop a system of standards-based instruction, the education community can look forward to:

- coordinated instruction that builds on what students have learned in previous years.
- assessment that is consistent from one teacher to the next, across schools and districts.
- smooth transitions when students move from school to school.
- a match between what's taught and what's tested.
- student advancement based on mastery of academic subjects instead of seat-time.
- a system that allows students additional time and help when they need it.
- clear communication within teaching staffs.
- a system of measuring student achievement that parents can understand and support.
- a new perception of the teacher as coach, helping students toward high achievement of state standards.
- a teaching environment built on clearly defined high expectations.

Much of the preliminary work of creating this visionary system is behind us. With extensive input from parents and teachers around the state, the State Board of Education adopted content standards, identifying what students should know and be able to do. Benchmarks specify what content will be covered in state tests and classroom work samples. Performance standards indicate levels of expected student achievement.

The success of Oregon's standards-based instruction system hinges on how the standards are implemented in districts and classrooms. It depends on a commitment from all teachers, with the support of their administrators, to embrace the vision, study the concepts and skills behind the content standards, and center everyday classroom activities around them.

For teachers, this means concentrating more than ever on what is expected of students and how classroom curriculum, instruction and assessment will work together to help them achieve results. This starts with understanding the content standards: those relevant to the subject area or benchmark level, and more specifically, those that students will be expected to meet. Once the content standards are understood, teachers can choose teaching strategies that promote the concepts and skills involved in each content standard and assessment activities that allow students to clearly demonstrate they have mastered these concepts and skills.

District-level curriculum decisions also pivot on the content standards. But it is just as important for other district decisions—budget, staffing, facilities, professional development, etc.—to be approached from the same standpoint: "How will this impact our ability to prepare students to meet the standards?"

Adapting to standards-based instruction demands planning, professional development and meeting time. This document suggests some steps in that process. It will be followed with other practical resource materials. More important than any technical assistance, though, is your commitment to build a more equitable, more accessible, and more effective education system.

The Science Classroom

Science is an integral part of contemporary life. Science is a body of knowledge, a way of thinking, a way of studying the world, and a way of solving problems. Learning and teaching K-12 science is an exciting, engaging, experiential-based process that stimulates the imagination of both students and teachers. Children are curious about the natural world. Children are curious about the natural world. Science teaching should build on this innate curiosity through active teaching. Learning is the exploration of questions, not just the knowing of answers; it is the practice of critical thought, not just the exercise of memory.

Effective science teaching balances multiple aspects of curriculum: concept and process development; career and practical application; student preconceptions; science in the context of the student's every day life and concerns; and understanding of the underlying principles of topics including life science, physical science, and the Earth and space sciences.

Teachers are collaborators in building a standards-based program over time. Teachers plan student work so that it intentionally focuses on standards. Teachers collect examples of student work to inform their own planning and to improve assessment. They plan curriculum and instruction that is deeply aligned with standards and is appropriate for the academic and instructional needs of students. Standards-based instruction provides multiple opportunities for success, communicates the value of science, uses research-based pedagogy, and is guided by teachers' understanding of their students.

With the increasing emphasis on hands-on, minds-on inquiry instruction at all levels, it is critically important that science teachers be as knowledgeable as possible about laboratory safety issues and their own responsibilities. For more on safety, refer to the science education safety information (pages 121-132) in Appendix 1.

Legislation

Two new measures that are related to science education have been approved by the 73rd Oregon Legislative Assembly in the 2005 Regular Session. A summary of each measure follows.

House Joint Resolution 3 designates that the Metasequoia, or dawn redwood, is the official fossil of the State of Oregon. The measure states that, "…the Metasequoia, or dawn redwood, is easily identified, is among the most abundantly found fossils in Oregon today and is widely distributed in the fossil record of western North America; … the Metasequoia represents Oregon's ancient past as it flourished in the Miocene epoch of 25 to 5 million years ago and left its record embedded in rocks across the Oregon landscape"

The complete text and history of HJR3 is available on the Oregon Legislative website at http://landru.leg.state.or.us/05reg/measures/hjr1.dir/hjr0003.en.html

The following Oregon Common Curriculum Goals (CCG) and Content Standards (CS) in science relate most directly to fossils and the fossil record:

- **Unifying Concepts and Processes**
  - CCG: Understand that any collection of things that have an influence on one another can be thought of as a system.

- CCG: Understand that both patterns of change and stability are important in the natural world.

- **Life Science**
  - CCG: Diversity/Interdependence: Understand the relationships among living things and between living things and their environments.
    - CS: Describe and analyze diversity of species, natural selection and adaptation
- **Earth and Space Science**
  - CCG: The Dynamic Earth: Understand changes occurring within the lithosphere, hydrosphere, and atmosphere of the Earth.
    - CS: Explain and analyze changes occurring within the lithosphere, hydrosphere, and atmosphere of the Earth.

Senate Bill 383 allows a kindergarten through grade 12 public school student to refuse to participate in and parents and legal guardians to refuse to allow student participation in dissection of any vertebrate or invertebrate animal as part of a public school course. The bill directs that any school district that includes dissection as part of its coursework shall permit students to demonstrate competency in the coursework through alternative materials or methods of learning that do not include the dissection of animals. The alternative materials and methods may include but are not limited to: Videotapes, DVDs and CD-ROMs; Models; Films; Books; Computer programs; Clay modeling; and Transparencies.

This legislation also requires:
A kindergarten through grade 12 public school teacher may not discriminate against a student or lower the grade of a student for not participating in the dissection of an animal.

and

A school district shall notify students who have dissection as part of their coursework and the parents and legal guardians of those students about these provisions.

This measure takes effect July 1, 2005. Districts are responsible to adopt policies and procedures to implement these requirements.

The complete text and history of SB383 is available on the Oregon Legislative website at
http://landru.leg.state.or.us/05reg/measures/sb0300.dir/sb0383.en.html

The following Oregon Common Curriculum Goals (CCG) and Content Standards (CS) in science relate most directly to animal biology:

- **Unifying Concepts and Processes**
  - CCG: Understand that any collection of things that have an influence on one another can be thought of as a system.
  - CCG: Understand that a model is a tentative scheme or structure with explanatory power.
  - CCG: Understand that both patterns of change and stability are important in the natural world.
  - CCG: Understand that changes in scale influence the characteristics, properties and relationships within a system.
- **Life Science**
  - CCG: Organisms: Understand the characteristics, structure, and function of organisms.
    - CS: Describe the characteristics, structure, and function of organisms.

Purpose and Use of this Document

The purpose of this science education document is to provide resources and advice for teachers, professional development personnel, and teacher educators to help them implement state standards in Oregon's schools. The resources within this document alone will not assure that students attain Oregon standards. To move all students to these standards, educators must have an environment where several things occur: (a) all teachers are informed and committed to improvement of science education; (b) professional staff are provided appropriate release time to reflect, plan, and implement district and school plans for science education; (c) teachers have job-embedded professional development opportunities; (d) parents are kept informed; (e) students take responsibility for their own learning with input from parents and teachers; and (f) teacher educators and pre-service teachers stay informed, collaborate with skilled classroom teachers, and are actively engaged in the improvement of science education.

This document lays out key aspects of the current knowledge of teaching and learning in science including standards, curriculum, instruction, and assessment. It also provides clear descriptions and examples of encouraging practices from Oregon schools. Teachers and other professional educators can pull these descriptions, examples, and essays together and apply them in ways appropriate for their own classrooms. Standards, curriculum, instruction, and assessment must be tightly aligned if Oregon students are to meet Oregon's science standards. With congruent standards, curriculum, instruction, and assessment practices, student achievement should meet or exceed expectations. Teachers and administrators should use this document during the 2005-2007 school years for examples of encouraging practices in Oregon schools, references to key documents and Internet resources, and for contacts to build a network of professionals working on implementing Oregon science standards.

STANDARDS-BASED EDUCATION

Introduction to Standards

Educational standards are criteria to judge quality – the quality of what students know and can do. **Common Curriculum Goals** are the broadest overview of what all districts must provide for students in instruction**. Content standards** are developed in more specific language directly related to student performance (e.g., *explain*, *describe*, and *apply*). They represent the complete set of learning outcomes Oregon students should attain to be judged proficient.

Common Curriculum Goals and content standards are applicable at all grade levels, however, specific assessment objectives are written for Benchmarks 1, 2, 3 and CIM (grades 3, 5, 8, 10). They provide checkpoints for student progress. Under each benchmark, bulleted lists describe eligible content. Eligible content specifies elements of the benchmarks that may be assessed by the state knowledge and skills content assessments. No assessment can test all eligible content, however, every multiple choice test item is aligned to the eligible content.

Oregon's Science Standards

Oregon's science content standards, initially developed in 1996, were revised in 2001 (see Appendix 4) through a process that involved educators, parents, the business community, and other concerned Oregonians. The Oregon Board of Education adopted the revised content standards on April 26, 2001. These more concise standards are based on both the *Benchmarks for Science Literacy* (1993) and the *National Science Education Standards* (1996). Several major changes were made in the latest revision:

- Beginning in the 2002-03 school year, unifying concepts and processes is no longer a score-reporting category on the statewide assessment, thus the eligible content has been removed. Aspects of unifying concepts and processes have been added to the eligible content in Earth/space science, life science, and physical science.
- As of the 2002-03 school year, the core process of scientific inquiry is no longer a score-reporting category on the statewide assessment, thus the eligible content has been removed.
- Beginning in 2003-04, scientific inquiry will be assessed through classroom work sample.
- The concepts of availability of Earth materials and recycling are strengthened in Earth/Space Science.

The content standards will continue to be reviewed and revised periodically. The next revision of Oregon's science content standards is slated for 2009.

Oregon's content standards, benchmarks and eligible content specify what is essential for all students to learn. Local districts, however, determine when and how the required content is delivered.

On April 17, 2003, the State Board of Education reviewed the finalized Grade Level Mapping of the Science Common Curriculum Goals. This extensive work is for assistance to schools, it is not required and there is no plan for it to be mandated. The mapping is based primarily on the Atlas for Science Literacy (AAAS, 2001), and is available in several formats, including grade-level alignment tools, on the web at http://www.ode.state.or.us/teachlearn/subjects/science/curriculum/gradelevel/.

Science Standards at the National Level

Scientific literacy is critical in modern society. Citizens who can understand the technical, social and ethical aspects of the science and technology that shape our world will be able to debate important issues and make informed choices. Standards will help our students become scientifically literate. According to the writers of the *National Science Education Standards* (National Research Council, 1996), page 2, "standards…outline what students need to know, understand, and be able to do to be scientifically literate at different benchmark levels. They describe an educational system in which all students demonstrate high levels of performance…Standards also highlight the need to give students the opportunity to learn science. "

Establishing and implementing science education standards has become a national goal over the last several years. Beginning with the *Science for All Americans* document of the American Association for the Advancement of Science (AAAS) published in 1985, continuing with *Benchmarks for Science Literacy* published by AAAS in 1993, the *National Science Education Standards* published by the National Academy Press in 1996, and the *Pathways to the Science Standards* published by the National Science Teacher Association in 1996, the nation's science leadership has developed a shared vision of what scientifically literate citizens should know and be able to do in science. Teaching to standards involves changing how and what is taught in science (see Figure 1 below). Realize that effective science teaching involves both emphases.

Figure 1: Changing Emphases of Science Teaching in a Standards-based Classroom

(Adapted from: *National Science Education Standards*, National Research Council, 1996)

Less Emphasis on	**More Emphasis on**
Treating all students alike and responding to the group as a whole	Understanding and responding to individual student's interests, strengths, experiences, and needs
Rigidly following curriculum Focusing on student acquisition of information	Selecting and adapting curriculum Focusing on student understanding and use of scientific knowledge, ideas, and inquiry processes
Presenting scientific knowledge through lecture, text, and demonstration	Guiding students in active and extended scientific inquiry
Asking for recitation of acquired knowledge	Providing opportunities for scientific discussion and debate among students
Testing students for factual information at the end of the unit or chapter	Continuously assessing student understanding
Maintaining responsibility and authority	Sharing responsibility for learning with students
Supporting competition	Supporting a classroom community with cooperation, shared responsibility, and respect
Working alone	Working with other teachers to enhance the science program

Curriculum and Instruction in Standards-Based Education

Definitions and Need for Alignment

A critical examination of the written curriculum and instructional materials used can help reduce repetition in successive grades, focus in-depth on fundamental ideas, and ultimately increase the number of students attaining educational standards.

When aligning district curriculum with Oregon's Common Curriculum Goals and content standards or aligning classroom instruction with the district curriculum, it is important to distinguish what is meant by the terms **Common Curriculum Goals**, **content standards, eligible content, curriculum,** and **instruction** (See Glossary, Appendix 3). In order for students to have an opportunity to meet the **performance standards** (see page 18), the district curriculum must be carefully aligned with the content standards. Since the statewide multiple-choice test items are based on the **eligible content**, careful consideration should be made to provide teachers and students thorough understanding of eligible content. The district curriculum will include more material than the eligible content because it is a minor sampling of skills and knowledge that students need to master the learning outcomes of the district curriculum.

Common Curriculum Goals describe the broad categories that comprise what all students should have the opportunity to learn. The **grade-level mapping** in science (formerly referred to as an instructional framework and optional curriculum) was developed to inform district curriculum specialists and teachers. The mapping provides a grade-by-grade continuum toward all Common Curriculum Goals – including those with no standards (Unifying Concepts and Processes, History and Nature of Science, Science in Human and Social Perspective, and Science and Technology). This mapping will **NOT** outline required instruction. It is only a model to assist districts and teachers who choose to use it. The science grade-level mapping is on the web at www.ode.state.or.us/teachlearn/subjects/science/curriculum/gradelevel/.

Content standards (and their grade-level benchmarks) define the learning outcomes that are to be achieved through instruction. The benchmarks describe the skills and knowledge that students should have at certain checkpoints. Recognizing that there are many different ways to align to standards, the Oregon Department of Education leaves the curriculum and instruction decisions to the individual schools and districts. These local decisions shape curriculum and instruction so they align with the standards.

Curriculum refers to a district's plan for what will be taught in each of the grades. For example, a curriculum document might call for all fourth-grade classes to include instruction on electric circuits. Curriculum alignment is most often accomplished by convening a group of teachers, administrators, and curriculum specialists to produce (or adapt) a curriculum document for the school or district. District documents that describe the entire curriculum from K-12 are often called "scope and sequence" or "articulation" documents because they define the scope of each grade-level and the sequence of curriculum from grade-to-grade.

Instruction refers to the specific activities and lessons that give students the opportunity to meet the curriculum's learning objectives. Lesson plans, for example, are instructional plans. Most often, districts define the curriculum but leave the instructional planning to the individual teachers. Therefore, even though all fourth grade teachers may teach about electric circuits, the specific classroom activities may vary from teacher to teacher. Teacher's instructional plans often vary greatly, even when they use the same textbook. Textbooks cannot be relied upon to create an aligned curriculum. Textbook labs will not necessarily provide the depth of understanding required by the standards. Teachers should carefully select appropriate, high quality materials and then plan to use fitting instructional strategies. Time for teachers to discuss and review instruction as they examine student work is a valid form of professional development (Loucks-Horsley 1999).

Districts are encouraged to provide opportunities to teachers to work together on plans for instruction. For teachers in lower grades, such opportunities often take the form of training in the use of instructional materials such as science kits while in upper grades, they occur in the form of collaborative planning of lessons. Either way, teachers must make sure that their instruction is aligned with both the district's curriculum and the state standards or the advantage of cooperative planning is lost.

Analyzing Curriculum Materials

Curriculum analysis begins with curriculum mapping exercises to determine how well the current curriculum matches the Common Curriculum Goals and content standards and what gaps are present. An analysis for scientific literacy can add depth to the process.

A helpful procedure for precise curriculum analysis has been developed by Project 2061 – an educational resource group within the American Association for the Advancement of Science. The intent of the Project 2061 procedure is to judge *how well curriculum materials are likely to contribute to the attainment of specific learning goals*. A second premise is that *both the content and instructional properties of the materials under examination* must be taken into account. It does little good for materials to simply include the content of specific learning goals if the instructional strategies recommended in the material are not consistent with what is known about how students learn. Students must be taught accurate content using sound research-based instructional strategies in order to meet the benchmarks.

What follows is an excerpt prepared by Dr. Camille L. Wainwright of Pacific University for her science methods classes. It summarizes the curriculum analysis procedures described in an article by Jo Ellen Roseman, Sofia Kesidou, and Luli Stern (Project 2061 staff). This analysis procedure can be applied to a review of a textbook at the time of adoption, or aspects of it can be used to critique an instructional unit, a lesson plan or a single activity.

Content Analysis: Determine whether the content in the material matches specific learning goals or benchmarks — not just whether the topic headings are similar.

1. Is the **substance** of the benchmark matched or is there only a topical match? Will students achieve an understanding of the content of the benchmark as a result of the lesson(s)?
2. Does it match the intended sophistication of the benchmark? That is, is it age- and grade-appropriate according to the research and the guidance of the Benchmarks?

Instructional Analysis: The purpose here is to estimate how well the instructional strategies in the material support student learning *those very ideas and skills* for which there is a content match. For more detail, see Ch. 13 in *Science for All Americans (AAAS, 1989),* Ch. 15 in *Benchmarks for Science Literacy (AAAS, 1993),* and Ch. 3 in *National Science Education Standards (NRC, 1996).*

Project 2061 has identified seven research-based clusters of criteria that are useful in analyzing the lesson, curriculum, or textbook for adoption.

Cluster I. Providing a Sense of Purpose: Part of planning a coherent curriculum involves deciding on its purposes and on what learning experiences will likely contribute to achieving those purposes. This cluster includes criteria to determine whether the material attempts to make its purposes explicit and meaningful, either by itself or by instructions to the teacher. Students are more engaged and successful when they understand the purpose of the tasks and lessons in which they are engaged.

Cluster II. Taking Account of Student Ideas: Fostering students' understanding requires paying attention to the ideas they already have coming in to the class – both ideas that are incorrect and ideas that can serve as a foundation for subsequent learning. Such attention requires that teachers are knowledgeable about prerequisite ideas/skills needed for understanding a benchmark and what their students' initial ideas are -- in particular, the ideas that may interfere with learning the scientific story. This cluster examines whether the material contains specific suggestions for identifying and relating to student prior concepts and misconceptions.

Cluster III. Engaging Students With Phenomena: Much of the point of science is explaining phenomena in terms of a small number of important principles or ideas. For students to appreciate this explanatory power, they need to have a sense of the range of phenomena that science can explain. "Students need to get acquainted with the things around them—including devices, organisms, materials, shapes, and numbers—and to observe them, collect them, handle them, describe them, become puzzled by them, ask questions about them, argue about them, and then try to find answers to their questions." (*AAAS (1993)*, p. 201)

Cluster IV. Developing and Using Scientific Ideas: *Science for All Americans* includes in its definition of science literacy a number of important yet quite abstract ideas—e.g., atomic structure, natural selection, modifiability of science, interacting systems, common laws of motion for earth and heavens. Such ideas cannot be inferred directly from phenomena and the ideas themselves were developed over many hundreds of years as a result of considerable discussion and debate about the cogency of theory and its relationship to collected evidence. This cluster includes criteria to determine whether the material attempts to provide links between phenomena and ideas and to demonstrate their usefulness in many contexts.

Cluster V. Promoting Student Reflection: No matter how clearly materials may present ideas, students (like all people) will make their own meaning out of it. Constructing meaning well is facilitated by having students (a) make their ideas and reasoning explicit, (b) hold them up to scrutiny, and (c) refine them as needed. This cluster includes criteria for determining whether the material suggests how to help students express, think about, and reshape their ideas to make better sense of the world.

Cluster VI. Assessing Progress: There are several important reasons for monitoring student progress toward specific learning goals. Having a collection of alternatives can ease the creative burden on teachers and increase the time available to analyze student responses and make adjustments in instruction based on them. This cluster includes criteria for whether the material includes a variety of goal-relevant assessments including formative assessments.

Cluster VII. Enhancing the Learning Environment: Many other important considerations are involved in the selection of curriculum materials—for example, the help they provide teachers in encouraging student curiosity and creating a classroom community where all can succeed, or the material's scientific accuracy or attractiveness. The criteria listed in this cluster provide reviewers with the opportunity to comment on these and other important features.

For the complete article, see www.project2061.org/publications/articles/roseman/roseman2.htm

Direct Teaching and Problem Centered Teaching

The Oregon Science Standards include a variety of benchmark standards that range from specific skills to more complex integrated processes. Instruction to meet the benchmark standards will involve many different strategies. Figure 2 below illustrates the relationships between **direct teaching** and **problem-centered teaching**. **Both strategies are useful** in today's science classroom.

Figure 2: Balancing Direct Teaching with Problem-Centered Teaching

(Adapted from Larry Flick, Mathematics and Science Education Department, Oregon State University)

Direct Teaching	Problem-Centered Teaching
Purpose To teach students information and skills that are hierarchical and can be understood in explicit steps.	**Purpose** To teach students to investigate open-ended problems, to critique and evaluate ideas or phenomena, and to engage in creative thinking.
Learning Students have the capacity to learn any quality, no matter how subtle, which is presented by examples. They also have the capacity to generalize on the basis of sameness to new examples. Teaching involves identifying critical features of the information and organizing examples to carefully regulate the presentation of these features.	**Learning** Knowledge is not passively received, but actively constructed by students. Ideas and thoughts are not directly communicated. Teacher presentations are intended to evoke meaning in actively engaged students.
Teaching Review previous and prerequisite learning; Clearly state learning goals; Present new material in small steps; Give clear, detailed instructions/explanations; Provide high levels of active practice for all students. Ask large numbers of questions and obtain responses from all students. Guide students during initial practice. Provide systematic feedback. Provide explicit instruction for independent practice and continually check for understanding.	**Teaching** Create a task that is perceived as problematic. Invite students to make decisions. Encourage "what if" questions. Encourage students to use their own methods. Promote discussion and communication. Facilitate the recognition of patterns. Facilitate the sense that the activity is leading somewhere. Encourage meaningful extensions to the problem.
Goal To teach students a skill or information that can be applied to new situations. To generate opportunities for meaningful practice with high levels of success. To make students independent in using these new skills and information.	**Goal** To create opportunities for students to use what they know by (a) being challenged with a problematic situation, (b) sharing ideas with others, and (c) by taking action with materials. To motivate students to reorganize their ideas to accommodate new information and new experiences.
Rosenshine, B. V. (April 1986). Synthesis of research on direct teaching. Educational Leadership, 60-69. Rosenshine, B. & Stevens, R. (1986). Teacher behavior and student achievement (pp. 376-391). In M. C. Wittrock, (Ed.) Handbook of research on teaching, 3rd edition. New York: Macmillan Publishing Company.	Wheatley, G. H. (1991). Constructivist perspectives on science and mathematics learning. Journal for Research in Science Teaching, 75, 9-21. Tobin, K., Tippins, D. J., & Gallard, A. J., (1994). Research on instructional strategies for teaching science. In D. L. Gabel (Ed.). Handbook of research on science teaching and learning. New York: Macmillan Publishing Company.

Results Expected from New Approaches

Oregon (and the nation) is engaged in a significant modification of our approach to science education across grade levels and disciplines. We seek to hold our students to high standards, to develop in students a true scientific literacy, and to make our students proficient in doing science. It's reasonable to ask what the results will be if our goals are achieved. How will a student that completes a K-12 science education in Oregon under our new approach differ from the students that graduated prior to the reforms? The answer is not simple or straightforward. Once these reforms have been fully implemented, however, we expect that students will:

- become critical thinkers in general, and will recognize that "scientific" thinking is never confined simply to the lab or classroom, but should be part of everyday life.
- be able to understand and appreciate the unique role that scientific enterprise plays in human society.
- understand the nature of inquiry. (When students read or hear about a new scientific discovery, they will know what had to have been observed by the researchers in order for the results to be considered valid.)
- be able to participate in debates about ethical issues raised by scientific discoveries.
- enjoy all aspects of science and not be intimidated by scientific information.

Assessment in Standards-Based Education

While the methods and uses of assessment vary in standards-based education, the essence of assessment is finding out what students know or know how to do. Assessment instruments can be used for **formative** purposes (as the teaching and learning occurs, to make immediate learning decisions) or **summative** purposes (at the end of the unit or at the end of a period of time, to ascertain what a student has learned to date). Some assessment tools can be used to provide both formative and summative information. An example of a dual-purpose assessment tool is the State's Scientific Inquiry Scoring Guide, pages 66-71, and on the ODE website at www.ode.state.or.us/teachlearn/testing/scoring/guides/. The guides (in three forms for different grade levels) are designed to provide a "summative" student work sample score, but they can also guide formative assessment necessary to help students build scientific inquiry skills.

Formative Assessment

Formative assessments are critical for building complex concepts in science and scientific inquiry skills. Formative assessments are checks on student understanding that provide timely information to the teacher and to the student that helps in modifying instruction. In a well-designed curriculum framework, formative assessment tools are carefully integrated into the overall curriculum structure. They can be used to evaluate student learning, classroom instruction, and progress toward achievement of curriculum goals. Because the teacher in the classroom administers formative assessments throughout the course of study, the information obtained is immediately useful to both teacher and student.

There are many types of formative assessments. One formative assessment that is frequently used is the pre-test. The information from a pre-test shows what the student knows at that time about the given topic for the purpose of guiding the learning sequence and pacing. Informal approaches to formative assessments include monitoring student learning through writings, drawings, and verbal explanations about what they are learning. Formative assessments open opportunities for giving students feedback in a form that will help them improve their knowledge and skills. Oregon's Scientific Inquiry Scoring Guides, pages 66-71, can be used to provide immediately useful information about student learning to the teacher and also may be used to structure specific feedback to students. Other examples of formative assessment tools are found in Figures 15-18. Student Language Scoring Guides, Figures 15-18, pages 73-82, are scoring guides adapted for student use when they plan or evaluate their own work. Figures 19-21, pages 83-85, are formative assessment tools for teachers to provide feedback to students. Figures 22-24, pages 86-88, are tools for students and teachers to compare their assessment of student work in scientific inquiry. Figure 25, page 89, is a formative assessment tool for teachers at benchmark 2.

In order to get the most out of a formative assessment, the teacher must clearly understand the skills or content that is being assessed so that any student misconceptions or misunderstandings can be recognized. It is important that teachers are aware of the research on student misconceptions in the different topics of science, because a well-designed formative assessment may reveal a student's thinking including misunderstandings. A lot of work has been done in the area of student misconceptions. Resources such as the American Association for the Advancement of Science's *Benchmarks for Science Literacy* are making the research more readily available and understandable.

(See Appendix 2, *References* for Driver, 1994 and 1985)

Summative Assessment

Schools, districts, the state, and the public use summative assessment data for several purposes. In Oregon's recent educational reform, both statewide assessment instruments—the Knowledge and Skills Science Test and the Scientific Inquiry Scoring Guide—are being developed primarily to determine if students have met the content standards. The data is used for policymaking, comparative studies over a period of time, and for awarding the Certificate of Initial Mastery (CIM).

Performance Standards describe the numeric score expected of students on statewide assessments and classroom work samples in order to meet or exceed the benchmark standards at grades 5 (Benchmark 2), grade 8 (Benchmark 3), or grade 10 (CIM).

Statewide Assessment on Science Knowledge and Skills Test		
	Meets Standard	**Exceeds Standard**
Benchmark 2 (Grade 5)	with a score of 223 out of 300	with a score of 239 out of 300
Benchmark 3 (Grade 8)	with a score of 233 out of 300	with a score of 247 out of 300
CIM (Grade 10)	with a score of 239 out of 300	with a score of 252 out of 300
Classroom Work Samples: See phase-in schedule on Figure 13, page 64, for the performance standards.		

Supports have been developed for the summative assessment process. **Sample tests** demonstrate the content and types of questions students at Benchmark 2, Benchmark 3 and CIM might encounter on the Oregon Statewide Assessment administered each spring. Items on the sample tests were taken from earlier years' Statewide Assessments. These items are no longer secure and have been released for public use. Sample tests are published on the web at:
www.ode.state.or.us/search/results/?id=226.

Other support includes official **anchor papers** that provide teachers with examples of student work scored with Oregon's Scientific Inquiry Scoring Guides. Anchor papers are available on the web at www.ode.state.or.us/search/results/?id=243. **Professional development materials** for training teachers in the use of Oregon's Scientific Inquiry Scoring Guides can be found in Figures 14 and 26, pages 65 and 90-93.

Science Knowledge and Skills Test Scores FAQ

1. What is a RIT score?

A Rasch Unit, or RIT, score is a scale score that can be used to measure a student's academic growth over time. RIT scores typically range from about 150 to 300. Each item on the Science Knowledge and Skills Test has an assigned RIT value that indicates the item's degree of difficulty. These values are determined using the item's performance data from past field or operational tests. In general, items that are answered correctly by only the highest performing students have higher RIT values and items that are answered correctly by many students have lower RIT values. The overall test score that students earn is based on the number of questions answered correctly out of the total number of questions on the test—taking into account the difficulty (RIT value) of each question.

2. Why are the scores required for students to meet or exceed the performance standard higher in science than in the other content areas at Benchmarks 2 and 3?

The science cut scores, as determined by the standards setting panel, were set without an expectation that science items and math and reading items are the same or that they "test" the same. Therefore, the cut scores in different content areas are not always the same. When the panel met, they determined which question/content difficulty was appropriate for meets and exceeds at each benchmark without "scale" restrictions or limits. The RIT scores for meets and exceeds in science are the same as the other content areas at the CIM level. When the standards were set at lower grades in science, however, they were set at higher levels than the other subjects. This was done because students scored considerably higher numerically in science than in the other content areas. The meets and exceeds scores in science were set so a comparable number of students met the standard in science as in the other subjects.

3. Why is the percent of questions needed to meet and exceed on the science sample test higher than the percent needed on some of the other content area sample tests?

Whether or not a student meets/exceeds the standard is not just a measure of the percent of items answered correctly. In fact, status is determined by a student's RIT score. The RIT scores that are used to determine whether or not a student meets or exceeds the standard are influenced by the difficulty of the items on the test. If the test has easier items, it will take more correct answers to get the same RIT score than if a test has more difficult items. The difficulty of the item is determined by the percentage of students who can get the item correct when the item is scaled for the RIT scoring system. The sample test is a small sampling of items created from a pool of items that have been retired after appearing in several testing cycles. So, part of this answer is that the items available for use in the science sample test were of a difficulty that required a higher percentage of correct answers in order to meet the standard.

Important Science Curriculum Components

Teaching Evolution in Oregon Classrooms

The debate about teaching evolution and creationism is in the national spotlight. As a result of that debate, local school districts and science teachers in Oregon have had to field questions about teaching evolution. The following information is meant to be a resource for teachers and districts.

Oregon Science Content Standards and Evolution: The Oregon Science Content Standards adopted in April of 2001 clearly require the teaching of evolution. All content standards are adopted through the legislative process and are required in the public schools in Oregon. In addition, each of these standards has underlying benchmarks and eligible content that can be addressed in statewide testing.

The following Oregon Common Curriculum Goals (CCG) and Content Standards (CS) relate most directly to evolution:

- **Life Science**
  - CCG: Heredity and CS: Understand the transmission of traits in living things.
  - CCG: Diversity/Interdependence: Understand the relationships among living things and between living things and their environments.
    - CS: Describe and analyze diversity of species, natural selection and adaptation
- **Earth and Space Science**
  - CCG: The Dynamic Earth: Understand changes occurring within the lithosphere, hydrosphere, and atmosphere of the Earth.
    - CS: Explain and analyze changes occurring within the lithosphere, hydrosphere, and atmosphere of the Earth.

The Law and Teaching Evolution: There are numerous state and federal court decisions related to teaching evolution. *Teaching About Evolution and the Nature of Science*, published in 1998 by the National Academy Press includes an appendix listing six significant court decisions regarding evolution and creationism issues. There is also an appendix giving statements supporting teaching of evolution from three science education organizations.

> An excerpt from the brochure, "Religion in the Public Schools: A Joint Statement of Current Law" published in 1995 by the U.S. Department of Education summarizes the body of law that existed at that time.
>
> *Schools may teach about explanations of life on earth, including religious ones (such as "creationism"), in comparative religion or social studies classes. In science class, however, they may present only genuinely scientific critiques of, or evidence for, any explanation of life on earth, but not religious critiques (beliefs unverifiable by scientific methodology). Schools may not refuse to teach evolutionary theory in order to avoid giving offense to religion nor may they circumvent these rules by labeling as science an article of religious faith. Public schools must not teach as scientific fact or theory any religious doctrine, including "creationism," although any genuinely scientific evidence for or against any explanation of life may be taught. Just as they may neither advance nor inhibit any religious doctrine, teachers should not ridicule, for example, a student's religious explanation for life on earth.*

The full text of the report can be found on the Internet at www.ed.gov/Speeches/04-1995/prayer.html.

The following are excerpts from important court decisions regarding evolution and creationism issues published in *Teaching About Evolution and the Nature of Science* in 1998 by the National Academy of Sciences.

1. In 1968, in *Epperson v. Arkansas,* the United States Supreme Court invalidated an Arkansas statute that prohibited the teaching of evolution. The Court held the statute unconstitutional on grounds that the First Amendment of the U. S. Constitution does not permit a state to require that teaching and learning must be tailored to the principles or prohibitions of any particular religious sect or doctrine. *(Epperson v. Arkansas,* 393 U. S. 97. (1968)

2. In 1981, the *Seagraves v. State of California*, the Court found that the California State Board of Education's *Science Framework*, as written and as qualified by its anti-dogmatism policy, gave sufficient accommodation to the views of Seagraves, contrary to his contention that class discussion of evolution prohibited his and his children's free exercise of religion. The anti-dogmatism policy provided that class distinctions of origins should emphasize that scientific explanations focus on "how," not "ultimate cause," and that any speculative statements concerning origins, both in texts and in classes, should be presented conditionally, not dogmatically. The court's ruling also directed the Board of Education to widely disseminate the policy, which in 1989 was expanded to cover all areas of science, not just those concerning issues of origins. *(Seagraves v. California,* No. 278978 Sacramento Superior Court (1981)

3. In 1982, in *McLean v. Arkansas Board of Education,* a federal court held that a "balanced treatment" statute violated the Establishment Clause of the U. S. Constitution. The Arkansas statute required public schools to give balanced treatment to "creation-science" and "evolution science." In a decision that gave a detailed definition of the term "science," the court declared that "creation science" is not in fact a science. The court also found that the statute did not have a secular purpose, noting that the statute used language peculiar to creationist literature in emphasizing origins of life as an aspect of the theory of evolution. While the subject of life's origins is within the province of biology, the scientific community does not consider the subject as part of evolutionary theory, which assumes the existence of life and is directed to an explanation of how life evolved after it originated. The theory of evolution does not presuppose either the absence or the presence of a creator. *(McLean v. Arkansas Board of Education,* 529 F. Supp. 1255, 50 (1982) U. S. Law Week 2412)

4. In 1987, in *Edwards v. Aguillard,* the U. S. Supreme Court held unconstitutional Louisiana's "Creationism Act." This statute prohibited the teaching of evolution in public schools, except when it was accompanied by instruction in "creation science." The Court found that, by advancing the religious belief that a supernatural being created humankind, which is embraced by the term *creation science,* the act impermissibly endorses religion. In addition, the Court found that the provision of a comprehensive science education is undermined when it is forbidden to teach evolution except when creation science is also taught. *(Edwards v. Aguillard,* 482, U. S. 578, 55 (1987) U. S. Law Week 4860, S. CT. 2573, 96 L. Ed. 2d510)

5. In 1990, in *Webster v. New Lennox School District*, the Seventh Circuit Court of Appeals found that a school district may prohibit a teacher from teaching creation science in fulfilling its responsibility to ensure that the First Amendment's establishment clause is not violated, and religious beliefs are not injected into the public school curriculum. The court upheld a district court finding that the school district had not violated Webster's free speech rights when it prohibited him from teaching "creation science," since it is a form of religious advocacy. *(Webster v. New Lennox School District #122*, 917 F.2d 1004 (7th Cir., 1990)

6. In 1994, in *Peloza v. Capistrano Unified School District*, the Ninth Circuit Court of Appeals upheld a district court finding that a teacher's First Amendment right to free exercise of religion is not violated by a school district's requirement that evolution be taught in biology classes. Rejecting plaintiff Peloza's definition of a "religion" of "evolutionism," the Court found that the district had simply and appropriately required a science teacher to teach a scientific theory in biology class. *(Peloza v. Capistrano Unified School District*, 37 F.3d 517 (9th Cir., 1994).

Note
1 Matsummura, M., ed. 1995. Pp 2-3 in Voices for Evolution. 2nd ed. Berkeley, CA: National Center for Science Education

Resources on Teaching Evolution

www.ed.gov/Speeches/04-1995/prayer.html This web site addresses broader issues of religion and education including a treatment of evolution. Published by the U.S. Department of Education.

www.nsta.org/evresources.asp A starting point for current information on teaching evolution. Published by the National Science Teachers Association

www.nap.edu/catalog/5787.html Teaching About Evolution and the Nature of Science, 1998, National Academy of Sciences, Washington, DC.

Reading in the Content Areas: Science

(From Mike Tomlinson (Tigard -Tualatin School District) and Larry Flick (Oregon State University))

The connection between reading and science is important, not only as a time management tool (for elementary teachers especially), but for science teachers interested in helping students understand the text. Instruction in teaching students about scientific inquiry and the use of its methods can compliment strategies for comprehending expository test. The reverse is also true. Approach a reading assignment as you would an inquiry investigation. Create an environment of discovery; one that promotes risk-taking and questioning. Provide students with many opportunities to interact with the assignment's concepts, preferably utilizing hands-on, manipulative-based experiences. Reading assignments should follow, not precede hands-on experiences with the content.

The Research Base for Developing Cognitive Strategies

There are four key cognitive strategies pertaining to reading comprehension that have been identified for use in an action research project. These four thinking strategies were selected for their relevance to reading comprehension as well as their applicability to all subject areas, especially scientific inquiry and abstract problem solving. It is important to note that these strategies are taught in an appropriate context and not subdivided into discrete parts. They are gleaned from the latest research efforts in cognitive development, reading comprehension, abstract problem solving and scientific inquiry. The four cognitive strategy areas listed below are in a general hierarchical ranking of importance. They are not distinctively separate from one another - they have a great deal of overlap:

1. Metacognition (self monitoring)
2. Relating Prior Knowledge
3. Setting the Purpose
4. Recognizing and Describing Patterns

Reading is thinking and teachers can model the process of thinking: *questioning* the text, *making* connections between prior knowledge and the text, *thinking* metacognitively, *setting* a purpose, and *recognizing* patterns. By modeling how to make predictions, *summarizing* what you've read, *creating* mental images of the text, *adjusting* reading rate, and *rereading* confusing sections of the text, you are providing your students with effective strategies for making sense of text. Teachers can also model interest in the content reading material. How can you expect your students to be interested in the text if you aren't?

Teachers in all disciplines and at all grade levels often find that students do not understand the text. The question arises, "I'm not a reading teacher, so how can I teach reading in science?" While many strategies exist, the most important interventions are far from technical. There are a number of "fix-it" strategies that can help students make meaning of the text. Frequently, students are not successful with informational text because the only strategy they rely on is sounding out words. Students must get beyond the words to develop understanding.

Reading Strategies

1. Make a connection between the text and your life, your prior knowledge of the world, or another text. Think of both big and little ways that you have experienced feelings, thoughts, actions, concepts and situations that are taking place in the text.

2. Make a prediction. Use what is happening in the text, combined with your prior knowledge to make a prediction about will happen in the text or what you will learn about next.

3. Think back over what you have just read. Try to summarize your reading.

4. Ask yourself a question. Your question might be about what is happening or why. It could also explore "what if" possibilities.

5. Write down a brief written reflection about the text.

6. Visualize the text. Create a mental image of what is happening in the text.

7. Use print conventions. Use the structure of the sentences and paragraphs to help understand what is going on in the text.

8. Retell. Tell in your own words what is being discussed in the text.

9. Reread. Read back over the portion of the text that you are having trouble understanding.

10. Notice patterns in the structure of the text, the way it is organized.

11. Adjust your reading rate. Slow down when reading confusing passages of text.

12. Use analogies, similes, and metaphors to represent main ideas and content. Relate prior knowledge to the text by making associations between the two.

13. Make notes to yourself as you read.

14. Develop questions about the text, the author and yourself related to your reading (e.g., Do I like this? What is the author's purpose? How can this information be useful?).

15. Review the Big Picture. Mentally review the big ideas to check understanding.

16. Skim or scan the text. Look at graphs, chapter titles, subheadings, boldface text, charts, tables, and photographs.

Mathematics Standards Support for Scientific Teaching

A draft document providing support for Scientific Inquiry Teaching through Mathematics Grade-level Standards is available on the Oregon Department of Education website at www.ode.state.or.us/teachlearn/subjects/science/curriculum/analintsciinq.aspx under the Support for Scientific Teaching through Mathematics Grade-Level Standards (Tab 6) section.

This guide is provided to help teachers understand math skills they can expect from their students at a specific grade level. For example, a teacher can use the 8th grade grade-level standards to see what their students may be capable of doing with scientific notation, conversions (rates and scales), which measures of central tendencies they can be expected to use when analyzing data, and a students' ability to represent, graph, and determine linear and nonlinear relationships as they relate to data gathered in a scientific inquiry activity.

Making Time for Scientific Inquiry

Many Uses of Available Time

Teachers face many time constraints, but they need to make time for students to experience concepts, not once, but periodically, in different contexts and at increasing levels of sophistication (AAAS, 1990). Time should be structured so that students can engage in extended investigations. Students **need time** to discuss and debate with one another, try out ideas, make mistakes, retry experiments, and reflect. Students need time to work together in small groups, share their ideas in whole-class discussions, and work on a variety of tasks, including reading, experimenting, reflecting, writing, and discussing (National Research Council, 1996). Students need time for exploring and taking wrong turns; testing ideas and doing things over again; building and collecting things; constructing physical and mathematical models for testing ideas; asking and arguing; and **time to revise their previous notions** of things (AAAS, 1990).

The *National Science Education Standards* (1996) recommend that teachers plan curriculum goals that are flexible so they can respond to students' needs and interests: "Teaching for understanding requires responsiveness to students, so activities and strategies are continuously adapted and refined to address topics arising from student inquiries and experiences. An inquiry might be extended or an activity added if it sparks the interest of students or if a concept isn't being understood."

Time Management Through Integration

Science as a discipline depends on skills and knowledge from English language arts and mathematics as well as social science, second languages and the arts. It is natural to integrate other disciplines while teaching science.

As teachers are faced with implementing standards in other disciplines, careful instructional planning for integration helps time management. Elementary teachers especially are finding links between standards in science, writing, speaking, reading, and mathematics. As a particular example, problem solving in mathematics has many standards that are closely related to the scientific inquiry standards. Similarly, many mathematics standards are the foundations for scientific inquiry. The connection between scientific inquiry and reading comprehension is explained in *Reading in the Content Areas: Science*, pages 24-25.

SCIENTIFIC INQUIRY

National Content Standards for Science as Inquiry

The national content standards treat inquiry as both a learning goal and a teaching method. As a result of activities in K-12, all students should develop an understanding of, as well as an ability to do, scientific inquiry. The fundamental abilities and understandings increase in complexity from kindergarten through grade 12 reflecting the cognitive development of students, as seen on pages 28 and 29 in Tables 2.2 and 2.3 from the National Research Council's "Inquiry and the National Science Education Standards." The standards require students to mesh processes with scientific knowledge as they use scientific reasoning and critical thinking. The approach requires students to participate in the evaluation of scientific knowledge, drawing on evidence and analytical tools.

Fundamental Abilities Necessary to do Scientific Inquiry

(From: *Inquiry and the National Science Education Standards: A Guide for Teaching and Learning,* NRC (2000)*)*

Table 2-2. Content Standard for Science as Inquiry: Fundamental Abilities Necessary to Do Scientific Inquiry

Grades K-4

- Ask a question about objects, organisms, and events in the environment.
- Plan and conduct a simple investigation.
- Employ simple equipment and tools to gather data and extend the senses.
- Use data to construct a reasonable explanation.
- Communicate investigations and explanations.

Grades 5-8

- Identify questions that can be answered through scientific investigations.
- Design and conduct a scientific investigation.
- Use appropriate tools and techniques to gather, analyze, and interpret data.
- Develop descriptions, explanations, predictions, and models using evidence.
- Think critically and logically to make the relationships between evidence and explanations.
- Recognize and analyze alternative explanations and predictions.
- Communicate scientific procedures and explanations.
- Use mathematics in all aspects of scientific inquiry.

Grades 9-12

- Identify questions and concepts that guide scientific investigations.
- Design and conduct scientific investigations.
- Use technology and mathematics to improve investigations and communications.
- Formulate and revise scientific explanations and models using logic and evidence.
- Recognize and analyze alternative explanations and models.
- Communicate and defend a scientific argument.

dents ought to draw on evidence and analytical tools to derive a scientific claim. In turn, students should be able to assess both the strengths and weaknesses of their claims. The development and evolution of knowledge claims, and reflection upon those claims, underlie the inquiry abilities presented in Table 2-2.

Note that the abilities from one grade level to the next are very similar but become more complex as the grade level increases. For example, K-4 students "use data to construct a reasonable explanation," while 5-8 students "recognize and analyze alternative explanations and procedures," and 9-12 students analyze "alternative models" as well. The abilities are designed to be developmentally appropriate to the grade level span.

Fundamental Understandings about Scientific Inquiry

(From: *Inquiry and the National Science Education Standards: A Guide for Teaching and Learning*, NRC (2000))

Table 2-3. Content Standard for Science as Inquiry: Fundamental Understandings About Scientific Inquiry

Grades K-4

- Scientific investigations involve asking and answering a question and comparing the answer with what scientists already know about the world.
- Scientists use different kinds of investigations depending on the questions they are trying to answer.
- Simple instruments, such as magnifiers, thermometers, and rulers, provide more information than scientists obtain using only their senses.
- Scientists develop explanations using observations (evidence) and what they already know about the world (scientific knowledge).
- Scientists make the results of their investigations public; they describe the investigations in ways that enable others to repeat the investigations.
- Scientists review and ask questions about the results of other scientists' work.

Grades 5-8

- Different kinds of questions suggest different kinds of scientific investigations.
- Current scientific knowledge and understanding guide scientific investigations.
- Mathematics is important in all aspects of scientific inquiry.
- Technology used to gather data enhances accuracy and allows scientists to analyze and quantify results of investigations.
- Scientific explanations emphasize evidence, have logically consistent arguments, and use scientific principles, models, and theories.
- Science advances through legitimate skepticism.
- Scientific investigations sometimes result in new ideas and phenomena for study, generate new methods or procedures for an investigation, or develop new technologies to improve the collection of data.

Grades 9-12

- Scientists usually inquire about how physical, living, or designed systems function.
- Scientists conduct investigations for a wide variety of reasons.
- Scientists rely on technology to enhance the gathering and manipulation of data.
- Mathematics is essential in scientific inquiry.
- Scientific explanations must adhere to criteria such as: a proposed explanation must be logically consistent; it must abide by the rules of evidence; it must be open to questions and possible modification; and it must be based on historical and current scientific knowledge.
- Results of scientific inquiry — new knowledge and methods — emerge from different types of investigations and public communication among scientists.

Instructional Approaches to Scientific Inquiry

Scientific Inquiry as a Core Process

Scientific inquiry is central to the work of scientists and to science education in general. In Oregon's terminology, scientific inquiry is a **Core Process**. Just as the core processes of English language arts (writing and speaking) and mathematics (problem solving), scientific inquiry will be assessed through classroom work samples by teachers using state scoring guides. On April 26, 2001, the Oregon Board of Education adopted a phase-in schedule for scientific inquiry work samples (Figure 13, page 64), which began during the 2003-2004 school year. Beginning in 2003-2004, scientific inquiry work samples will be a state requirement for a Certificate of Initial Mastery in science. In 2005-2006 sophomores (and middle school students) are required to have scores in all four dimensions (forming, designing, collecting and analyzing) reported for school district work sample management. Designing and collecting must be from the same work sample. Forming and analyzing may be on the same or a separate work sample. Elementary students (grades 4 and 5) are required to have scores for the designing, collecting and analyzing dimensions reported. Designing and collecting must be from the same work sample. Analyzing may be on the same or a separate work sample. Teachers are expected to provide instruction and classroom assessment in all four dimensions of the scoring guide.

Two of the three uses of the word "inquiry" in science teaching address what students should know about and be able to do in regards to scientific inquiry. The third use of the term relates most directly to the nature of the teaching that will support students' learning with and about inquiry. The scientific inquiry work samples address both of the first two uses of the terms, with an emphasis on the students' ability to do scientific inquiry. The three uses of the word inquiry in teaching science are:

1. **Ability of students to do scientific inquiry.** Learning environments that support the development of students' abilities to engage in scientific inquiry reflect the wide variety of ways that practicing scientists carry out their work in the different disciplines of science. Just as there is no single "Scientific Method," there is no single teaching or learning strategy by which students gain the skills and knowledge necessary to engage in scientific inquiry. All types of scientific inquiry, however, require the scientist or the student to engage in the systematic study of some aspect of the natural world and to carry out careful and detailed observations as they collect information and organize and manipulate that data in order to identify patterns that support conclusions. Most importantly, scientific inquiry requires both the scientist and the science student to support conclusions or explanations with evidence from their investigations.

   Scientific inquiry is carried out in a variety of ways. Some scientists engage in ***descriptive*** *scientific inquiry* as they describe current conditions through direct observation, correlations, surveys, case studies, or growth studies. Students studying a particular ecosystem or the growth pattern of embryonic chicks would be carrying out descriptive scientific inquiry. Some scientists engage in ***analytical*** *scientific inquiry* as they reason from the interrelationships of the parts in the study of a system such as the nature of the movement of tectonic plates. Students analyzing the interactions of compounds in a complex chemical reaction or the actions of erosion and deposition of soil over time are engaging in such scientific inquiry. Still other scientists engage in the design and implementation of controlled ***experimental*** *scientific inquiry* as they identify, manipulate and control relevant independent variables.

Considered the epitome of scientific inquiry, the controlled experiment best supports the identification of cause and effect relationships. Students are frequently led by the teacher through typical steps of identification, manipulation and control of independent variables, determination of a dependent variable, the consistent control of observations, and the attempt to draw conclusions regarding the relationships between independent variables and dependent variable. The various disciplines of science - biology, chemistry, physics, Earth and space, and environmental science, all use the various types of inquiry to develop answers to specific types of questions (Gummer, 2002 a, b).

Scientific inquiry in the classroom has a number of origins. At the beginning of a student's study of a scientific discipline, the teacher may be the source of observational experiences that unfold into scientific questions that can be addressed through inquiry. Some scientific inquiry starts with the student's *own scientific questions* individually or in groups. Other scientific inquiry originates in the identification and design of *service learning projects* that require systematic collection and analysis of data that address problems of concern to the student's community. In addition, both teachers and students can initiate the exploration of *science-technology-society issues* that prompt collaborative class inquiry. In the classroom, the goal of teaching scientific inquiry is for students to inquire into authentic questions that originate from their own experiences as they develop the skills and knowledge necessary to answer those questions. Although parts of the student's investigation could be done collaboratively with classmates, teachers should strive toward student inquiries in which the student is solely accountable for producing his or her own work in anticipation of the scientific inquiry work sample requirements of the state wide assessment. The Oregon Scientific Inquiry-Scoring Guides (pages 66-71) are designed to assess individual student performance of scientific inquiry as taught in any of the manners described on the previous page.

2. **Understanding scientific inquiry.** This is knowledge about the characteristics of scientific inquiry. These characteristics include: identifying ways of formulating questions; constructing appropriate and systematic designs; understanding rules of evidence; using scientific concepts, principles models and theories in proposing explanations, and analyzing scientific conclusions with legitimate skepticism. In particular, understanding scientific inquiry requires that students recognize that scientific results are tentative and subject to change, and that they are affected by culture and personalities. These aspects of scientific inquiry are addressed in the *Benchmarks for Science Literacy* (1993) within the context of the nature of science and in the *National Science Education Standards* (1996) benchmark level sections as students' understanding about scientific inquiry.

   In understanding scientific inquiry, it is important to know that scientific investigations are based on asking and answering scientific questions about the natural world. Understanding scientific inquiry also requires students to recognize that different questions are investigated using methods that are appropriate for the question being asked. The uses of technology and mathematics are integral to the development and analysis of the information that scientific inquiry produces. Scientific results become the evidence that scientists and students use in a logically consistent argument to develop scientific explanations.

3. **Understanding of science content through inquiry teaching approaches**. When teachers teach science content (life science, physical science, Earth/space science) by asking students to work together to solve problems and questions about phenomena, they are said to be using an inquiry approach. Inquiry, as an instructional strategy, can be carried out by a wide range of activities that engage students in asking questions, making observations, designing investigations, collecting and analyzing data and constructing evidence-based explanations. In addition, teachers need to provide activities that allow students to identify and critically review secondary sources of scientific information. All of these activities should be carried out in a classroom environment that enables teachers and students to work together as a community of learners. The teacher must strive to identify the best strategy to teach appropriate topics by engaging students in in-depth study that furthers their understanding of scientific principles and concepts. Teaching science as inquiry provides teachers with the opportunity to develop student abilities and to enrich student understanding of science (National Research Council, 1996).

Examples of Scientific Inquiry Instruction

The following scenarios (Bybee, 2000) are presented as springboards for discussion about the three ways educators commonly use the word inquiry in the science classroom.

A science teacher wanted to see inquiry in action so she visited three different classrooms. Her considerations included the content of lessons, the teaching strategies, student activities, and the outcomes – that is, what students learned. During five days in each classroom, she made the observations presented below and on the following page.

Classroom 1: Ability to do Scientific Inquiry. The students engaged in an investigation initiated by significant student interest. A student asked what happened to the water in a watering can. The can was almost full on Friday and almost empty on Monday. One student proposed that Willie the pet rabbit left his cage at night and drank the water. The teacher encouraged the students to find a way to test this idea. The students devised a test in which they covered the water so Willie could not drink it. Over several days they observed that the water level did not drop. The teacher then challenged the students to think about other explanations. The students' questions resulted in a series of full investigations about the disappearance of water from the container. The teacher emphasized strategies such as asking students to consider alternative explanations, using evidence to form their explanations, and designing simple investigations to test an explanation. The science teacher never did explain evaporation and related concepts.

<u>Classroom 2</u>: Understanding Scientific Inquiry. In this advanced science classroom, students selected from among several books that provided extended discussions of scientific work. Readings included *The Double Helix*, *The Beak of the Finch*, *An Imagined World*, *and A Feeling for the Organism*. Over a three-week period, each student read one of the books as homework. Then, in groups of four, all student groups discussed and answered the same questions: What led the scientist to the investigation? What conceptual ideas and knowledge guided the inquiry? What reasons did the scientist cite for conducting the investigation(s)? What role did mathematics play in the inquiry? Was the scientific explanation logically consistent? Based in evidence? Open to skeptical review? Built on a knowledge based of other experiments? After reading the books and completing the discussion questions, the teacher had the groups prepare oral reports on the topic, "The Role of Inquiry in Science."

<u>Classroom 3</u>: Understanding Science Content. Students investigated fossils to learn about biological evolution. The teacher distributed two similar, but slightly different molds with dozens of fossil brachiopods. The students measured the lengths and widths of the two populations of brachiopods. The teacher asked if the differences in length and width might represent evolutionary change. As the students responded, the teacher asked: How do you know? How could you support your answer? What evidence would you need? What if the fossils were in the same rock formation? Are the variations in length and width just normal variations in the species? How would difference in length or width help a brachiopod adapt better? The fossil activity provided the context for students to learn about the relationships among (1) the potential for a species to increase its numbers, (2) the genetic variability of offspring due to mutation and recombination of genes, (3) the finite supply of resources required for life, and (4) the ensuing competition among organisms to survive and leave offspring. In the end, students learned about changes in the variations of characteristics in a population: biological evolution.

Figure 3: Summary of inquiry observations and assessment procedures in each of the three classrooms. *(Bybee 2000)*

	Classroom 1 **Ability to do scientific inquiry**	**Classroom 2** **Understanding scientific inquiry**	**Classroom 3** **Understanding scientific content**
Observations			
• **Content of Lessons**	Changing water level of an open container	Reading stories of scientists and their work	Investigating variations of fossils
• **Teaching Strategies**	Challenge students to think about proposed explanations and use evidence to support conclusions	Provide questions to focus discussions of readings	Provide molds of fossils and ask questions about student measurements and observations
• **Student Activities**	Design simple, but full, investigations	Read and discuss a book about scientific investigations	Measure fossils and use data to answer questions
Assessment			
• **Student Outcomes**	Develop the ability to reason using logic and evidence to form an explanation	Understand scientific inquiry as it is demonstrated in the work of scientists	Understand some of the basic concepts of biological evolution
• **Assessment Tools**	Work samples	Locally determined classroom assessments	State knowledge and skills assessment

Scientific Inquiry Teaching Models

The K-W-L Model

The K-W-L (what you *know*, what you *want* to know, and what you've *learned*) charts are another useful tool for getting students into scientific inquiry. Perhaps a teacher is starting something on snow. The teacher could ask students what they already know about it and what they want to know about it. Out of that discussion, questions are raised. Students become engaged in the activity, and that leads them into inquiry. Following this model also allows teachers to identify misconceptions and informally assess whether prior teaching is brought forward to new application.

K-W-L charts are traditionally used at the elementary grades, but are **equally effective in middle and high school.** Teachers' knowledge of the **content area becomes critical** in these inquiry strategies. Typically, elementary teachers have been trained as generalists because they must teach all subjects to their students. But when teachers are doing full inquiry at any grade level, they often will find themselves dipping deeper into their knowledge reserves. In the example above, teachers will need to know the science behind snow – at least enough to know where to help their students look for answers. Teachers can reinforce their content knowledge by seeking out mentors; talking to professionals in the fields of science and mathematics; using other organizations and the Internet as resources; reading widely; and taking advantage of professional development opportunities. Knowing it all, however, is not only impossible, it's unnecessary. An important aspect of inquiry teaching is being able to say to students, "I don't know, let's find out." In a community of learners, teachers and students work side-by-side, collaboratively constructing knowledge.

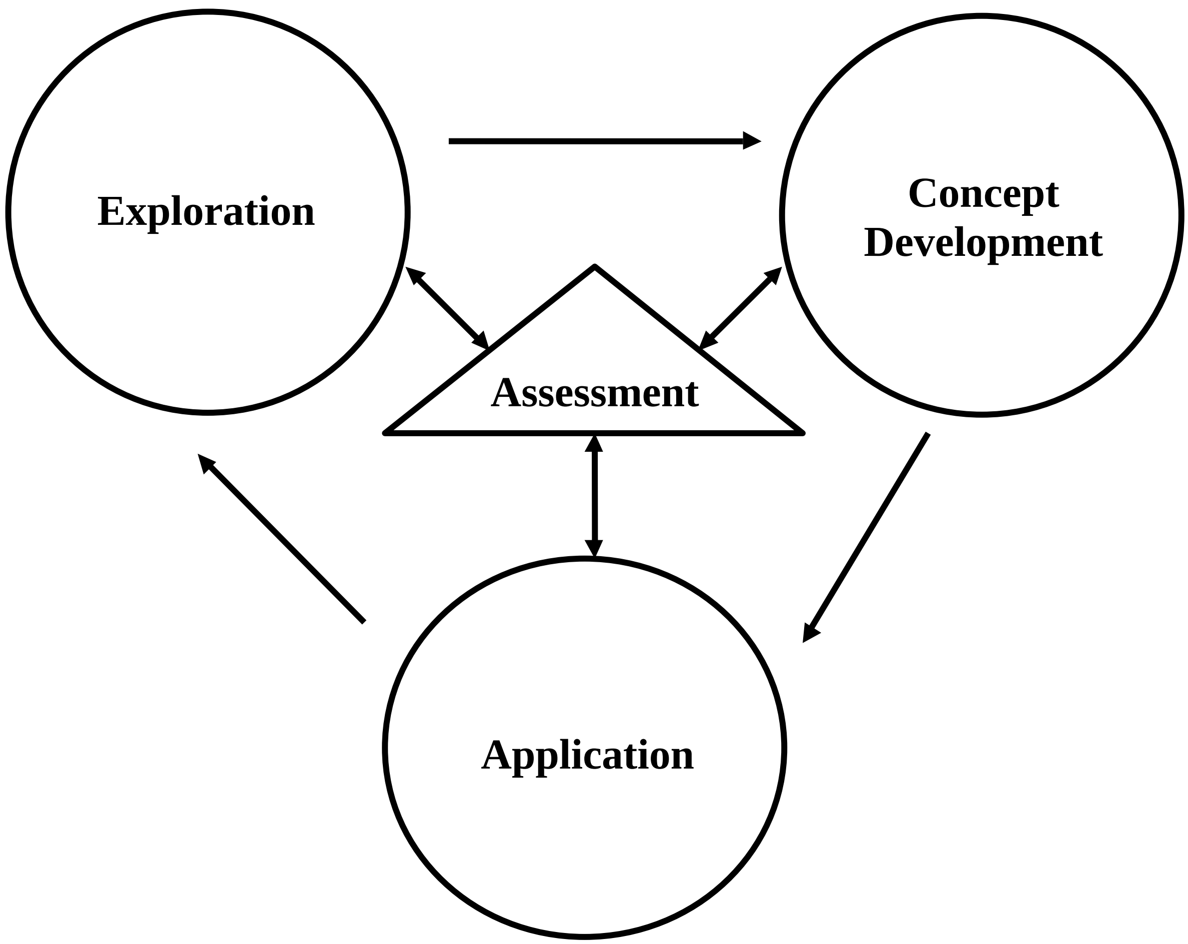
What We **Know**	What We **Want** to Know	What We **Learned**

The Learning Cycle

The learning cycle is an instructional model that can be used to facilitate scientific inquiry. Developed in the 1960s as part of the Science Curriculum Improvement Study (sponsored by the National Science Foundation), the strategy uses questions, activities, experiences, and examples to help students develop a concept, deepen their understanding of the concept, and apply the concept to new situations (Beisenherz & Dantonio, 1996).

In the learning cycle, students first explore the skills and knowledge in an authentic manner that stimulates their need to know. Then the teacher introduces the skills and knowledge that underlie the learning objective. Finally, the teacher provides a context in which the students apply the skills and knowledge. Throughout the entire cycle, attention is paid to formative assessment.

Figure 4: Learning Cycle Diagram



Learning Cycle Components

Exploration: At the beginning of the learning cycle, students **actively explore** materials, phenomena, problems, and ideas to make observations and collect data. (Hands-on activities are preferable but activities may include a variety of media, including video and text.) An initial, less structured exploration allows students to explore objects and systems at their own pace and with little guidance. Students often become highly motivated when they are permitted to do hands-on explorations before the concept is introduced. Then another, **more structured** exploration allows students to reexamine the same objects and systems more scientifically. During this time, students generate questions and form and test their own hypotheses (Beisenherz & Dantonio, 1996).

Concept Development: During this phase, **instruction focuses on content**, including scientific inquiry and nature of science. In order for students to be successful with scientific inquiry, they must have both content knowledge and procedural knowledge. While direct instruction can be effectively utilized in this phase, scientific inquiry should also be used to teach content. Model scientific inquiry through a variety of investigations, both group and independent, and demonstrations. The teacher can further explain the concept by using textbooks, audiovisuals aids, and other materials (Beisenherz & Dantonio, 1996).

Application: **Depth of understanding** is facilitated when the concept is reinforced or expanded during the application phase, usually through the use of hands-on activities. Activities in this phase will often do double duty, serving as the initial activity in the exploration phase of a new, closely related concept that will be developed in a separate learning cycle.

Hands-on activities in the exploration and application phases can motivate students as they encounter problems that arouse their curiosity (Beisenherz & Dantonio, 1996). Sometimes problems can be introduced by using **"discrepant events"** – encounters that students find perplexing. Before being presented with a discrepant event, students should have a familiarity with the concepts, skills, and techniques that allow them to recognize a discrepant event, and to suggest hypotheses and procedures for collecting data. Beisenherz and Dantonio (1996) provide an example: "The observation that water expands when it freezes is discrepant to students only if they have been led to infer from previous activities that liquids expand when heated and contract when cooled." Using discrepant events to introduce a new topic is particularly effective at piquing students' curiosity.

The Learning Cycle Planner

After completing the first two phases of the learning cycle, students have a solid grounding in both content and procedural knowledge. They have been exposed to scientific inquiry in a variety of contexts and are ready for the last phase – the application of their knowledge and experience to new scientific problems. **The Learning Cycle Planner on the next page helps you plan the steps leading to the application phase.** Begin with the Common Curriculum Goal that you want for your focus. Next, select the topic that you will use to organize your instruction. Choose learning objective(s) from the Content Standards and Benchmarks. After this groundwork is completed, continue planning the exploration and concept development phases.

Figure 5

Learning Cycle Planner

Common Curriculum Goal:

Topic:

Learning Objective:

Concepts to be Covered:

Exploration Phase:

Hands-on Activity:

Exploration Through Media:

Concept Development Phase:

Concepts to be Taught:

Procedures to be Taught:

Activities:

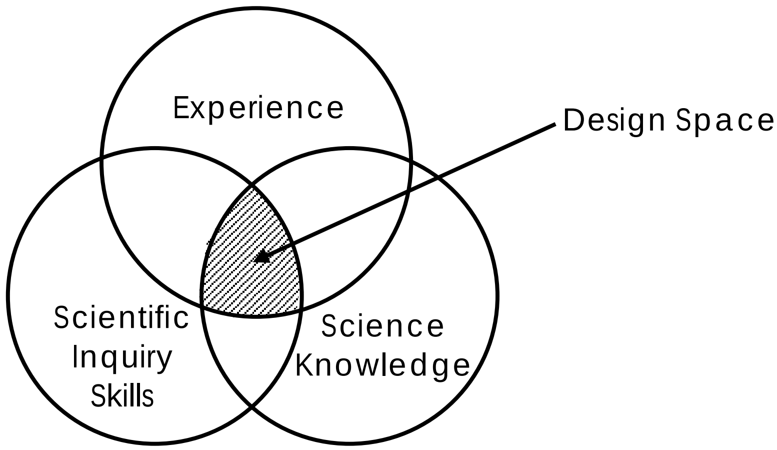
Guided Inquiry	Group Inquiry	Individual Inquiry

Design Space

Planning a unit of instruction is a complex process. The Learning Cycle, as described earlier, is one framework that is useful for planning. Another tool focuses on the idea of design space. In this case the teacher has a specific final scientific inquiry task in mind and designs the unit to support the inquiry. Attention to design space helps teachers assure that students have (1) *experience* with the phenomena on which the inquiry will be based, (2) relevant *scientific inquiry skills* (e.g., the knowledge of applicable procedures), and (3) applicable *science knowledge* (facts, principles, theories and scientific laws). Design space is the overlap of these three components (see Figure 6). The Design Space idea and The Learning Cycle can be used together to identify and develop activities for a standards-based science unit.

Figure 6: Design Space

(From Dr. Dave Hamilton, Science Assessment Specialist, Portland Public Schools)



Experience	Science Knowledge	Scientific Inquiry Skills
Prior Knowledge and experiences students have had inside and outside of the classroom with the science phenomena that are being investigated.	Applicable science knowledge including science concepts and appropriate vocabulary.	Abilities necessary to do scientific inquiry including accepted procedures for gathering data, recording observations systematically, controlling variables, making models, and more.

Explanation of Design Space Components

- ***Experience***

One component of design space is the experience the student has with the phenomena that are being investigated. For example, a student who has extensive experience playing with isopods may already know quite a bit about their behavior. This student has a large 'space' of experience with isopods and might successfully investigate questions such as "do isopods favor light or dark?" Because of the student's prior experience with isopods, this question would seem reasonable and logical, growing naturally out of experience (isopods are often found in dark, moist places). Another student with little or no experience with isopods, asked to investigate the same question, may see it as arbitrary or illogical. While this second student may be able to complete all the tasks of the inquiry, he or she is unlikely to learn the important traits of scientific inquiry.

In more complex investigations, personal experience is even more important. Brian Woolnough describes the importance of "personal knowledge" which he differentiates from "public knowledge" – the kind that is written in books, journals, and our content standards[1]. Personal knowledge is gained through private experience and practice and it relates both to understanding the world and to the procedures required to problem-solve. When students are designing investigations, they need such personal knowledge about the phenomena they are studying. "Scientists in their professional life rely on their personal knowledge, their intuition, and their creativity as much as their public knowledge, if not more" (Woolnough, 2000, p.440). Providing students with opportunities to personally experience the phenomena they are to investigate allows them a chance to gain such personal knowledge and will result in more authentic inquiry.

- ***Scientific Inquiry Skills***

Another component of design space is the set of scientific inquiry skills the student has. There are two types of inquiry skills students need. First, they need to know *applicable techniques*. These techniques are accepted procedures for gathering data. For example, placing an organism in an environment with both light and dark areas, then recording its position every 15 seconds is a technique for determining whether the organism favors light or dark. Consider an inquiry about something more complex, for example, an investigation of the effectiveness of antacids. If students know that acids and bases can be tested with pH paper or other indicators, they can investigate antacids with those tools (see the next section regarding the wisdom of this approach). Students who also know about titration have a larger design space because they can sensibly investigate antacids in multiple ways.

The second type of scientific inquiry skill needed is knowledge of *acceptable practices*. Acceptable practices in scientific inquiry include such things as repeating trials and averaging to reduce error, recording observations systematically, and controlling variables. It is important to note that different practices are acceptable in different types of inquiry. Controlled experiments, for example, require that one variable is changed at a time. Field studies, on the other hand, do not attempt to control variables, but may include sketching, mapping, noting environmental conditions, etc. Inquiry in earth science may take the form of making models of earth systems and observing changes (e.g., the construction of a stream table to investigate the effect of grade on erosion patterns). Making models, controlling variables, and recording observations are all examples of acceptable practices.

Knowledge of acceptable practices is especially important when investigating living organisms or dangerous materials – students must know safe and ethical practices.

Together, knowledge of specific techniques and the more general acceptable practices allows students greater opportunity to make reasonable decisions when designing investigations.

- ***Knowledge of Applicable Science Knowledge***

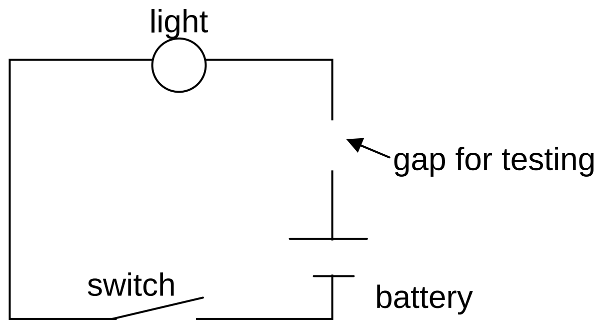
The third component of design space is the applicable science knowledge. Consider the investigation of antacids mentioned above. Antacids are called weak bases because, when dissolved in water, they do not completely dissociate into ions that make the water alkaline. Since the effectiveness of an antacid depends not on the pH it produces, but on its ability to neutralize acid, testing antacids with indicators would be inappropriate. Titration is a much better choice. A student who does not understand the concept of neutralization may not understand why simply using pH paper would not be a good procedure.

For an elementary example, consider an experiment to see whether plants grow better in light or dark. Of course, the science content connection is that green plants use energy from sunlight to make food and grow. But many students will plant seeds and measure their growth for a short period of time (a few days). These students may find that the seeds in the dark grow just as much as those in the light. This is because seedlings use the energy stored in the seed for their growth.

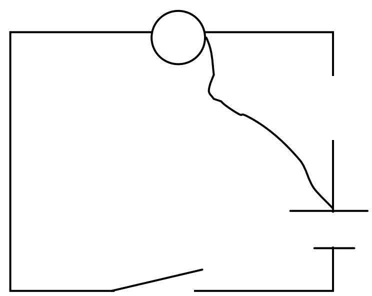
If the reason for doing scientific inquiry is to be able to produce evidence-based explanations, then teachers must assure that inquiry activities are aimed at either using or forming important explanatory concepts. One way to do that is to use inquiry activities during the Application phase of the Learning Cycle. Students are then expected to apply their science content knowledge to explaining the phenomena. But inquiry is perfectly appropriate during the exploration phase as well. When inquiry is exploratory, it provides experiences and observations that students use to build the explanatory concepts. Students then propose tentative explanations or simply note patterns or observations that lead to the development of new concepts.

Why Worry About Design Space?

Attention to design space is important for teacher-directed investigations because students often misunderstand such activities. Consider the case of two students who were told to build the following circuit to test materials to see if they are conductors or insulators[2].



The intention was for them to place objects in the gap to see if the light comes on. The students were concerned when they made the circuit and the bulb was not lit. Therefore, they added another wire:



Happy that the bulb was now lit, the students tested their materials and found that everything they tested was a conductor. These students did not understand enough about electricity to test for conductivity. Even if the teacher had corrected their circuit, it is likely they would have not understood their own investigation because it was outside their design space.

It seems apparent that if design space is important in doing teacher-directed lab experiences, it is even more important when students are making their own design decisions.

[2] Osborne & Freyberg (1985) **Learning in Science: The implications of children's science**, Heinemann, Auckland, NZ

Figure 7: Worksheet to plan instruction using the idea of Building Design Space

(From Dr. Dave Hamilton, Science Assessment Specialist, Portland Public Schools)

EXPERIENCE — *Students will gain experience with the phenomena they are to investigate by engaging in*:

- ❑ Open exploration(s)
- ❑ Teacher guided exploration(s)
- ❑ *Prescribed* lab(s) with an emphasis on observation
- ❑ Other

Outline of plan:

SCIENCE CONTENT KNOWLEDGE — *The task is intended to*:

- ❑ Assess students' prior knowledge
- ❑ Apply recently learned content
- ❑ Introduce new content (exploratory investigation)
- ❑ *Identify patterns to be* explained by new content
- ❑ Other

Teacher's specific content goals:

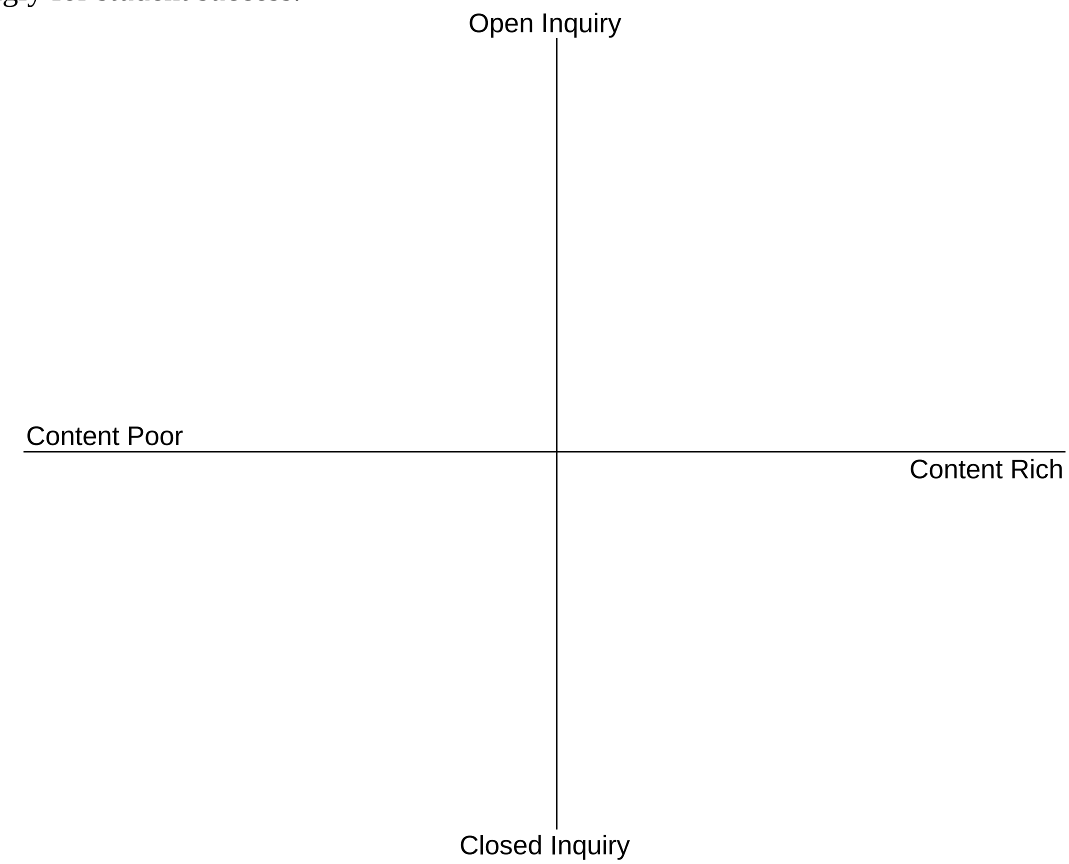
SCIENTIFIC INQUIRY SKILLS — *You will assure that students can perform applicable procedures* by:

- ❑ *Choosing* tasks that involve simple techniques and practices students already know.
- ❑ *Teaching* applicable techniques and practices immediately prior to task.
- ❑ *Teaching* applicable techniques and practices in prior units.
- ❑ Other

Figure 8: Grid for Evaluating Scientific Inquiry Tasks

(From Dr. Dave Hamilton, Science Assessment Specialist, Portland Public Schools)

Evaluating scientific inquiry tasks is a key component of planning a lesson. The grid below and indicators of content richness and open inquiry allow you to evaluate your lesson and plan accordingly for student success.



Indicators of Content Richness:

- Students are compelled to engage in evidence-based explanations in order to successfully complete the task.
- Age-appropriate content knowledge is directly applicable to the evidence-based explanation (see Oregon Standards, NSES, AAS).
- Task taps students' prior knowledge (either content knowledge studied previously or personal knowledge of the phenomena being studied). In other words, the task is embedded in the classroom context.
- The inquiry is not likely to contribute to misconceptions.

Indicators that Inquiry is Open:

- Learner has a part in determining what question/hypothesis will be investigated.
- Learner determines what evidence will be needed and how to collect it.
- Learner decides how to organize and present the evidence they collect.
- Learner formulates an explanation on her own. (Students may be prompted to explain, but if they are answering specific questions, the inquiry is less open.)

Instructional Design for Rich Scientific Inquiry

Teaching in the inquiry style is an intensive process that goes in depth and beyond scientific inquiry work samples and activities. This becomes a concept-based approach rather than a skill-based approach. The following text describes the important decision points that a teacher must address to choose, adapt or design scientific inquiry instruction, including assessment tasks for students. This is not a linear process, though here it is described as a set of steps that the teacher takes to plan scientific inquiry instruction and assessment for their students. An expanded version of the following discussion was published in *The Oregon Science Teacher* (Gummer, 2002 a & Gummer, 2002 b).

The process is extensively recursive, with teachers reflecting on what scientific inquiry involves and how scientific inquiry forms an integral component of the science content they intend students to learn. The steps entail a set of questions that the teachers might ask themselves as they plan science instruction for their students. The steps are modeled on the view of essential features of classroom inquiry that are found in the National Research Council's text on scientific inquiry (Olson & Loucks-Horsley et al, (2000) *Inquiry and the* ***National Science Education Standards****: A Guide for Teaching and Learning* available at www.nap.edu/catalog/9596.html) and communicated in Figures 9 and 10, pages 50 and 51. They also address the analysis of inquiry teaching and learning criteria developed by science education researchers such as Lufts (1999) and Dana (2000). Engaging in this reflective process of instructional and assessment planning provides the teacher with a framework within which to begin to document the opportunity students have to learn science in their classrooms. This instructional design strategy used to develop and implement rich learning experiences for students also contributes to the professional development of the teacher of science.

Decision Point: Connection to Common Curriculum Goals and Contest Standards - *What standards does the instruction address?*

Standards-based instruction starts with the common curriculum goals and content standards for the discipline involved. However, teachers and textbooks are more frequently topics-based in terms of deciding what science content to address. Grounding this development in the standards increases the likelihood that students will be addressing important content as well as scientific inquiry process skills in the construction of their work samples.

Decision Point: Role of the Teacher – *Will I be able to act as a 'guide on the side' or will my students need more direct instruction for this set of lessons?*

This question addresses how much structure the teacher will need to supply to students as they go about engaging in scientific inquiry. If students have apparent understanding of the antecedents to the inquiry, the teacher may not need to provide extensive support. However, if students are unfamiliar with the science content, or have gaps that will hinder their abilities to engage, the teacher needs to decide what the nature of the support should be. This requires teachers to find out what students already know and can do with specific science content. Students develop understandings (both misconceptions and correct conceptualizations) of science content in a variety of ways including previous instruction and personal life experiences.

Decision Point: Scientifically Oriented Questions – *What is the best way to identify questions that reflect the authentic science content that we are addressing?*

The identification of questions or relevant experiences and activities that lead students to be able to engage in inquiry in science is the most difficult aspect of instructional design. The Learning Cycle described on pages 36-38 identifies one way to go about helping students determine the appropriate questions to ask that will lead to using scientific inquiry to answer them.

Another method takes a more deductive approach, and, in this case, the initial questions might come from the teacher. Students are presented with a claim made by the teacher, the textbook, or the popular press and challenged about how they might investigate the scientific phenomenon represented in the claim.

Asking students to determine what evidence they would want to collect to evaluate a claim made in their textbooks is a good way to move from statements that they might read or preliminary experiences they might have to the generation of new questions about scientific phenomenon, which is the heart of inquiry. A KWL chart (page 35) might examine what students know, what they want to ask as questions and what evidence they would look for that would provide them with an explanation for the statement. This process facilitates a deductive approach to science teaching.

Decision Point: Assigning a Priority to Evidence – *How can I get my students to focus on the important data to collect in order to produce evidence they can use to reason from results and conclusions to explanations about scientific phenomena*?

Students need help to determine what evidence will assist their development of an explanatory answer to the question driving the scientific investigation. One method of linking evidence to question is to transform the question to the form of **if….then** statements to emphasize the importance of using prior knowledge to form hypotheses.

Students need to know that a hypothesis is more than an educated guess. Students must learn how development of a hypothesis helps establish the importance of evidence and identification of the variables that need to be defined, measured, manipulated or kept constant in the subsequent investigation. This also gives priority to explanations that tie the results from the investigation to the students' growing understanding of the scientific phenomenon under investigation.

Decision Point: Designing a Scientific Investigation – *What materials, knowledge, and skills will my students need in order to design an appropriate investigation?*

This is the heart of scientific inquiry, and it relates directly back to the description of the Design Space on pages 39-42. Every scientific investigation requires some initial understanding of the underlying scientific concepts and principles and of the investigation skills that the students will need to use in order to address the question of the scientific phenomenon they have identified.

A "reasonably rich learning environment" in which the students are presented with activities and experiences that have sufficient detail, enable students to identify patterns and begin to reason about the problem or question they are investigating (Gummer, 2002c). Instructional planning is vital so students are not overwhelmed by the sheer volume of scientific concepts and principles they need to know in order to proceed. On the other hand, if the knowledge and skills required by the investigation are not available to the students, they will not be able to proceed. Teachers have to balance the information load of the learning experience.

Decision Point: Conducting a Scientific Investigation and Collecting Data – ***How much structure should I give my students to help them implement the investigation and collect data?***

If students have not had experiences writing their own investigations, then a teacher- or text-based description of the investigation design may be necessary in order to facilitate students' implementation of the investigation. In addition, students need experiences that focus students on the necessary data to collect to provide evidence for their subsequent analysis, conclusions and evidence-based explanations. To be successful students need teacher assistance. The amount of assistance that the teacher gives to the students is one of the multiple decisions that the teacher makes as students engage in scientific investigations.

Decision Point: Presenting and Analyzing Data – ***How much structure and guidance do my students need in order to accurately present their findings and analyze their results?***

Data reduction, presentation and analysis make up a major portion of scientific investigations. The construction of a data table is a crucial aspect of scientific investigations, but it requires explicit instruction in how and why to construct such a display.

Students need to be taught how using such an organizational framework facilitates subsequent display and analysis of data. They must have multiple opportunities to examine the ways in which data displays are used throughout their scientific investigations in multiple content disciplines.

Classroom discussions that focus on the appropriate use of data at the middle school level include issues about the proper analytic techniques (Is an average value appropriate for these data? What type of graphic representation best displays these results?). Lehrer and Schauble (2002) describe a number of instructional strategies for helping students analyze data in *Investigating Real Data in the Classroom: Expanding Children's Understanding of Math and Science*.

Decision Point: Formulating Explanations That Connect Evidence to Scientific Knowledge – ***How can I help my students move beyond simply stating whether or not their hypothesis is supported to using the evidence they have produced to explain the scientific phenomenon they are investigating?***

Evidence-based explanations are the desired results of scientific investigations. Many students feel that if their results support or disconfirm their hypotheses, then they have completed their investigation. However, without the use of their results as evidence to provide an explanation of the scientific phenomenon, the students have only moved to a partial demonstration of their understandings.

Students need experiences where their results might support alternate explanations or where potential errors in scientific design leave them unable to draw sufficient conclusions and move toward an evidence-based explanation. For example, a symposium where each pair of students present their results and explain how their results helps to provide evidence that helps the class explain the statement about photosynthesis. This venue enables the teacher to raise issues of alternate explanations for results, to model for them the sorts of scientific reasoning he or she is trying to develop. This classroom "debriefing" session is essential to help the students develop explanations of how the evidence that they have gathered contributes to the overall understanding they are developing about the particular scientific phenomenon under investigation.

Human errors are those most frequently identified by students as they attribute inconclusive evidence to errors in measurement of variables or to inabilities to accurately carry out investigations. Teachers need to model evaluations of incomplete design to show students how they might think about the adequacy of their design to supply evidence for an explanation.

Deciding how much scaffolding with individual and class discussions is an important instructional decision for teachers. If students have not had sufficient experience reasoning from results to evidence-based explanations, teachers need to provide some structure in the forms of open-ended questions that students might answer. Deciding on the extent of the direction such questions provide is another important consideration.

Decision Point: Communicating and Justifying Explanations – *How much assistance do my students need to communicate and justify their explanations?*

Written communication of scientific results is difficult for some students, yet the teacher may know that the student understands the scientific phenomenon being investigated. Highly structured steps and procedures for communicating scientific results may be important for the students who have such difficulties or for students who have not had supported experiences in determining what the teacher wants communicated in evidence-based explanations.

Once students have had initial experiences with teacher expectations, the guidelines for communication might be made more broad and general until students are able to construct reasoned evidence-based explanations independently. Determining the amount and nature of the support for student communication is an important instructional step.

Decision Point: Assessment – *What evidence will I accept that students know about and can carry out scientific inquiry?*

Assessment is data that inform some decision that the teacher needs to make. The teacher needs to decide what evidence is needed that students have learned the targets of instruction and ensure that those data are sufficiently rigorous for the decision that the data support. Formative assessment permeates the initial stages of scientific inquiry as the teacher works with students to determine key investigation questions.

A pre-assessment of student knowledge informs the teacher’s decisions on how to proceed with instruction. The various questions that are asked during instructional sequences supply the teacher with information about what understandings (or misunderstandings) the students are developing. This helps with the day-to-day pacing decisions of instruction.

The final report that the students write individually provide the teacher with the evidence of the students summative understanding of the scientific concepts and principles under investigation and of scientific inquiry content in the form of question-posing, investigation design and implementation, data analysis, and the development of evidence-based explanations.

Having assessment as the last item in this table does not suggest that assessment is the final stage of scientific inquiry instructional design and assessment. Rather the principles of “backwards design” articulated by McTighe and Wiggins (2000) suggest that assessment design should be tightly connected to the decision of what scientific content (both of science concepts and principles, and scientific inquiry) are the target of instruction. They place assessment design up front in the instructional design process to ensure that goal setting, instruction and assessment are all aligned.

Documentation of Instructional Design – Putting it all together to strengthen teaching with and about scientific inquiry.

Figures 9 and 10, pages 50 and 51, present these steps in standards-based inquiry teaching in tabular formats. This does not signify that there is necessarily a linear process to this instructional design. Nor does it intend that instructional design only requires teachers to fill out a number of boxes to ensure good teaching and subsequent student learning. Scientific inquiry-based instruction is a multi-faceted process that results in a complex picture of what the student knows about and can do with scientific inquiry as seen in the student's scientific inquiry work sample that represents their responses to a task given them by their teachers. Sharing and discussing aspects of student work is one of the most beneficial professional development experiences for teachers. As teachers in Oregon develop and share examples of those work samples, they also need to be able to demonstrate the opportunity to learn that they have provided. Using the Instructional Design steps above frames that opportunity and provides the structure of that instructional documentation. Reform of science education in the state of Oregon is dependent on support for teachers to fold documentation into the work they do as part of their profession.

Modifying Activities for Scientific Inquiry

Designing materials to align with Oregon's science content standards can be a time consuming process and it is unlikely that there will be commercially available materials to meet all standards. Consequently, most teachers will wish to modify existing materials for scientific inquiry.

Using Essential Features of Classroom Scientific Inquiry

Figure 9, below, shows the essential features of classroom inquiry as identified by the National Research Council (Olson & Loucks-Horsley, *(2000) Inquiry and the* ***National Science Education Standards****: A Guide for Teaching and Learning* available at www.nap.edu/catalog/9596.html). These criteria describe the learning experiences that a teacher develops in order to facilitate students learning how to do and what to understand about scientific inquiry. Figure 10, page 51, relates the essential features of inquiry to the Oregon Scientific Inquiry Scoring Guide dimensions and illustrates possible variations in student involvement. In reviewing these variations and the phase- in schedule for scientific inquiry assessments (Figure 13, page 64), it becomes apparent that lower levels of student involvement may be appropriate as students are learning the inquiry process (e.g., elementary students might not be required to formulate their own questions). The goal is to move toward a student-centered approach since this approach better supports the inquiry process. Activities that are teacher centered have significant value in teaching science concepts and principles and may ultimately be more suitable for direct instruction. When developing your own inquiry activities, check for the essential features. Examine what it is that you are having the students do during the learning experiences and ensure that they are involved in the development of scientific *explanations*, a key criteria in the essential features of classroom inquiry (Figure 10, page 51).

Figure 9: Essential Features of Classroom Scientific Inquiry

(Adapted from: *Inquiry and the National Science Education Standards,* National Research Council (2000))

- Learners are engaged by scientifically oriented questions.
- Learners give priority to evidence, which allows them to develop and evaluate explanations that address scientifically oriented questions.
- Learners formulate explanations from evidence to address scientifically oriented questions.
- Learners evaluate their explanations in light of alternative explanations, particularly those reflecting scientific understanding.
- Learners communicate and justify their proposed explanations.

Figure 10: Essential Features of Classroom Inquiry and Their Variations

(Adapted from: *Inquiry and the National Science Education Standards,* National Research Council (2000))

	Essential Features	Variations More ← Amount of Learner Self-Direction → Less			
Forming	**Learner engages in scientifically oriented questions**	Learner poses a question.	Learner selects among questions, poses new questions.	Learner sharpens or clarifies question provided by teacher, materials, or other source.	Learner engages in question provided by teacher, materials, or other source.
Designing and Collecting	**Learner gives priority to evidence in responding to questions**	Learner determines what constitutes evidence and collects it.	Teacher directs learner to collect certain data.	Teacher gives learner data and asks learner to analyze.	Teacher gives learner data and explains how to analyze.
Analyzing	**Learner formulates explanations from evidence**	Learner formulates explanation after summarizing evidence.	Teacher guides learner in process of formulating explanations from evidence.	Teacher gives learner possible ways to use evidence to formulate explanation.	Teacher provides learner with evidence.
	Learner connects explanations to scientific knowledge	Learner independently examines other resources and forms the links to explanations	Teacher directs learner toward areas and sources of scientific knowledge.	Teacher gives learner possible connections.	
	Learner communicates and justifies explanations	Learner forms reasonable and logical argument to communicate explanation.	Teacher coaches learner in development of communication.	Teacher provides learner broad guidelines to sharpen communication.	Teacher gives learner steps and procedures for communication.

Assessing an Activity for Scientific Inquiry

The *Assessing an Activity* chart (Figure 11, page 53) helps teachers assess how much an instructional activity or inquiry work sample task is student-centered or teacher-centered. The chart also helps the teacher ascertain the extent to which the activity/task provides the students with the opportunity to learn with or about scientific inquiry. Using the chart to evaluate an inquiry task helps the teacher decide whether the task provides the student with the opportunity to demonstrate what he or she knows about and can do with scientific inquiry.

The fifteen items in the checklist are linked to the dimensions of Oregon Scientific Inquiry Scoring Guide and to the essential features of classroom scientific inquiry (Figure 10, page 51). To use the tool, select a classroom activity or a work sample task and analyze it for the amount of teacher/student involvement in each of the fifteen items. If you need to modify the activity to make it more student oriented or inquiry oriented, consider:

- implementing a different teaching strategy.
- addressing a specific step in the *Learning Cycle* (Figure 4, page 36).
- adding an essential feature of inquiry (Figure 9, page 50).
- developing student expertise in one or more of the scientific inquiry dimensions.

Figure 11: Assessing an Activity For Scientific Inquiry

(Developed by Oregon Science Teacher Leader Cadre including Dave Hamilton (Portland Public School), Jodie Harnden (Pendleton School District), and Cindy Russell (Tigard/Tualatin School District))

Stage	Question	Student — Shared — Teacher
Forming	**Does the task/activity lead to formulation of a question/hypothesis that requires students to develop an evidence-based explanation of a natural phenomenon?**	Student Shared Teacher
	1. Who decides on the topic (e.g., enzymes, plate tectonics, acids & bases)?	|————————|
	2. Who specifies the question to be answered?	|————————|
	3. Who chooses the variables to investigate?	|————————|
	4. Who decides which concepts/principles inform the investigation?	|————————|
Designing	**Does the task/activity lead to a design that will produce evidence that can be used to explain/predict a natural phenomenon?**	Student Shared Teacher
	5. Who decides what materials are to be used?	|————————|
	6. Who decides on the specific procedures to be followed?	|————————|
	7. Who decides when and how to modify procedures?	|————————|
	8. Who determines what data and how much data to collect?	|————————|
	9. Who writes up the description of procedures actually followed?	|————————|
Collecting	**Does the task/activity lead to the collection of data that can be analyzed/explained by the students?**	Student Shared Teacher
	10. Who determines the format for recording data?	|————————|
	11. Who decides when sufficient evidence (data) has been collected?	|————————|
	12. Who decides how to transform the data for analysis (e.g., line graph, bar graph, diagram, calculations)	|————————|
Analyzing	**Does the task/activity prompt students to explain the results as they relate to the topic of study?**	Student Shared Teacher
	13. Who formulates the response to the question/hypothesis?	|————————|
	14. Who guides the thinking of the response (e.g., does the teacher list questions to answer or does the student write a free form conclusion?)	|————————|
	15. Who determines which concepts/principles to apply when explaining the results?	|————————|

Introduction to Claims/Evidence Approach

(From Tom Thompson, Science Teacher, Philomath School District)

A great deal of science involves applying basic principles, theories, or laws to new and interesting questions. The claims/evidence approach to scientific inquiry is based on this particular view of science. Students are first exposed to a claim that may be a scientific hypothesis, theory, or law. Students are exposed to the claim through a series of well-structured activities or possibly some carefully chosen reading material. Once the scientific claim is identified, students are asked to investigate a novel situation where the claim might apply. The purpose of the investigation is to collect evidence to support or refute the validity of the claim as it applies to the specific context. A biology class may be introduced to the food pyramid and trophic levels. They read about the claim that predatory species should be fewer in number and biomass than prey species. Students then develop a way to investigate this claim in the context of a local stream where they collect evidence such as the number and trophic level of different invertebrates in the stream.

On the surface this may appear to be a typical confirmation lab or activity. However, unlike most confirmation labs, students develop the approach to collect meaningful data to use as evidence. A claims/evidence approach may also result in data that could refute the original claim which can then lead to discussions about errors, limitations, and general strength of evidence. This is a much closer approximation of real science than a confirmation activity where the data collection is designed to guarantee a specific result.

Perhaps the most important aspect of a claims/evidence approach to scientific inquiry is the connection to important scientific ideas. By making the original claim explicit and linking it to an important principle, students seem to be able to make stronger connections between scientific inquiry and important scientific content.

Help! I'm Trying to Teach Content Through Inquiry!

(From Emmely Briley, Science Teacher, Molalla River School District)

An Easy-to-Use Tool for Getting the Most out of Scientific Inquiry

Recently, I became involved in the planning meetings for the Oregon Science Teacher Leaders Institute where I heard about the Claims-Evidence approach to teaching scientific inquiry. It has been very helpful to me in encouraging independent thinking regarding experimental design and scientific principles, focusing my students' inquiry on specific content, and inspiring critical thinking when it comes to deciding what the results of an experiment mean. All three of those areas really needed improvement in my teaching. It is so simple and easy-to-use that I feel that it might be of interest to other science teachers. I'd like to share how I used it in my classroom and the pleasing results I observed.

Previous Attempts at Teaching Inquiry

At the time of this project, I was in my second year teaching, and my physics class was made up of mostly juniors with a senior and sophomore or two thrown in for good measure. I had done one or two homemade inquiry labs with them previously. They were usually canned labs that I tried to make into inquiry activities by deleting certain parts and then asking the students to come up with their own hypotheses and procedures. I left the same questions that usually come at the end of a lab and then required a formal lab write-up. These first attempts at teaching inquiry, however, did not produce the results I wanted.

One such lab was when I asked the students to design an experiment to verify that the acceleration due to gravity (g) on earth was 9.81 m/s^2. As I wandered around the room to approve each group's procedure, I noticed that most of the groups had not thought much about the problem on their own. It became clear that during our class discussion, the students found out what the "smartest" kids were doing and then copied their method. I had ten groups all dropping and timing blocks. It seemed like the groupthink had converged on the "right" method, and nobody wanted to do it "wrong."

When the lab was finished and I began reading the conclusions my students had written, I was disappointed by the weak analyses. Most of my students seemed to write something like, "Our results were very accurate. We proved our hypothesis that g is equal to 9.81 m/s^2. We could improve our lab next time by using better equipment." "Ugh!" I thought, "Where is all this critical thinking that I'm supposed to be seeing."

The last, and I think most eye-opening, discovery that I made about my inquiry teaching was that much of the content that I was hoping to get across by doing the lab had dissolved into mist along the way. I went around to each group and discussed with them what they had learned from the lab. I quizzed them on certain concepts relating to acceleration, and to my horror, I realized that a significant number of my students still thought that heavier objects fall faster than lighter ones! I felt like my budding career as a physics teacher was withering on the vine. Not only that, but I remember thinking, "I'm doing inquiry like I'm supposed to. If this is such a great way to teach science, why aren't my students gaining any conceptual ground?" Right then, I was really tempted to give up on inquiry and get out my lecture chalk, but I knew there had to be a better way to get content across while doing inquiry if I could just discover it.

The Claims-Evidence Approach in Action - Day One: Open Planning

After hearing about the Claims-Evidence approach, I decided to try it in my physics class. We were studying conservation of momentum in Chapter 6 of Holt Physics. This time, instead of giving them a canned lab that was tweaked to make it more inquiry-like, I kept the process more open by using Figure I as the only prompt as they began planning their experiments. I used the grid to focus the content of the inquiry but still give them the leeway to pose their own question by asking the class to skim the chapter and come up with a claim from the chapter which they could test. A “claim” is a statement that can be tested.

What is the Claim?	What is the Question I want to ask?	What evidence would I accept to support the claim?	What evidence did I actually get?

Figure I.

The class brainstormed a few claims from the chapter such as “Momentum is mass times velocity,” “A change in momentum over a longer time requires less force,” etc. I wrote the ideas up on the class claim grid on the chalk board, and then they voted on the one that they liked the best. During this time, I talked about keeping the claim simple and testable, and the use of controls and variables. I tried to give pros and cons of each claim idea attempting to steer the students toward a claim that would be manageable with a simple experiment. In the end, the students chose a claim to test that would not have been my first choice, but that they, nonetheless, could relate to.

They chose the claim, “Kinetic energy is conserved in an elastic collision.” They all wrote the same claim in the first column of the grid and then were left to fill in the last three columns themselves. In the second column, most students simply rewrote the claim in the form of a question. Column three was space for students to start thinking about the evidence they would need to support the claim. At this point, students were allowed to work in groups of two or three. The grid was their planning space, but they were to write the details of their procedures and results in their lab notebooks.

Since this was the first time our class used this format, we also brainstormed some ideas for column three together as a class. Although the question is "What evidence would I accept to support the claim?" it was clear that students were not used to making a connection between the data they gathered during a lab and the actual question they were attempting to answer. At first, students just started throwing out variables. As I filled in our classroom column three up on the board, students shouted out things like, "speed," "time," "distance," "mass," etc. I was unpleasantly surprised to hear nothing about the definition of kinetic energy or collisions or relationships they should be looking for. I tried to probe the class by asking questions. "What is kinetic energy?" I asked. A student or two gave the mathematical formula after looking it up. I hoped that this lab would give them understanding of kinetic energy beyond its formula. Next, we talked about what it meant to be conserved. I probed them more. I asked them, "How will you know if kinetic energy is conserved or not?" Eventually, a student or two said that kinetic energy should be the same before and after a collision. I gave them the assignment to think about how they might design an experiment to test this prediction and come back the next day with a rough sketch of a hypothesis and a procedure.

The Claims-Evidence Approach in Action - Day Two: Independent Experimental Design

The next day, I read each group's procedure before allowing them to begin the lab. Some of the groups had a good start, meaning they could eventually calculate kinetic energies with the data they were collecting and their experiments were feasible. I knew that some of these groups would run into practical problems with losses due to friction and inelastic collisions, but I let them begin anyway because I wanted them to have experience working out the difficulties on their own.

Other groups, however, needed more guidance. They described their experimental set-up, but had no idea what data they should collect. Others were collecting the right variables but made no mention of the data's connection to kinetic energy. Still others had creative but overly complex experimental set-ups. I asked these groups a few probing questions using the claim form. I asked them to think about the original claim, "Kinetic energy is conserved in elastic collisions." Then, I asked them to write down how the data they were going to collect would support the claim and then revise their procedures as necessary. This prodding helped most of the groups focus a little better, and their rewritten procedures were more applicable if not stellar. The really pleasing thing I noticed about the students' experimental designs was that they were all different. During this activity, they did not seem interested in copying what the "smart kids" were doing. I believe that because they were thinking so hard on their own, they all felt smart.

Lively Discussion of Scientific Principles

As I wandered around the room while students were performing the experiments they had created, what struck me most were the differences in their conversations from those during a regular, more guided lab. Students often talk about what step to do first, second, or third without reference to why they are collecting a certain datum. During the claims lab, I heard students discussing and debating the scientific principles involved. They disagreed and gave reasoned arguments for why colliding two marbles was better than colliding one with the wall, for example. Most of the groups revised their procedures as they ran into practical problems. I was thrilled that my students were actually *thinking* about science and experimental procedures.

Tighter Focus on Core Content

I had some students that struggled with lab work. Even during cookbook labs, they usually became overwhelmed by all the steps they needed to perform, let alone how their data related to the scientific content we were investigating. The openness of the claims-evidence inquiry lab felt even more overwhelming at first. They were unsure of how to get started, of what they were "supposed" to do.

By using the grid worksheet, however, I could help the students to focus on the overall purpose of their experiment by asking a simple question, "What is the claim you are trying to test?" Usually, this question was all the students needed to get going in the right direction. I think the non-intimidating language of the worksheet helps students to think about scientific problems in their own terms.

The grid also helped to keep the main idea of the lab before the students' eyes at all times. Maybe it was the simple fact that there was a big box around the claim, "Kinetic energy is conserved in elastic collisions," that helped my students be able to articulate the core concept we were working with. When the time came for them to write about what their data meant, they had already been thinking about it for a long time. The content did not get lost in the inquiry.

Critical Thinking When Analyzing Data

A nice result that I observed from using the claims-evidence approach was the improvement in what students at all ability levels had to say in their conclusions. They went into more detail than usual about what happened during the lab, what their results meant, what accounted for the losses they observed, and how the experiment could be improved in the future. I had one student who was thinking about the physics of kinetic energy conservation so much that he went out and did extra research on his own to try to understand it.

Summary

Using the open claims-evidence approach as a planning tool for students and as a means to keep the focus of inquiry on the scientific content at hand, I saw improvements in student learning from an inquiry activity. There was more creative experimental design, minds-on discussions of the meaning of what they did in lab while they did it, better focus on the concepts I wanted to get across, and more detailed written conclusions. Some challenges I experienced using this approach were that students chose a claim that was not the one I would have chosen. Also, many students initially lacked a meaningful connection between variables and the concept of kinetic energy, and some students felt overwhelmed by planning their own experiment from scratch. I think these issues will improve as I continue to use this approach, and my students and I gain more competence doing open inquiry. Many versions of the grid can be made and adapted as needed. Next time, I want to use a column heading that asks, "How can I make my evidence as strong as I can?" I found the claims-evidence approach a helpful tool for my classroom, and if you think it might be helpful to you too, I hope you'll try it!

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Figure 12: Table to Help Students Think About Claims And Evidence Related To an Investigation

(From Tom Thompson, Science Teacher, Philomath School District)

Heat Transfer Example (What students would write is in italics)

What is the claim?	How might I test the claim?	What evidence would I accept if the claim were supported?	What evidence did I actually find?
Light colors reduce heat loss by reflecting heat energy.	*Wrap one cup in aluminum foil and keep the other one normal.*	*The temperature of the water in the cup with foil should not drop as much in 5 minutes as the other cup.*	*The temperature of the water in the cup with the foil dropped 10 degrees and the water in the other cup dropped 12 degrees.*

Rates of Reaction Example (What students would write is in italics)

What is the claim?	How might I test the claim?	What evidence would I accept if the claim were supported?	What evidence did I actually find?
Powdered solids have more surface area so particles collide with it more often.	*Use different sized pieces of marble and measure how fast the gas is produced.*	*The bigger pieces of marble should produce gas slower than the small chips.*	*The test tube filled with gas in 1 minute and 35 seconds for the large chips. For the small chips it took only 20 seconds.*

Whatever the reasons, I am getting better arguments related to student investigations. Students give specific evidence why the claim is supported or not supported. They also discuss the strength of the evidence rather than canned responses about human error or better technology. Perhaps what is most obvious is that students seem to be learning important content while doing inquiry better than when I used more inductive discovery approaches.

Measuring Up To Standards

Across the region, states hone their science standards and assessments
(By Marilyn Deutsch, Northwest Regional Educational Laboratory, Spring 2005)

PORTLAND, Oregon—If physics is how things work, then the physics of how students work and learn in Bonnie Magura's eighth-grade physical science class can be summed up in these four words: motion, energy, thought, and creativity. Magura rarely sits or stands behind her desk lecturing. Rather, the 2003 Presidential Award Winner for Excellence in Math and Science Teaching spends the bulk of her instructional time alongside her students teaching them how to "do" science. Today, the lesson is on energy transfer and conversion: The students are building wind turbines based on their own designs.

While across the United States science educators are feverishly grappling with the challenges, demands, and time constraints of creating science standards and assessments mandated by the No Child Left Behind Act, there is no such panic in Oregon. NCLB requires states to have their science standards in place next school year and to test students on these standards by 2007–2008. Students must be tested at least once in grades 3–5, 6–9, and 10–12.

Oregon adopted new science standards back in 2001, although they're frequently reviewed and revised in a continuing process of raising and rising expectations. Educators in the state believe they've found a successful formula for K–12 science education, based on the claims-evidence approach to "inquiry-based" science.

INQUIRING MINDS

Inquiry-based instruction is more than just hands-on learning. Proponents say this teaching approach encourages critical thinking. Before starting any scientific inquiry, teacher and students write "claim statements." For example, this is the claim statement for the wind turbine project in Bonnie Magura's classroom: "Energy cannot be created nor destroyed but only changed from one form to another. Mechanical advantage plays a role in how efficiently energy can be transferred or converted to new forms."

Teachers like Magura say the claim statement is key to students developing deep scientific understanding. The claim gives students a concept to test and guides them as they collect and analyze their data.

Dave Hamilton—who has taught science for 26 years— has worked with teachers around the state on implementing the claims-evidence approach. A teacher at Portland's Franklin High School, Hamilton says the claim statements are "powerful because they anchor the entire investigation," so that students look for evidence that either supports or refutes their claims.

For teachers, inquiry-based science may require more upfront planning, but it is the only way Magura has ever taught. She says, "You have to let go and let students struggle and do it, fail, pick it up again, and do it …" and in the process, help them learn that it's OK not to succeed the first time. Magura provides the point-to-point checks that keep her students focused and on track.

PUTTING INQUIRY TO THE TEST

To find out how well Oregon science students are doing, the state has devised two sets of tests. There's the traditional multiple-choice test given in fifth, eighth, and 10th grades with both a paper-and-pencil format and a Web-based version. However, a second test defies traditional A, B, C, or D answers. Students must submit work samples that demonstrate whether they can clearly and concisely pose a scientific question, state their hypothesis, proceed with an experiment, show data and results, graph tables, and reach a conclusion. Work samples are scored on a scale of 1–6. A score of 4 meets standards while scores of 5 and 6 exceed standards.

One work sample provided by a fifth-grader looking into the nature of magnetism and magnets asks, "Does the edge of a circular magnet have the same strength/magnetic force as the north and south pole of that same magnet?" The student hypothesizes that he doesn't think the edge of the circular magnet will be equal in force to the north and south magnet poles. The question and hypothesis rate a "5" from the scorers because they're stated clearly and show that the student understands what he's doing.

Another student looks into the relationship between sunlight and the growth of seeds, but never poses a clear question. Instead, the student writes, "For my question, I am going to do sunlight and no sunlight." This work sample rates a "2."

Teachers—not state testers—evaluate these samples, looking for a student's understanding of science that goes beyond content. Hamilton says, taken as a whole, Oregon's assessment tests give teachers, students, and parents a "more complete picture of student achievement."

But does this work? In the two years of testing, science achievement has actually slipped a couple of percentage points, from a high of 71 percent of fifth-graders meeting and exceeding state standards in 2001–2002 down to 69 percent in 2003–2004. Eighth-graders and 10th-graders slipped one percentage point to 58 percent and 59 percent, respectively. Oregon's Science Assessment Specialist Aaron Persons says with just two rounds of testing, there aren't enough data to draw any conclusions.

However, preliminary testing elsewhere across the nation suggests that inquiry-based science teaching not only improves students' scientific knowledge, but also has other benefits: Students who learn this way show marked improvements in their reading and math scores.

Still, it is estimated that 80 percent of schools across the United States take a more "textbook" or direct approach to science instruction. And some researchers and educators believe this more "direct style" of teaching is best suited for complex science lessons.

As NCLB focuses on science, the critical discussion will continue over the best ways to teach science to elementary and secondary school students: inquiry/discovery, the direct approach, or a combination of both. In Oregon, however, the road ahead is already charted. At West Salem High School in Salem, Oregon, science teacher Steve Holman sums it up. Science, he says, is "a process, where the critical thinking you learn from science will stay with you longer than your ability to recall the periodic table."

The complete article is printed in Science Under the Microscope (Spring 2005, Volume 10, No. 3), and is available on the NWREL website at www.nwrel.org/nwedu/10-03/.

ASSESSMENT OF SCIENTIFIC INQUIRY

Using Scientific Inquiry Scoring Guide Dimensions and Threads

Students' ability to do inquiry is assessed through Scientific Inquiry Work Samples. These work samples result from classroom lessons (tasks) embedded in the content described by the district's science curriculum. Scientific Inquiry Work Samples can be scored with the Oregon Scientific Inquiry Scoring Guides.

The Dimensions of the Scientific Inquiry Scoring Guide include:

- Forming a Question or Hypothesis,
- Designing an Investigation,
- Collecting and Presenting Data, and
- Analyzing and Interpreting Results.

The criteria that make up each Dimension are anchored with three different Threads that describe important organizing components of scientific inquiry. The Threads include:

- Application of Scientific Knowledge
  the importance of connecting inquiry to scientific concepts and principles found in the examination of scientific phenomena
- Nature of Scientific Inquiry,
  the need for the development of evidence-based explanations by students as they engage in answering questions about those scientific phenomena
- Communication
  the importance of developing students' abilities to communicate clearly about results and explanations, especially in light of alternative explanations that might be generated

On the following pages you will find:

- The implementation schedule for required student Scientific Work Samples for the state of Oregon is shown in Figure 13 on page 64.
- The relationship of the Threads to the Dimensions of the Scoring Guide in Figure 14 on page 65.
- Oregon's Official Scientific Scoring Guides for Benchmarks 2, 3, and CIM (pages 66 to 71).

To help students understand and prepare for the Scientific Inquiry Work Sample process, formative assessment tools can be useful. Student language adaptations of the Official Scientific Inquiry Scoring Guides can be found on pages 73 through 78. Students use them when planning or evaluating their own work in scientific inquiry. An alternate student language tool is the Essential Elements of Scientific Inquiry Checklist on pages 79 through 82.

Figure 13: Work Sample Implementation Schedule

Scientific Inquiry Scoring Guides are Composed of Four Dimensions:

- Forming a Question or Hypothesis
- Designing an Investigation
- Collecting and Presenting Data
- Analyzing and Interpreting Results

Teachers are expected to provide instruction and classroom assessment **in all four dimensions** of the scoring guide. However, only the dimensions indicated below must be reported for school district work sample management.

Students In	Benchmark	2003-04 (2005-06 graduates)	2004-05 (2006-07 graduates)	2005-06 (2007-08 graduates)
Grades 4 and 5	**2** Scored with the Benchmark 2 Scoring Guide	Report scores on one dimension: • Collecting **Performance Standard:** The Collection dimension must have a rating of 4 or higher.	Report scores on two dimensions: • Designing • Collecting **Performance Standard:** Both dimensions must have a rating of 4 or higher and be on the same work sample.	Report scores on three dimensions: • Designing • Collecting • Analyzing **Performance Standard:** Each dimension must have a rating of 4 or higher. Designing and Collecting must be on the same work sample. Analyzing may be on a separate work sample.
Grades 6, 7, and 8	**3** Scored with the Benchmark 3 Scoring Guide	Report scores on two dimensions: • Designing • Collecting **Performance Standard:** Both dimensions must have a rating of 4 or higher on the same work sample.	Report scores on three dimensions • Designing • Collecting • Analyzing **Performance Standard:** Each dimension must have a rating of 4 or higher. Designing and Collecting must be on the same work sample. Analyzing may be on a separate work sample.	Report scores on four dimensions: • Forming • Designing • Collecting • Analyzing **Performance Standard:** Each dimension must have a rating of 4 or higher. Designing and Collecting must be on the same work sample. Forming and Analyzing may be on the same or separate work samples.
High school students working toward CIM	**CIM** Scored with the CIM Scoring Guide	Report scores on two dimensions: • Designing • Collecting **Performance Standard:** Both dimensions must have a rating of 4 or higher on the same work sample.	Report scores on three dimensions: • Designing • Collecting • Analyzing **Performance Standard:** Each dimension must have a rating of 4 or higher. Designing and Collecting must be on the same work sample. Analyzing may be on a separate work sample.	Report scores on four dimensions: • Forming • Designing • Collecting • Analyzing **Performance Standard:** Each dimension must have a rating of 4 or higher. Designing and Collecting must be on the same work sample. Forming and Analyzing may be on the same or separate work samples.

www.ode.state.or.us/teachlearn/subjects/science/curriculum/phasesched02102005.pdf

Figure 14: Relationship of Threads to the Dimensions in the 2005-2007 Scientific Inquiry Scoring Guides

(Adapted from work of Beaverton School District and Sue Squire Smith, Salem-Keizer School District).

	Scoring Guide Dimensions			
Threads	**Forming a Question or Hypothesis**	**Designing an Investigation**	**Collecting and Presenting Data**	**Analyzing and Interpreting Data/Results**
A - Application of Scientific Knowledge	Background information or observations are relevant to investigation.	Logical, safe and ethical procedures are proposed.	Reasonable and accurate data is collected in a manner consistent with planned procedure.	Scientific terminology is used to correctly to report results.
N - Nature of Scientific Inquiry	Question or hypothesis can be answered or tested.	Practical design is presented that provides sufficient data to answer the question or test the hypothesis.	Data transformations are valid and complete and are useful in making interpretations.	Procedures and results are critiqued. (not applicable at 5th grade)
C - Communication	The question or hypothesis and background information is clearly expressed.	The design and procedures are communicated.	Organized displays of data (e.g., tables or other formats) communicate observations or measurements.	Results support conclusions and conclusions address the question or hypothesis.

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Benchmark 2

	Forming a Question or Hypothesis *Make observations. Ask questions or form hypotheses based on those observations which can be explored through scientific investigations.*	**Designing an Investigation**. *Design a* simple scientific *investigation to answer questions or test hypotheses*.	
6	A) Explains the origin of the question or hypothesis based on background that is relevant to the investigation. N) Forms a question or hypothesis that can be answered or tested using data and provides focus for a simple scientific investigation. C) Communicates (A) & (N) clearly and effectively.	A) Records logical procedures with an obvious connection to the student's scientific knowledge. (Teacher guidance in safety and ethics is acceptable.) N) Presents a practical design appropriate for answering the question or testing the hypothesis with evidence of recognition of some important variables. C) Communicates an organized design and detailed procedures.	**6**
5	A) Links background to the question or hypothesis. N) Forms a question or hypothesis that can be answered or tested using data gathered in a simple scientific investigation. C) Communicates (A) & (N) clearly.	A) Records logical procedures that imply a connection to student's scientific knowledge. (Teacher guidance in safety and ethics is acceptable.) N) Presents a practical design for an investigation that addresses the question or hypothesis and attempts to provide a fair test. C) Communicates a general plan including some detailed procedures.	**5**
4	A) Provides some support or background (prior knowledge, preliminary observations, or personal interest and experience) which is relevant to the investigation. N) Forms a question or hypothesis that can be explored using data in a simple scientific investigation. C) Communicates (A) & (N) understandably.	A) Records logical procedures with only minor flaws. (Teacher guidance in safety and ethics is acceptable.) N) Presents a practical plan for an investigation that addresses the question or hypothesis. C) Communicates a plan and some procedures, but it may generally lack detail.	**4**
3	A) Background is either irrelevant or missing. N) Forms a question or hypothesis that provides limited opportunity for data collection. C) Communicates a question or hypothesis that is incomplete or only partially understandable.	A) Records generally logical procedures having flaws. (Teacher guidance in safety and ethics is acceptable.) N) Presents a practical plan related to the topic that minimally addresses the question or hypothesis. C) Communicates an incomplete plan, with few procedures.	**3**
2	A) Not Applicable N) Forms a question or hypothesis that cannot be explored through a simple scientific investigation. C) Communicates a question or hypothesis that is not understandable.	A) Records procedures that are significantly flawed. (Teacher guidance in safety and ethics, if offered, may not have been incorporated.) N) Presents a plan somewhat related to the topic which may not address the question or hypothesis. C) Communicates an incomplete plan that is difficult to follow.	**2**
1	A) Not Applicable N) Not Applicable C) Does not express the purpose of the investigation as either a question or a hypothesis.	A) Records procedures that are wholly inappropriate. N) Presents a plan that is impractical or unrelated to the topic. C) Communicates a plan or procedures that cannot be followed.	**1**

[A=Application of Scientific Knowledge N=Nature of Scientific Inquiry C=Communication]

2005 - 2007 Official Scientific Inquiry Scoring Guide

Benchmark 2

	Collecting and Presenting Data *Collect, organize, and summarize data from investigations.*	***Analyzing and Interpreting Results*** *Summarize, analyze and interpret data from investigations.*	
6	A) Records accurate data and/or observations consistent with complex procedures. N) Transforms data into a student-selected format that is most appropriate to clarify results. C) Designs a data table (or other format) for communicating observations and/or measurements which is efficient, organized and uses appropriate units.	A) Reports results and identifies simple relationships (e.g., connecting one variable to another). N) Not Applicable C) Explicitly uses results to address the question or hypothesis and illustrate simple relationships.	**6**
5	A) Records accurate data and/or observations completely consistent with the planned procedure. N) Transforms data into a student-selected format which is complete and useful. C) Designs a data table (or other format) for communicating observations and/or measurements that is organized and uses appropriate units.	A) Reports results accurately and identifies obvious patterns (e.g., noting a pattern of change for one variable). N) Not Applicable C) Explicitly uses results to address the question or hypothesis.	**5**
4	A) Records reasonable data or observations generally consistent with the planned procedure. N) Transforms original data into a useful format (e.g., graphs, averages, percentages, diagrams, tables) with teacher support and with minimal errors. C) Designs a data table for collection and organization of data using teacher suggestions.	A) Reports results accurately. N) Not Applicable C) Responds to the question or hypothesis with some support from results.	**4**
3	A) Records reasonable data or observations consistent with the planned procedure, with some obvious errors. N) Does not transform data into a teacher-recommended format. C) Uses teacher-supplied data tables for data collection with minor errors.	A) Reports results incompletely or in a misleading way. N) Not Applicable C) Responds to the question or hypothesis without support from the results.	**3**
2	A) Records insufficient data and/or observations inconsistent with the planned procedure. N) Not Applicable C) Uses a teacher supplied data table with minimal errors.	A) Reports results inaccurately. N) Not Applicable C) Provides a response(s) to the question or hypothesis that is unrelated to the investigation.	**2**
1	A) Records data and/or observations unrelated to the planned procedure. N) Not Applicable C) Does not correctly use a teacher-supplied data table.	A) Omits results in reports. N) Not Applicable C) Does not respond to the question or hypothesis.	**1**

[A=Application of Scientific Knowledge N=Nature of Scientific Inquiry C=Communication]

2005- 2007 Official Scientific Inquiry Scoring Guide

Benchmark 3

	Forming a Question or Hypothesis *Based on observations and scientific concepts, ask questions or form hypotheses that can be explored through scientific investigations.*	**Designing an Investigation** *Design a scientific investigation to answer a question or test a hypothesis.*	
6	A) Provides a focused rationale for the investigation by using the most relevant background scientific knowledge or preliminary observations. N) Forms a question or hypothesis which can be answered or tested using data and that points toward an investigation of scientific relationships (e.g., dependency, correlation, causation). C) Expresses question or hypothesis along with the application of background information clearly enough to imply an appropriate investigative design.	A) Proposes precise, safe and ethical procedure that demonstrates application of relevant scientific principles and procedures. N) Presents a practical design that should provide data of sufficient quantity and quality to answer the question or test the hypothesis and investigate possible relationships (i.e., cause/effect). C) Communicates a unified design and logical, detailed procedures that can be replicated.	**6**
5	A) Provides background scientific knowledge or preliminary observations and shows how they are connected to the investigation. N) Forms a question or hypothesis that can be answered or tested using data and provides focus for a scientific investigation. C) Expresses question or hypothesis along with the explanation of background information clearly enough to imply an appropriate investigative approach.	A) Proposes logical, safe, and ethical procedures in a design with no scientific errors. N) Presents a practical design that should provide data of sufficient quantity and quality to answer the question or test the hypothesis (i.e. fair test). C) Communicates an organized design and detailed procedures.	**5**
4	A) Provides background information or observations relevant to the investigation. N) Forms a question or hypothesis that can be answered or tested using data gathered in a scientific investigation. C) Expresses a question or hypothesis along with background information.	A) Proposes logical, safe, and ethical procedures in a design with only minor scientific errors. N) Presents a practical design that should provide data applicable for answering the question or testing the hypothesis, although the quantity of data may be insufficient. C) Communicates a plan including important specific procedures.	**4**
3	A) Provides background science knowledge or preliminary observations that are either irrelevant or incomplete. N) Forms a question or hypothesis that can be investigated using data but not directly answered or tested. C) Either question, hypothesis or the explanation of background information is unclear or incomplete.	A) Proposes safe, ethical procedures in a design that contains some significant scientific errors. N) Presents a design that should provide data somewhat applicable to the question or hypothesis. C) Communicates a general plan with few procedures, and generally lacks detail.	**3**
2	A) Provides background science knowledge or preliminary observations that are inappropriate or substantially incorrect. N) Forms a question or hypothesis that cannot be investigated using data. C) The question or hypothesis is included with no supporting explanation.	A) Uses little scientific knowledge or does not consistently use reasonable, safe, or ethical procedures in a proposed design. N) Presents a design that is impractical or likely to produce flawed data. C) Communicates an incomplete plan.	**2**
1	A) Background information not included. N) Forms a question or hypothesis that cannot be answered or tested. C) No hypothesis or question included.	A) Uses minimal or incorrect scientific knowledge and unacceptable procedures in a proposed design. N) Presents a design that will not provide applicable data. C) Communicates a plan that is unclear or illogical.	**1**

[A=Application of Scientific Knowledge N=Nature of Scientific Inquiry C=Communication]

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Benchmark 3

	Collecting and Presenting Data *Collect, organize, and display sufficient data to support analysis.*	Analyzing and Interpreting Results *Summarize and analyze data including possible sources of error. Explain results and offer reasonable and accurate interpretations and implications.*	
6	A) Records accurate data completely consistent with complex procedures. N) Transforms data into graphic displays/formats that highlight information and patterns to support interpretation of relationships. C) Creates displays (e.g. data tables) for communicating observations or measurements, using appropriate units, precisely and thoroughly in a logical and organized fashion.	A) Uses scientific concepts, models, and terminology to report results, discuss relationships, and propose explanations. N) Provides evidence that design, procedures, and results have been reviewed to identify some important limitations and sources of error. C) Explicitly analyzes the results of the investigation to support conclusions that address the question or hypothesis and any relationships discovered.	**6**
5	A) Records accurate data completely consistent with the planned procedure. N) Transforms data into displays/formats that present and clarify results and facilitate scientific analysis and interpretation. C) Creates displays (e.g., data tables) for communicating observations or measurements, using appropriate units, in a logical and organized fashion.	A) Uses scientific terminology to report results, identify patterns and propose explanations. N) Provides evidence that the design or procedures have been reviewed to identify some obvious limitations and sources of error. C) Explicitly uses the results of the investigation to support conclusions that address the question or hypothesis.	**5**
4	A) Records reasonable data consistent with the planned procedure. N) Chooses data transformations that are valid and complete (but do not necessarily facilitate scientific analysis and interpretation). C) Creates displays (e.g. data tables) for communicating observations or measurements, using appropriate units, in an organized fashion.	A) Uses scientific terminology with minimal errors to report results and identify patterns, and attempts to propose explanations. N) Provides evidence that the design or procedures have been reviewed to identify some obvious limitations or sources of error. C) Uses the results of the investigation to generate conclusions that address the question or hypothesis.	**4**
3	A) Records reasonable data consistent with the planned procedure with some obvious errors. N) Chooses data transformations that are sometimes invalid or incomplete. C) Creates displays for communicating observations or measurements that are somewhat incomplete or disorganized.	A) Uses scientific terminology with major errors to report results and identify obvious patterns, or fails to propose explanations. N) Provides evidence that the design or procedures have been reviewed, but reported errors are trivial or illogical. C) Develops conclusions related to the question or hypothesis, but support from the investigation is lacking.	**3**
2	A) Records data inconsistent with the planned procedure. N) Chooses data transformations that are substantially incomplete. C) Creates displays for communicating observations or measurements that are substantially inaccurate, incomplete, or disorganized.	A) Uses scientific terminology incorrectly to propose explanations to report results or to identify patterns or proposed explanations. N) Provides minimal evidence that the design or procedures have been reviewed and reports the investigation ignoring errors. C) Presents conclusions that are not clearly related to the question or hypothesis.	**2**
1	A) Records data unrelated to the planned procedure. N) Presents results in ways that are confusing or incorrect. C) Does not display data.	A) Does not relate explanation to investigation or explanation has been omitted. N) Does not review or report the investigation. C) Develops conclusions unrelated to the question or hypothesis.	**1**

[A=Application of Scientific Knowledge N=Nature of Scientific Inquiry C=Communication]

2005 - 2007 Official Scientific Inquiry Scoring Guide
CIM

	Forming a Question or Hypothesis *Based on observations and scientific concepts, ask questions or form hypotheses that can be answered or tested through scientific investigations.*	***Designing an Investigation*** *Design a scientific investigation that provides sufficient data to answer a question or test a hypothesis.*	
6	A) Provides a focused rationale for the investigation by using the most relevant background science knowledge or preliminary observations. N) Forms a question or hypothesis that focuses and defines an investigation of scientific relationships (e.g., interaction, dependency, correlation, causation). C) Expresses question or hypothesis along with the application of background information clearly enough to suggest specific investigative procedures.	A) Applies knowledge of scientific research and procedures to create or adapt a design that is controlled, precise, safe, ethical, and consistent with accepted scientific practice. N) Presents a practical design that should provide reliable and valid data sufficient to answer the question or test the hypothesis and to explain the relationship(s). C) Communicates a unified (but flexible) design and logical, detailed procedures that can be fully replicated anticipating possible need for adjustment.	**6**
5	A) Provides background science knowledge or preliminary observations which are connected to the investigation. N) Forms a question or hypothesis that generally points toward an investigation of scientific relationships (e.g., interaction, dependency, correlation, causation). C) Expresses question or hypothesis along with the explanation of background information clearly enough to imply a particular investigative design.	A) Applies scientific knowledge to create or adapt a design with precise, safe, and ethical procedures. N) Presents a practical design that should provide data of sufficient quantity and quality to answer the question or test the hypothesis and investigate possible relationships. C) Communicates a unified design and logical, detailed procedures that can be reviewed, replicated, and revised.	**5**
4	A) Provides background science knowledge or preliminary observations that are relevant to the investigation. N) Forms a question or hypothesis that can be answered or tested using data gathered in a scientific investigation. C) Expresses question or hypothesis along with the explanation of background information clearly enough to imply an appropriate investigative approach.	A) Proposes scientifically logical, safe, and ethical procedures in a design with only minor scientific errors. N) Presents a practical design that should provide data of sufficient quantity and quality to answer the question or test the hypothesis (i.e., fair test). C) Communicates an organized design and procedures that have enough detail that they could be followed and revised.	**4**
3	A) Provides background science knowledge or preliminary observations that are either irrelevant or incomplete. N) Forms a question or hypothesis that can be investigated using data but not directly answered or tested. C) Expresses a question or hypothesis along with the explanation of background information that is understandable, but does not imply a direction for an investigation.	A) Proposes safe, ethical procedures in a design that contains some significant scientific errors. N) Presents a design that should provide relevant data but not sufficient to fully answer the question or test the hypothesis. C) Communicates a general plan and some procedures that can be followed.	**3**
2	A) Provides background science knowledge or preliminary observations that are inappropriate or substantially incorrect. N) Forms a question or hypothesis that cannot be investigated using data. C) Either question or hypothesis or background information is unclear.	A) Uses little scientific knowledge or does not consistently use reasonable, safe, or ethical procedures in a proposed design. N) Presents a design that should provide data somewhat applicable to the question or hypothesis. C) Communicates a summary of a plan that generally can be followed.	**2**
1	A) States a question or hypothesis without supporting background information. N) Forms a question or hypothesis that cannot be answered or tested. C) Background information is not included.	A) Uses minimal or incorrect scientific knowledge and unacceptable procedures in a proposed design. N) Presents a design that will not provide applicable data. C) Communicates a plan that is unclear or illogical.	**1**

[A=Application of Scientific Knowledge N=Nature of Scientific Inquiry C=Communication]

2005 - 2007 Official Scientific Inquiry Scoring Guide
CIM

	Collecting and Presenting Data *Collect, organize, and display sufficient data to facilitate scientific analysis and interpretation.*	***Analyzing and Interpreting Results*** *Summarize and analyze data, evaluating sources of error or bias. Propose explanations that are supported by data and knowledge of scientific terminology.*	
6	A) Records accurate data consistent with complex procedures and deals with anomalous data, as needed. N) Transforms data into visually powerful displays/formats that clarify and highlight relationship(s) to be analyzed and explained. C) Creates precise and thorough displays (e.g., tables) for communicating observations or measurements, using appropriate units, in a logical and organized fashion.	A) Apply scientific terminology or notation correctly to analyze and explain relationship(s) investigated. N) Analyzes and critiques the design and procedures in light of the results and suggests insightful revisions or extensions. C) Explicitly analyzes the results of the investigation to support conclusions that address the question, hypothesis and relationship(s) investigated.	**6**
5	A) Records accurate data completely consistent with the planned procedure. N) Chooses data transformations that highlight information and patterns and support interpretation of relationships. C) Creates thorough displays (e.g., tables) for communicating observations or measurements, using appropriate units, that are logical and organized.	A) Uses scientific terminology or notation with minimal errors to report results, discuss relationships, and propose explanations. N) Provides evidence that the design, procedures, and results have been reviewed to identify important limitations and sources of error, suggesting design improvements when appropriate. C) Explicitly analyzes the results of the investigation to support conclusions that address the question or hypothesis and any relationships discovered.	**5**
4	A) Records reasonable data consistent with the planned procedure. N) Chooses data transformations that are valid and facilitate scientific analysis and interpretation. C) Creates displays (e.g., tables) for communicating observations or measurements, using appropriate units, that are logical and organized.	A) Uses scientific terminology with minimal errors to report results, identify patterns, and propose explanations. N) Provides evidence that the design, procedures, and results have been reviewed to identify some obvious limitations or sources of error. C) Explicitly uses the results of the investigation to support conclusions that address the question or hypothesis.	**4**
3	A) Records reasonable data consistent with the planned procedure with some obvious errors. N) Chooses data transformations that are valid and complete but do not facilitate scientific analysis and interpretation. C) Creates displays (e.g., tables) for communicating observations or measurements that are understandable, but somewhat incomplete or disorganized.	A) Uses scientific terminology, with some significant errors, to report results, identify patterns and propose explanations. N) Provides evidence that the design, procedures, and results have been reviewed but deals with errors and limitations in a trivial or illogical manner. C) Develops conclusions related to the question or hypothesis, but support from the investigation is either incomplete or not explicit.	**3**
2	A) Records data inconsistent with the planned procedure. N) Chooses data transformations that are sometimes invalid or incomplete. C) Creates displays (e.g., tables) for communicating observations or measurements that are substantially inaccurate, incomplete, or disorganized.	A) Uses scientific terminology incorrectly to report results, identify patterns or propose explanations. N) Provides minimal evidence that the design, procedures, and results have been reviewed. C) Presents interpretations or conclusions that are not clearly related to the question or hypothesis or supported by the results.	**2**
1	A) Records data unrelated to the planned procedure. N) Presents results in ways that are confusing or incorrect. C) Does not display data.	A) Does not clearly explain results or use scientific knowledge correctly. N) Does not provide evidence that the design or procedures have been reviewed. C) Does not present any interpretations.	**1**

[A=Application of Scientific Knowledge N=Nature of Scientific Inquiry C=Communication]

Student Language Scoring Guides and Other Formative Assessment Tools

Formative assessment tools can take the form of student language scoring guides. The student guides on the following pages are adaptations of the official Scientific Inquiry Scoring Guides. Students use them when planning or evaluating their own work in scientific inquiry. Figures 15-17, pages 73-78, are examples of student language scoring guides for Benchmarks 2, 3 and CIM. Figure 18, pages 79-82, is a CIM level student language scoring guide with added checklists. These student guides are not official and may be modified. Teachers may also develop their own student language scoring guides.

Other formative assessment tools are found on pages 83-89. In Figures 19-21, pages 83-85, teachers provide feedback on student work in scientific inquiry while in Figures 22-24, pages 86-88; both students and teachers score student work in scientific inquiry. Figure 25, page 89, provides a tool for teachers at benchmark 2.

Figure 15: Student Language Scoring Guide at Benchmark 2

(Adapted from the work of Dr. Dave Hamilton, Physics Teacher, Franklin High School, Portland School District)

SCIENTIFIC INQUIRY	FORMING A QUESTION OR HYPOTHESIS

TASK:

☑ Tell what led you to your question or hypothesis – mention your science knowledge, observations you have made, and/or things that interest you.

☑ Write your idea as a question or hypothesis.

☑ In your own words, explain the question you want to answer or the hypothesis you want to test.

Not There Yet	Meeting the Standard	Exceeding the Standard
• Leave out the background or give background that is not important to your investigation. • Write a question or hypothesis that you cannot collect data for. • Express a question or hypothesis and background information so it is hard to understand.	• Tell what background (science knowledge, observations or interests) led to the idea for the investigation. • Write a question or hypothesis that you <u>can</u> collect data for. • Express your question or hypothesis and background information so it can be understood.	• *Tell how* the background led to the idea for the investigation. • Write a question or hypothesis that *can be answered or tested* using data from an investigation and that provides a *focus*. • Express your question or hypothesis and background information *clearly by explaining your thinking.*

Benchmark 2

SCIENTIFIC INQUIRY	DESIGNING AN INVESTIGATION

TASK:

☑ Decide what must be done to have a <u>fair</u> <u>test</u> of your question or hypothesis.

☑ Do your investigation. Remember (or write down) what you did.

☑ After finishing the investigation, explain what you did.

Not There Yet	Meeting the Standard	Exceeding the Standard
• Decide on a plan that has errors or is <u>not</u> logical. • Collect data or observations that will <u>not</u> help with the question or hypothesis. • Describe only part of what you did.	• Make sure you are logical in deciding how to do your investigation. • Be sure to collect data or observations that help you with your question or hypothesis. • Describe how you did the investigation – include the steps you followed.	• *Use your science knowledge to make sure your plan is a good one.* • Make sure that you plan a *fair test* of your question or hypothesis. • *Be organized and include many details* when you describe how you did the investigation.

Benchmark 2

SCIENTIFIC INQUIRY	COLLECTING AND PRESENTING DATA

TASK:
- ☑ Design a data table or other format for your measurements and/or observations.
- ☑ Carry out your investigation, recording the measurements and observations you need to answer your question or test you hypothesis.
- ☑ Transform your measurements or observations (by doing calculations, reorganizing, making graphs, etc.) to make them easier to understand.

Not There Yet	Meeting the Standard	Exceeding the Standard
• Make mistakes when recording your measurements and observations.	• Carefully and correctly record your measurements and observations.	• Correctly record measurements and observations *from a complicated investigation.*
• Make mistakes while transforming your data.	• Correctly transform your data into displays (for example, a graph) that your teacher tells you to use.	• Decide for yourself how to transform your data into displays that make the results easier to understand.
• Design a data table (or other format) that does <u>not</u> work well for your investigation – or use a table that was given to you.	• Design a data table (or other format), which is useful for recording observations or measurements.	• Design an *organized* data table or other format useful for recording observations or measurements (*including units).*

Benchmark 2

SCIENTIFIC INQUIRY	ANALYZING AND INTERPRETING RESULTS

TASK:
- ☑ Report the results of your investigation and identify patterns that you find.
- ☑ Use your results to answer your question (or tell if your hypothesis was correct). If you cannot answer your question (or tell if your hypothesis was correct), tell why.

Not There Yet	Meeting the Standard	Exceeding the Standard
• Decide your results incorrectly or incompletely.	• Describe your results correctly.	• Describe your results *and point out patterns or relationships you found.*
• Make a conclusion that does <u>not</u> answer your question or hypothesis – do <u>not</u> use your results to help make your conclusion.	• Use the results to help you make your conclusions – make sure you <u>try</u> to answer your question or say if your hypothesis was correct or not).	• *Show <u>how</u> your results support* your conclusions *and any patterns or relationships you found.*

Figure 16: Student Language Scoring Guide at Benchmark 3

(Adapted from Dr. Dave Hamilton, Physics Teacher, Franklin High School, Portland School District)

SCIENTIFIC INQUIRY	FORMING QUESTION OR HYPOTHESIS

TASK:

- ☑ Describe the background knowledge or preliminary observations that helped your frame your question/hypothesis.
- ☑ Write your idea as a question you want to answer or a hypothesis you want to test.
- ☑ Clearly explain your question or hypothesis.

Not There Yet	Meeting the Standard	Exceeding the Standard
• Describe background knowledge or preliminary observations that are incomplete or only partly related to the investigation. • Write a question or hypothesis that can be investigated, but cannot be directly answered or tested. • Describe your question or hypothesis and background information in a way that is hard to understand or incomplete.	• Describe background knowledge or preliminary observations that relate to the investigation. • Write a question or hypothesis that you can answer or test by doing a scientific investigation and gathering data. • Describe your question or hypothesis and background information.	• Explain the *most important* background information *and show how it relates to your investigation.* • Write a question or hypothesis that *focuses on scientific relationships.* • Clearly describe your question, hypothesis, and background information *so readers can guess what kind of investigation will follow*.

Benchmark 3

SCIENTIFIC INQUIRY	DESIGNING AN INVESTIGATION

TASK:

- ☑ Decide what must be done to have a <u>fair test</u> of your question or hypothesis.
- ☑ Keep notes about the procedures you use as you do the investigation.
- ☑ After finishing the investigation, write out the procedures that you actually used.

Not There Yet	Meeting the Standard	Exceeding the Standard
• Follow a plan with scientific errors in it. • Collect flawed data that will not help answer the question or test the hypothesis. • Describe a general plan without giving any details about what you actually did.	• Make sure your design is logical, safe, and ethical. • Collect the right kind of data to help answer your question or test your hypothesis. • Describe a general plan and include details on some of the procedures that you did.	• Design an investigation *that shows correct application of scientific knowledge.* • Make sure your design gives you *enough* of the right kind of data to answer your question or test your hypothesis *and to look for relationships.* • Make sure your procedures are *detailed enough for someone to follow what you did*.

Benchmark 3

SCIENTIFIC INQUIRY	COLLECTING AND PRESENTING DATA

TASK:

☑ Design a data table or other format for your measurements and/or observations.

☑ Carry out your investigation, recording the measurements and observations you need to answer your question or test you hypothesis.

☑ Transform your measurements or observations (by doing calculations, reorganizing, making graphs, etc.) to make them easier to understand.

Not There Yet	Meeting the Standard	Exceeding the Standard
• Allow error into your data (e.g., use equipment incorrectly, be careless, fail to control important variable). • Transform your data into displays that are somewhat incomplete or inappropriate. (e.g., make errors or choose inappropriate displays). • Create a display that is unorganized, inaccurate, or incomplete (leave out the <u>units</u> of measurement).	• Record your measurements and observations carefully and correctly. • Transform your data into displays (e.g., graphs, tables) that are complete and somewhat useful in making interpretations. • Create an organized display (e.g., a data table) for observa-tions or measurements (<u>including units</u>).	• Record data that comes from *complex procedures.* • Transform your data in ways that *highlight the patterns and relationships* you wish to explain. • Make your displays *logical*, *precise* (just right), and *thorough* (complete).

Benchmark 3

SCIENTIFIC INQUIRY	ANALYZING AND INTERPRETING DATA

TASK:

☑ Report the results of your investigation, identify patterns, and propose explanations. Use science concepts, models and terminology in your explanations.

☑ Address your question (answer it or explain why you cannot) and/or explain how the test of your hypothesis came out – use your results to support your conclusions.

☑ Review your investigation for possible errors in the measurements or observations. Explain the limitations of your conclusions.

Not There Yet	Meeting the Standard	Exceeding the Standard
• Report results but <u>do not try to explain them</u> – make serious science errors. • Review the investigation but deal with errors and limitations in a trivial or illogical manner. • State conclusions that are <u>not</u> supported by your results or are unrelated to your question or hypothesis.	• Report the results, identify patterns and use your science knowledge to propose explanations. • Review the design or procedures and suggest improvements, if possible. • Use the results to make conclusions that address your question or hypotheses.	• Use your scientific knowledge correctly to report results and *to discuss relationships.* • Review the design, procedures and results; identify *important* limitations and sources of error. • Show how your results support your conclusions; address your question or hypothesis *and any relationships you found*.

Figure 17: Student Language Scoring Guide CIM

(Adapted from work of Dr. Dave Hamilton, Physics Teacher, Franklin High School, Portland School District)

SCIENTIFIC INQUIRY	FORMING A QUESTION OR HYPOTHESIS

TASK:
- ☑ Describe the background knowledge or preliminary observations that helped your frame your question/hypothesis.
- ☑ Write your idea as a question you want to answer or a hypothesis you want to test
- ☑ Clearly explain your question or hypothesis.

Not There Yet	Meeting the Standard	Exceeding the Standard
• Describe background knowledge or preliminary observations, which are incomplete or only partly relate to the investigation.	• Describe background knowledge or preliminary observations that relate to the investigation.	• Explain the *most important* background knowledge *and show how it relates to your investigation.*
• Write a question or hypothesis that can be investigated, but cannot be directly answered or tested.	• Write a question or hypothesis you can answer or test by doing a scientific investigation and gathering data.	• Write a question or hypothesis that *focuses on scientific relationships.*
• Describe the question or hypothesis and background information in an unclear manner.	• Describe your question or hypothesis and background clearly enough for a reader to guess what kind of investigation will follow.	• Describe your question or hypothesis and background clearly so that *a reader could predict some of the procedures you will use.*

CIM

SCIENTIFIC INQUIRY	DESIGNING AN INVESTIGATION

TASK:
- ☑ Decide what must be done to have a <u>fair test</u> of your question or hypothesis.
- ☑ Keep notes about the procedures you use as you do the investigation.
- ☑ After finishing your investigation, write out the procedures that you actually used.

Not There Yet	Meeting the Standard	Exceeding the Standard
• Follow a plan with scientific errors.	• Make sure your design is scientifically logical, safe and ethical.	• Make sure your design is *precise* (exactly right on)-*use accepted scientific procedures if possible.*
• Collect <u>some</u> data, but not enough of the right kind to <u>really</u> answer your question or test your hypothesis.	• Make sure your design is practical and gives <u>enough of the right kind</u> of data to answer your question or test your hypothesis (i.e., fair test).	• Make sure your design gives you *enough* of the right kind of data to answer your question or test your hypothesis *and to explain relationships.*
• Write out a general plan and <u>some</u> procedures that can be followed.	• Describe organized and logical procedures with enough detail for another person to follow what you did.	• Make sure your procedures are *detailed enough for someone to repeat exactly what you did.*

CIM

SCIENTIFIC INQUIRY	COLLECTING AND PRESENTING DATA

TASK: ☑ Design a data table or other format for your measurements and/or observations.

☑ Carry out your investigation, recording the measurements and observations you need to answer your question or test you hypothesis.

☑ Transform your data (by doing calculations, reorganizing, making graphs, labeling diagrams, etc.) to help you look for patterns, trends, and an answer to your question.

Not There Yet	Meeting the Standard	Exceeding the Standard
• Allow some error in your data (e.g., use equipment incorrectly, be careless, fail to control important variable).	• Record observations and measurements carefully and correctly.	• Record data that comes from *complex procedures and note anything unusual* (e.g., data that you suspect are in error).
• Transform your data into displays that are somewhat appropriate and complete but do not help you make interpretations.	• Transform your data into displays (i.e. graphs, tables) that clarify the results and help you analyze them.	• Transform your data in ways that *highlight patterns and relationships* you wish to explain.
• Be somewhat unorganized, inaccurate, incomplete or illogical in your presentation of data; leave out the units of measurement.	• Create an organized display (e.g., a data table) for observations or measurements (including units) that is logical and organized.	• Make your displays *logical*, *precise* (just right), and *thorough* (complete).

CIM

SCIENTIFIC INQUIRY	ANALYZING AND INTERPRETING RESULTS

TASK: ☑ Report the results of your investigation, identify patterns, and propose explanations. Use science concepts, models and terminology in your explanations.

☑ Address your question (answer it or explain why you cannot) and/or explain how the test of your hypothesis came out – use your results to support your conclusions.

☑ Review your investigation for possible errors in the measurements or observations. Explain the limitations of your conclusions.

Not There Yet	Meeting the Standard	Exceeding the Standard
• Use scientific knowledge incorrectly in your explanations or explain your results without using any scientific knowledge.	• Report results, identify patterns and purpose explanations - use your science knowledge to propose explanations.	• Report results and use your scientific knowledge to correctly *discuss and explain relationships.*
• Review the investigation but deal with errors and limitations in a trivial or illogical manner.	• Review the design, procedures and results; identify some obvious limitations or sources of error.	• *Critique* the design, procedures and results; identify *important* limitations *and* sources of error.
• State conclusions that are not clearly related to your question or hypothesis, or fail to use the results for your support.	• Relate your conclusions to the question or hypothesis and support with data.	• Relate your conclusions to the question or hypothesis *and the relationships investigated.*

Figure 18: Student Language Scoring Guide at CIM Level with Checklist
(From Anne Kern, Science Teacher, Newberg High School, Newberg School District)

Scientific Inquiry: Forming a Question or Hypothesis

Based on observations and scientific concepts, ask questions or form hypotheses that can be answered or tested through scientific investigations.

Thread	Thread Question	To meet the standard, YOU NEED TO DO:
Application of Scientific Knowledge: Background information or observations are relevant to the investigation.	How well is the background information used to provide a context for the investigation?	Describe background knowledge or preliminary observations that relate to the investigation.
Nature of Scientific Inquiry: Question or hypothesis can be answered or tested.	How well can the question or hypothesis be answered or tested by a student through scientific investigation?	Write a question or hypothesis you can answer or test by doing a scientific investigation and gathering data.
Communication: The question or hypothesis and background information is clearly expressed.	How clearly has the question or hypothesis and background information been explained?	Describe your question or hypothesis and background clearly enough for a reader to guess what kind of investigation will follow.

Check off list:

Make sure you review these things before you hand in your task.

- ❑ Have you described what you are going investigate and how you are going to do it?
- ❑ Explain what you already know about what you are investigating, such as: What is density? What do you know about different types of matter? How should different types of matter affect density?
- ❑ What "scientific" information, theories, or models can you relate to this investigation?
- ❑ Can you describe what outcome you expect? Explain it.
- ❑ Have you provided enough "background" information about the question or hypothesis to setup your investigation?

CIM

Scientific Inquiry: Designing an Investigation

Design a scientific investigation that provides sufficient data to answer a scientific question or test a hypothesis.

Thread	Thread Question	To meet the standard, YOU NEED TO DO:
Application of Scientific Knowledge: Logical, safe and ethical procedures are proposed.	How well has appropriate scientific knowledge been incorporated into the design?	Make sure the design is scientifically logical, safe and ethical.
Nature of Scientific Inquiry: Practical design is presented that provides sufficient data to answer the question or test the hypothesis.	How well suited is the design to answering the question or testing hypothesis?	Make sure the design is practical and gives enough of the right kind of data to answer the question or test the hypothesis (i.e., fair test).
Communication: The design and important procedures are communi-cated.	How well has the procedure been described?	Describe organized and logical procedures with enough detail for another person to follow what you did.

Check off list:

Make sure you review these things before you hand in your task.

- ❑ List all materials and equipment
- ❑ Explain all necessary measurements, detail what is to be done. A "cook book" list of steps is good when appropriate.
- ❑ Are the steps safe?
- ❑ Is the procedure organized well?
- ❑ Is the procedure logical?
- ❑ Do the steps give all the necessary data?
- ❑ Do the steps lead to a logical conclusion?
- ❑ Can someone who does not know what you did reproduce your procedure and get similar results?

CIM

Scientific Inquiry: Collecting and Presenting Data

Collect, organize, and display sufficient data to facilitate scientific analysis and interpretation.

Thread	Thread Question	To meet the standard, YOU NEED TO DO:
Application of Scientific Knowledge: Reasonable and accurate data is collected in a manner consistent with planned procedure.	How reasonable is the data and how accurately has it been recorded?	Record observations and measurements carefully and correctly.
Nature of Scientific Inquiry: Data transformations are valid and complete and are useful in making interpretations.	How useful are data transformations in making interpretations?	Transform your data into displays (i.e. graphs, tables) that clarify the results and help you analyze them.
Communication: Organized displays of data (i.e. tables or other formats) communicate observations or measurements.	How logical, organized and useful are displays of results?	Create an organized display (i.e. a data table) for observations or measure-ments (<u>including units</u>), that is logical and organized.

<u>Check off list:</u>

Make sure you review these things before you hand in your task.

- ❑ Have you collected all the data you need?
- ❑ Is your data labeled so someone who isn't familiar with the activity can understand it?
- ❑ Is the data you have collected consistent with your procedure? And is it clear and readable?
- ❑ Do you have enough data to make some sort of reasonable analysis of the question/hypothesis?
- ❑ Have you "reconstructed" your data, i.e. graph, formulate, table.
    - ✓ If you have a graph: have you labeled all parts? Does your title tell about the information that is in the graph; what, when, who?
    - ✓ If you have formulas, are your units correct, have you shown your work?
- ❑ Does your "reconstructed" data give you more information about the lab and your results?

CIM

Scientific Inquiry: Analyzing and Interpreting Data

Summarize and analyze data, evaluating sources of error or bias. Propose explanations that are supported by data and knowledge of scientific terminology.

Thread	Thread Question	To meet the standard, YOU NEED TO DO:
Application of Scientific Knowledge: Scientific terminology is used to correctly report results.	How well has scientific knowledge been applied to the reporting and explanation of results?	Report results, identify patterns and propose explanations-use your science knowledge to propose explanations.
Nature of Scientific Inquiry: Procedures and results are critiqued.	How well has the investigation been critiqued with regard to errors and limitations?	Review the design, procedure, and results; identify some obvious limitations <u>or</u> sources of error.
Communication: Results support conclusions and conclusions address the question or hypothesis.	How well do the results support conclusions and conclusions address the question or hypothesis?	Relate conclusions to the question or hypothesis and support with data.

<u>Check off list:</u>

Make sure you review these things before you hand in your task.

- ❑ Have you *summarized* the procedure and described your data and results?
- ❑ Can you describe patterns you see in your data?
- ❑ Do you *support* your conclusions with reference to your data?
- ❑ Do you comment on the accuracy of your procedure and identify sources of errors in your procedure and the data you collected?
- ❑ Are there any *odd*, *questionable*, or *unexpected* results? Explain why you think you got these strange results.
- ❑ Do you make suggestions for improvements or further studies that would make the investigation better or stronger?

Figure 19: Formative Assessment Tool for Benchmark 2 (teacher feedback on student work)
(Adapted from the work of Medford School District)

Name ____________________________________ Date___________ Period________ #______

		Not there yet	Meeting	Exceeding
FORMING	A) Provides some support or background which is relevant to the investigation.			
	N) Forms a question or hypothesis which can be explored using data gathered in a simple scientific investigation.			
	C) Communicates (A) & (N) understandably.			
DESIGNING	A) Records logical procedures with only minor flaws.			
	N) Presents a practical plan for an investigation that addresses the question or the hypothesis.			
	C) Communicates a plan and some procedure but may generally lack detail.			
COLLECTING	A) Records reasonable data or observations generally consistent with planned procedure.			
	N) Transforms data into useful format with teacher support and minimal errors.			
	C) Designs data table for collection and organization of data using teacher suggestions.			
ANALYZING	A) Reports results accurately.			
	N) NA			
	C) Responds to question or hypothesis with some support from results.			

[A=Application of Scientific Knowledge N=Nature of Scientific Inquiry C=Communication]

Figure 20: Formative Assessment Tool for Benchmark 3 (teacher feedback on student work)
(Adapted from the work of Medford School District)

Name ____ Date____________ Period_________ #______

		Not there yet	Meeting	Exceeding
FORMING	A) Provides background information or preliminary observations which are relevant to the investigation.			
	N) Formulates a question or hypothesis which can be answered or tested using data gathered in a scientific investigation.			
	C) Expresses a question or hypothesis along with an explanation of background information that is understandable.			
DESIGNING	A) Proposes logical, safe and ethical procedures in a design with only minor scientific errors.			
	N) Presents a practical design that should provide data applicable for answering the question or testing the hypothesis, although the quantity of data may be insufficient.			
	C) Communicates a general plan including some detailed procedures.			
COLLECTING	A) Records reasonable and accurate data consistent with the planned procedure.			
	N) Transforms data into displays that are complete and are somewhat useful in making interpretations.			
	C) Creates displays (e.g., data tables) for observations or measurements (using appropriate units) in an organized fashion.			
ANALYZING	A) Uses scientific terminology with minimal errors to report results and identify patterns; attempts to propose explanations.			
	N) Provides evidence that the design and/or procedures have been reviewed for obvious limitations or sources of error.			
	C) Uses results of the investigation to generate conclusions that address the question or hypothesis.			

[A=Application of Scientific Knowledge N=Nature of Scientific Inquiry C=Communication]

Figure 21: Formative Assessment Tool for CIM (teacher feedback on student work)
(Adapted from the work of Medford School District)

Name ____ Date____________ Period_________ #______

		Not there yet	Meeting	Exceeding
FORMING	A) Provides scientific background information or preliminary observations that are relevant to the investigation.			
	N) Forms a question or hypothesis that can be answered or tested using data gathered in a scientific investigation.			
	C) Expresses a question or hypothesis along with the explanation of background information clearly enough to imply an appropriate investigate approach.			
DESIGNING	A) Proposes scientifically logical, safe and ethical procedures in a design with only minor scientific errors.			
	N) Presents a practical design that should provide data of sufficient quantity and quality to answer the question or test the hypothesis.			
	C) Communicates an organized design and procedures that have enough detail that they could be followed and revised.			
COLLECTING	A) Records reasonable data consistent with the planned procedure.			
	N) Chooses data transformations that are valid and facilitate scientific analysis and interpretation.			
	C) Creates displays (e.g., data tables) for communicating observations or measurements, using appropriate units, that are logical and organized.			
ANALYZING	A) Uses scientific terminology with minimal errors to report results and identify patterns; attempts to propose explanations.			
	N) Provides evidence that the design and/or procedures have been reviewed to identify some obvious limitations or sources of error.			
	C) Explicitly uses results of the investigation to support conclusions that address the question or hypothesis.			

[A=Application of Scientific Knowledge N=Nature of Scientific Inquiry C=Communication]

Benchmark 2
Figure 22: Formative Assessment Tool (student/teacher assessment comparison)
(Adapted from the work of Newberg School District)

Directions: Evaluate how you did in each of the traits by circling a number between 1 to 6 on the left side of the form. I will look at your work and your self-evaluation and record my score on the right side of the form. Make sure you read my comments for information about what you did well and what you need to work on next time. If you have any comments you want to share with me, please put them at the bottom of the page.

Self-Evaluation	Dimensions and Traits (Bulleted traits describe a score of 4)	Teacher Evaluation	Teacher Comments
1 2 3 4 5 6	**Forming a question or hypothesis** ♦ Provide background support. ♦ Form a question/ hypothesis that can be explored using data in a simple scientific investigation. ♦ Communicate question or hypothesis and background information understandably.	1 2 3 4 5 6	
1 2 3 4 5 6	**Designing an Investigation** ♦ Record safe and logical procedures. ♦ Presents a practical plan that addresses question/hypothesis. ♦ Communicate a plan with important procedures.	1 2 3 4 5 6	
1 2 3 4 5 6	**Collecting and Presenting Data** ♦ Record usable data consistent with the planned procedure. ♦ Transform data into displays that are useful. ♦ Design organized data table for observations/measurements.	1 2 3 4 5 6	
1 2 3 4 5 6	**Analyzing and Interpreting Results** ♦ Report results accurately. ♦ NA ♦ Include support from results.	1 2 3 4 5 6	

Benchmark 3

Figure 23: Formative Assessment Tool (student/teacher assessment comparison)

(Adapted from the work of Newberg School District)

Directions: Evaluate how you did in each of the traits by circling a number between 1 to 6 on the left side of the form. I will look at your work and your self-evaluation and record my score on the right side of the form. Make sure you read my comments for information about what you did well and what you need to work on next time. If you have any comments you want to share with me, please put them at the bottom of the page.

Self-Evaluation	Dimensions and Traits (Bulleted traits describe a score of 4)	Teacher Evaluation	Teacher Comments
1 2 3 4 5 6	**Forming a question or hypothesis** ♦ Provide a question/hypothesis using relevant background information or observations. ♦ Form a question/hypothesis that can be answered or tested in a scientific investigation. ♦ Express question or hypothesis and background information clearly.	1 2 3 4 5 6	
1 2 3 4 5 6	**Designing an Investigation** ♦ Propose safe and logical procedures. ♦ Present a practical procedure that will provide data for answering question/hypothesis. ♦ Communicates a plan with important procedures.	1 2 3 4 5 6	
1 2 3 4 5 6	**Collecting and Presenting Data** ♦ Record usable data consistent with the planned procedure. ♦ Transform data into displays that are valid and complete. ♦ Design organized displays for observations/measurements .	1 2 3 4 5 6	
1 2 3 4 5 6	**Analyzing and Interpreting Results** ♦ Use scientific terminology to report patterns or results, and to propose explanations. ♦ Review design procedures to identify limitations or sources of error. ♦ Use results to generate conclusions that address question/ hypothesis.	1 2 3 4 5 6	

Benchmark: CIM

Figure 24: Formative Assessment Tool (student/teacher assessment comparison)

(Adapted from the work of Newberg School District)

Directions: Evaluate how you did in each of the traits by circling a number between 1 to 6 on the left side of the form. I will look at your work and your self-evaluation and record my score on the right side of the form. Make sure you read my comments for information about what you did well and what you need to work on next time. If you have any comments you want to share with me, please put them at the bottom of the page.

Self-Evaluation	Dimensions and Traits (Bulleted traits describe a score of 4)	Teacher Evaluation	Teacher Comments
1 2 3 4 5 6	**Forming a question or hypothesis** ♦ Provide relevant background science knowledge or observations. ♦ Forms a question/hypothesis that can be answered or tested. ♦ Express question or hypothesis and background information clearly.	1 2 3 4 5 6	
1 2 3 4 5 6	**Designing an Investigation** ♦ Propose safe, logical, and ethical procedures. ♦ Develop a practical procedure for providing data to answer question/hypothesis. ♦ Communicate a plan with procedures that could be followed.	1 2 3 4 5 6	
1 2 3 4 5 6	**Collecting and Presenting Data** ♦ Record reasonable data consistent with the planned procedure. ♦ Transform data into displays that are valid and are useful in making interpretations. ♦ Create organized displays for observations/measurements using appropriate units.	1 2 3 4 5 6	
1 2 3 4 5 6	**Analyzing and Interpreting Results** ♦ Use scientific terminology to report results, indentify patterns, and propose explanations. ♦ Review design procedures to identify limitations or sources of error. ♦ Use results to support conclusions that address question/ hypothesis.	1 2 3 4 5 6	

Figure 25: Formative Assessment Tool – Benchmark 2

(From Terry Tucker, Elementary Teacher, Salem-Keizer School District)

Dimensions and Traits	1	2	3	4	5	6
Forming a Question or Hypothesis						
∗ Background	NA	NA	Missing	Some background	Links background	Relevant to question or hypothesis
∗ Forming	NA	Cannot be explored	Limited	Can be explored	Can be answered	Provides focus
∗ Communicates	Does Not	Cannot understand	Incomplete	Can be understood	Clear	Clear and effective
Designing an Investigation						
∗ Logical Procedures	Inappropriate	Flawed somewhat	Generally logical	Minor flaws	Implies a connection	Obvious connection
∗ Plan Addresses Question or Hypothesis	Unrelated	Somewhat related	Minimal	Practical	Fair Test	Important Variables
∗ Communicates	Cannot be followed	Incomplete	Few Procedures	Lacks detail	General Plan	Detailed, Organized
Collecting and Presenting Data						
∗ Records Data or Observations	Unrelated	Insufficient Data	Reasonable, some errors	Generally consistent	Accurate, consistent	Complex procedures
∗ Transforms Data	NA	NA	Does not transform	Useful format	Student selected, complete, useful	Appropriate, clarify results
∗ Designs organized data table	Not Correct	Teacher supplied data table	Teacher supplied-minor errors	Designs with teacher support	Organized, appropriate	Organized, Efficient
Analyzing and Interpreting Data						
∗ Reports results	Omits results	Inaccurate results	Incomplete, misleading	Accurately	Accurately identifies patterns	Identify relationships
∗ Uses results to address the Question or Hypothesis	No response	Response unrelated	Without support	Some Support	Explicitly identifies patterns	Explicitly identifies relationship

Figure 26: The Key Distinctions Worksheet

(Adapted from the work of Dr. David Hamilton, Portland Public Schools).

In a training session this worksheet can be used to:

- Identify the dimensions and threads in the scoring guide (threads are designated by letters in the guide). Threads are summarized in Figure 18 on the previous page.
- Review questions that give meaning to each thread.
- Identify evidence of student performance: Oregon classroom teachers have identified possible evidence– add yours or change the list depending on your experience and grade level.
- Identify key distinctions in student performance by reviewing the Scientific Inquiry Scoring Guides and locating key words that illustrate differences in performance levels.

Dimension	**Threads**		
	Application of Scientific Knowledge	**Nature of Scientific Inquiry**	**Communication**
Forming	**Question:** How well is background information used to provide a context for the investigation?	**Question**: How well can the question or hypothesis be answered or tested through scientific investigation?	**Question:** How clearly has the question or hypothesis and background information been explained?
	Possible Evidence: ❖ Science knowledge, ideas, and concepts are included that lead to the student's question or hypothesis. ❖ Prior observations are mentioned.	**Possible Evidence:** ❖ Question or hypothesis is formed and stated. ❖ The investigation provides an opportunity for testing the question or hypothesis.	**Possible Evidence:** ❖ An understandable and clear question or hypothesis and background information is present (complete question or statement including correct or appropriate concepts).
	Key Distinctions: *Exceeds: *Meets: *Not Yet:	**Key Distinctions:** Exceeds: Meets: Not Yet:	**Key Distinctions:** Exceeds: Meets: Not Yet:

* Exceeds: 5 or 6 on the appropriate scientific inquiry scoring guide; Meets: 4; Not Yet: 1, 2, 3

Dimension	Threads		
	Application of Scientific Knowledge	**Nature of Scientific Inquiry**	**Communication**
Designing	**Question:** How well has appropriate scientific knowledge been incorporated into the design?	**Question:** How well suited is the design to answering the question or testing the hypothesis?	**Question:** How well has the procedure been described?
	Possible Evidence: ❖ Appropriate, logical scientific procedures and plans are included in the design.	**Possible Evidence:** ❖ Design supports the question or hypothesis ("fair test"). ❖ Data collection procedures and volume of data are appropriate.	**Possible Evidence:** ❖ Steps of plan are communi-cated with details and explanations.
	Key Distinctions: Exceeds: Meets: Not Yet:	**Key Distinctions:** Exceeds: Meets: Not Yet:	**Key Distinctions:** Exceeds: Meets: Not Yet:

* Exceeds: 5 or 6 on the appropriate scientific inquiry scoring guide; Meets: 4; Not Yet: 1, 2, 3

Dimension	Threads		
	Application of Scientific Knowledge	**Nature of Scientific Inquiry**	**Communication**
Collecting and Presenting	**Question:** How reasonable is the data and how accurately has it been recorded?	**Question:** How useful are data transformations in making interpretations?	**Question**: How logical, organized and useful are the displays of results?
	Possible Evidence: ❖ Data is accurate and matches procedures.	**Possible Evidence:** ❖ Data is transformed into a form that is useful (e.g., tables, graphs) in interpreting results. ❖ Data is aligned with question/hypothesis and purpose of investigation.	**Possible Evidence:** ❖ Appropriate/organized display is created (e.g., data table) to communicate observations or measurements (including units).
	Key Distinctions: Exceeds: Meets: Not Yet:	**Key Distinctions:** Exceeds: Meets: Not Yet:	**Key Distinctions:** Exceeds: Meets: Not Yet:

* Exceeds: 5 or 6 on the appropriate scientific inquiry scoring guide; Meets: 4; Not Yet: 1, 2, 3

Dimension	Threads		
	Application of Scientific Knowledge	**Nature of Scientific Inquiry**	**Communication**
Analyzing and Interpreting	**Question:** How well has science knowledge been applied to the reporting and explanation of results?	**Question:** How well has the investigation been critiqued with regard to errors and limitations?	**Question:** How well do the results support the conclusions and address the question or hypothesis?
	Possible Evidence: ❖ Scientific concepts, terminology, and background information is used to report results and propose explanations. ❖ Evidence of patterns are present.	**Possible Evidence:** (Not applicable at Benchmark 2) ❖ Data supports conclusions/explanations. ❖ Conclusions are related to question or hypothesis.	**Possible Evidence:** ❖ Error analysis is connected to the procedures. ❖ Design improvements are made, if possible.
	Key Distinctions: Exceeds: Meets: Not Yet:	Key Distinctions: (Benchmark 2 – NA) Exceeds: Meets: Not Yet:	Key Distinctions: Exceeds: Meets: Not Yet:

* Exceeds: 5 or 6 on the appropriate scientific inquiry scoring guide; Meets: 4; Not Yet: 1, 2, 3

Scientific Inquiry Work Samples Questions and Answers

1. When will scientific inquiry work samples be required?

Scientific inquiry work samples are now required. This is the third year of a 3-year phase-in for the reporting of scores as part of district work sample management. (see Phase-in Schedule, Figure 13, page 64, and on the web under "Science Standards" at: www.ode.state.or.us/search/results/?id=240). Teachers will provide instruction and classroom assessment in all four dimensions of the scoring guide at Benchmarks 2, 3, and CIM. Official scientific inquiry anchor papers are available at this web site; also, stronger and more varied anchor papers are being developed.

2. I'm not too familiar with the process. I need more ideas for scientific inquiry. Are there methods I can use to enhance my lessons?

Investigations should relate to the units you currently teach (see Modifying Activities for Scientific Inquiry, pages 50-62). Use the dimensions of the Scientific Inquiry Scoring Guide to plan your lessons and help students develop their work samples.

3. Are work samples supposed to be controlled experiments?

Scientific Inquiry Scoring Guides do not limit students to controlled experiments. The guides are designed to be used with student work from a variety of situations (see pages 32-33 for examples of ways to engage in scientific inquiry).

4. How do you score a dimension when some threads are very low and others very high?

Teachers should be able to justify a response using the language of the scoring guide. Use professional judgment to determine the predominant score or composite score for the threads within the dimension.

5. What teaching strategies can I use to help students analyze the evidence they have collected? Middle school students can design investigations and collect data but analysis is a challenge.

Try scaffolding questions using Bloom's taxonomy until students get used to higher level self-reflection (e.g., What do you know about…? How can you explain…? How can you apply…? What part of this shows…?).

6. Some students cannot write well, but can do scientific inquiry. Are there ways other than writing for students to produce a work sample?

The scoring guides do not specify one form of scientific inquiry work sample. Students may complete either written or oral work samples. In fact, some districts find a science activity can satisfy both the scientific inquiry and speaking requirements with proper planning and documentation. Teachers report that some students use Power Point displays and others use more traditional poster boards. Concept maps may work well for some.

7. At what point does the work become the student's own work? How much revision is allowed?

Refer to Figure 10, page 51, for an illustration of how students move from teacher-directed to student-directed scientific inquiry. Student-directed scientific inquiry is the goal, but most students will need some teacher direction, especially at first and in the earlier grades.

Teachers should NOT suggest specific revisions. If students resubmit a work sample, teacher feedback should focus on scoring guide language that does not give away solutions (e.g., Does your design match the question?). Also, if students get on the wrong track, it is OK for teachers to ask them questions about their procedures to guide them in the right direction.

8. Can students work together?

The individual student should assemble the final explanation of the work. Science is often a collaborative process, so students may work together designing an investigation and collecting data. Teachers who have had students work together collaboratively report that they find members of a group produce distinctly different final products if they are required to work on the final product as an individual.

9. What kind of assistance can I give to special needs students?

Numerous options are available to meet the special needs of students. Many of the techniques described in the answers to questions 6, 7 and 8 can be used for this purpose (various forms of scientific inquiry work samples, opportunities for different levels of teacher direction, and opportunities for collaboration).

10. How many work samples are required to demonstrate student performance?

A student may meet the requirement with one work sample, or may include multiple samples as indicated on the implementation schedule (Page 64).

11. Do students have to complete the entire work sample or can one dimension be collected?

Teachers are expected to provide instruction and classroom assessment **in all four dimensions** of the scoring guide. However, only the dimensions indicated on page 64 must be reported for school district work sample management.

Questions and Answers about Work Samples In General

Collecting Work Samples

1. What is state policy regarding the collection of work samples?

State requirements relating to the collection of work samples are those found in the Board of Education-adopted performance standards, which identify the number and types of work samples that must be collected at the benchmark and grade levels. Board of Education policy, adopted on February 17, 2000, requires that local school districts collect and score the following:

- at least one work sample per year in grades 3 through 8 and at the CIM level in the areas of writing, speaking, and mathematics problem solving,
- one work sample per year from grades 4 through 8 in scientific inquiry,
- and may collect one work sample per year from grades 4-8 and at the CIM level in social science analysis.

Districts maintain flexibility in the design and administration of work samples although the state may provide examples or models of content area lessons or "tasks" which can be utilized by districts as local assessments are being developed.

2. Are work samples in Social Sciences Required?

Beginning in 2005-2006, social science analysis work samples are required to be collected, scored and maintained by the school district for students who are working toward a Social Sciences Endorsement. Teachers are required to provide instruction in social science analysis for all students. To ensure all students know and can do social science analysis by the CIM level, teachers should collect one work sample per year for grades 6-8.

3. Must all work samples be completed in a classroom situation under direct teacher supervision?

Districts have the flexibility to set guidelines on how work samples are collected, which would include procedures to ensure that final products reflect a student's own work. "On-demand" assessments, completed in class under a teacher's supervision, are one way to make this assurance. However, longer projects, such as research papers, statistical experiments, or speaking presentations, may require allowing work outside of class, where additional evidence may be needed (e.g., note cards, outlines, data collection, presentations) to verify that the finished product is the student's own work.

4. How does the option of combining scores from multiple scientific inquiry and social science analysis work samples to meet the performance standard affect the collection of work samples in these content areas?

A student may meet the scientific inquiry or social sciences analysis performance standard on a single work sample. A student may also meet the performance standard in these subject areas by combining scores from two work samples that each meets part of the requirement. This option to combine scores to meet the performance standard is unique to the science and social science work samples.

5. To what extent can work samples be a product of group work?

Although individual products may grow out of preliminary group work, the work sample is a means for students to demonstrate they can independently apply their learning. Work samples should represent the individual's own work, completed at a certain point in time, and scored using an official state scoring guide in those subjects for which one has been adopted.

6. To what extent can peer responses and editing be used as part of collecting work samples?

While peer editing can be a valuable instructional tool, use of peer feedback during the collection of work samples should be approached with caution. Unrestricted peer editing has the potential of invalidating the sample as the student's own original work.

7. How much teacher coaching/feedback is allowed as students are completing work samples?

An underlying premise of work samples is that they are completed independently after students have been given sufficient instruction to prepare them for a more formal assessment. Given that work samples should reflect a student's own work, districts should help teachers understand the difference between providing needed clarification as opposed to inappropriate assistance which could lead to an invalid representation of what a student can independently accomplish. Providing scores is appropriate feedback, but specific suggestions like "this paragraph is a run-on sentence" or "type of soil is another variable that should be considered in this investigation" are not appropriate.

8. May students revise work samples that do not quite meet standards and submit them for re-scoring?

Districts may adopt policies to allow students to be given opportunities to revise their work, especially when a sample is close to meeting standards. As long as the work remains the product of the student's efforts, revision is a reasonable alternative to starting over again, particularly on longer projects. It would not be appropriate for the teacher to give a lesson, or other direct input, specifically addressing issues the student encounters while completing or revising a work sample. At the completion of the revision cycle, the teacher should be able to verify that, to the best of his or her knowledge, the sample is the student's own work.

9. How can districts assure that the tasks/problems they develop for collecting work samples are appropriate in difficulty and consistent in rigor with other districts across the state?

Districts can feel confident their work samples are appropriately difficult by closely matching the task content to the adopted grade level standards or curriculum for the targeted grade. Additionally, the Department regularly releases some prompts, tasks, and scored student work through its web site that can be used to help guide task development and monitor task difficulty.

Scoring Work Samples

1. What are state requirements regarding scoring work samples?

State requirements for scoring work samples are that they be scored using an official state scoring guide in those subjects for which one has been adopted. These scoring guides are specifically designed for the core process being assessed, in each trait/dimension where performance standards indicate there is a minimum score to meet a standard. Individuals (usually and preferably teachers) participating in scoring need to be trained for the current scoring guide or guides they will be using to score work samples.

2. Does a work sample have to be scored in the "non-required" traits/dimensions on a scoring guide?

Teachers are encouraged to score all work samples against all traits or dimensions on the applicable official state scoring guide in order to give as much feedback to students about specific strengths and weaknesses as possible. However, the traits/dimensions that must be reported in the district management system are those listed in the Board-adopted performance standards.

3. What training opportunities exist to assist teachers in becoming proficient in using scoring guides?

Training on official state scoring guides can be obtained from a variety of sources. This year, the Department of Education is providing training at regional Educational Service Districts (ESDs) for the scoring of on-demand performance assessments in writing. In previous years, the Department has provided training at regional ESDs in mathematics problem solving. Professional organizations like the Oregon Science Teacher Association, Oregon Council of Teachers of Mathematics and ESDs typically have cadres of trainers who have participated in ODE-sponsored professional development activities whose services can be arranged for through an initial contact with a local ESD. Many districts have developed their own group of trainers who provide this opportunity during inservice activities.

4. How do district scorers know that their scores are consistent with other teachers across the state?

Again, resources exist that are designed to help make scoring reliable and consistent. ODE has developed resource materials in most subjects that serve as benchmark "anchors" or exemplars of each of the score points for each trait of the official scoring guides. On the ODE website, under each content area, is a section focused on support for performance assessments, including samples of student work, scores and commentaries. Copies of videotapes for speaking are available upon request from the Office of Assessment. Additionally, the OPEN network has an on-line scoring application for both writing and mathematics problem solving (www.openc.k12.or.us/scoring) which can be used to check scoring reliability.

5. Do work samples need to be scored by more than one rater?

There is no state requirement that work samples must be scored by more than one rater. However, districts can assure parents that scores are more reliable if a percentage of work samples are scored by at least two trained raters who can compare notes and resolve differences by reviewing "anchor" papers. Such cases of "multiple" scoring are done to increase reliability and are implemented at the district's discretion rather than being a state requirement.

Managing the Work Sample Results

1. What are the state requirements regarding managing work sample results?

Districts are responsible for awarding the Certificate of Initial Mastery and CIM subject area endorsements. One aspect of the award process is tracking student progress toward meeting State performance standards on the required work samples. In addition, districts are required by statute to use the assessment data to report academic progress of the student body to their community.

2. What is state-level policy regarding keeping and reporting results of work samples?

There is a statutory requirement that districts have locally adopted policies in place.

3. How can we gain access to work samples of students who move into our district?

Contact the district from which the student came. Districts may be able to provide a summary of evidence of students' work samples performance and others may provide electronic evidence.

4. What physical evidence must be kept by school districts to document work sample scores? How long must the actual work samples be kept?

School districts may set policy to either retain work samples for a set time or return samples to students after scores have been entered in the school's/district's record-keeping system. Records relating to CIM and CIM subject area endorsement achievement should be kept through the time a student exits the public school system.

5. How do state assessments that meet standards figure into the work samples?

State assessments that meet the standard for writing (a composite score of 40 or above) may be used as one of a student's required work samples at the CIM level only. To be used, the state assessment must be in a different mode than the other sample(s) in the collection so that it completes the range of samples required by performance standards (i.e., in writing the collection must have a persuasive and expository sample plus a narrative or imaginative sample).

6. How does the designation "conditionally meets" on a state assessment in writing affect the work sample collection?

A "conditionally meets" result does **not** affect the requirements for that student's work samples—the same number and types of samples are needed as outlined in the performance standards. The difference between a "meets" and a "conditionally meets" result on a state test is that a student who meets or exceeds the standard on the state test can use that assessment as one of his/her work samples, while a test that "conditionally meets" may **not** be substituted for one of the required work samples.

7. How does the option of combining scores from multiple scientific inquiry work samples to meet the performance standard affect the management of work sample results?

A scientific inquiry work sample that does not have a score of four or higher in each of the required dimensions does not meet the performance standard. However, two work samples that each meets part of the requirement may be combined to meet the overall performance standard. At least one ESD has decided to use the term "partially met" to describe these work samples in their data management system. If "partially met" is used, it is important to note that although the individual work sample satisfies part of the scientific inquiry performance standard, it does **not** meet the performance standard on its own merit.

Definitions Relating to Work Sample Implementation

Certificate of Initial Mastery (CIM): An award earned by students who have met CIM standards on state tests and classroom work samples in English, mathematics, and science.

CIM Subject Area Endorsement: A "value added" award earned by students who have met CIM standards and have met or exceeded performance requirements for social sciences, the arts, second languages (world languages), physical education and/or health education.

Core Process: A central theme to the study of a particular subject area. In Oregon, the core processes of English/language arts are writing, reading and speaking, of mathematics is problem solving, of science is scientific inquiry, and of social science is social science analysis.

Local Performance Standards: Local standards that describe the level of performance expected of students on locally developed assessments in the arts, second languages (world languages) physical education and/or health education to achieve Oregon's benchmark standards.

Official State Scoring Guide: Specific, consistent criteria on a 1-6 point scale used to evaluate state performance assessments and classroom work samples. Scoring guides may be used by teachers, students, parents, and others. Copies of current scoring guides are on the Web at (www.ode.state.or.us/teachlearn/testing/scoring/guides/).

Oregon Statewide Assessment System (OSAS): Official name for state tests and work samples.

State Performance Standards: These standards describe the scores expected of students on state (English, mathematics, science and social sciences) assessments and classroom work samples.

Trait/Dimension: A subcategory of an official state scoring guide that corresponds to academic standards adopted for that specific content area. Each trait/dimension lists descriptive criteria used by scorers to rate student work samples/performance assessments on a 1 to 6 scale. For example, in writing the seven traits are ideas/content, organization, voice, word choice, sentence fluency, conventions, and citing sources. In scientific inquiry the four dimensions are forming a question or hypothesis, designing an investigation, collecting and presenting data, and analyzing and interpreting results.

Work Sample: Student work scored using the official state scoring guide. This student work may be the product of classroom assignments in the case of writing, speaking, mathematical problem solving, and scientific inquiry, or on-demand assignments in the case of writing and mathematics problem solving.

Oregon Department of Education
Development of Scientific Inquiry Anchor Papers

Name: ____

Building and District: ______________________________________

Phone: ______________________ e-mail: __________________________

Do you need more information? Contact Leslie Phillips at: leslie.phillips@state.or.us

Classroom Plan for Scientific Inquiry	Type of Scientific Inquiry
Anticipated: Date Papers will be available: ____________ Number of Student Papers: ____________ Parental Permission Forms (attached) will be available for each paper? ( ) yes ( ) no Context of lesson will be described on attached form? ( ) yes ( ) no	Physical Science ☐ Observational Investigation ☐ Controlled Experiment ☐ Other: ____________________ Life Science ☐ Observational Investigation ☐ Controlled Experiment ☐ Other: ____________________ Earth/Space Science ☐ Observational Investigation ☐ Controlled Experiment ☐ Other: ____________________

Would you like to have an in-service on Scoring Scientific Inquiry Work Samples in your school or district? ☐ Yes ☐No If yes, ☐ 1 day or ☐ 2 days

Possible Dates: ____

School Building: ____________________ District: _________________________

Contract Person: ____________________ e-mail: _________________________

Phone: ______________________________

Mail this form or fax at (503) 378-5156 to:

Leslie Phillips
Office of Assessment and Evaluation Science
Oregon Dept. of Education
255 Capitol Street, NE
Salem, OR 97310

Oregon Department of Education
Instructional Context for Scientific Inquiry
Student Work Sample Submission

The wording of the scoring guide was developed for use by the classroom teacher to score work samples generated in his or her own classroom. Few student work samples are totally self-explanatory independent of some understanding of the instructional context. The following information will assist those scoring and identifying anchor exemplars of student work to have a picture of the classroom experiences that lead to the production of the work sample.

For each ***set*** of student work samples please provide the following:

Briefly describe the instruction that lead up to the students producing the work sample. Specifically explain student background knowledge.

What was the prompt to which the students are responding *(you may attach a copy of your lesson if you prefer)*? What particular question are they addressing?

What specific assistance did the teacher provide for students *(i.e., data table, data format, or safety/ethical issue)*?

Oregon Department of Education
255 Capitol Street, NE
Salem, OR 97310

Office of Assessment and Evaluation
Science –in care of Leslie Phillips

<u>Permission Form For Releasing Student Work in Science</u>

Grade ________

Dear Parent or Guardian,

During this school year your child participated in state tests in various subject areas. The assessments are designed to measure student progress toward recently adopted academic standards in Oregon.

This form is to ask permission to use your child's work in materials that inform teachers and the public about these student achievement standards. Only a small sample of work will be selected for this purpose. **If your child's work is selected for inclusion, it will be carefully examined to remove names and any other personally identifying information.** We are strictly interested in the academic work your child did, and we do not ask questions related to anything else.

Please sign below and have your child return this form to his/her teacher.

Please check the appropriate space:

______ I give permission for ____'s
(print student's name)
work to be included in materials, printed or prepared for the Internet, with the understanding that the name of my child, the teacher, school and town will not be included on any material.

OR

______ I give permission for ____'s
(print student's name)
work to be included only in printed materials, with the understanding that the name of my child, the teacher, school and town will not be included on any written material.

OR

______ I do not give permission for ____'s
(Print student's name)
work to be duplicated for any purpose.

My permission is effective until such date as I may revoke my permission in writing to Phyllis Rock, Assessment Director, Oregon Department of Education, 255 Capitol Street, NE, Salem, OR 97310. I understand that revocation of my permission will apply to subsequent copies of the material and not to copies already published and distributed.

Signature: ____

Parent/Guardian's Name: ____
(Ppease print)

Relationship to Child: ___________________________________ Date: ___________________

(Teacher to mail completed forms to: Leslie Phillips, Assessment Specialist, Oregon Department of Education, 255 Capitol Street, NE, Salem, OR 97310)

Professional Development

(Adapted from: *Designing Professional Development for Teachers of Science and Mathematics (2nd Edition)*, Loucks-Horsley et .al. 2003)

Professional Development can take many different forms each one valuable for a specific reason. It is important to develop your goals and then determine the appropriate type of professional development necessary to meet those goals. Some professional development tools and opportunities take place at the individual level, while others take place at the state and even the national level. Each tool is important and can be valuable if used appropriately to meet your goals.

Curriculum Alignment and Materials Selection

Although many schools/districts still adopt curriculum and materials based on a vote or individual teacher decision, some districts have begun to take a more systematic approach through the use of rubrics used to score appropriate materials and then pilot testing materials.

Key Elements of This Approach:

- Teachers are essential participants in the process of aligning curriculum, selecting instructional materials, and implementing those materials.
- Teachers undertake a process of examining curriculum and instructional materials that leads to a new product and learning.
- Aligning curriculum and selecting instructional materials require a clearly articulated procedure that addresses all aspects of the process.
- Curriculum alignment and instructional materials selection is a collaborative activity.

Partnerships With Scientists and Mathematicians in Business, Industry, and Universities

These partnerships can take a variety of forms including mentorship's, working to improve teaching strategies across grade levels, and involving others in school-based activities. All of these activities have the ultimate goal of improving teaching and learning of science and mathematics in classrooms.

Key Elements of This Approach:

- Partners are equal.
- Roles for scientists and mathematicians are clearly defined.
- All partners share consistent values, goals, and objectives.
- There are benefits to teachers.
- There are benefits to scientists and mathematicians.

Action Research

Action research involves teachers examining their own practice though teaching methods and student learning through gathering data, collaborative discussion, and critical reflection in order to improve student learning. It can be both an intensive and valuable endeavor.

Key Elements of This Approach:

- Teachers contribute to or formulate their own questions, and collect the data to answer these questions.
- Teachers use an action research cycle.
- Teachers are linked with sources of knowledge and stimulation from outside their schools.
- Teachers work collaboratively.
- Learning from research is documented and shared.

Immersion in the World of Scientists and Mathematicians

In this professional development opportunity, teachers work within the fields of science and mathematics. The teachers take part in research project and become a key participant in that project.
Key Elements of This Approach:

- The experiences are designed as mentored research opportunities for teachers, as apprentice researchers, to learn the content, process, culture, and ethos of scientific or mathematics research and development work.
- Teachers attend lectures and seminars and read materials on the science or mathematics topics related to the research.
- Teachers actively participate as members of research teams, which include scientists or mathematicians or university faculty.
- The program includes planning for how to connect learning to teachers' classrooms.
- There are opportunities for follow-through with implementation and dissemination at local, regional, and national levels, as well as opportunities for ongoing communication.
- Teachers document their learning and reflect on their experiences.

Mentoring

Mentoring is a valuable tool that can't be underestimated. This is an opportunity to gain insight into teaching pedagogy, content, school environment, and so much more for both the mentor and mentee. Both unique individuals bring with them understandings and knowledge that is valuable when shared and discussed between participants.

Professional Learning Teams and Communities

Another valuable professional development tool is participation in a professional learning team and/or community. These opportunities allow you to discuss with other professional different things that are going on in your classrooms and are important to you. These discussions can take place in a variety of ways including through face-to-face discussion and meetings, videoconferencing, teleconferencing, instant messaging, and emails. The most important aspect is that each meeting/discussion has a goal and the participants stick to that goal. The *PLT Fast Facts* and the *Practical Inquiry* articles on the following pages outline some of the important aspects of professional learning teams/communities.

Professional Learning Teams/Communities

Fast Facts: What Are PLTs?

(Reprinted from: *Quality Teaching and Learning*, Northwest Regional Educational Laboratory, Winter 2005)

What is a Professional Learning Team (PLT)?

Imagine teachers using proven methods for increasing student achievement in which they work collaboratively, and continuously, in cycles that are teacher initiated and teacher led. Imagine them taking ownership of the process of working together to improve teaching and learning – because they know how to do it themselves. Imagine a PLT as:

- ✓ A study group
- ✓ An action research team
- ✓ A "critical friends" group
- ✓ All of the above

A PLT is a small, highly collaborative teacher team of four to six members that engages in professional learning to improve student learning. PLTs meet regularly, at least every other week, for about 90 minutes during the school day. This time is protected by administrators, to be used to focus on improving teaching and student learning. With the schoolwide PLT process, all teachers are organized into PLTs. The process connects the school's student data and the teachers' knowledge and experience to the research and best practices shown to increase student achievement.

What do PLTs do?

Although individual school needs define how the PLT Process looks at each school, PLTs typically use the following four key strategies in their efforts to change classroom practice. They:

1. Focus on data. To focus their efforts to improve student learning, PLTs use school and classroom data. Staff examine student achievement data and identify high-priority student learning challenges to be addressed in the upcoming school year. This analysis aligns PLTs with schoolwide goals and gives direction to the PLTs, which are formed based on this examination of data. PLTs also use a variety of classroom assessments throughout the process to better understand the causes of student learning gaps and to measure progress they make in improving teaching and learning.

2. Share and reflect on classroom practices. Teachers in PLTs share in-depth details about their individual classroom practices to explore how they can improve student learning. Their discussions break down traditional barriers to learning, leading teachers to reflect in new ways on their classroom practices. Teachers are encouraged to share and reflect on areas where they or their students struggle, as these are often the most productive areas to mine.

3. Apply research and best practices. Teachers analyze and evaluate research critically so they can understand its implications for their own classroom practice. They explore many different avenues for this work, including reading, observing, and contacting local and national experts.

4. Improve teamwork and collaboration skills. Teachers in PLTs consciously improve their team process by learning to run effective meetings, assign and rotate team roles, build trust, reach consensus, resolve conflicts productively, and collaborate well. These skills are developed throughout the PLT process using structured protocols and tools. These same skills have application in the classroom with students.

All four strategies contribute to a process of refining, improving, and changing instructional practices to improve student achievement. Teachers use these practices deliberately, with a clear picture of how to improve their practices and measure progress. After several months, they have gathered enough information to share with one another and to evaluate the likelihood that this practice will be successful in the future, with more students. This information is shared schoolwide, periodically throughout the year, to ensure that the whole school benefits from the lessons learned in each individual PLT.

Why should we use PLTs for professional learning? What does the research say?

According to research, teacher quality affects student learning (NCTAF, 1996; Darling-Hammond, 1999). However, teachers' years of classroom experience do not translate to greater teacher quality (Rosenholtz, 1989; Wenglinsky, 2000; Mayer, et al., 2000), particularly after five years of experience. Furthermore, traditional professional development, typically in the form of isolated training, also does not improve teacher quality (Smylie, et al., 2001).

What the research indicates does improve teacher quality is team-based professional learning focused on the subjects teachers teach—the type of learning fostered in PLTs. In fact, all six of the features that have been linked to changes in teacher performance and/or student learning are present in the schoolwide PLT process as described in this Fast Fact, including: reform-oriented organization (e.g., study group, teacher network, mentoring relationship); collective participation and collaboration between teachers from same school, department, or grade level; opportunities for active learning, including engagement in meaningful analysis of teaching and learning (e.g., reviewing student work); and sustained time and duration, including total number of contact hours and span of time over which activity occurs (McLaughlin and Talbert, 1993; Porter et al., 2000; Garet, et al., 2001; Desimone, et al., 2002; Cohen & Hill, 1998; Kennedy, 1998).

The role of school leadership in the PLT Process

Principals and other school leaders have an important role to play in developing and supporting a schoolwide PLT effort. They make decisions that influence the value of PLTs to staff and the school overall. PLT efforts that are well supported involve principals in the following roles and activities:

- Providing dedicated and protected time for professional development and collaboration during the school day whenever possible and compensating staff for time spent outside of the school day
- Focusing school improvement and PLT efforts on the same goals
- Advocating the use of data for making decisions, and making data available, in a variety of formats, to staff to use in instructional planning
- Building and supporting relationships based on trust
- Helping staff feel safe to share information about their classroom practices and to try new strategies in their efforts to improve instruction
- Assuring accountability for the time teachers spend in PLTs
- Creating avenues for two-way communication, including involving community, staff, and students in decision-making wherever possible
- Celebrating success throughout the process.

How will we know if the PLT Process is working?

Evaluation is a critical piece of implementing any professional learning strategy. Teachers must ask themselves: (a) Am I learning about what I teach in my classroom? (b) Am I applying what I'm learning in ways that change my classroom practices, thereby improving student learning? If yes, how? If not, why not and what needs to change? (3) How will I know students are achieving at higher levels?

Teachers ask and answer these questions individually and in PLTs. They complete surveys about their attitudes, skills, and classroom practices at the start and end of their PLT effort. They also use a rubric such as the Implementation Rubric for PLTs developed by NWREL to arrive at a consensus about their PLT efforts across six dimensions: using data, sharing and reflecting on classroom practice, studying and using research, increasing research-based classroom practice, using effective collaborative and teamwork skills, and being supported by school leadership.

Another way to assess progress is to keep a portfolio documenting the work of a PLT. Teachers can include notes, data, action plans, logs, and other artifacts that capture the learning, and changes in instruction, that their PLT fostered.

Summary

Teachers drive the schoolwide PLT process. They are the ones delivering instruction, the ones on whom schools depend to improve student achievement. By accomplishing four tasks – examining and using data, sharing and reflecting on practices, applying research and best practices, and developing teamwork and collaboration skills – schools allow teachers to take ownership of their professional growth, which is the only truly sustainable method for raising student achievement.

Where can I find more information?

Additional Resources

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Supporting Science Teachers as a Professional Learning Community

(Reprinted from: *Practical Inquiry*, Northwest Regional Educational Laboratory, Fall 2000)

Mathematics and science teachers face an increasingly demanding job. They must deal with changing ideas of effective practice, growing diversity among their students, and higher standards for both teaching and learning. While the national mathematics and science standards advocate more rigorous curriculum and instruction, both documents also recognize the need for a supportive learning environment. The standards recommend that teachers think of their classrooms as communities in order to encourage and assist students in learning challenging mathematics and science.

The literature on school improvement and effective professional development also suggests that learning communities are equally important for teachers. A sense of community helps to create a dynamic and congenial workplace and establishes relationships that encourage continuous inquiry and improvement (Collay, Dunlap, Enloe, & Gagnon, 1998; Lieberman & Miller, 1999). In addition, teachers take on roles as scholars, showing their students that learning is exciting and worthwhile.

The process of creating and sustaining a professional learning community is a complex and challenging endeavor. It requires time, trust, and commitment from all participants, especially school leaders. Some people may dismiss the idea as another buzzword or a vague ideal intended to make teachers feel better about their schools and their work. However, research on school improvement suggests that the presence of a professional learning community in a school has a positive impact on student achievement and is an essential component of effective teaching and learning (Hord, 1997; Newmann & Wehlage, 1995).

Characteristics of a Learning Community

Thinking about the school as a community is not a new idea. John Dewey is often credited with developing the concept, and his approach is helpful in understanding what community means in a school. For Dewey, community is not just a name for a collection of individuals or an ideal of harmony and collaboration. It is a process of people living, working, and especially learning together: asking questions, listening to other viewpoints, comparing ideas, and imagining alternatives. “One cannot share in intercourse with others without learning—without getting a broader point of view and perceiving things of which one would otherwise be ignorant” (Dewey, 1916).

There is no step-by-step process that schools can implement as they strive to establish a learning community. However, there are a number of school characteristics associated with professional learning and collaboration, which are described briefly on the right (Adajian, 1996; Hord, 1997; Kruse, Louis, & Bryk, 1994; Zederayko & Ward, 1999).

It may be helpful to begin by looking at the characteristics and thinking about what they might mean in a specific school or district. Are there elements of a learning community that are already in place at this school? What characteristics are not in place? A second step will then be to consider the implications for school leaders and to engage the school staff in thinking about the questions on the next page.

***Building trust, protecting ideas, and establishing new norms of caring and concern for one another as well as for students takes time, and capacity. They are the glue that holds a professional community together.* -Ann Lieberman & Lyn Miller, 1999**

The key characteristics of a professional learning community include:

Common Goals

Teachers take on collective responsibility for student learning, which provides the shared purpose and criteria of success for all efforts. In spite of the overarching focus on students learning, the specific goals will be articulated and negotiated by the teachers.

Collective Inquiry

Teachers are accustomed to observing and discussing each other's teaching methods and philosophies. All staff engage in learning new ways to talk about teaching. Teachers work together to develop materials, activities, and strategies and to choose and create professional development opportunities.

Reflective Dialogue

Teachers talk to each other about their practice and their students. Topics may include content knowledge, assumptions and rationale behind instructional decisions, or the process of adopting new strategies, to name just a few.

Supportive and Shared Leadership

Teachers have the freedom and authority to make decisions and to explore alternatives and innovations in instruction. The organizational norms and structures support and encourage collaboration and inquiry.

Mutual Trust and Respect

Teachers have a sense of emotional safety that enables them to share their thinking and their practice. They are willing to open up their classrooms to each other, observing instruction and providing each other with feedback.

Continuous Learning Opportunities

The professional learning community is not a one-time effort, but a way of working together that is embedded in the school culture. All staff put in the time and effort required to maintain collaborative relationships and focus on inquiry and improvement. Teacher learning is given a high priority and teachers' efforts are supported and celebrated by the whole school.

The Mathematics and Science Education Center produces *Practical Inquiry* twice yearly. The topical series is intended to help keep school and district administrators abreast of critical issues in mathematics and science teaching and learning. Readers will find examples and suggestions of how to support teachers as they strive to improve classroom practices and encourage student learning.

Leading a professional learning community

School leaders have an important role to play in the professional learning community, although it may be quite different than the traditional model of educational leadership. The leader will move beyond the traditional means of establishing authority, instead "leading from the center" (Dufour, 1999) and engaging with teachers as a co-learner and co-teacher.

Acting as a learner is likely to be an unfamiliar leadership role. As teachers work to change and improve their practice, it is important for principals and other school leaders to understand the rationale for the changes. Standards-based mathematics and science teaching may be very different from administrators' expectations about effective teaching methods. Learning with and from teachers in order to understand and support their work is essential to improving mathematics and science (Nelson, 1999).

The process of sharing authority with teachers should not be misinterpreted as a hands-off approach to leadership. While it often involves giving up some of the usual demonstrations of authority—such as setting agendas, making isolated decisions, and directing policies—there are a number of new responsibilities that leaders must take on (Hord, 1997). Some of the biggest challenges involve knowing when to facilitate, when to step in, when to be silent, and when to change directions. In addition, a high priority will be mediating conflicts and accommodating differences as teachers strive to collaborate. Other duties include:

- Building consensus and establishing common goals
- Sharing authority and responsibility with teachers
- Helping to create a climate of trust and respect
- Working with teachers to design and implement processes for professional learning
- Establishing interdependence
- Honoring teachers' learning and accomplishments
- Creating forums for teachers to share their ideas and accomplishments
- Providing teachers with needed information and time
- Advocating for teachers as learners

Questions To Consider

What knowledge and skills do we need to function as a professional learning community?

How big a transition will be involved? Are there norms and structures already in place, or will a major shift in school culture be required?

Are there current policies and practices that may interfere with our efforts? How can we deal with possible barriers?

Are there individuals who will be resistant to changes? How can their concerns be addressed?

How can we use time and other resources more effectively as we pursue our goals?

How will improvements and innovations be sustained?

Are there incentives for professional learning and growth?

Are there opportunities for collaborative learning?

Are teachers encouraged to try new ideas and learn from their mistakes?

What avenues are in place for teachers to share what they learn?

How frequently do teachers talk about their work and exchange information and ideas?

(Dufour, 1999; Watkins & Marsick, 1993)

Developing a Common Focus

Without a common focus, the efforts of a professional learning community are not likely to succeed (Senge, 1990). Individual teachers may pursue their own interests, perhaps even undermining each other's efforts. The staff may be tempted to take on too many problems at the same time, fragmenting their energies and attention.

The collective focus or shared vision can be a catalyst for change when it inspires teachers' commitment. Such an approach is more likely to encourage continuous improvement than policies imposed on teachers.

The articulated focus can also provide energy and encouragement when the staff encounter difficulties and can help ensure that efforts proceed on track.

There are two possible ways to think about the common focus of the learning community. One is the idea of shared vision developed by the teachers. Often the first step is for teachers to develop their own personal visions of what their school should be like, what they should teach, and what learning they want students to achieve. The staff then shares their visions, perhaps seeking contributions from students and parents as well, and works to connect their individual ideas and to reach consensus about their collective vision for the school.

An alternative approach is to begin by posing common questions or problems. Teachers share topics that they are wondering about or problems that they encounter. Again, the idea is to negotiate areas for inquiry and learning.

The following questions may be helpful in developing a common focus for the learning community (Dufour, 1999):

- What is our vision of the school we are trying to create?
- What goals should we establish in order to achieve our vision?
- What strategies will we use to accomplish our goals?
- What criteria will we use to evaluate our success?
- Is professional development tied to concerns about student learning? Is it congruent with our vision and goals?

Whatever process is used to develop the common focus for the learning community, the next step is for teachers to decide on areas for action. They will develop strategies to address goals or questions, deciding how they will go about learning what they need to know. The teachers take on responsibility for improving teaching and learning and creating the environment that will support their collaboration and professional growth.

Creating a Supportive and Inspiring School

Many of the elements that characterize an effective classroom environment also support teachers as a community of learners. Research on classroom environment has identified the following key areas of mathematics and science learning communities:

- Supportive relationships
- Active participation in creating norms, making decisions, and setting goals
- Clear expectations and responsibilities
- Opportunities for collaboration
- Adequate time
- Interesting and meaningful activities

Ensuring Effective Collaboration

Relationships are the heart of a professional community—learning requires emotional safety, caring, and respect. Participation hinges on teachers' abilities to question each other, to explain their ideas, to take intellectual risks, and to give and receive help.

Effective collaborative learning will not automatically result from convening a group of teachers and giving them time to work together. Most teachers are accustomed to working autonomously in their classrooms. The work of the learning community will require teachers to learn the skills of collaborative learning.

Mutual trust and respect

When teachers share their thinking and their instructional practices, they are subjected to the judgment of their peers. This creates the potential that teachers' differences will be placed in the spotlight and that they will feel threatened. Teachers are often reluctant to make changes in their teaching because they are afraid of making mistakes. The learning community must expect differences and appreciate the learning that is a result of divergent ideas and mistakes (Collay, et al., 1998).

More teachers will be encouraged to share their ideas and take risks when they know that their contributions will be treated with respect. Teachers must believe that their colleagues are making an effort to grasp their approaches and ideas, rather than looking for their mistakes. All interactions must be free of ridicule, quick dismissal, or humiliation.

Establishing ground rules

It will be beneficial for the learning community members to establish guidelines and norms for their work together from the very beginning. They can establish informal rules for ensuring equal opportunities to participate, methods for sharing their learning, dealing with conflicts, and providing support (Senge, 1990).

One way to begin is by exploring the questions: What intellectual and emotional qualities are necessary for professional learning and collective inquiry? What skills are necessary for collaboration?

The group might also begin by brainstorming the characteristics of effective teams, moving on to discuss how they can develop or maintain those characteristics. A sample list is provided below. Going back to the list from time to time will help ensure that the agreed-upon norms are still present.

Characteristics of Effective Teams

- Communication is open and honest, there is a climate of trust
- Mistakes are viewed as opportunities for learning
- Members share energy and enthusiasm
- Information is shared both inside and outside the team
- All members are held accountable for their actions
- A common purpose or direction is shared by all
- Members are encouraged to challenge and support each other
- Creativity and flexibility are encouraged
- Methods for resolving conflict are established and agreed upon

(Preskill & Torres, 1999)

Engaging in Discourse

Discourse plays an important role in a professional community as a means of generating and sharing knowledge. Senge (1990) distinguishes between two types of discourse in learning organizations. Discussion is the more familiar type, and it is focused on making decisions. The process involves accumulating different points of view in order to choose the best one or to get the right answer. Participants usually attempt to persuade others to share their own opinions or perspectives.

The purpose of dialogue is to bring together a diverse pool of viewpoints, looking for areas of both commonality and incoherence. Dialogue often focuses on complex issues, with participants trying to achieve clarity and deeper insights (Senge, 1990). All must be willing to listen and attempt to understand. Rather than finding answers, dialogue involves wondering and asking questions.

The skills of the facilitator are important in maintaining the conditions of dialogue, because it easily shifts into discussion. If this shift occurs, the facilitator can help to get the group back on track by asking participants if the conditions of dialogue are being met. It is important to note that the facilitator's role is focused on the process—she does not act as an expert on the subject matter. The facilitator will generally become less important as the group learns dialogue skills and becomes accustomed to the process. The members of the group may also take turns acting as dialogue facilitators.

In the dialogue process, the group members will take turns expressing their points of view. As each person does this, the other participants will concentrate on suspending their judgments and listening intently. At this stage, rather than looking for agreement, the group is looking for a range of possibilities. After all have had an opportunity to talk, the group will look at the pool of different responses, concentrating on what has been said rather than who said what.

For example, a group of elementary teachers are working with the principal to develop a common approach to using calculators. The teachers have read several articles on the subject, and have also considered the position statement on calculators from the National Council of Teachers of Mathematics.

The facilitator is a teacher who brought the topic of calculators to the group's attention. He asks that the group members begin by sharing their thoughts and ideas, and urges all members to back up their assertions with explanations and evidence.

After each person speaks, the facilitator will ask for other participants who agree to share their own thoughts and examples. The next step is to talk about contrary opinions and examples. Throughout the dialogue, the facilitator asks for any needed clarification and checks for understanding of what is being said. As the next step, the teachers agree to choose and create some activities with calculators that are appropriate for their students. They will share what they have learned and developed at their next meeting.

Monitoring Progress

- Do you believe that the team's efforts will result in action?
- Do you feel that you have learned more about yourself and your colleagues?
- Does the team process allow all voices to be heard and valued?
- What are the problem areas in the team process? What strategies can we use to solve them?

(Preskill & Torres, 1999)

Dealing with Conflict

Community does not mean that everyone must always agree. Above all, the professional learning community should not be used to manipulate teachers toward conformity. Rather, the school must be a place where teachers can be open and honest and where their ways of thinking and teaching are valued.

While many teachers tend to deny or avoid conflict whenever possible, it is inevitable and it can be a positive force when dealt with openly and honestly (Lieberman & Miller, 1999). Diverse opinions serve to strengthen inquiry by providing crucial information and contributing to collective wisdom.

Leaders help teachers to deal with conflict by establishing a sense of safety and by modeling respect for diverse points of view. When conflicts do arise, it may be helpful for everyone involved to reflect on the source. For example, does the disagreement arise from different philosophies, beliefs, or experiences; personality conflicts; or past events? It is helpful if the group has guidelines in place for dealing with disagreements (Preskill & Torres, 1999).

Patience and willingness to accommodate uncertainty are important, as well as providing the time necessary to work out mutually agreed-upon solutions. All members of the group must attempt to listen openly to their colleagues and to withhold judgment. When conflicts prove difficult to resolve, teachers may need to develop questions that will help them come to an agreement and to test the areas of dissent.

A group will deal with conflict more effectively if all members agree to (Preskill & Torres, 1999):

- Listen and focus on the problem, rather than the people involved
- Allow each other to express some anger and frustration
- Accept responsibility for their actions
- Give the process adequate time
- Try to see the issue from another person's perspective
- Trust the perceptions of their colleagues

Sharing Professional Knowledge

One of the primary characteristics of a professional learning community is that learning is shared among all of its members (Watkins & Marsick, 1993). This is true even for teachers' individual learning experiences. Whenever possible, the knowledge of community must be accessible to all, with useful and timely avenues for sharing.

One strategy will be for teachers to create portfolios to document what they have learned. Teachers might work together to write an article for a professional journal. They might develop a presentation to inform parents of changes that are happening in the classroom. Some teachers might even develop learning experiences for their colleagues based on what they have learned.

Sharing information and learning is also important on an ongoing basis, not just at the end of a learning experience. E-mail can be an important internal communication tool. Because teachers have different schedules, e-mail may be the most timely and efficient way for teachers to collaborate, even when their classrooms are next door. Electronic communication is not intended to replace face-to-face interaction, but supplements and supports it.

Sharing results and learning in a professional community serves an additional purpose beyond communicating knowledge and information. It is also a means of celebrating learning and honoring teachers as scholars (Lieberman & Miller, 1999). Celebrating teachers' learning helps to provide the energy and inspiration for continuous inquiry.

Lesson Study

A professional learning community model from Japan

Most schools and teachers cannot produce the kinds of learning demanded by the new reforms—not because they do not want to, but because they do not know how, and the systems in which they work do not support them in doing so.

— National Commission on Teaching and America's Future

The statement above points to a widespread problem in education, one that is becoming more prominent as educators examine the progress of the reform of mathematics and science. In their book *The Teaching Gap* (1999), Stigler and Hiebert suggest that changes in teachers' practice will not come about merely as a product of different policies or tests.

Teaching is cultural activity embedded in teachers' experiences from the time they are young children. The problem lies not with the teachers' capabilities or their lack of awareness of policies, but with their lack of opportunities to develop and share professional knowledge of what standards-based teaching is.

Even teachers who acknowledge that their current practices are not as effective as they could be often lack superior alternatives with which to replace them. Developing new approaches requires intensive and deep thought, inquiry, and collaboration.

Stigler and Hiebert suggest the lesson study process that Japanese mathematics teachers use as an effective model for building professional knowledge. They note that the process serves as a means of developing new ideas of teaching, as well as a common language for discussing teaching practices.

In Japan, teachers invest significant amounts of time in collaborating to develop a single lesson. While the main goal is the lesson itself, the teachers also attempt to understand the broader issues of how and why the lesson works. The process flows through the following steps:

1. Defining the Problem
The subject for the lesson study often comes from a problematic concept that the teachers have observed in their own classrooms. However, administrators or policy-makers may also suggest a topic.

2. Planning the Lesson
The teachers read books and articles about the problem they are working on. They develop the lesson together, sometimes submitting their plan to other colleagues for feedback.

3. Teaching the Lesson
One teacher is selected to present the lesson in his classroom. The other teachers observe and take notes on what the students are doing and saying during the lesson, and it may also be videotaped for future viewing.

4. Reflecting and Evaluating
The group meets after school to discuss the lesson and their observations. The teacher who presented the lesson speaks first, outlining how he thinks the lesson went and identifying problems he observed. The other teachers contribute their own observations and opinions. The focus of discussion is the lesson itself, not the teaching methods used. The group approaches the lesson as their collective product, so they are critiquing their own work.

5. Revising the Lesson
Based on the problems identified in the first presentation, the study group makes changes in the lesson. Changes are usually based on student misunderstandings that the teachers noticed during their observation.

6. Teaching the Revised Lesson
The lesson is presented again to a different group of students. The same person may teach the lesson a second time or a different teacher may try it out. All the teachers in the school are invited to observe the revised lesson.

7. Reflecting and Evaluating
The whole faculty will participate in the second debriefing session, which may cover more general issues of learning and instruction.

8. Sharing results

Teacher share the lessons they develop through this process, giving them a bank of meticulously crafted lessons to draw upon. The teachers will often publish a report about their study. In addition, teachers from outside the school may be invited to observe the teachers present the lesson.

It may not be practical for schools in the United States to adopt the lesson study process outright. Yet, it can be a useful model for delivering intensive, school-based professional development that districts may want to adapt to their own needs.

Creating Time for Collaboration

Providing time is only the first step in the process of creating a professional learning community. Without common goals, skills for collaboration, and activities that are well thought-out, the added time is not likely to make a difference.

- Bringing in substitute teachers, administrators, or retired teachers to cover classes
- Making use of time students spend with specialist teachers or coordinating elective blocks
- Planning community-based learning experiences for students
- Early release for students one day a week
- Team teaching, combining different grade levels or different subject areas to allow teachers to meet.
- Scheduling shared planning or preparation times
- Creating time for extended "working lunches"
- Using e-mail for administrative tasks in order to dedicate staff meetings to professional learning
- Providing time for teachers during student assemblies or meetings

(Loucks-Horsley et al., 1998)

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APPENDICES

APPENDIX 1: Science Education Safety

Although there are no specific Oregon academic standards related to safety, safety is an important consideration when establishing and implementing a standards-based program. The changed emphasis on active and extended scientific inquiry, opens the door to a variety of safety issues.

To many science teachers, school science safety is a paradoxical term: the teaching of science involves pairing potentially hazardous materials with inexperienced, untrained students and staff. To make matters worse, the science-learning environment often lacks the necessary and appropriate safety equipment. In the case of laboratory safety, a teacher should be concerned with

1. preparing and planning prior to the activity.
2. clearly expressing to students the means by which the activity may be safely completed.
3. thoughtfully describing possible safety hazards.
4. being present at all times in the science room during the activity.
5. carefully monitoring student activity.

To safely plan a science lab activity; teachers should always ask themselves:

- ❖ What can possibly go wrong?
- ❖ What can be done to prevent that event?
- ❖ What must I do if it does happen?

In the case of choosing an activity or experiment that has some element of potential harm, it is useful to ask:

- ❖ Is this activity so educationally desirable that we can afford the risk?
- ❖ If there are hazardous chemicals required, can the same effect be demonstrated if less hazardous chemicals are substituted?
- ❖ Is there a better (safer) activity that can demonstrate the same skill or knowledge?

Science labs provide a rich learning experience for students, and one cannot eliminate every activity that has an element of risk. Therefore the teacher should adhere to some common sense practices to insure the safety of everyone in the science lab. General Lab Safety recommendations are given in Figure 28, pages 126-127. Not all recommendations below apply to all classrooms.

Criteria for scheduling special needs students into laboratory classes should be established by a team of counselors, science teachers, special education teachers, and school administrators. Aides or special equipment should be made available to the science teacher in order to accommodate the special students. All students should have opportunities for learning science!

Elimination of Mercury in Oregon Schools

Mercury Elimination Policy (OAR 581-021-0021) requires all Oregon School districts to:

- Prohibit purchase of elemental mercury, mercury compounds, and mercury-added instructional materials.
- Eliminate all elemental mercury and mercury compounds that are maintained for educational purposes, for example, vials of liquid mercury and samples of mercury compounds contained in chemistry class stockrooms.
- Eliminate the use of mercury-added instruments and equipment (i.e. thermometers, barometers).; and
- Eliminate the use of items and products containing elemental mercury or mercury compounds, as those items and products are replaced at the end of their normal useful lives with cost-effective mercury-free alternatives.

As instructional materials, items and products containing elemental mercury are replaced, school districts should work with the Oregon Department of Environmental Quality in the proper disposal of the materials, items and products.

Safety Standards Guidelines for Secondary Science Laboratories (OAR 581-22-1420): The state of Oregon has prepared safety guidelines for the laboratory room, safety equipment that is built in, personal protective equipment and the storerooms for chemicals. The facilities and equipment should be conveniently located, present in sufficient quantity for the students, and equipment be properly maintained and tested on a regularly basis.

Several safety checklists for secondary science laboratories are given

- General Lab Safety Recommendations (Figure 28, page 126)
- Safety Checklist for the Laboratory Room (Figure 29, page 128)
- Safety Equipment that is Built in or Mounted on the Wall (Figure 30, page 129)
- Personal Protective Equipment (Figure 31, page 130)
- Storeroom for Chemicals (Figure 32, pages 131-132)
- Teacher Preparation and Area for Preparation (Figure 33, page 132)

Biology Laboratory Safety: The biology classroom presents special safety considerations because of the use and handling of biological specimens. The National Association of Biology Teachers (NABT) and the National Institutes of Health (NIH) both have guidelines, which are recommended when working with live animals, viruses, bacteria and other microscopic organisms, human body fluids and DNA. All laboratory animals should be protected and treated humanely and ethically.

Animals in the Classroom: Ethical Considerations: Following National Association of Biology Teachers (NABT) guidelines, the study of organisms, is essential to the understanding of life on Earth. Teachers should foster a respect for life. Classroom experiences that involve nonhuman animals range from observation to dissection. NABT supports these experiences so long as they are conducted with the long established guidelines of proper care and use of animals, as developed by the scientific and educational community. The use of nonhuman animals in the classroom must have sound educational objectives.

In addition, in Oregon when the teacher determines that the most effective means to meet the objectives requires dissection, the teacher must be sensitive to student and parent or guardian objections to dissection and must provide appropriate lessons for those students. Teachers who include animal dissection in their coursework should review the details of Senate Bill 383 (page 8). This 2005 legislation directs that any school district that includes vertebrate or invertebrate animal dissection as part of its coursework shall permit students to demonstrate competency in the coursework through alternative materials or methods of learning that do not include the dissection of animals. SB 383 also requires that a kindergarten through grade 12 public school teacher may not discriminate against a student or lower the grade of a student for not participating in the dissection of an animal, and that a school district shall notify students who have dissection as part of their coursework and the parents and legal guardians of those students about these provisions.

Living vertebrate animals should not be taken from the environment. The teacher should use good judgment in obtaining any invertebrate animals from the environment. It is best to obtain all animals from authorized suppliers. Vertebrate animals should be used only for observational activities and to teach students the proper care and handling. No invasive procedures should be done on living vertebrate animals. When invertebrate animals are used for observational and genetic experiments (for example, fruit fly experiments), care should be taken to anesthetize the organisms properly. Living organisms have special needs. All animals should be handled gently. They should be given adequate nourishment, water and ventilation. Cages should be cleaned regularly. Leather gloves should be worn when handling animals, which have the ability to bite or claw.

Allergic Reactions to Animals: The teacher must take into account whether any of your students may be susceptible to allergic reactions due to their interaction with classroom organisms. The National Association of Biology Teachers (NABT) encourages the presence of live animals in the classroom with appropriate consideration to the age and maturity level of the students. The presence of the animals should not cause any harm to members in the classroom.

Before releasing any animals, check with local agencies, e.g. Oregon State Fish and Wildlife Department, Oregon State University Extension Office, or your local animal control.

NABT endorses and adopts the "Principles and Guidelines for the Use of Animals in Precollege Education" of the Institute of Laboratory Animals Resources (National Research Council). Copies of the "Principles and Guidelines" may be obtained from the ILAR at 500 Fifth Street NW, Washington, DC 20001, phone 202 334-2590, e-mail ILAR@nas.edu. The Principles and Guidelines may be downloaded at http://dels.nas.edu/ilar/prin_guide.asp.

Microorganisms: Because of the hazards involved in handling, identification and proliferation, it is strongly recommended that specimens be obtained from reliable supply companies or other sources that can validate species or strains. Known pathogens should never be used. However, all microorganisms should be handled as though they are pathogens. This emphasizes proper lab technique. The key to handling any microorganisms or DNA molecules in the laboratory is to follow *Standard Microbiological Practice* as described in the manual, *Biosafety in Microbial and Biomedical Laboratories.* Center for Disease Control and the National Institutes of Health, GPO, Washington, DC 20402

DNA: Many classrooms use hands-on science labs dealing with topics of molecular biology and work with DNA is the core of these activities. Spooling, enzymatic digestion, and electrophoresis of this molecule to study its chemical and physical properties, as well as manipulating bacterial cells to introduce new genetic properties, have become commonplace. Safety, as always, is a crucial part in the performance of these activities. Guidelines in *Standard Microbiological Practice* should be followed. The National Institutes of Health (NIH) has developed a set of guidelines for conducting research using recombinant molecules and organisms. (*NIH Guidelines for Research Involving Recombinant Molecules*. National Institutes of Health, GPO, Washington, DC 20402.)

Figure 27: Web sites of State and Federal Agencies Regulating Safety in Schools

American Chemical Society	http://pubs.acs.org
Center for Disease Control	http://www.cdc.gov
Environmental Protection Agency	http://www.epa.gov
Material Safety Data Sheet	http://msdsprovider.net
National Association of Biology Teachers	http://www.nabt.org
National Institute of Health	http://www.nih.gov
National Safety Council	http://www.nsc.org
National Science Resource Center	http://www.si.edu/nsrc/start.htm
National Science Teachers Association	http://www.nsta.org
Oregon Department of Education	http://www.ode.state.or.us
Oregon Department of Environmental Quality	http://www.deq.state.or.us
Oregon Department of Transportation	http://www.odot.state.or.us
Oregon State Fire Marshall	http://www.sfm.state.or.us
Oregon Occupational Safety and Health Division	http://www.cbs.state.or.us/external/osha/
Occupational Safety and Health Administration	http://www.osha.gov
US Consumer Product Safety Commission	http://www.cpsc.gov
US Department of Transportation	http://www.dot.gov

Figure 28: General Lab Safety Recommendations: Prevent accidents through careful planning and student supervision.

1. Carefully plan your lab activity: Never assume that an activity is free from safety hazards just because it is in print or that an accident didn't happen last time.

2. Always perform an experiment or demonstration prior to allowing students to replicate the activity. Look for possible hazards. Alert students to potential dangers.

   Give consideration to the National Science Teachers Association's recommendation to limit science classes to 24 students or less for safety.

   All work surfaces and equipment in the chemical or biological laboratory should be thoroughly cleaned after each use.

3. Safety instructions should be given orally and be posted each time an experiment is begun.

4. A positive student attitude toward safety is imperative. Students should not fear doing experiments, using reagents, or equipment, but should respect them for potential hazards. Students should read the lab materials in advance noting all cautions (written and oral).

5. Rough play or mischief should not be permitted in science classrooms or labs.

6. Constant surveillance and supervision of student activities are essential.

7. Teachers must set good safety examples when conducting demonstrations and experiments by modeling good lab safety techniques such as wearing aprons and goggles.

   Closed-toed shoes are required for labs involving liquids, heated or heavy items that may injure the feet.

   Confine long hair and loose clothing. Laboratory aprons should be worn.

   Proper eye protection devices must be worn by all persons engaged in supervising, or observing science involving potential hazards to the eye.

   Never use mouth suction in filling pipettes with chemical reagents. Use a suction bulb.

   Never force glass tubing into rubber stoppers.

   Use heat-safety items such as safety tongs, mittens, aprons, and rubber gloves for both cryogenic and very hot materials.

   Use safety shields or screens whenever there is potential danger of an explosion or implosion of an apparatus.

   Protective (rubber or nitrile) gloves should be provided when students dissect laboratory specimens. Avoid the use of latex gloves due to possible allergic reactions. Students with latex allergies can have symptoms such as hives and rashes, and in extreme cases may cause anaphylactic shock.

   Several chemical authorities believe that contact lenses do not pose additional hazards to the wearer and that contact lenses are allowed when appropriate eye and face protection are used.

The wearing of contact lenses in the science laboratory has been a concern because of possibility of chemicals becoming trapped between the lenses and the eye in the event of a chemical splash.

Never conduct experiments in the laboratory alone or perform unauthorized experiments.

Never eat or drink in the laboratory or from laboratory equipment. Keep personal items off the lab tables and do not use lab refrigerators for food items.

8. Students should wash their hands after handling chemicals. They must avoid transferring chemicals they have handled to their faces.

9. Students should properly note odors or fumes with a wafting motion of the hand.

10. Students should understand that many plants, both domestic and wild, have poisonous parts and should be handled with care.

11. All laboratory animals should be protected and treated humanely.

12. Make certain all hot plates and burners are turned off when leaving the laboratory.

13. Laboratories should contain safety equipment appropriate to their use such as emergency shower, eyewash station (15 minutes of potable water that operates hands free), fume hood, protective aprons, fire blankets, fire extinguisher, and safety goggles for all students and teacher(s).

14. Smoke, carbon monoxide, and heat detectors are recommended in every laboratory. Units should be placed in the laboratory and related areas (storerooms, preparation rooms, closets, and offices).

15. A bucket of 90% sand and 10% vermiculite, or kitty litter (dried bentonite particles) should be kept in all rooms in which chemicals are either handled or stored. The bucket must be properly labeled and have a lid that prevents other debris from contaminating the contents.

16. A single shut-off for gas, electricity, and water should be installed in the science laboratory. It is especially important that schools in the earthquake zones to have such a switch.

17. Chemistry laboratories should be equipped with functional fume hoods. Fume hoods should be available for activities involving flammable and/or toxic substances.

18. There should be frequent laboratory inspections and school staff should conduct an annual, verified safety check of each laboratory.

19. School staff should conduct frequent inspection of the laboratory's electrical, gas, and water systems.

20. MSDS (Material Safety Data) sheets must be maintained on all school chemicals. Schools should maintain an inventory of all science equipment.

21. Install ground fault circuit interrupters at all electrical outlets in science laboratories

22. New laboratories should have two unobstructed exits. Consider adding another to old labs if only one exit exists.

Figure 29: Safety checklist for Secondary Science Laboratories: The Laboratory Room-Floor Plan, Design, and Utilities

— There are two exits, one near the front of the room and the other near the back of the room.

— The exits have a highly visible placard or electrically lighted sign.

— Emergency exit procedures are posted, easily read and highly visible.

— There is ample counter space for each individual workstation; work surface of non-porous, chemical-resistant material.

— There are wide aisles to provide movements of equipment, cart and passage of people without collisions.

— There is a central located counter area or table for dispensing materials.

— Laboratory room has floor to ceiling forced air ventilation.

— A well-lighted lab room and ample Ground Fault Indicator (GFI) grounded electrical outlets are strategically placed at each workstation and teacher instructional area so that no extension cords are necessary.

— There is a master electrical cut-off switch in the laboratory, which is readily accessible to the teacher in an emergency.

— There is proper arrangements of sinks and water faucets, which are easily accessible to the teacher in an emergency.

— There is a master water cut-off valve in the laboratory, which is readily accessible to the teacher in an emergency.

— There is proper placing of gas outlet at each workstation so that burners can be placed in position to prevent students from reaching over a lighted burner.

— There is a master gas cut-off valve in the laboratory, which is readily accessible to the teacher in an emergency.

— There is a general alarm system (which could be a telephone, inter-com, siren or loud bell) to inform people in the building of an emergency. In a newly built facility, smoke alarms and an overhead sprinkler system should be installed in the laboratory room.

— Teacher and principal have keys to lock the lab room when it is not under supervision.

— Safety rules in large print are posted in the lab room.

— All emergency procedures are posted and highly visible (e.g., chemical spills).

— There is a proper shower facility available for use in an emergency.

— There is an approved eye wash station available for use in an emergency.

Figure 30: Safety checklist for Secondary Science Laboratories: Safety Equipment that is built in or Mounted on the Wall

— Proper fume hoods are in physical science and chemistry lab rooms where chemicals are used which give off fumes or vapors that are toxic, corrosive, strong irritants or any type of health hazard and organic solvents with highly flammable vapors. The fume hood has the power to move the air upward at a velocity of 100 feet per minute.

— The fume hood has safety-glass window sashes that pull down easily and have electric and gas outlets, an overhead light and preferably a small sink with running water. There should be ample workspace for several students at the hood.

— The hood is kept clean and not cluttered or used for storage of chemicals.

— There is an approved, overhead mounted safety shower with a highly visible sign showing its location and a visibly marked square on the floor showing its position. This is readily accessible from any workstation within 10 seconds. Safety showers are present in chemistry and physical science lab rooms.

— Face and body drench hose is present in all other science laboratories.

— Eyewash fountains present in all science laboratories that will deliver running water for at least 20 minutes. The fountain is easy to activate. Eyes are held open and copiously washed with water for at least 15 minutes; longer is advisable.

— There are mounted fire extinguishers of general ABC type. They are accessible to all parts of the room within 10 seconds. A large room may need several fire extinguishers that must be rigorously maintained. The position of the extinguishers must be clearly marked with a highly visible placard. Teachers and students know how to use these fire extinguishers.

— A bucket of sand should be available for fire safety. Sand can be used to put out all four classes (A, B, C, D) of fires.

— Approved Fire Code fire blankets and their location are identified with a highly visible sign. Teachers are trained to properly use the fire blanket.

— Special safety spark-proof refrigerator is present if needed (ordinary household refrigerators are not acceptable). No food or drinks are placed in a refrigerator used to store chemicals or biological materials.

— First aid and fluid spill kits are available, kept supplied, and clearly marked.

— Appropriate spill kits for acids, bases and organic solvents are kept in a designated position, clearly marked and accessible.

— There is a very heavy polyethylene or ceramic container, marked "ONLY FOR BROKEN GLASS", lined with a very tough plastic liner to contain the broken glass. The broken glass must be visible to the custodians, who can remove the liner without handling the broken glass.

— There are separate containers for paper trash.

Figure 31: Safety Checklist for Secondary Science Laboratories: Personal Protective Equipment

— Approved (ANSI: Z87.1) eye goggles are available in the lab room for all students and visitors. Chemical splash-proof eye goggles are worn in the lab and by anyone working with chemicals and/or chemically preserved biological specimens. All-purpose approved (ANSI:Z87.1) are worn when conducting other biological lab work. Impact resistant eye goggles are worn when doing mechanical lab activities in physical science and earth science.

— A means of sanitization, such as a UV sanitizer, is required to sterilize the goggles between uses.

Less expensive procedures for sanitizing goggles are described below:

> Place a little dishwashing detergent in a dishpan or other large container. Fill it halfway with warm water. Make a bleach solution in a second dishpan, using ¼ cup of bleach for each gallon of water. Swish the goggles in the soapy water, and then soak them in the bleach solution for 10 minutes. Rinse the goggles thoroughly in clean water, and let the goggles air-dry. This process cleanses and disinfects the lenses and straps, although it might eventually cause the lenses to turn yellow and cloudy.
>
> Purchase individually wrapped alcohol pads from a local pharmacy. The pads cost approximately 3 cents each and are available in boxes of 100. Wipe the lenses and straps of one pair of goggles with a fresh alcohol pad. Then dispose of the used pad in its original package. Allow the goggles to air dry.

— A laboratory apron is worn when working with chemicals including specimen preservatives. The apron is made of chemical resistant material; usually rubber or heavy vinyl plastic.

— Appropriate protective gloves are worn when handling materials that have been heated. Long handled tongs or clamps are available to handle hot crucibles or hot glassware.

— Protective leak-proof containers are available for use when transporting corrosive chemicals. Acid carriers are composed of heavy polyethylene with an inner ridge structure that holds the container in place and protects from bumps or blows. These containers work well for bases and other corrosive chemicals. Plastic coated bottles for corrosive chemicals are acceptable.

— Special carrying cans with flame arrestor are available for use when transporting flammable materials. Approved metal cans or special heavy polyethylene cans are available.

— All chemicals in the lab room are properly labeled, indicating all the hazards of that chemical and stating what precautions should be taken; this includes all protective equipment that must be worn/used. (Detailed labeling applies to chemicals that have been removed from the original manufacturer's container and places in reagent bottles or other bottles. COLOR CODED LABELS attract attention and alert one that a hazard exists; HEALTH hazards are coded BLUE and then the specific hazard is stated such as TOXIC, CAUSTIC. FLAMMABLE hazards are coded RED, highly reactive chemicals, such as oxidizers are coded YELLOW.)

— Only small amounts of flammable chemicals are in the laboratory room and the container is an approved safety container for flammable material.

— Poisonous chemicals are locked up in a secure cabinet in the storeroom. Poisonous chemicals with very high health hazards should not be stored or used in the laboratory room.

— All chemicals used in the activity, and the products formed, are disposed of properly. (As an example see Flinn reference book for Chemical Reference disposal. http://flinnsci.com/homepage/sindex.html)

Figure 32: Safety checklist for Secondary Science Laboratories: Storeroom for Chemicals

— The storeroom has a telephone or some means of fast communication so help can be summoned when needed.

— There is ample space to store the amounts of each chemical normally kept in stock. Larger containers are placed on the lower shelves.

— Aisles are wide enough to easily move around when handling containers of chemicals.

— Aisles are kept clear.

— The storeroom has floor to ceiling continuously forced air-ventilation, completely changing the air in the storeroom at least four times per hour.

— There is an OSHA approved stepladder to reach upper shelves. Hazardous chemicals are not stored on the upper shelves. The shelves have lip edges.

— There are two exits. One is near the front, the other near the back to ensure a second escape route. Exits are marked with a highly visible placard or a light.

— Chemicals are stored according to their chemical properties. Those chemicals having hazardous properties are stored in special protective cabinets. COLOR CODED LABELS are used.

— Flammable chemicals are stored in approved fire-resistant cabinets.

— Acids are stored on special corrosive-resistant cabinets (concentrated nitric acid is stored apart from other acids since it is an oxidizing agent).

— Strong bases are stored in a separate corrosive cabinet.

— Oxidizing agents are stored apart from reducing agents (all fuels are reducing agents).

— Storeroom has an easily accessible ABC wall-mounted fire extinguisher and a smoke alarm.

— Storeroom has appropriate spill clean-up kits.

— If storeroom is used as a preparation area; it has a sink and fume hood.

— Water-reactive chemicals are stored where they will not get wet.

— All chemicals are properly labeled with hazards indicated as stated.

— There are no unlabeled containers of chemicals. Old, unstable and deteriorating chemicals are disposed of properly.

— Very hazardous or dangerous compounds, if used, are kept in small quantities and clearly marked as to the nature of the hazard or danger.

— The storeroom is off limits to students and is kept locked.

— Personal protective equipment, such as goggles, gloves, aprons, are available in the storeroom and are used when handling chemicals. Goggles are worn in the storeroom.

— Sensitive electronic equipment and optical equipment are not stored in the same room with chemicals.

— Special horizontal bins are used to store glass tubing.

— Sufficient sturdy carts are available for transporting chemicals and equipment.

— Protective equipment such as acid carriers is used to transport corrosive chemicals.

— All persons enter the storeroom only when wearing protective equipment.

Figure 33: Safety checklist for Secondary Science Laboratories: Teacher Preparation and Area for Preparation

— An area with sink and ample counter space is well lighted and ventilated.

— A fume hood is in the same area or very close, as is a fire extinguisher.

— All the necessary Personal Protective Equipment, such as goggles, gloves, and apron, are available and worn by the teachers as they are preparing solutions.

— Teachers know how to use all the safety equipment.

— A sturdy lab cart is available to the teacher for transporting materials.

— Teacher notifies the principal and department chair and school safety committee in writing if the necessary safety equipment is not available or if it is not functioning properly.

APPENDIX 2: References

Teaching and Learning to Standards: Science Information on where to obtain some resources

Project 2061: *Science for All Americans, Benchmarks for Science Literacy, Resources for Science Literacy*, and *Blueprints for Reform* can be purchased directly from Oxford University Press, 198 Madison Avenue, New York NY 10016-4314 or call (toll-free) 1-800-451-7556

Project 2061: *Atlas of Science Literacy (2001)* (ISBM 0-87168-668-6) can be purchased from AAAS Distribution Center, PO Box 521, Annapolis Junction, Maryland 20701 or by calling 1-800-222-7809.

Classroom Assessment and the National Science Education Standards. 2001. Washington DC: National Academy Press – see below.

Designing Mathematics or Science Curriculum Programs: A Guide to Using Mathematics and Science Education Standards. 1999 This 56-page book from the National Resource Council (**ISBN** 0-309-06527-5) is available from the National Academy Press - see below.

Inquiry and the National Science Education Standards: A Guide for Teaching and Learning (2000). This 200-page book from the National Research Council (**ISBN** 0-309-06476-7) is available from the National Academy Press:

- By phone: Toll-free 1-888-624-8422 or (202) 334-3313
- By internet: http://www.nap.edu/bookstore
- By mail: National Academy Press, 2101 Constitution Avenue, NW, Lockbox 285, Washington DC 20555

National Center for Improving Science Education. 1991. *The High Stakes of High School Science*. Washington DC: The NETWORK, Inc.

National Research Council. 1996. *National Science Education Standards.* Washington DC: National Academy Press.

National Research Council. 2000. *Inquiry and the National Science Standards*. Washington DC: National Academy Press.

National Science Resource Center. 1997. *Science for All Children: A Guide to Improving Elementary Science Education in Your School District.* Washington, DC: National Academy Press.

National Science Teachers Association. 1996. *NSTA Pathways to the Science Standards: Guidelines for Moving the Vision into Practice.* Arlington, VA: NSTA.

Northwest Regional Educational Laboratory, Mathematics and Science Education Center: Resource Collection for NW Educators (1999 update, over 1000 titles available on loan to Northwest educators).

- Bibliography: Elementary Science
- Bibliography: Inquiry-Based Science
- Bibliography: Middle School Science
- Bibliography: Secondary Science
- Bibliography: Professional Development – Science
- *Inquiry Strategies for Science and Mathematics Learning: It's Just Good Teaching*. 1997. By Denise Jarrett. Pub. Northwest Regional Educational Laboratory.
- A video companion on *Inquiry Strategies for Science and Mathematics Learning*. Available from:
- Northwest Regional Educational Laboratory
  Mathematics and Science Education Center
  101 SW Main Street, Suite 500
  Portland, Oregon 97204
  (503) 275-9500

Annenberg videos including:
Minds of Our Own **ISBN**: 1-57680-064-4
Learning Science through Inquiry **ISBN**: 1-5680-392-9
Private Universe Project **ISBN**: 1-57680-370-8

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APPENDIX 3: Glossary

Academic Content Standards
These standards define what students are expected to know and be able to do in English, mathematics, science, social sciences, the arts, second languages (world languages), and physical education.

Benchmark Standards
In science a student's progress toward the Certificate of Initial Mastery can be checked at or about grades 3, 5, 8, and 10. In April 2002, the State Board of Education adopted grade-level standards in mathematics. Grade-level standards in English/language arts were adopted for grades K-3 in June 2002 and grades 4-8 and CIM in January 2003.

Certificate of Initial Mastery (CIM)
An award earned by students who have met CIM standards on state tests and classroom work samples in English, mathematics, and science.

Common Curriculum Goals
The same course of study (curriculum) used in all Oregon school districts from kindergarten through grade 12. The Common Curriculum Goals include the academic content standards and essential learning skills.

Core Process
A central theme to the study of a particular subject area. In Oregon, the core processes of English/language arts are writing, reading and speaking, of mathematics is problem solving, or science is scientific inquiry, and of social science is social science analysis.

Design Space
An instructional model that helps teachers identify and develop scientific inquiry activities based on whether students have applicable experiences, procedures and science knowledge.

Eligible Content
Statements related to the content standards that are eligible for inclusion in the statewide knowledge and skills assessment.

Knowledge and Skills Assessment
An assessment that measures a student's content knowledge and understanding of related skills.

Learning Cycle
An instructional model that facilitates scientific inquiry through exploration, concept development and application.

Official State Scoring Guide: Specific, consistent criteria on a 1-6 point scale used to evaluate state performance assessments and classroom work samples. Scoring guides may be used by teachers, students, parents, and others. Copies of 2002-04 scoring guides are on the Web at www.ode.state.or.us/asmt/scoring/guides/.

Oregon Statewide Assessment System (OSAS)
Official name for state tests and work samples.

Grade-Level Mapping
A curriculum framework that provides a grade-by-grade continuum toward all Common Curriculum Goals, including those with no standards. This curriculum is NOT required. It is meant to inform.

State Performance Standards
These standards describe the scores expected of students on state (English, mathematics, science) assessments and classroom work samples to achieve the benchmarks at grades 3, 5, 8, and 10. Social Sciences performance standards will be available 2003-04.

Scientific Inquiry
A set of complex processes students use to develop new ideas, concepts, theories, and scientific laws; a core process of science.

Trait/Dimension: A subcategory of an official state scoring guide that corresponds to academic standards adopted for that specific content area. Each trait/dimension lists descriptive criteria used by scorers to rate student work samples/performance assessments on a 1 to 6 scale. For example, in writing the seven traits are ideas/content, organization, voice, word choice, sentence fluency, conventions, and citing sources. In scientific inquiry the four dimensions are forming a question or hypothesis, designing an investigation, collecting and presenting data, and analyzing and interpreting results.

Work Sample
Student work scored using the official state scoring guide. This student work may be the product of classroom assignments in the case of writing, speaking, mathematical problem solving, and scientific inquiry, or on-demand assignments in the case of writing and mathematics problem solving.

APPENDIX 4: Science Content Standards

(Adopted April 26, 2001, basis for Statewide Assessment since 2002-03)

On the web at:
www.ode.state.or.us/teachlearn/subjects/science/curriculum/whatstudentsneedtoknow.aspx

SCIENCE

Adopted April 2001

Student accountability on statewide assessments for these standards began 2002-03.

Science is the rational and systematic observation, identification, description, experimental investigation, and theoretical explanation of natural events. The interrelated areas of scientific study attempt to answer questions about the physical and living universe.

PHYSICAL SCIENCE: Understand structures and properties of matter and changes that occur in the physical world.

Common Curriculum Goals	Content Standards	Benchmark 1 (Grade 3)	Benchmark 2 (Grade 5)	Benchmark 3 (Grade 8)	CIM/CAM	PASS Criteria
MATTER Understand structure and properties of matter.	Understand structure and properties of matter.	Describe objects according to their physical properties.	Identify substances as they exist in different states of matter. *Distinguish among solids, liquids, and gases.* *Identify unique properties of each state of matter.*	Compare properties of specific substances. *Describe how to measure characteristic properties including boiling and melting points, solubility, and density.* *Recognize that substances may be grouped by their physical properties.* *Use the concept of density to evaluate which objects will float or sink in water.*	Describe properties of elements and their relationship to the periodic table. *Explain atoms and their base components (protons, neutrons, and electrons) as a basis for all matter.* *Read and interpret the periodic table, recognizing the relationship of the chemical and physical properties of the elements to their position on the periodic table.* *Recognize that the historical development of atomic theory demonstrates how scientific knowledge changes over time, and how those changes have had an impact on society.*	Know and apply fundamental concepts of the physical sciences. Understand and correctly use essential principles, organizations, concepts, terminology, and notations from a field of science. Use information, skills, and investigative processes employed in a field of science. Investigate, through research and inquiry, important principles, theories, and relationships from a field of science.

Italicized text defines eligible content that may appear on the 2005-07 Oregon Statewide Assessment.

Common Curriculum Goals	Content Standards	Benchmark 1 (Grade 3)	Benchmark 2 (Grade 5)	Benchmark 3 (Grade 8)	CIM/CAM	PASS Criteria
Understand chemical and physical changes.	Describe and analyze chemical and physical changes.	Describe changes that occur in matter.	Describe the ability of matter to change state by heating and cooling. *Recognize that heating and cooling cause changes in states of matter.* *Identify changes in states of matter seen in the environment.*	Compare physical and chemical changes. *Distinguish between examples of chemical changes and physical changes.* *Describe processes that will separate the components of physical mixtures.* *Describe events that accompany chemical changes, but not physical changes.* *Explain how our understanding of the nature of matter and chemical reactions has changed over time.*	Analyze the effects of various factors on physical changes and chemical reactions. *Describe how transformations among solids, liquids, and gases occur (change of state).* *Identify factors that can influence change of state, including temperature, pressure, and concentration.* *Describe chemical reactions in terms of reactants and products.* *Describe the factors that affect the rate of chemical reactions.* *Recognize examples that show when substances combine or break apart in a chemical reaction, the total mass remains the same (conservation of mass).*	(See Previous Page)

Common Curriculum Goals	Content Standards	Benchmark 1 (Grade 3)	Benchmark 2 (Grade 5)	Benchmark 3 (Grade 8)	CIM/CAM	PASS Criteria
FORCE Understand fundamental forces, their forms, and their effects on motion.	Describe fundamental forces and the motions resulting from them.	Describe an object's position and how to affect its movement.	Describe and compare the motion of objects. *Recognize and describe the motion of an object in terms of one or more forces acting on it.*	Explain interactions between force and matter and relationships among force, mass, and motion. *Recognize and describe the motion of an object based on its mass and the force exerted on it.* *Predict the change in direction or speed of an object by changing the forces acting on it.* *Explain inertia.*	Describe and explain the effects of multiple forces acting on an object. *Understand and apply the relationship F=ma in situations in which one force acts on an object.* *Recognize that equal and opposite forces occur when one object exerts a force on another.* *Describe the forces acting on an object, based on the motion of that object.*	(See Previous Page)
			Identify examples of magnetism and gravity exerting force on an object. *Recognize that magnets attract and repel each other and other materials.* *Recognize that things on or near Earth are pulled*	Recognize that every object exerts gravitational force on every other object. *Describe the effect of gravitational force on objects at the Earth's surface.*	Recognize that gravity is a universal force. *Describe the relationship of mass and distance to gravitational force.*	(See Previous Page)

Italicized text defines eligible content **that may appear on the 2005-0***7 Oregon Statewide Assessment.*

Common Curriculum Goals	Content Standards	Benchmark 1 (Grade 3)	Benchmark 2 (Grade 5)	Benchmark 3 (Grade 8)	CIM/CAM	PASS Criteria
			toward it by Earth's gravity.			
ENERGY Understand energy, its transformations, and interactions with matter.	Explain and analyze the interaction of energy and matter.	Identify common types and uses of energy.	Identify forms of various types of energy and their effects on matter. *Identify various forms of energy including heat, light, sound, and electricity.* Describe examples of energy transfer.	Compare forms and behaviors of various types of energy. *Distinguish between the forms of energy including heat, chemical, mechanical, and gravitational potential energy.* Describe and explain various energy transfers and resulting transformations.	Describe differences and similarities between kinds of waves, including sound, seismic, and electromagnetic, as a means of transmitting energy. *Recognize that waves of all kinds have energy that can be transferred when the waves interact with matter.* *Apply the concepts of frequency, wavelength, amplitude, and energy to electromagnetic and mechanical waves.* Describe and analyze examples of conservation of energy.	(See Previous Page)
			Identify the direction of heat transfer on a diagram showing objects at different	*Trace the flow of energy transformations in a*	*Recognize that heat energy is a by-product of most energy*	(See Previous Page)

Common Curriculum Goals	Content Standards	Benchmark 1 (Grade 3)	Benchmark 2 (Grade 5)	Benchmark 3 (Grade 8)	CIM/CAM	PASS Criteria
			temperatures. *Identify ways to produce heat including light, burning, electricity, friction, and as a by-product of mechanical and electrical machines.* *Identify examples of energy transfer in the environment.*	*system.* *Explain the principle that energy is conserved, neither created nor destroyed.* *Identify how technological advances have changed humankind's use of energy.*	*transformations.* *Describe ways in which energy can be transferred, including chemical reactions, nuclear reactions, and light waves.* *Explain the difference between potential and kinetic energy.* *Analyze the flow of energy through a system by applying the law of conservation of energy.*	

Italicized text defines eligible content **that may appear on the 2005-0***7 Oregon Statewide Assessment.*

LIFE SCIENCE: Understand structure, functions, and interactions of living organisms and the environment.

Common Curriculum Goals	Content Standards	Benchmark 1 (Grade 3)	Benchmark 2 (Grade 5)	Benchmark 3 (Grade 8)	CIM/CAM	PASS Criteria
ORGANISMS Understand the characteristics, structure, and functions of organisms.	Describe the characteristics, structure, and functions of organisms.	Recognize characteristics that are similar and different between organisms.	Group or classify organisms based on a variety of characteristics.			Know and apply fundamental concepts of the life sciences. Understand and correctly use essential principles, organizations, concepts, terminology, and notations from a field of science. Use information, skills, and investigative processes employed in a field of science. Investigate, through research and inquiry, important principles, theories, and relationships from a field of science.
			Classify a variety of living things into groups using various characteristics.			
			Describe the function of organ systems.	Describe and explain the relationship and interaction of organ systems.		
			Classify organs by the system to which they belong.	*Identify organ systems at work during a particular activity and describe their effect on each other.*		
		Describe the basic needs of living things.	Describe basic plant and animal structures and their functions.	Describe and explain the structure and functions of an organism in terms of cells, tissues, and organs.	Describe, explain, and compare the structure and functions of cells in organisms.	

Italicized text defines eligible content that may appear on the 2005-07 Oregon Statewide Assessment.

Common Curriculum Goals	Content Standards	Benchmark 1 (Grade 3)	Benchmark 2 (Grade 5)	Benchmark 3 (Grade 8)	CIM/CAM	PASS Criteria
			Associate specific structures with their functions in the survival of the organism.	*Identify differences and similarities between plant and animal cells.* *Recognize how structural differences among organisms at the cellular, tissue, and organ level are related to their habitat and life requirements.* *Identify photosynthesis as the process by which plants use the energy from light to make sugars out of carbon dioxide and water, and that this food can be used immediately for fuel or materials or it may be stored for later use.* *Explain how our understanding of cells and microbes has changed over time.*	*Describe how biological systems can maintain equilibrium (homeostasis).* *Identify unique structures in cells from plants, animals, and prokaryotes.* *Identify cell organelles and state how their activities contribute to a particular type of cell carrying out its functions.* *Explain the role of the cell membrane in cell transport.* *Distinguish between active and passive transport, including diffusion and osmosis, explaining the mechanics of each.* *Describe photosynthesis as a chemical process and part of the carbon cycle.* *Explain how the development of tools and technology, including*	(See Previous Page)

Common Curriculum Goals	Content Standards	Benchmark 1 (Grade 3)	Benchmark 2 (Grade 5)	Benchmark 3 (Grade 8)	CIM/CAM	PASS Criteria
					microscopes, has aided in the understanding of cells and microbes.	
HEREDITY Understand the transmission of traits in living things.	Understand the transmission of traits in living things.	Describe how related plants and animals have similar characteristics.	Describe the life cycle of an organism. *Describe the life cycle of common organisms.* *Recognize that organisms are produced by living organisms of similar kind, and do not appear spontaneously from inanimate materials.*	Describe how the traits of an organism are passed from generation to generation. *Distinguish between asexual and sexual reproduction.* *Identify traits inherited through genes and those resulting from interactions with the environment.* *Use simple laws of probability to predict patterns of heredity with the use of Punnett squares.* *Explain how our understanding of heredity has changed over time.*	Explain laws of heredity and their relationship to the structure and function of DNA. *Describe the structure of DNA and the way that DNA functions to control protein synthesis.* *Recognize and understand the differences between meiosis and mitosis in cellular reproduction.* *Recognize that changes in DNA (mutations) and anomalies in chromosomes create changes in organisms.* *Apply concepts of inheritance of traits, including Mendel's laws, Punnett squares, and pedigrees, to determine the*	(See Previous Page)

Common Curriculum Goals	Content Standards	Benchmark 1 (Grade 3)	Benchmark 2 (Grade 5)	Benchmark 3 (Grade 8)	CIM/CAM	PASS Criteria
					characteristics of offspring. *Recognize the existence of technology that can alter and/or determine inherited traits.*	
DIVERSITY/ INTER-DEPENDENCE Understand the relationships among living things and between living things and their environments.	Explain and analyze the interdependence of organisms in their natural environment.	Describe a habitat and the organisms that live there.	Describe the relationship between characteristics of specific habitats and the organisms that live there.	Identify and describe the factors that influence or change the balance of populations in their environment.	Describe and analyze the effect of species, including humans, on an ecosystem.	(See Previous Page)

Common Curriculum Goals	Content Standards	Benchmark 1 (Grade 3)	Benchmark 2 (Grade 5)	Benchmark 3 (Grade 8)	CIM/CAM	PASS Criteria
			Use drawings or models to represent a series of food chains for specific habitats. *Identify the producers, consumers, and decomposers in a given habitat.* *Recognize how all animals depend upon plants whether or not they eat the plants directly.* *Explain the relationship between animal behavior and species survival.* *Describe the living and nonliving resources in a specific habitat and the adaptations of organisms to that habitat.*	*Identify that sunlight is the major source of energy in most ecosystems and that energy then passes from organism to organism in food webs.* *Identify populations of organisms within an ecosystem by the function that they serve.* *Differentiate between relationships among organisms including predator-prey, producer-consumer, and parasite-host.* *Explain the importance of niche to an organism's ability to avoid direct competition for resources.*	*Predict outcomes of changes in resources and energy flow in an ecosystem.* *Explain how humans and other species can impact an ecosystem.* *Explain how the balance of resources will change with the introduction or loss of a new species within an ecosystem.*	(See Previous Page)
	Describe and analyze diversity of species, natural selection, and adaptations.	Identify how some animals gather and store food, defend themselves, and find shelter.	Describe how adaptations help a species survive. *Describe changes to the environment that have caused the population of some*	Describe and explain the theory of natural selection as a mechanism for evolution. *Identify and explain how random variations in species can be preserved*	Analyze how living things have changed over geological time, using fossils and other scientific evidence. *Recognize that, over time, natural selection may result in development of a*	(See Previous Page)

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Common Curriculum Goals	Content Standards	Benchmark 1 (Grade 3)	Benchmark 2 (Grade 5)	Benchmark 3 (Grade 8)	CIM/CAM	PASS Criteria
			species to change. *Identify conditions that might cause a species to become endangered or extinct.*	*through natural selection.* *Describe how animal and plant structures adapt to environmental change.*	*new species or subspecies.* *Recognize that natural selection and its evolutionary consequences provide an explanation for the fossil record as well as an explanation for the molecular similarities among varied species.* *Explain how biological evolution can account for the diversity of species developed over time.* *Explain the relationship between genetics, mutations, and biological evolution.* *Explain how our understanding of evolution has changed over time.*	

EARTH AND SPACE SCIENCE: Understand physical properties of the Earth, how those properties change, and the Earth's relationship to other celestial bodies.

Common Curriculum Goals	Content Standards	Benchmark 1 (Grade 3)	Benchmark 2 (Grade 5)	Benchmark 3 (Grade 8)	CIM/CAM	PASS Criteria
THE DYNAMIC EARTH Understand the properties and limited availability of the materials which make up the Earth.	Identify the structure of the Earth system and the availability and use of the materials that make up that system.	Recognize physical differences in Earth materials.	Identify properties and uses of Earth materials.	Recognize that Earth materials are limited, and explore strategies for addressing this problem.	Describe how the importance and use of resources has changed over time with changes in economic and technological systems.	Know and apply fundamental concepts of the earth and space sciences. Understand and correctly use essential principles, organizations, concepts, terminology, and notations from a field of science.
			Recognize that Earth materials are used in different ways based on differences in their physical and chemical properties. *Recognize that soils vary in color, texture, components, reaction to water, and ability to support the growth of plants.* *Recognize that the supply of many resources is limited, and that resources can be extended through recycling and decreased use.*	*Identify ways in which various resources can be recycled and reused.*	*Predict consequences of increased consumption of renewable and non-renewable resources.*	Use information, skills, and investigative processes employed in a field of science. Investigate, through research and inquiry, important principles, theories, and relationships from a field of science.

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Common Curriculum Goals	Content Standards	Benchmark 1 (Grade 3)	Benchmark 2 (Grade 5)	Benchmark 3 (Grade 8)	CIM/CAM	PASS Criteria
			Recognize that discarded products contribute to the problem of waste disposal.			
Understand changes occurring within the lithosphere, hydrosphere, and atmosphere of the Earth.	Explain and analyze changes occurring within the lithosphere, hydrosphere, and atmosphere of the Earth.	Identify daily and seasonal weather changes.	Describe patterns of seasonal weather. *Describe weather in measurable quantities including temperature, wind direction, wind speed, and precipitation.* *Interpret data over a period of time and use information to describe changes in weather from day to day, week to week, and season to season.*	Explain the water cycle and its relationship to weather and climatic patterns. *Explain the water cycle.* *Identify factors that cause or affect weather patterns.* *Identify factors that, affect the rate of evaporation, condensation, and cloud formation.* *Identify the difference between weather and climate.* *Explain how geography affects climate.*	Analyze the relationship between global energy transfer and climate. *Describe the effect of various gases in the atmosphere on the amount of energy retained by the Earth system.* *Describe how solar radiation and the amount that reaches Earth is affected by stratospheric ozone.* *Describe how differential heating of the Earth's surface, atmosphere, and oceans produces wind and ocean currents.*	(See Previous Page)

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Common Curriculum Goals	Content Standards	Benchmark 1 (Grade 3)	Benchmark 2 (Grade 5)	Benchmark 3 (Grade 8)	CIM/CAM	PASS Criteria
			Identify causes of Earth surface changes. *Identify effects of wind and water on Earth materials using appropriate models.* *Identify effects of rapid changes on Earth's surface features including earthquakes and volcanoes.*	Describe the Earth's structure and how it changes over time. *Recognize the solid Earth is layered with a lithosphere, a hot convecting mantle, and a dense metallic core.* *Identify the processes that result in different kinds of landforms.* *Identify factors affecting water flow, soil erosion, and deposition.* *Give examples of landform changes that occur at different rates.* *Describe the evidence for and the development of the theory of plate tectonics.* *Explain the rock cycle in terms of constructive (crustal deformation, volcanic eruption, and sediment deposition) and destructive*	Analyze evidence of ongoing evolution of the Earth system. *Describe methods of determining ages of rocks and fossils.* *Use rock sequences and fossil evidence to determine geologic history.* *Describe and analyze theories of Earth's origin and early history using scientific evidence.* *Describe how earthquakes, volcanic eruptions, mountain building, and continental movements result from slow plate motions.* *Describe how the evolution of life caused dramatic changes in the composition of the Earth's atmosphere, which did not originally contain oxygen.* *Identify how volcanic eruptions and*	(See Previous Page)

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Common Curriculum Goals	Content Standards	Benchmark 1 (Grade 3)	Benchmark 2 (Grade 5)	Benchmark 3 (Grade 8)	CIM/CAM	PASS Criteria
				(weathering and erosion) forces in land formation. *Describe that the total amount of Earth material stays the same as its forms change in the rock cycle.*	*impacts of huge rocks from space can cause widespread effects on climate.*	
THE EARTH IN SPACE Understand the Earth's place in the solar system and the universe.	Explain relationships among the Earth, sun, moon, and the solar system.	Identify and trace the movement of objects in the sky.	Describe the Earth's place in the solar system and the patterns of movement of objects within the solar system using pictorial models. *Describe Earth's position and movement in the solar system.* *Recognize that the rotation of the Earth on its axis every 24 hours produces the night-and-day cycle.*	Explain the relationship of the Earth's motion to the day, season, year, phases of the moon, and eclipses. *Explain the relationship between the cycle of seasons and the tilt of the Earth on its axis.*	Explain how mass and distance affect the interaction between Earth and other objects in space. *Recognize that the sun's gravitational pull holds the Earth and other planets in their orbits, just as the planets' gravitational pull keeps their moons in orbit around them.* *Explain that the force of gravity between Earth and other objects in space depends only upon their masses*	(See Previous Page)

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Common Curriculum Goals	Content Standards	Benchmark 1 (Grade 3)	Benchmark 2 (Grade 5)	Benchmark 3 (Grade 8)	CIM/CAM	PASS Criteria
					and the distances between them.	
THE UNIVERSE Describe natural objects, events, and processes outside the Earth, both past and present.						(See Previous Page)

SCIENTIFIC INQUIRY: Use interrelated processes to pose questions and investigate the physical and living world. See 2002-04 Scientific Inquiry Scoring Guides on pages 51-56 for performance criteria and page 49 for the Scientific Inquiry Performance Standards.

Common Curriculum Goals	Content Standards	Benchmark 1 (Grade 3)	Benchmark 2 (Grade 5)	Benchmark 3 (Grade 8)	CIM/CAM	PASS Criteria
FORMING THE QUESTION/ HYPOTHESIS Formulate and express scientific questions or hypotheses to be investigated.	Make observations. Formulate and express scientific questions or hypotheses to be investigated based on the observations.	Make observations. Based on these observations, ask questions or form hypotheses, which can be explored through simple investigations.	Make observations. Ask questions or form hypotheses based on those observations, which can be explored through scientific investigations.	Based on observations and scientific concepts, ask questions or form hypotheses that can be explored through scientific investigations.	Based on observations and scientific concepts, ask questions or form hypotheses that can be answered or tested through scientific investigations.	Determine areas of inquiry, frame scientific problems, and pose research questions and hypotheses involving scientific relationships.
DESIGNING THE INVESTIGATION Design safe and ethical scientific investigations to address questions or hypotheses.	Design scientific investigations to address and explain questions or hypotheses.	Plan a simple investigation.	Design a simple scientific investigation to answer questions or test hypotheses.	Design a scientific investigation to answer questions or test hypotheses.	Design a scientific investigation that provides sufficient data to answer a question or test a hypothesis.	Design scientific investigations that use precise and appropriate methodology to address questions, examine scientific relationships, and test hypotheses.
COLLECTING AND PRESENTING DATA Conduct procedures to collect, organize, and display scientific data.	Collect, organize, and display scientific data.	Collect data from an investigation.	Collect, organize, and summarize data from investigations.	Collect, organize, and display sufficient data to support analysis.	Collect, organize, and display sufficient data to facilitate scientific analysis and interpretation.	Conduct scientifically accepted procedures to collect, organize, and display data.

Common Curriculum Goals	Content Standards	Benchmark 1 (Grade 3)	Benchmark 2 (Grade 5)	Benchmark 3 (Grade 8)	CIM/CAM	PASS Criteria
ANALYZING AND INTERPRETING RESULTS Analyze scientific information to develop and present conclusions.	Analyze scientific information to develop and present conclusions.	Use the data collected from an investigation to explain the results.	Summarize, analyze, and interpret data from investigations.	Summarize and analyze data including possible sources of error. Explain results and offer reasonable and accurate interpretations and implications.	Summarize and analyze data, evaluating sources of error or bias. Propose explanations that are supported by data and knowledge of scientific terminology.	Analyze and interpret data and relationships, evaluate investigations, and develop supported explanations.

Instruction in the Common Curriculum Goals of Unifying Concepts and Processes, History and Nature of Science, Science in Personal and Social Perspectives, and Science and Technology is required in all Oregon school districts; however, they are not included on the statewide assessment except as specifically indicated in the eligible content in Earth/Space Science, Life Science, or Physical Science.

UNIFYING CONCEPTS AND PROCESSES: Understand and apply major concepts and processes common to all sciences.

COMMON CURRICULUM GOALS:

- Understand that any collection of things that have an influence on one another can be thought of as a system.
- Understand that a model is a tentative scheme or structure with explanatory power.
- Understand that both patterns of change and stability are important in the natural world.
- Understand that changes in scale influence the characteristics, properties and relationships within a system.

HISTORY AND NATURE OF SCIENCE: Understand science as a human endeavor, the nature of scientific knowledge and the history of science as it relates to and clarifies scientific inquiries.

COMMON CURRICULUM GOALS:

- Understand that science is a human endeavor practiced by individuals from many different cultures.
- Understand that scientific knowledge is subject to change based on new findings and results of scientific observation and experimentation.
- Understand that scientific knowledge distinguishes itself through the use of empirical standards, logical arguments, and skepticism.

SCIENCE IN PERSONAL AND SOCIAL PERSPECTIVES: Understand that science provides a basis for understanding and acting on personal and social issues.

COMMON CURRICULUM GOALS:

- Describe the role of science and technology in local, national, and global issues.
- Describe how daily choices of individuals, taken together, affect global resource cycles, ecosystems, and natural resource supplies.
- Explain risks and benefits in personal and community health from a science perspective.

SCIENCE AND TECHNOLOGY: Understand the interconnections among science, technology, and society.

COMMON CURRICULUM GOALS:

- Understand the relationship that exists between science and technology.
- Understand the process of technological design to solve problems and meet needs.

Science Teaching & Learning to Standards

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Oregon Teacher Resources

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