STATE BOARD OF EDUCATION

HEARING TYPE: _X_ ACTION

DATE: May 14, 2008

SUBJECT: **APPROVAL OF DAVID HEIL REPORT ON SCIENCE STANDARDS REVIEW**

SERVICE UNIT: Ms. Edie Harding, Executive Director
State Board of Education

PRESENTER: Mr. Jeff Vincent, Board Lead, SBE
Dr. Kathe Taylor, Policy Director, SBE
Mr. David Heil, CEO, David Heil & Associates
Dr. Rodger Bybee, Co-Director of Science Standards Review Project, David Heil & Associates
Mr. Harold Pratt, Co-Director of Science Standards Review Project, David Heil & Associates

BACKGROUND:

The team of David Heil and Associates will review their final recommendations for changes to the K-10 science standards. The recommendations were developed after an analysis of the standards conducted by the Expert Review Panel assembled by David Heil and Associates, Inc. The Science Standards Advisory Panel reviewed and discussed the draft recommendations at panel meetings held on February 28, 2008 and April 16, 2008. OSPI curriculum and assessment staff members have been present at all panel meetings.

In addition, the recommendations were informed by feedback from participants in six focus groups conducted in Spokane, Wenatchee, and Seattle. An on-line survey posted on the Board's website elicited over 600 responses. These were analyzed, as well.

Once the recommendations are approved, the Superintendent of Public Instruction will revise the essential academic learning requirements and grade level expectations (standards) for science by December 1, 2008. The Heil Team and the Science Standards Advisory Panel will review the revisions in the fall.

EXPECTED ACTION:

Approval of the report.

Washington State Board of Education

Working to Raise Student Achievement Dramatically

Washington State Science Standards: An Independent Review

Final Report

Submitted
May 7, 2008

PROJECT TEAM

David Heil
Rodger W. Bybee
Harold A. Pratt
Kasey McCracken

DAVID HEIL & ASSOCIATES, INC.
Innovations in Science Learning

Table of Contents

Executive Summary

Washington's State Board of Education (SBE) contracted with David Heil & Associates, Inc. (DHA), to conduct a comprehensive review of Washington's current K-10 science standards. The goal of the review was to provide recommendations to improve the science education standards so Washington students will be better prepared with the science knowledge and skills needed to successfully participate in post-secondary education, meet the workforce needs of tomorrow, and contribute to Washington's future economic growth. This final report summarizes findings from DHA's review of the Washington science standards, discusses important themes from public input on the recommendations that were presented in the *Interim Report of the Washington State Science Standards Review* (March 14, 2008), and presents a final set of recommendations for a new set of K-12 science standards for the state of Washington.

The DHA project team approached the review process for the Washington science standards in a series of five steps, with the outcomes from each step progressively informing the subsequent steps. The review process included 1) research and review of relevant state and national documents; 2) assessment of the standards' strengths and weaknesses in view of their current use statewide; 3) selection of benchmark states and nations to use in an Expert Panel's review of the standards; 4) the development and implementation of a rigorous review methodology to evaluate the Washington science standards against the benchmark states and nations and the 9 criteria requested by the Washington SBE; and 5) a public input process based on preliminary recommendations presented in the interim report.

Following the presentation of the interim report, the document was posted to the SBE website and public input was solicited through an online survey and a series of six focus groups in three locations across the state of Washington. Findings from the public input phase suggest that stakeholders largely endorse the recommendations presented in the interim report. However, a few important themes emerged that resulted in DHA making clarifications in the final recommendations presented in this report. In addition to the survey and focus groups, meetings with the Washington Science Advisory Panel also provided input to inform the development and clarification of the final recommendations.

The recommendations are based on a disciplined and scientific review of the current science standards, providing a vision for a new set of science standards for the state of Washington. Although the current Washington science standards rated relatively well when compared to the benchmark states and nations, the state of Washington faces the critical challenge of moving from a "good" set of science standards to an "excellent" set of science standards for the future.

The following recommendations are intended to guide the state of Washington in their efforts to develop and implement new science standards. The first section, *Recommendations to Inform Policy and Implementation Decisions* contains four broad recommendations focused on implementation. The second section, *Recommendations to Inform the Design and Writing of a New Science Standards Document*, contains seven more specific recommendations focused on the task of rewriting the Washington science standards.

Recommendations to Inform Policy and Implementation Decisions

1 Based on our review and analysis of the current science standards for the state of Washington, we recommend the development of a new science standards document.

- Washington should assemble a Science Standards Revision Team to incorporate the changes detailed in this report.
- The new science standards document should build on the strengths of the current science standards document.
- The Science Standards Revision Team should include teachers, a curriculum specialist, an assessment specialist, a university science educator, scientists from each of the three major disciplines, a professional with experience developing standards at the state or national level, a math educator who worked on the development of the math standards, and a professional editor.

2 The new science standards should be a comprehensive K-12 document that sets high expectations for all students.

- The document should be expanded to include grades 11 and 12.
- The document should describe the knowledge, skills, and abilities that all students need to be prepared for post-secondary education.

3 The science standards should create a vision for the science content, methods of science, and applications appropriate for all K-12 students in the state of Washington.

- The new science standards should be clear on their purpose, audience, and voice.
- The document's purpose should reflect the values of the stakeholders in the state of Washington.

4 Implementation of the science standards should result in greater coherence across the full spectrum of the education system - including curriculum development, selection of instructional materials, professional development, and assessment.

- The standards must not be presented as the curriculum.
- Supporting documents are necessary to ensure reliable alignment between the science standards, development and selection of instructional materials, professional development, classroom instruction, and assessment.
- Supporting documents should provide guidance on development and selection of standards-based instructional materials, professional development, instructional strategies, and assessment that support student achievement of the science standards and the measurement of that achievement.

Recommendations to Inform the Design and Writing of a New Washington Science Standards Document

5 Simplify the organization of the Washington science standards document.

- Reduce the number of organizing elements to improve user navigation of the document.
- Organize the discipline content, currently provided in EALR 1, by life sciences, earth and space sciences, and physical sciences.
- Include the same clear delineation of science content, methods of science, and applications that is provided in the current document.
- Continue to provide standards for grade spans rather than for grade levels, including expanding the high school span to integrate grades 11 and 12.

6 Increase the clarity and specificity of the Washington science standards document.

- The science standards should not depend on scientific vocabulary alone to convey the meaning of an outcome statement of what students should understand or be able to do. Scientific vocabulary within the content statements is acceptable if the term is explained as part of the standard.
- The science standards should provide a more complete, detailed, and specific description of the content to be learned, with special attention to the Life Science content. Minimize the use of external references for defining the science content that is to be learned.
- The verbs used in the standards should specifically delineate what students are to understand/know or be able to do.
- The science standards should use content statements to detail the science content that is to be learned. Model the format of these statements after statements provided in reference documents such as the *2009 National Assessment of Educational Progress* and the *National Science Education Standards*.

7 Increase the rigor of the Washington science standards document.

- Some concepts currently introduced in grades 3-5 should be introduced earlier.
- Increase the level of cognitive demand of the standards at all grade spans.
- With the addition of grades 11 and 12, the learning progression across grade spans for each standard should be revisited and content redistributed, with special attention to grade spans 6-8 and 9-12.
- Use the most current research on learning progressions within disciplines to establish what students should know and be able to do at each grade span.

8 Strengthen the standards for inquiry in the state of Washington.

- Devote more attention to the "abilities" of inquiry in addition to the "understandings" of inquiry. Students at all grade levels should be expected to demonstrate the abilities of inquiry.
- Incorporate linkages to the Washington State K-12 Mathematics Standards.
- Provide guidance to clarify the purpose of the inquiry standards as defining learning outcomes for students rather than outlining instructional strategies.

9 Improve the standards for Science and Technology.

- In addition to the "understandings" of technological design, increase focus on the "abilities" of technological design.
- Provide relevant "real world" examples to illustrate the concepts that are articulated in the standards.

10 Develop standards to address Science in Personal and Social Perspectives

- Include the Science in Personal and Social Perspectives content found in the *NSES*.

11 The Washington science standards should reflect the balance and depth of content found in the National Science Education Standards.

- Focus on fundamental concepts and abilities presented in the *NSES*.
- With the development of the new K-12 document, ensure that the Washington Standards contain all of the content from the *NSES*, with particular attention to Life Sciences.
- Eliminate areas of redundancy found in the current Washington science standards.

The recommendations presented in this report are based on the analysis and findings of an Expert Review Panel, public input from a preliminary set of recommendations, input from the Washington Science Advisory Panel, and the collective experience of the DHA project team developing and implementing national and state-level science standards. The recommendations provide a foundation for the development of a set of science standards that set high expectations for all students in Kindergarten through 12th grade in the state of Washington. They also provide guidance for the policies and practices that must be in place to ensure the science standards support a coherent science education system. The state of Washington will be well served by SBE and the Office of Superintendent of Public Instruction (OSPI) undertaking this effort to develop a new set of science standards and guidelines for implementation of those standards. This effort today will help provide Washington with the educated citizenry necessary to meet the workforce needs of tomorrow, positioning the state to realize its full potential as a global leader in science and technology, as well as the diverse economies dependent on science and technology to thrive.

Introduction

Washington's State Board of Education (SBE) contracted with David Heil & Associates, Inc. (DHA) to conduct a review of Washington's current K-10 science standards. The DHA project team conducted a comprehensive review of relevant state and national documents, assessed the strengths and weaknesses of the science standards in view of their current use in practice statewide, developed a methodology to review and benchmark Washington's science standards to exemplar states and nations selected for their strategic relevance to Washington, and convened an Expert Panel to complete a rigorous analysis of the current standards using nine criteria and the benchmark states and nations. Findings from the Expert Panel's review, along with public input and input from the Washington Science Advisory Panel, informed the development of the final 11 recommendations. The goal of the recommendations is to improve the science education standards so Washington students will be better prepared with the science knowledge and skills needed to successfully participate in post-secondary education, meet the workforce needs of tomorrow, and contribute to Washington's future economic growth.

This final report presents findings from the Expert Panel's review of the Washington science standards, summarizes important themes from public input on a preliminary set of recommendations, and provides final recommendations for a new set of K-12 science standards for the state of Washington. The recommendations are presented in two sections:

- **Recommendations to Inform Policy and Implementation Decisions** (four recommendations)
- **Recommendations to Inform the Design and Writing of a New Science Standards Document** (seven recommendations)

Review Methodology

The DHA project team approached the review process for the Washington science standards in a series of five steps, with the outcomes from each step progressively informing the subsequent steps. The review process included 1) research and review of relevant state and national documents; 2) assessment of the standards' strengths and weaknesses in view of their current use statewide; 3) selection of benchmark states and nations to use in an Expert Panel's review of the standards; 4) the development and implementation of a rigorous review methodology to evaluate the Washington science standards against the benchmark states and nations and the 9 criteria requested by the Washington SBE; and 5) a public input process based on preliminary recommendations presented in the interim report. In addition, the Washington Science Advisory Panel provided input at each phase of the project to inform the recommendations.

Research and Review of Relevant Documents

The DHA project team assembled and reviewed state and national reports, studies, and reviews relevant to a review of the Washington science standards. During this process, the team reviewed a number of established national and international reports including the *Science Framework for the 2009 National Assessment of Educational Progress (NAEP Framework), the Trends in International Mathematics and Science Study (TIMSS), the Programme for International Student Assessment (PISA), the National Science Education Standards (NSES)*, and the *American Association for the Advancement of Science (AAAS) Benchmarks for Science Literacy (Benchmarks)* with attention to their implications for the Washington science standards. The team also analyzed the *Science College Readiness Definitions* prepared by the Higher Education Coordinating Board in preparation for considering the development of Washington science standards for grades 11 and 12. These documents and reports were summarized in the *Preliminary Report of the Washington State Science Standards Review* (January 7, 2008). The summaries are included as Appendix A of this report.

Assessment of the Strengths and Weaknesses of the Science Standards

During the first Washington Science Advisory Panel meeting David Heil facilitated a discussion exploring the strengths and weaknesses of the current Washington science standards. After brainstorming a list of 25 strengths the panel members independently ranked the top ten most significant strengths of the current standards. This process was repeated for weaknesses with a list of 31 recorded and rank ordered. The *Preliminary Report of the Washington State Science Standards Review* (January 7, 2008) presents findings from this facilitated discussion.

Selection of Benchmark States and Nations

The project team used independent studies and published reviews of state and international standards to inform the selection of states and nations to serve as appropriate benchmarks for the review of the Washington science standards. This included comparison studies of state standards reviews (such as reports prepared by Education Week, the Thomas B. Fordham Institute, and the American Federation of Teachers) and findings from national and international assessments (such as *NAEP*, *TIMSS*, and *PISA*). In addition to these reports, states' performance on the *2002 State New Economy Index* was used to provide additional context for selecting appropriate benchmarks. *Washington Learns* (2006) identified states that performed well on this index as important benchmarks for the state of Washington in the new economy. Findings from these documents were summarized in the *Preliminary Report of the Washington State Science Standards Review* (January 7, 2008), and are included in Appendix B of this report.

Expert Review Panel Methodology

The Expert Panel's review of the Washington science standards provided the quantitative and qualitative findings presented in this report. The findings were fundamental to the development of the recommendations also provided in this report. Recognizing the need for a broad based review of the science standards, DHA assembled eight experienced content and grade level experts in science education to form the Expert Review Panel. The panel included representation from each of the benchmark states, as well as individuals with broad experience evaluating and/or implementing standards-based science programs in Washington State and across the nation. Appendix D provides biographies for each of the Expert Review Panel members.

Based on the project team's review of national and international studies and reports, the following states and nations were selected as benchmarks for the review of the Washington Science Standards:

- *California*
- *Colorado*
- *Massachusetts*
- *Finland*
- *Singapore*

The Washington SBE requested that nine criteria be used to review the Washington science standards. The DHA project team developed the definitions of the criteria, shown in Figure 1, based on a review of similar criteria employed by Achieve, Inc. to review science standards in other states, and criteria used during the 2007 review of the Washington mathematics standards. In order to conduct the review with scientific precision and ensure inter-rater reliability, these definitions were presented to the Expert Panel Review and discussed prior to the review in order to clarify their meaning and effective use in the review process.

Figure 1 **Final Review Criteria Definitions**

Accessibility. The document contains enough detail for use by curriculum developers and assessment specialists, and the document can be easily navigated.

Balance. There is an appropriate allocation of Grade Level Expectations (GLEs) for each of the three disciplines and there is an appropriate distribution of GLEs representing subject matter content, skills and processes of inquiry, and applications.

Content. GLEs include the most fundamental concepts/outcomes in the science disciplines, matching well-respected benchmarks, and GLEs are scientifically accurate.

Specificity. The description of the content or skill is detailed enough to provide an adequate definition of the learning outcome.

Depth. Fundamental concepts/outcomes are fully developed in each content area.

Clarity. GLEs have a minimum of technical vocabulary and no jargon.

Measurability. The Evidence of Learning statements (ELs) provide guidance for the assessment of the GLEs.

Coherence. GLEs build on the knowledge and skill from the previous grade levels in a manner such that the learning progression of content from one grade level to the next level is recognizable.

Rigor. GLEs and ELs are written at an appropriate level for the student's age and the grade level to which they are assigned.

The definitions of the nine criteria are further operationalized in the scoring guides that were developed for the Expert Panel's review of the standards. The scoring guides include four-point rating scales for the criteria that provide anchors for each numerical rating. For cases in which the definition includes more than one dimension, the scoring guide includes two rating scales. The rating scales use national standards documents, primarily the *NSES*, but also the *NAEP Framework*, to establish reference points for the criteria that facilitate the comparison of Washington's science standards to the benchmark states and nations. The rating scales are displayed in the charts for the criteria that are provided in the *Findings* section of this report. In addition to providing guidance for the quantitative ratings, the scoring guides and protocols were designed to facilitate the capture of reviewers' qualitative feedback as well.

The Expert Panel's review was conducted over a two and a half day period, during which reviewers worked individually and as teams. The review was organized into four review blocks, each lasting approximately three hours; covering specific criteria for Essential Academic Learning Requirements (EALRs) 1, 2, and 3; and using two to three reviewer teams organized by content area or grade spans. For each review block, with the exception of the block for the review of *Accessibility* and *Balance*[1], reviewers first conducted an individual review and then met as a team to discuss their findings, clarify differences in their scores with examples, and develop consensus scores as a team. In addition to the four review blocks for the nine criteria, the Expert Panel's review included a facilitated discussion regarding the development of science standards for grades 11 and 12 (including a review of the *Science College Readiness Definitions* prepared by the Higher Education Coordinating Board) and a discussion of policy and implementation considerations.

Public Input

Following the presentation of the interim report to the Washington SBE, the document was posted to the SBE website and public input was solicited through an online survey and a series of six focus groups in three locations across the state of Washington. The online survey opened April 7, 2008 and closed April 21st, 2008. Stakeholders were made aware of the survey through announcement at the SBE meeting, professional networks, and through representatives of organizations such as the Washington Science Teachers Association (WSTA). During the two-week period, 616 respondents completed the survey.

In addition to the online survey, a total of six two-hour focus groups were hosted in Spokane, Wenatchee, and Seattle between April 9, 2008 and April 15, 2008. Two focus groups were hosted in each location. For the first group in each location DHA recruited a group of local educational professionals, such as district-level staff, Education Service District (ESD) staff, teachers, principals, and representatives from higher education and informal science education. A local recruitment firm was used to recruit a second group that included general public stakeholders, such as parents of students in the K-12 public education system, 11th and 12th grade students, local employers, individuals ages 18 to 22 attending college, and individuals ages 18 to 22 who have not attended college. Findings from the online survey and focus groups are summarized in the *Public Input* section of this report.

1 The review for *Accessibility* and *Balance* included individual reviews during which Expert Reviewers provided ratings and comments on the science standards for Washington, Massachusetts, Singapore, and Finland. Following the individual reviews, median ratings were calculated and the reviewers convened for a full panel discussion of their collective findings.

Washington Science Advisory Panel Input

The Washington Science Advisory Panel (see Appendix E for panel member biographies) provided early input into the review process and help with clarifying and refining the recommendations. The DHA project team facilitated three full-day meetings with the Panel during the period of work leading up to this final report. During the first meeting, the project team facilitated a discussion that resulted in assessment of the strengths and weaknesses of the current standards, summarized in the *Preliminary Report of the Washington State Science Standards Review* (January 7, 2008). The second meeting of the Washington Science Advisory Panel solicited input from panel members on the initial set of recommendations that were developed based on findings from the Expert Panel's review. During the third meeting DHA presented findings from public input on the preliminary set of recommendations from the *Interim Report of the Washington State Science Standards Review* (March 14, 2008) and facilitated a discussion to inform the development of the final recommendations.

Although the *Findings* section of this report is based on the analysis and interpretation of the data compiled from the Expert Panel's review, the *Recommendations* section specifically references comments and concerns by participants in the public input process and by members of the Washington Science Advisory Panel. In this manner, the recommendations are informed by the input that was provided through the public input process and by the Washington Science Advisory Panel.

Findings from the Expert Panel's Review

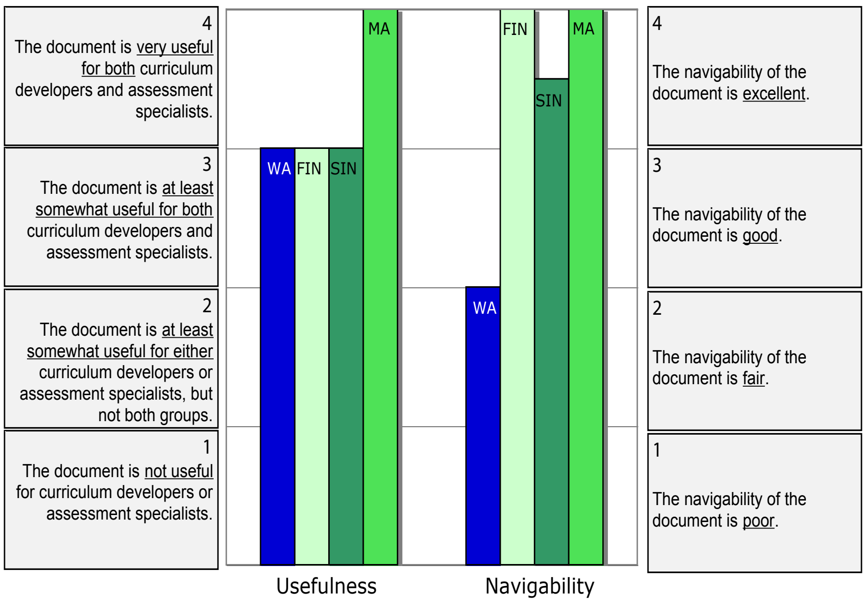
This section summarizes findings from the Expert Panel's review of the Washington science standards for each of the nine criteria employed in the review: accessibility, balance, content, depth, specificity, clarity, measurability, coherence, and rigor. In some cases, the review provided separate findings for EALRs 1, 2, and 3. When this occurs the findings for the criterion on the specific EALRs are presented individually. Each criterion summary includes the following:

- **A summary of quantitative findings** from the review based on the rating scales developed for each criterion;
- **Specific findings** from the review based on qualitative data collected during the review; and
- **An example** to illustrate key findings from the review.

Accessibility. The document contains enough detail for use by curriculum developers and assessment specialists, and the document can be easily navigated.

Reviewers found the Washington science standards to be somewhat useful for both curriculum developers and assessment specialists (a median rating of 3), but noted that the document is more useful for assessment specialists than for curriculum developers.

Reviewers found the navigability of the document to be fair (a median rating of 2). They found the Finland, Singapore, and Massachusetts documents to be more navigable than the Washington document, providing median ratings of 4, 3.5, and 4 respectively.



Example: Excerpt from the MA Science Standards Table of Contents

As shown in this section of the Table of Contents from the Massachusetts science standards the document is organized by discipline and includes front-matter that discusses the vision, purpose, and nature of the standards. Reviewers found the document easy to navigate.

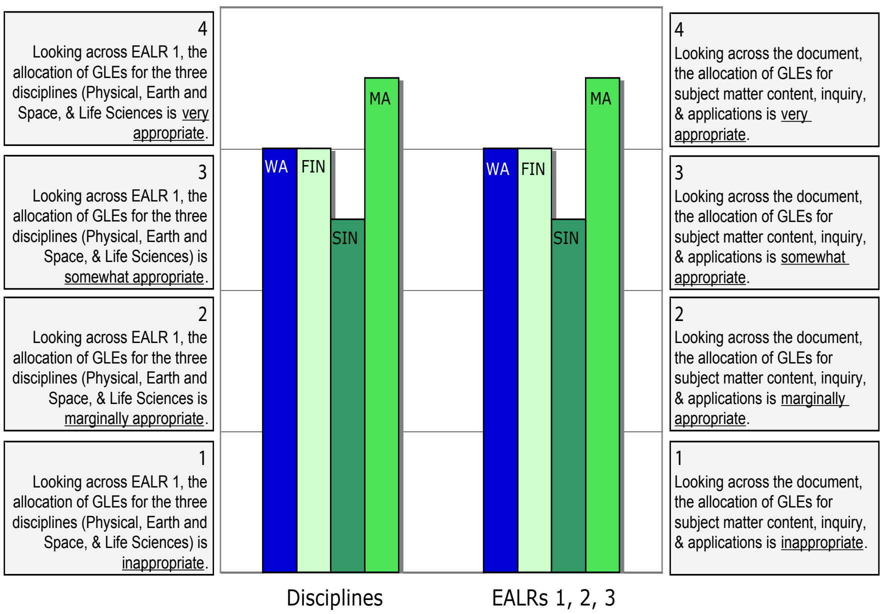
MA Science and Technology/Engineering Curriculum Framework
Table of Contents

Specific Findings

- The organization of the GLEs by content strand and the utilization of the GLE tags are helpful and support the overall navigability of the document.
- The document is less useful for curriculum developers because the level of specificity of the science content is not sufficient to support curriculum development. The lack of detail in the science content also undermines the development of consistent assessments.
- The hierarchy of the systems framework makes it difficult to navigate the document.
- The Component feature in the standards forces the reader to read through too many layers to achieve an adequate depth of understanding and results in an organization of content that is of little value to most users.
- Unlike the Washington document, the Massachusetts and Finland documents are organized by discipline content.
- Although they were not reviewed by the Expert Review Panel, it is notable that in addition to the Science K-10 Grade Level Expectations document, OSPI provides a number of online resources at www.k12.wa.us/CurriculumInstruct/.

Balance. There is an appropriate allocation of GLEs for each of the three disciplines and there is an appropriate distribution of GLEs representing subject matter content, skills and processes of inquiry, and applications.

Reviewers found that looking across EALR 1 the allocation of GLEs for the three disciplines (Physical, Earth & Space, and Life Sciences) is somewhat appropriate (a median rating of 3). Similarly, they found that the allocation of GLEs for subject matter content, inquiry and applications is somewhat appropriate (a median rating of 3).Overall the reviewers found an appropriate balance of the content in the Washington science standards. Massachusetts was the only comparison state/nation to receive more favorable ratings.



Example: Singapore Inquiry Science Standards

Unlike the Washington inquiry standards, the Singapore inquiry standards (labeled skills and processes) are presented in conjunction with the disciplinary content. Although this approach mirrors best practices for teaching inquiry concepts in the classroom, it can also allows the inquiry standards to become lost within the content standards.

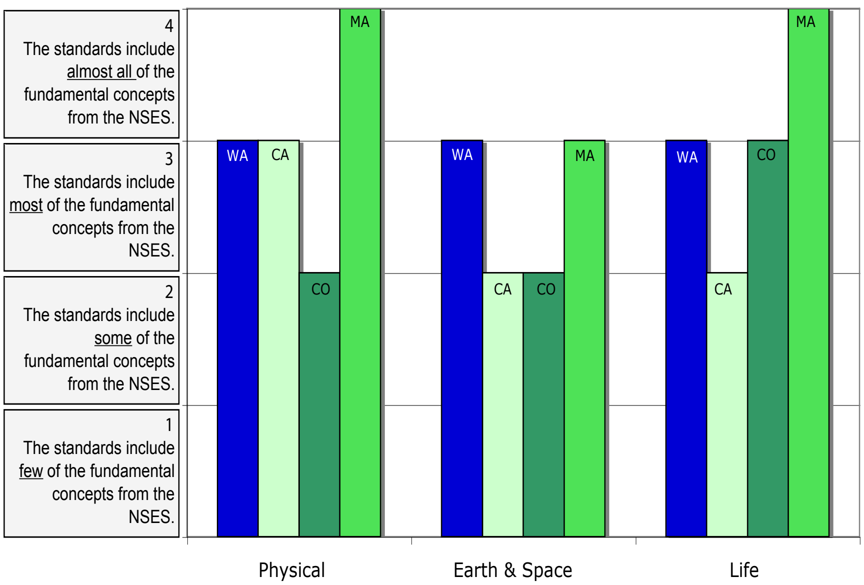
Singapore Primary Science Standards (P5 and P6): Cycles in Plants and Animals	
Knowledge, Understanding, and Application	**Skills and Processes**
State the processes in the sexual reproduction of flowering plants. • Pollination • Fertilization (seed production) • Seed dispersal • Germination State the process of fertilization in the sexual reproduction of humans.	Observe and compare the various ways in which plants reproduce and communicate findings. • Spores • Seeds

Specific Findings

- The standards provide appropriate weight to the importance of inquiry and applications.
- Panelists disagreed over whether it is most appropriate for inquiry standards to be integrated with content standards, as in the Singapore document or to be presented separately, as in the Washington document. Some expressed that integrating the standards makes it difficult to locate the inquiry standards, and others felt that integrating the standards models the manner in which these concepts should be handled in the classroom.
- Presenting the standards for the discipline, inquiry, and science & technology content separately ensures that the inquiry and science & technology standards stand alone as student learning outcomes. However, this presentation makes it is essential to provide guidance to support the use of instructional practices that integrate inquiry, science & technology, and discipline content in the classroom.

Content: EALR 1. GLEs include the most fundamental concepts in the science disciplines, matching well-respected benchmarks, and GLEs are scientificially accurate.

The Washington standards in EALR 1 compared favorably to the standards for California, Colorado, and Massachusetts for all three disciplines. Panelists concluded that overall, the Washington standards reflect most of the fundamental concepts from the *NSES* (a rating of a 3). Massachusetts is the only state that received higher ratings, with 4's for both the Physical and Life Sciences. Panelists found that a weakness of the Washington standards is that important *NSES* content has been omitted.



Example: NSES Content That is Not Included in the WA Science Standards

NSES Content Standard D (grade span 9-12). As a result of activities in grades 9-12, all students should develop an understanding of… geochemical cycles:

- The earth is a system containing essentially a fixed amount of each table chemical atom or element. Each element can exist in several different chemical reservoirs. Each element on earth moves among reservoirs in the solid earth, oceans, atmosphere, and organisms as part of geochemical cycles.
- Movement of matter between reservoirs is driven by the earth's internal and external sources of energy. These movements are often accompanied by a change in the physical and chemical properties of the matter. Carbon, for example, occurs in carbonate rocks such as limestone, in the atmosphere as carbon dioxide gas, in water as dissolved carbon dioxide, and in all organisms as complex molecules that control the chemistry of life.

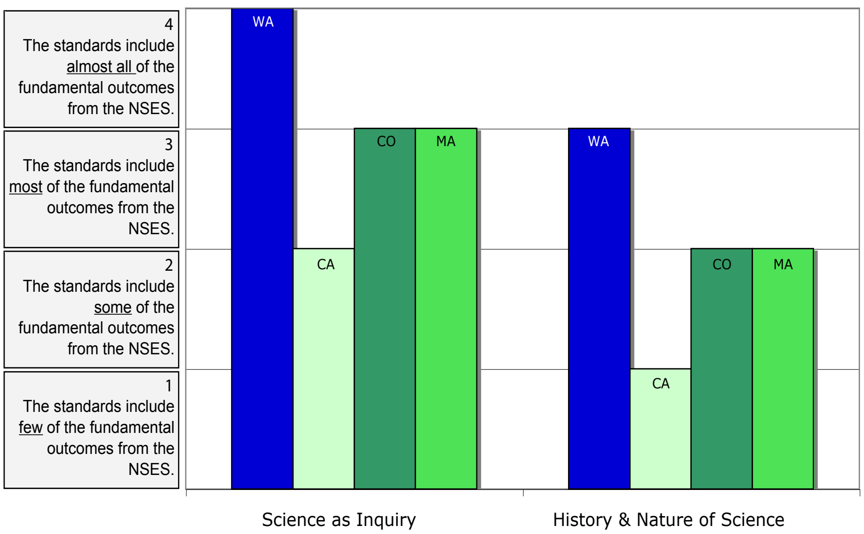
Specific Findings

- The GLEs include most of the *NSES* content for the physical sciences. Missing content in the GLEs includes heat, electrical forces, electrical circuits, relation between current and magnetism, electromagnetic waves, and light and spectrum.
- The GLEs are missing *NSES* content for the earth and space sciences in the areas of plate tectonics/earth history (with the exception of fossils), water, climate, energy from the sun, gravity, energy in earth systems, geochemical cycles, and the sun as a source of energy.
- The GLEs are missing *NSES* content for the life sciences in the areas of failure of structure and function and the development of disease. Some *NSES* content areas receive limited attention, such as the role of behavior, the organism in the environment, and interaction/human impact on the environment. In addition, there is an unusually heavy emphasis on human biology, and too much emphasis on classification.

Content: EALR 2. GLEs include the most fundamental concepts in the science disciplines, matching well-respected benchmarks, <u>and</u> GLEs are scientificially accurate.

Washington performed much more strongly with regard to the inclusion of *NSES* inquiry and history and nature of science standards than did California, Colorado, or Massachusetts. Reviewers found that the Washington standards in EALR 2 include almost all of the inquiry standards from the *NSES* (a rating of 4) and most of the fundamental history and nature of history science standards from the *NSES* (a rating of 3).

Compared to other states, Washington has made substantial progress towards the inclusion of inquiry in the science standards. Colorado provides a thorough treatment of inquiry that is similar to the *NSES*; in California, the treatment of inquiry is more focused on investigation and experimentation within the content than on actual inquiry; and the Massachusetts standards provide useful examples of inquiry, but do not explicitly provide standards for inquiry for grades K-8.



Example: Understanding Inquiry vs. the Abilities of Inquiry

Washington GLE 2.1.1, shown below, describes understanding inquiry rather than the abilities of inquiry as reflected in the corresponding *NSES* content statement. Note that although the ELs for this GLE describe the abilities of inquiry, the GLE itself is framed as an understanding of inquiry.

WA GLE 2.1.1: Grade Span 9-10	NSES Science as Inquiry Standard: Grade Span 9-12
Understand how to generate and evaluate questions that can be answered through scientific investigations. • Generate a new question that can be investigated with the same materials and/or data as a given investigation. • Generate questions, and critique whether questions can be answered through scientific investigation.	**As a result of activities in grades 9-12, all students should develop abilities necessary to do inquiry.** Identify questions and concepts that guide scientific investigations. Students should formulate a testable hypothesis and demonstrate the logical connections between the scientific concepts guiding a hypothesis and the design of an experiment.

Specific Findings

- The fundamental standards for inquiry are evident in the Washington standards. However, the GLEs focus primarily on "understanding" with little attention to "abilities." The *NSES* indicates that the standards on inquiry should include both "understanding" and "abilities" of inquiry:

  "The standards of inquiry highlight the ability to conduct inquiry and develop understanding about scientific inquiry. Students at all grade levels and in every domain of science should have the opportunity to use scientific inquiry and develop the ability to think and act in ways associated with inquiry." (*NSES*, pg. 105)

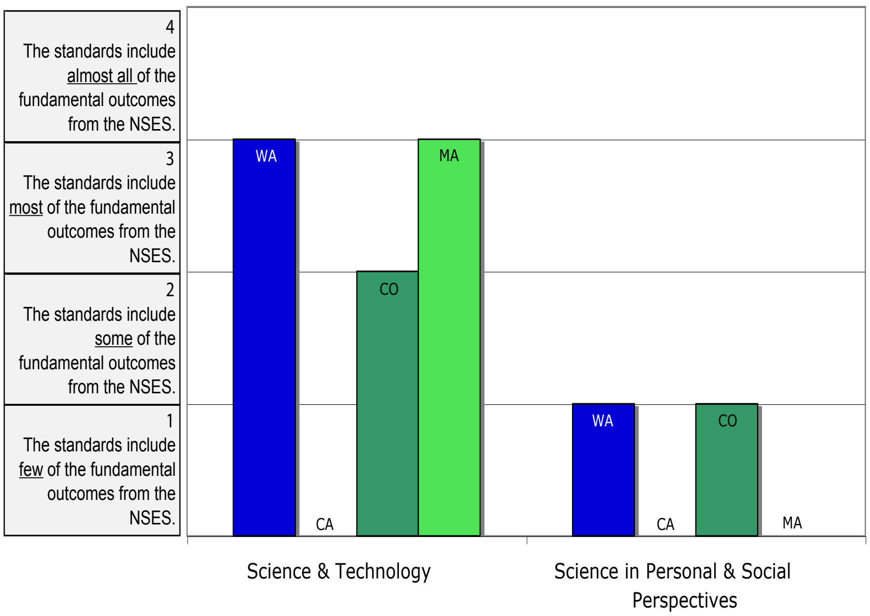
  Of the 5 inquiry GLEs, only 3 of them address the abilities of inquiry, and these do so only at the 6-8 and 9-10 grade spans. However, in some cases the ELs for GLEs that describe the "understanding" of inquiry reflect the "abilities" of inquiry.

- Inquiry concepts are less developed for the 9-10 grade span than for other grade spans.

- Although the inquiry standards are treated more broadly in the Washington standards than in the *NSES*, most of the fundamental outcomes are included in the Washington standards. In this regard the Washington standards perform better than any of the comparison states, which lack much of the *NSES* content for history and nature of sciences.

Content: EALR 3. GLEs include the most fundamental concepts in the science disciplines, matching well-respected benchmarks, and GLEs are scientificially accurate.

The Washington standards include most of the fundamental concepts from the *NSES* for science and technology (a rating of 3), but lack many concepts for science in personal and social perspectives (a rating of 1). Washington performs similarly to the comparison states in this regard. Reviewers noted that Washington is particularly strong with regard to the standards related to design.



Example: Science in Personal and Social Perspectives

As shown in this example, the Washington K-2 science standards include few GLEs that address *NSES* science in personal and social perspectives. The standards lack GLEs to address personal health, or characteristics and changes in populations.

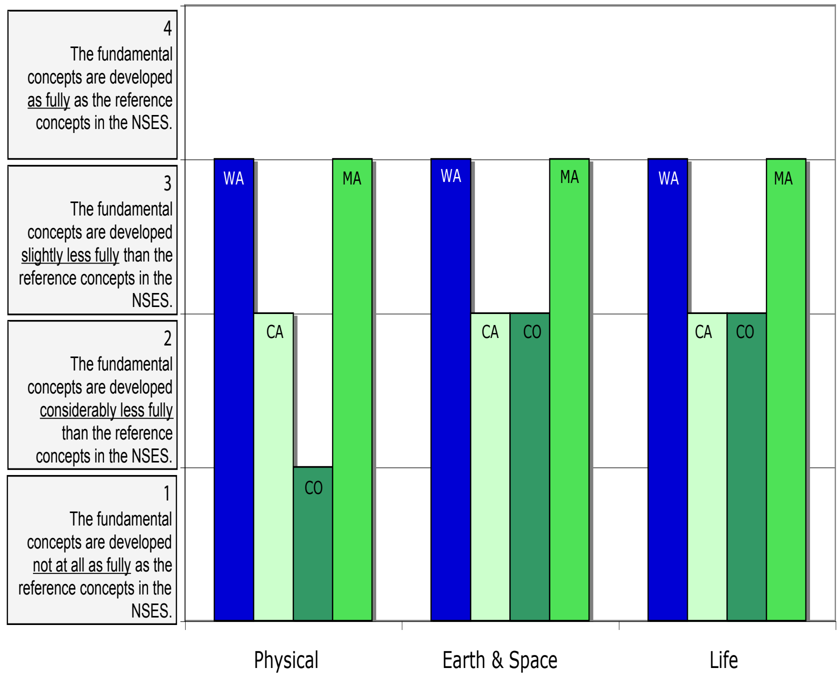
WA K-2 GLEs Related to Science in Personal and Social Perspectives	NSES Science in Personal and Social Perspectives: Grade Span K-4
GLE 3.2.2: Know that people have invented tools for everyday life. GLE 3.2.4: Understand how humans depend on the natural environment.	All students should develop an understanding of: • Personal health • Characteristics and changes in populations • Types of resources • Changes in environments • Science and technology in local challenges

Specific Findings

- Although most of the *NSES* science and technology content is addressed in the Washington standards, the document does lack content in some areas. Missing content includes:
  - for the K-4 grade span: constraints, teams or individual work, and the distinction between the natural and designed world;
  - for the 5-8 grade span: implementation, "imperfect design," constraints, and consequences; and
  - for the 9-10 grade span: implementation, alternative solutions, the scientist perspective, and creativity and imagination.
- Like the standards for other states, most of the *NSES* personal and social perspectives content is missing from the Washington standards, including: the impact of population growth, health, hazards, and local and global changes.
- GLE 3.2.3 addresses careers and occupations that use science, mathematics, and technology. This content is not found in the *NSES*.

Depth: EALR 1. Fundamental concepts/outcomes are fully developed in each content area.

Panelists concluded that overall, the fundamental concepts are developed slightly less fully than the reference concepts in the *NSES* (ratings of 3) for each of the three discipline groups in the Washington standards. These results are equivalent to those for Massachusetts and better than those for California and Colorado. The primary criticism of the Washington standards with regard to depth is that the organization of the document requires the reader to read through many layers to comprehend the required level of depth, which is provided by the ELs. In some cases reviewers found that the ELs provide the required depth, but that the completeness of the content is limited by the fact that these statements are written as a sample of "illustrations of learning" to support assessment rather than to detail the scientific content.



Example: WA GLE vs. Corresponding MA and NSES Standard

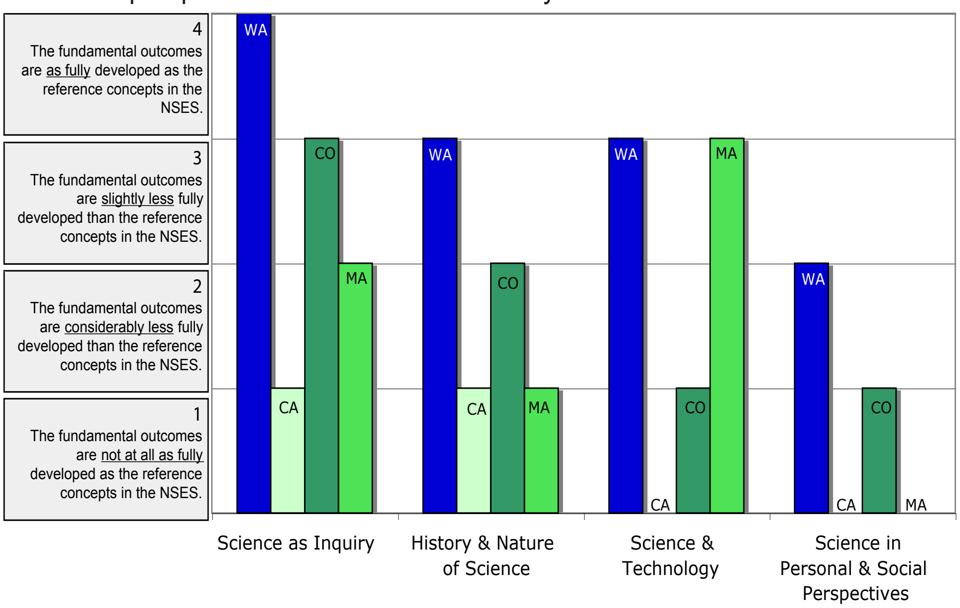
The Washington GLE statement alone does not provide sufficient depth to the science content. To obtain a fuller development of the concept it is necessary to read to the level of the EL statements, which by definition are not exhaustive. Notice that the Massachusetts standards provide more depth of content in the statement of the standard itself.

WA GLE 1.2.6: Grade Span 3-5	MA Life Science Standards 3-5: Grade Span 3-5	NSES Content Standard C: Grade Span K-4
Understand the life cycles of plants and animals and the differences between inherited and acquired characteristics. • Observe and describe the life cycle of a plant or animal. • Describe that the young of plants and animals grow to resemble their parents as they mature into adults. • Describe inherited characteristics (e.g. leaf shape, eye color) and learned characteristics (e.g., languages, social customs).	3. Recognize that plants and animals go through predictable life cycles that include birth, growth, development, reproduction, and death. 4. Describe the major stages that characterize the life cycle of the frog and butterfly as they go through metamorphosis. 5. Differentiate between observed characteristics of plants and animals that are fully inherited (e.g., color of flower, shape of leaves, color of eyes, number of appendages) and characteristics that are affected by the climate or environment (e.g., browning of leaves due to too much sun, language spoken).	**All students should develop understanding of… life cycles of organisms.** • Plants and animals have life cycles that include being born, developing into adults, reproducing, and eventually dying. The details of this life cycle are different for different organisms. • Plants and animals closely resemble their parents. • Many characteristics of an organism are inherited from the parents of the organism, but other characteristics results from an individual's interactions with the environment. Inherited characteristics include the color of flowers and the number of limbs of an animal. Other features, such as the ability to ride a bicycle, are learned through interactions with the environment and cannot be passed on to the next generation.

Depth: EALRs 2 & 3. Fundamental concepts/outcomes are fully developed in each content area.

Reviewers found that for EALR 2 the inquiry outcomes are developed as fully as the reference outcomes in the *NSES* (a rating of 4) and the outcomes corresponding to the *NSES* history and nature of science standards are developed almost as fully as the reference outcomes (a rating of 3). Washington performs better than all of the comparison states for the depth of treatment of both inquiry and the history and nature of science.

Reviewers found that for EALR 3 (applications) the fundamental outcomes are developed almost as fully as the reference concepts in the *NSES*, and concluded that Washington should be commended for its treatment of this material. Like the comparison states, the Washington standards do not develop the science in personal and social perspectives outcomes at all as fully as the *NSES*.



Specific Findings

- Some History and Nature of Science GLEs could be improved with regard to depth. For example, GLE 2.2.2 for grade spans 6-8 and 9-10 should provide a more fully developed content description.
- The Washington science and technology standards are weak on the description of team-work and the development of the relationship between science and technology.

Example: WA Inquiry Standard vs. Comparison State Standards

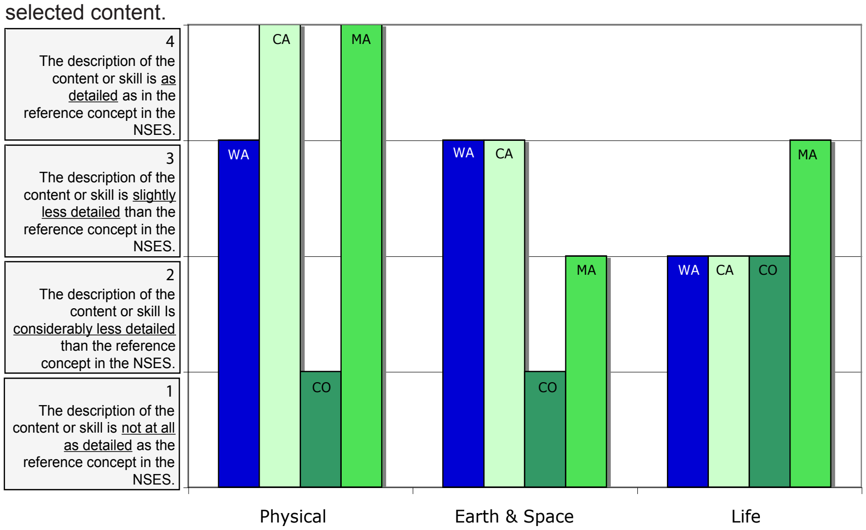
The following example displays the Washington GLE for inquiry, the corresponding Colorado standard, and notes regarding the treatment of inquiry in the California and Massachusetts documents. Notice that the Washington document provides a much fuller description of the inquiry content than do any of the comparison states.

WA GLE 2.1.3: Grade Span K-2	CO Standard 1: Grade Span K-4	Notes Regarding CA & MA Standards
Understand how to construct a reasonable explanation using evidence. • Categorize and order observational data from multiple trials. • Explain an event or phenomenon using observations as evidence (e.g., shape, texture, size weight, color, motion, and/or other physical properties).	In grades K-4, what students know and are able to do includes: • Using data based on observations to construct a reasonable explanation.	The California document includes standards for Investigation and Experimentation, but the standards do not include content that is comparable to that in GLE 2.1.3. The Massachusetts document includes a section outlining the skills of inquiry for the PreK-2 grade span, but does not include specific standards for this grade span.

Specificity: EALR 1. The description of the content or skill is detailed enough to provide an adequate definition of the learning outcome.

Panelists concluded that the Washington standards for the Physical and Earth & Space sciences provide a description of the content that is slightly less detailed than the reference concepts in the *NSES* (a rating of 3), and that the standards for the Life Sciences provide a description that is considerably less detailed than the *NSES* (a rating of 2). These results are better than those for Colorado across all three disciplines. The Massachusetts standards for the Physical and Life Sciences received higher ratings than did Washington. Interestingly, reviewers found the California standards to be very specific, in spite of the inclusion of inappropriate content.[1]

1 The ratings for California varied across disciplines from 4 for Physical Sciences to 2 for Life Sciences, but in the discussion reviewers attributed this variation to differences in the rating teams' approaches to scoring standards that are very specific about inappropriately selected content.



Example: WA Life Sciences GLE and Corresponding MA standard

The following example displays a Washington GLE and one of its ELs, along with the corresponding Massachusetts standard for the same content. Notice that the Massachusetts standard provides much more detail about the science content to be learned.

WA GLE 1.2.6: Grade Span 9-10	MA Biology, High School
Understand cellular structures, their functions, and how specific genes regulate these functions. • Describe how genes (DNA molecules) provide instructions for assembling protein molecules in cells.	**3. Genes allow for the storage and transmission of genetic information. They are a set of instructions encoded in the nucleotide sequence of each organism. Genes code for the specific sequences of amino acids that comprise the proteins characteristic to that organism.** • Describe the basic process of DNA replication and how it relates to the transmission and conservation of the genetic code. Explain the basic processes of transcription and translation, and how they result in the expression of genes. Distinguish among the end products of replication, transcription, and translation.

Specific Findings

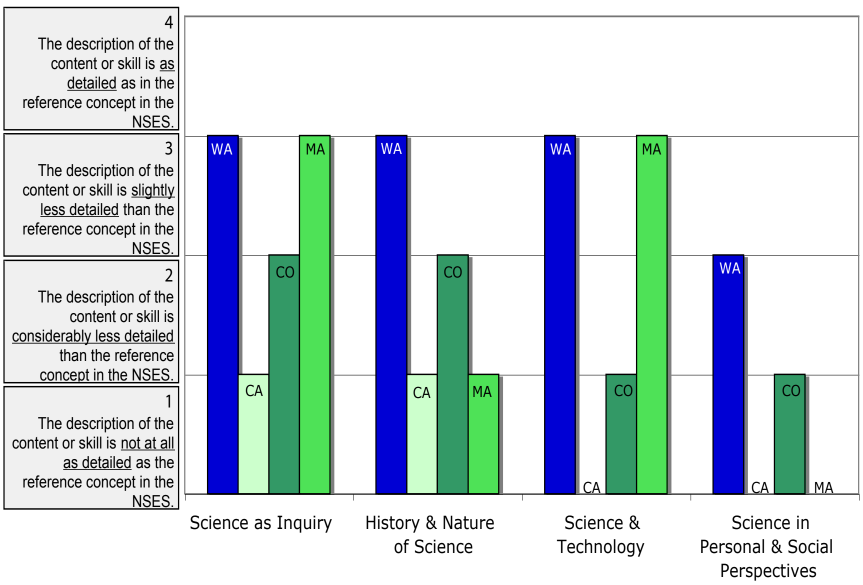
Reviewers based their ratings of specificity on a review of both the GLEs and their supporting ELs. A key finding with regard to specificity is that the GLEs themselves are of a very large grain size and are not at all specific. Although many of the ELs are specific, the use of the ELs to provide specificity to the standards is problematic because:

1. The level of specificity varies among the ELs.
2. The ELs are intended to provide a sample of "illustrations of learning" and are therefore not comprehensive.
3. The ELs are not always appropriately aligned to the GLEs.
4. The verbs used in the ELs, such as *describe*, *compare*, and *observe*, do not reference specific outcomes that describe what is to be learned. They tend to be terms used to suggest means of instruction.
5. The ELs are more specific with regard to what students should do than with regard to the details of the science to be learned.

Specificity: EALRs 2 & 3. The description of the content or skill is detailed enough to provide an adequate definition of the learning outcome.

Reviewers found outcomes in EALR 2 to be slightly less detailed than the reference outcomes in the *NSES* (ratings of 3), in this regard Washington performed better than all of the comparison states, except Massachusetts for inquiry (which received the same rating as Washington).

For EALR 3 reviewers determined that the descriptions of the skills are only slightly less detailed than the corresponding content in the *NSES* (a rating of 3). EALR 3 content received a rating of 2, indicating that the content is considerably less detailed than the corresponding personal and social perspectives standards in the *NSES*.



Specific Findings

- The design portion of EALR 3 is well detailed.
- EALRs 2 and 3 suffer from the same problems of specificity that are outlined in the specific findings for EALR 1.
- For some inquiry GLEs, such as GLEs 2.1.2 and 2.1.3, the ELs provide too much detail.
- For the Applications GLEs, the ELs would benefit from additional "real-world" examples.
- In some cases the Applications standards, such as GLE 3.1.3, provide redundant detail.

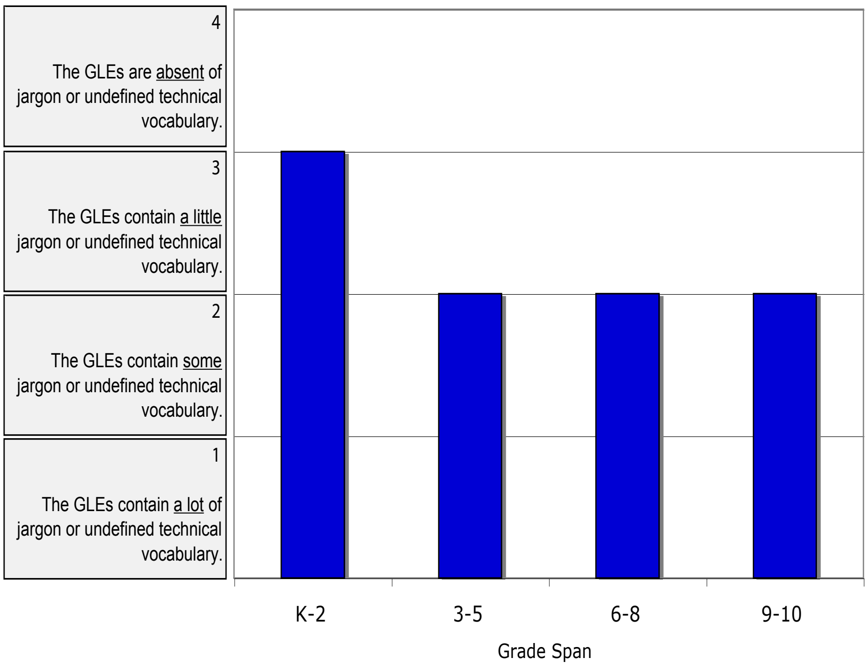
Example: WA Science and Technology Standard and Corresponding MA Standard

Although the Washington EL details the skills that students are to learn, notice how the examples that are provided in the Massachusetts standard provide further specificity.

WA GLE 3.1.2: Grade Span 3-5	MA Technology/Engineering: Grade Span 3-5
Understand how the scientific design process is used to develop and implement solutions to human problems. • Propose, implement, and document the scientific design process used to solve a problem or challenge: define the problem, scientifically gather information and collect measurable data, explore ideas, make a plan, list steps to do the plan, scientifically test solutions, and document the scientific design process.	**Engineering design requires creative thinking and strategies to solve practical problems generated by needs and wants.** • Identify a problem that reflects the need for shelter, storage, or convenience. • Describe different ways in which a problem can be represented, e.g., sketches, diagrams, graphic organizers, and lists. • Identify relevant design features (e.g., size, shape, weight) for building a prototype of a solution to a given problem. • Compare natural systems with mechanical systems that are designed to serve similar purposes, e.g., a bird's wings as compared to an airplane's wings.

Clarity. GLEs have a minimum of technical vocabulary and no jargon.

Reviewers found that the Washington standards for grade spans 3-5, 6-8, and 9-10 contain some jargon or undefined technical vocabulary and that the K-2 standards contain a little jargon or undefined technical vocabulary. Reviewers also noted that the standards often suffer from a vagueness that undermines the clarity of the standards.



Specific Findings

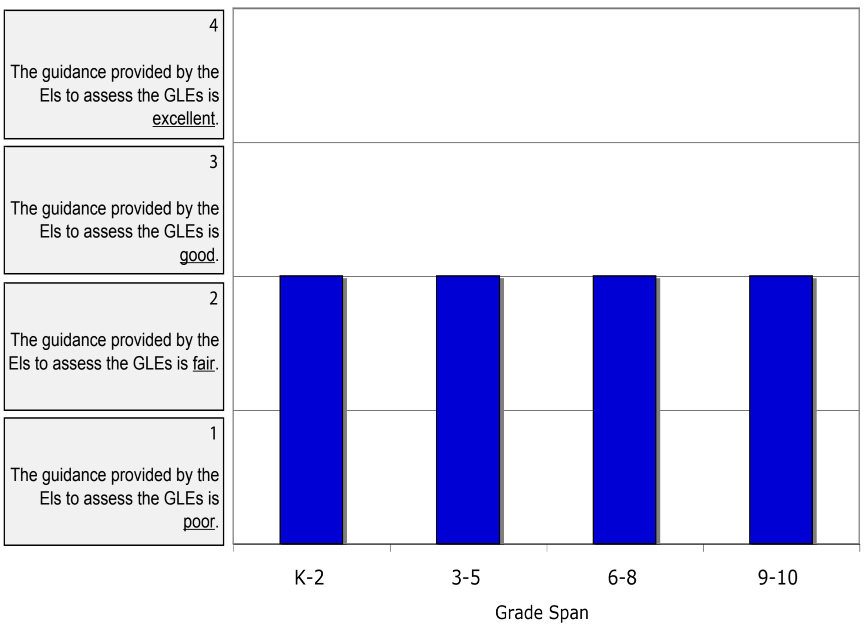
- Some of the GLEs for grade spans 6-8 and 9-10 contain excess wording.
- In some cases it is difficult to discern what students are being asked to demonstrate. For example, GLE 1.1.1 for grade span 6-8 states, "identify an unknown substance using the properties of a known substance."
- The following GLEs are especially problematic due to poor clarity that extends throughout the ELs and across grade spans: GLE 1.2.1, GLE 2.2.5, and GLE 3.1.2.
- Additional examples would help to clarify expectations, particularly in EALRs 2 and 3.

Example: WA GLEs That Demonstrate Poor Clarity

WA GLE Example	Concern About Clarity
1.3.6, 6-8 (GLE): Analyze the relationship between weather and climate and how ocean currents and global atmospheric circulation affect weather and climate.	The GLE and its supporting ELs do not define or describe "weather," "climate," or "global atmospheric circulation."
1.3.10, 3-5 (EL): Describe the role of an organism in a food chain of an ecosystem (i.e., predator, prey, consumer, producer, decomposer, scavenger).	The EL does not define "predator," "prey," "consumer," "producer," "decomposer," or "scavenger."
1.1.1, 6-8 (EL): Recognize that the mass of an object is the same when measured anywhere in the universe at any normal speed.	What is "normal" speed?
1.3.9, 9-10 (GLE): Analyze the scientific evidence used to develop the theory of biological evolution and the concepts of natural selection, speciation, adaptation, and biological diversity.	The GLE and its supporting ELs do not define or describe "natural selection," "speciation," "adaptation," or "biological diversity."

Measurability. The Evidence of Learning statements (ELs) provide guidance for the assessment of the GLEs.

Reviewers found that the guidance provided by the ELs to assess the GLEs is fair for all of the grade spans (a rating of 2), but they noted that measurability varies considerably across the GLEs. Reviewers primary attributed the low ratings for measurability to the lack of specificity and clarity with regard to the science content itself, making it difficult to ensure consistency in assessments between different assessment developers. In addition, they found that there is frequently poor alignment between the EL statements and the GLE statements.



Specific Findings

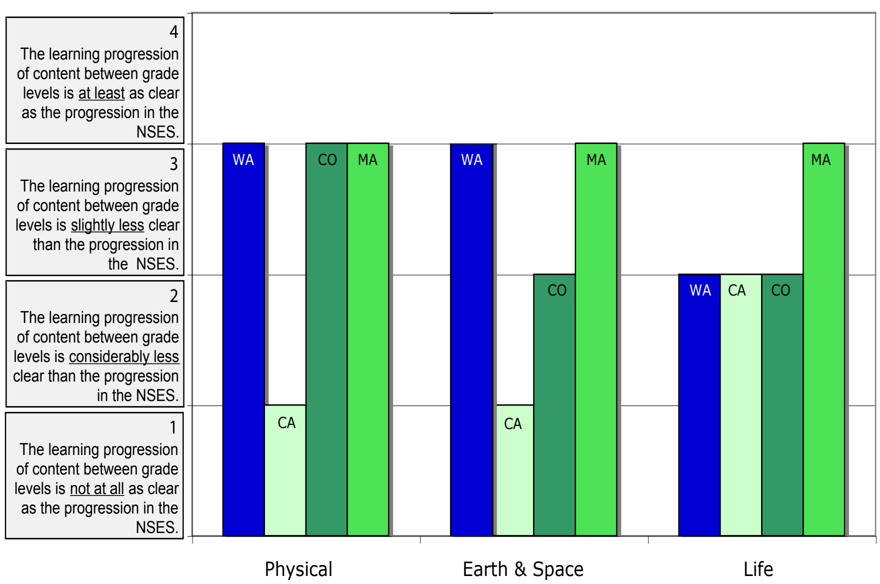
- In some cases the problem of vagueness, as discussed in the findings for clarity, impacts the ability to consistently develop appropriate assessments based on the ELs. For example, it would be challenging to develop assessments based on the information provided for GLE 3.2.4.
- As discussed for specificity, the use of verbs such as "wonder," "experience," "observe," and "investigate" in the ELs makes the assessment of the related GLE very difficult.

Example: WA ELs that Demonstrate Poor Measurability

WA GLE Example	Concern About Measurability
2.1.1, K-2 (EL): Wonder and ask questions about objects, organisms, and events based on observations of the natural world.	How does a student demonstrate "wonder?"
2.1.4, 3-5 (EL): Investigate phenomena using a simple physical or computer model or simulation.	How does an assessment specialist design an item to measure "investigate?"
3.2.4, 6-8 (EL): Explain the effects that the conservation of natural resources has on the quality of the life of ecosystems.	This EL does not provide sufficient detail about what students should know about the effects of conservation of natural resources to ensure consistency in the development of assessment items.
1.2.8, 9-10 (EL): Analyze the patterns and arrangements of Earth systems and subsystems including the core, the mantle, tectonic plates, the hydrosphere, and layers of the atmosphere. • Identify and describe sources of Earth's internal and external thermal energy.	The EL statement is not well aligned with the GLE statement.

Coherence: EALR 1. GLEs build on the knowledge and skill from the previous grade levels in a manner such that the learning progression of content from one grade level to the next level is recognizable.

Washington compares favorably to California and Colorado and is comparable to Massachusetts for coherence ratings, with reviewers finding that the learning progressions between grade levels for the Physical and Earth & Space Sciences content is only slightly less clear than in the *NSES* (a rating of 3) and that the learning progression for the Life Sciences is considerably less clear than in the *NSES* (a rating of 2). Reviewers found that the Washington document clearly demonstrates an effort to consider learning progressions in the development of content. However, they note that the progression appears to be based on the structure of knowledge in the discipline instead of what the students can understand at each grade span.



Specific Findings

- For the Physical Sciences, the conceptual development of the content is not always clear. For example, K-2 could include additional content about the structure of matter, and integrating the concepts of forces and motion would increase coherence
- For the Life Sciences, the handling of classification is redundant, without progressive development from grade-to-grade. In addition, there are gaps in the progression of content for the early grade levels (e.g. fossils are covered in the K-2 grade span without providing the context for time).

Example: WA Life Sciences Grade Span Progression for GLE 1.1.6

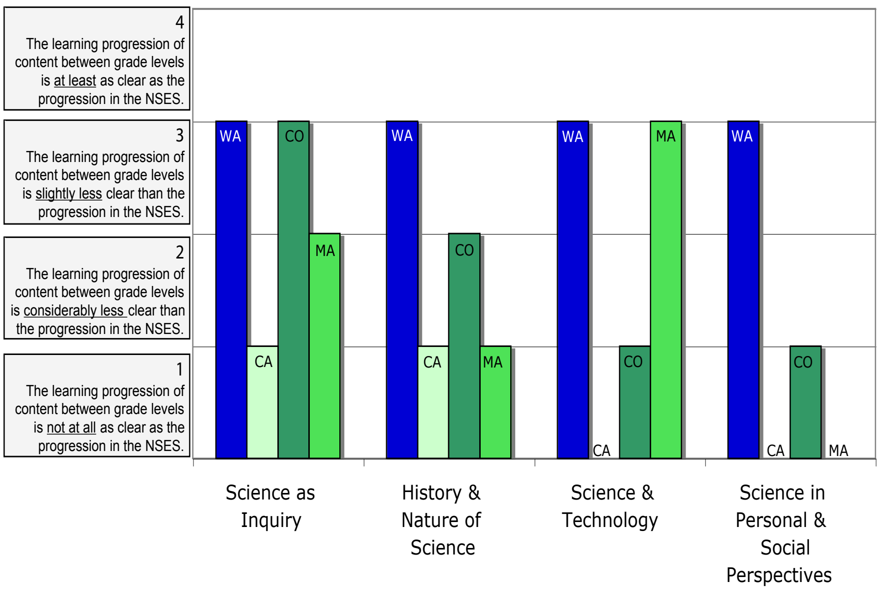
Reviewers found that although there is some progression between the K-2 and 3-5 grade spans for this GLE, the incremental gains in content knowledge are not sufficient, resulting in redundant information between grade spans.

WA GLE 1.1.6: Grade Span K-2	WA GLE 1.1.6: Grade Span 3-5
Understand characteristics of living organisms. • Identify observable characteristics of living organisms (e.g. spiders have eight legs; birds have feathers; plants have roots, stems, leaves, seeds, flowers). • Observe and describe characteristics of living organisms (e.g., spiders have eight legs; birds have feathers; plants have roots, stems, leaves, seeds, flowers).	**Understand how to distinguish living from nonliving and how to use characteristics to sort common organisms into plant and animal groups.** • Describe the characteristics of organisms. • Describe and sort organisms using multiple characteristics (e.g., anatomy such as fins for swimming or leaves for gathering light, behavior patterns such as burrowing or migration, how plants and animals get food differently). • Classify and sort common organisms into plant and animal groups.

Coherence: EALRs 2 & 3. GLEs build on the knowledge and skill from the previous grade levels in a manner such that the learning progression of content from one grade level to the next level is recognizable.

Reviewers found the learning progression for inquiry in EALR 2 to be only slightly less clear than the learning progression for the *NSES* standards (ratings of 3). With the exception of the treatment of inquiry in the Colorado standards, which also received a 3, the ratings for coherence for the Washington standards were higher than the ratings for the comparison states.

Reviewers found EALR 3 content in the Washington standards to have learning progressions that are only slightly less clear than the science and technology and science in personal and social perspectives content in *NSES* (ratings of 3).



Specific Findings

- There is redundancy in the inquiry content between grade spans, especially within the EL statements.
- In some cases there does not appear to be sufficient incremental gain between grade spans.
- Although the WA standards lack much of the *NSES* content for science in personal and social perspectives, the content that is evident is developed appropriately from grade span to grade span.
- Although a developmental sequence is implied through the use of Bloom's taxonomy, higher level thinking, should not be restricted to the highest grade levels.

Example: WA Inquiry Grade Span Progression for GLE 2.1.5

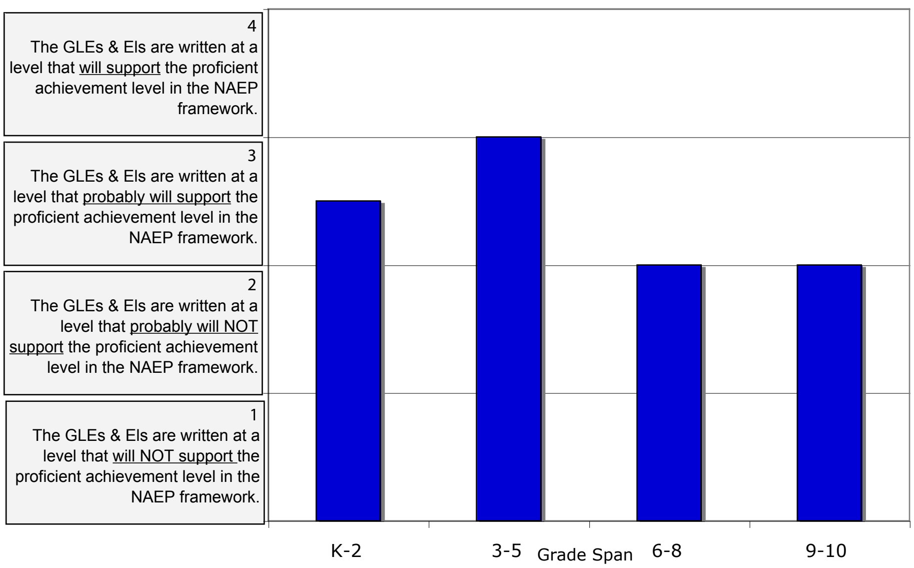
Notice that there is little incremental gain in expectations from the 3-5 grade span to the 6-8 grade span, and there is an over-reliance on Bloom's Taxonomy to imply a developmental sequence that is not supported by the detail included in the ELs. The 6-8 GLE differs from the 3-5 GLE based on the use of "Apply" in place of "Understand." However, most of the supporting ELs are the same for both grade levels.

WA GLE 2.1.5: Grade Span 3-5	WA GLE 2.1.5: Grade Span 6-8
Understand how to report investigations and explanations of objects, events, systems and processes. • Report observations or data of simple investigations without making inferences. • Summarize an investigation by describing: reasons for selecting the investigative plan; materials used in the investigation; observations, data, results; explanations and conclusions in written, mathematical, oral, and information technology presentation formats; safety procedures used.	**Apply understanding of how to report investigations and explanations of objects, events, systems and processes.** • Report observations or data of simple investigations without making inferences. • Summarize an investigation by describing: reasons for selecting the investigative plan; materials used in the investigation; observations, data, results; explanations and conclusions in written, mathematical, oral, and information technology presentation formats; ramifications of investigations; safety procedures used. • Describe the difference between an objective summary of data and an inference made from data.

Rigor. Grade Level Expectations (GLEs) and Evidences of Learning (ELs) are written at an appropriate level for the student's age and the grade level to which they are assigned.

Reviewers found that the GLEs for grand span 3-5 will probably support the proficient achievement level in the *NAEP Framework* (a rating of 3); they were unsure whether the GLEs for grade span K-2 would support the proficient achievement level (a rating of 2.5); and they found that the GLEs for grade spans 6-8 and 9-10 probably will not support the proficient achievement level. Consistent with findings related to depth and specificity, reviewers also noted that many ELs have language to support *NAEP* proficiency, but this is not reflected in the GLEs.

The *NAEP Framework* includes items categorized as *Identifying Scientific Principles* and *Using Scientific Principles*, and it requires that the majority of items be in the *Using Scientific Principles* category. Reviewers found that the level of cognitive demand required for the Washington GLEs does not support proficiency for the *Using Scientific Principles* category of items in the *NAEP Framework.*



Specific Findings

- Content that is currently included in grade span 9-10 could be more appropriately distributed across grades 9-12.
- The expectations tend to be low for the K-2 grade span. In some cases first grade appears to be absent from the progression of content. For example, the WA standards do not introduce the concepts of the strength and direction of a force until the 3-5 grade span (GLE 1.3.1), whereas the MA standards introduce these concepts in the K-2 grade span.
- In some cases the lack of specificity in the ELs leaves the degree of rigor open to the interpretation of the reader. For example, GLE 1.2.4 for grade span 3-5.
- The use of the verbs from Bloom's Taxonomy, in some cases results in lowered expectations for students.

Example: WA GLE 1.3.3 vs. NAEP Performance Expectations for States of Matter

The example displays the Washington grade span 6-8 GLE for Conservation of Matter and Energy and the corresponding *NAEP* Performance Expectations for the same content. Notice that the GLE and ELs provided in the example support a level of performance that is more consistent with *Identifying Science Principles* than with *Using Science Principles*.

WA GLE 1.3.3: 6-8	NAEP Performance Expectations for States of Matter: Grade 8*
Understand that matter is conserved during physical and chemical changes. • Observe and describe evidence of physical and chemical changes of matter (e.g., change of state, size, shape, temperature, color, gas production, solid formation, light). • Observe and describe that substances undergoing physical changes produce matter with the same chemical properties as the original substance and the same total mass (e.g., tearing paper, freezing water, breaking wood, sugar dissolving in water). • Observe and describe that substances may react chemically to form new substances with different chemical properties and the same total mass (e.g., baking soda and vinegar; light stick mass before, during, and after reaction).	**Identifying Science Principles:** Given an animation of molecules in motion, identify the substance that is being illustrated as a solid, liquid, or gas. **Using Science Principles:** Predict how the mass of a sample of iodine will change after sublimation. Justify the prediction based on what occurs during sublimation at a molecular level.

* Source. *Science Framework for the 2009 NAEP*, page 87.

Summary of Public Input on the Preliminary Recommendations

Based on the previous findings, an interim report with preliminary recommendations was posted to the SBE website and public input was solicited through an online survey and a series of six focus groups in three locations across the state of Washington. Details regarding the dates and locations of the survey and focus groups are provided in the Methodology section of this report. This section provides brief descriptions of the online survey and the focus groups, followed by summaries of the quantitative results from the online survey and major themes from the open-ended survey items and focus groups with regard to the *Recommendations to Inform Policy and Implementation Decisions* and the *Recommendations to Inform the Design and Writing of a New Washington Science Standards Document*.

Online Survey

The survey asked respondents to rate each of the 11 recommendations in the interim report on a 4-point scale from strongly disagree (1) to strongly agree (4). Respondents were also asked to provide comments on the set of *Recommendations to Inform Policy and Implementation Decisions* and on the set of *Recommendations to Inform the Design and Writing of a New Washington Science Standards Document*. Finally, respondents were asked to list their top priorities for undertaking a revision of the science standards.

The survey was completed by 616 respondents, the majority of whom identified themselves as K-12th grade teachers (64.1%), parents/guardians of K-12th grade students (23.2%), and district-level science specialists (5.7%). Other categories of respondents included K-12th grade students, school administrators, district and ESD staff, professors of science and science education, informal science educators, and school board members. Respondents identified their areas of residence as Puget Sound (37.2%), Northwest Washington (23.5%), Central Washington (16.2%), Southwest Washington (10.7%), Southeast Washington (5.8%), Northeast Washington (5.5%), and areas outside of Washington (1.0%).

Focus Groups

As described in the Methodology section, an educator and a general public focus group were held in three locations across Washington. Participants in the general public group were asked to comment on Recommendations 1 through 4 and 8 through 10 in the interim report. These recommendations are appropriate for comment from a general public audience because they address policy and implementation considerations along with priorities for what students in the state of Washington should know and be able to do by Grade 12. Participants in the educator focus group were asked to comment on all of the recommendations provided in the interim report. Because this group includes practitioners in the field of science education, their backgrounds and experiences working with science standards allowed them to provide more in-depth feedback on both sets of recommendations.

The general public focus groups included a diverse range of stakeholders with connections to the K-12 education system. Across the three groups, local employers (6), college students (7), recent high school graduates not attending college (4), high school students (5), and parents of students in grades Kindergarten through 12 (10) participated in the groups. The parents represented a mix of different levels of educational attainment. All focus group participants had completed high school; five had completed some college; two had competed a bachelors degree; and one had completed a masters degree. The local employer representatives were recruited based on their experiences hiring or managing staff and included an electrical engineer, a software development manager, an acupuncturist, a manager of an organization that provides services to students who have dropped out of school, and two human resources managers.

Across the educator focus groups representatives from nine different school districts participated, along with representatives of a number of organizations that are important stakeholders in science education in the state of Washington. For the 23 educator focus group participants with a background in K-12 formal education, their numbers of years in education ranged from 3 years to 36 years, with a median of 20 years of experience. The majority of the educator focus group participants reported that they were at least somewhat familiar with the Washington science standards and approximately two-thirds of them had reviewed the interim report before participating in the focus group.

Sample of Educator Focus Group Participant Affiliations:

- **WSTA**
- **Leadership Assistance for Science Education Reform (LASER)**
- **Seattle Pacific University, Physics**
- **University of Washington, Science Education**
- **Spokane City Lab**
- **Wenatchee Valley College, Nursing**
- **Mathematics, Engineering & Science Achievement Program (MESA)**

Quantitative Results and Major Themes from Public Input on Recommendations to Inform Policy and Implementation Decisions

As shown in Table 1, most survey respondents agreed with the recommendations to inform policy and implementation decisions. For Recommendations 2 through 4, at least 90% of respondents indicated that they “agree” or “strongly agree” with each recommendation. Recommendation 1, which proposes developing a new science standards document received the lowest levels of agreement, with 78% of respondents expressing agreement. Major themes from the open-ended survey comments and focus groups, discussed below, provide further insight into these findings.

Table 1 Recommendations to Inform Policy and Implementation Decisions

Recommendation	Strongly Disagree	Disagree	Agree	Strongly Agree	Rating Average	Valid n
1. Develop a new science standards document. (n = 510)	7.5%	14.1%	**44.9%**	33.5%	3.05	510
2. The new science standards should be a comprehensive K-12 document that sets high expectations for all students. (n = 550)	4.7%	4.4%	36.0%	**54.9%**	3.41	550
3. The science standards should create a vision for the science content, methods of science, and applications appropriate for all K-12 students in the state of Washington. (n = 553)	5.6%	3.1%	36.7%	**54.6%**	3.40	553
4. Implementation of the science standards should result in greater coherence across the full spectrum of the education system - including curriculum development, selection of instructional materials, professional development, and assessment. (n = 551)	6.2%	4.0%	33.6%	**56.3%**	3.40	551
					answered question	561
					skipped question	55

Note. 561 respondents answered this set of items. Respondents who selected "no opinion" for an item were excluded from the analysis for that item.

Although focus group participants and respondents to the online survey provided recommendations for improving the current science standards, stakeholders from both groups indicated that they believe that efforts to revise the standards should build on the existing standards and not discard the work the has already been completed. These stakeholders noted strengths of the current standards, such as their alignment with the *NSES*, their treatment of inquiry, and their comprehensiveness. Some participants in the educator focus groups also pointed out that many districts in the state of Washington have invested substantial resources in developing curricula and professional development to support the current standards, and they expressed concern that abandoning the current standards would undermine these efforts.

We should not lose what is best about our current standards nor the work schools have been doing in the process of aligning coursework to state standards. **– Survey respondent**

Teachers across the state are working hard to help their students to know and be able to do what is in the current set of standards. Changing just for the sake of change without a compelling reason will not serve any of us well. **– Survey respondent.**

Obviously there are things that can be improved in the document but the thing that comes to mind is what about all of the work that's already been done and all of the school districts that have spent thousands of dollars for kits or for release time to actually put together their own power standards or core standards. **– Educator Focus Group participant**

As shown in Table 1 above, the concept of having K-12 science standards that set high expectations for all students (Recommendation 2) received strong support. Most survey respondents and focus group participants agree that the science standards should be expanded to cover grades 11 and 12. In general, most stakeholders also believe that the standards should apply to all students. Many stakeholders pointed out that it is important to remember that not all students will go to college and suggested that the standards should be written so that they are achievable by all students, whether they are college-bound or not. Some stakeholders did note that special provisions should be made for identifiable groups of students, such as English-Language Learners, students with at an economic disadvantage, students with a learning disability, and students who have been identified as gifted and talented.

The standards should be realistically attainable for average, hardworking well-taught 10th grade students who may or may not be college bound. **– Survey respondent**

Make them minimum standards… ones that will be beneficial in every-day adult living. **– Survey respondent**

I think [we should expect students to learn the science that is going to get them into college] because a lot of my friends… they're freshmen this year at a four year university or community colleges and because the bar was set too low… they have to take… classes that don't count for college credit, but they still have to pay for it because it wasn't taught in high school. **– General Public Focus Group participant, recent high school graduate**

Stakeholders noted the importance of shifting the focus from revising the standards, to providing teachers with the support that they need to ensure that students are able to achieve the science standards, including appropriately aligned curricula, professional development, and effective instructional strategies. These comments and discussions highlighted the need to balance providing teachers with the tools that they need for effective instruction with the need to also provide teachers with flexibility in their classrooms. They also elicited regional differences in how the current science standards are being used throughout the state, differences which must be attended to as the new science standards are implemented.

> ***Make sure that all districts have access to solid curriculum, supplies, science kits… that will help teach these standards.*** **– Survey respondent**
>
> ***The standards are not the problem. The problem is everyone is guessing at how to cover the standards. Why not spend time finding materials that accomplish the standards instead of moving the target?*** **– Survey respondent**
>
> ***Teachers should have the flexibility and the creativity to teach in a manner that fits their unique students as long as the students are learning the content covered in the standards.*** **– Survey respondent**
>
> ***Teachers aren't used to giving up their authority on their curriculum.*** **– Educator Focus Group participant**
>
> ***I'm in a small district so I don't have the value of having people with specific content knowledge to help develop the curriculum. And when we're assessed on the standard, that then becomes the target and/or the curriculum. So I don't know how to delineate [the standards] from being the curriculum when it's tested.*** **– Educator Focus Group participant**

Quantitative Results and Major Themes from Pubic Input on Recommendations to Inform the Design and Writing of a New Washington Science Standards Document

Table 2 displays the results of the online survey for the Recommendations 5 through 11, which address the design and writing of a new Washington science standards document. The percentage of survey respondents expressing agreement with these recommendations varied from 60% for Recommendation 7 to 92% for Recommendation 5. Comments from the focus groups and open-ended survey items are consistent with this input and help to provide additional context for understanding the quantitative results.

Table 2	Recommendations to Inform the Design and Writing of a New Washington Science Standards Document					
Recommendation	**Strongly Disagree**	**Disagree**	**Agree**	**Strongly Agree**	**Rating Average**	**Valid n**
5. Simplify the organization of the Washington science standards document. (n = 496)	2.2%	5.0%	39.3%	**53.4%**	3.44	496
6. Increase the clarity and specificity of the Washington science standards document. (n = 497)	3.4%	5.8%	35.6%	**55.1%**	3.42	497
7. Increase the rigor of the Washington science standards document. (n = 491)	6.9%	33.2%	**37.7%**	22.2%	2.75	491
8. Strengthen the standards for inquiry in the state of Washington. (n =492)	6.7%	21.5%	**43.1%**	28.7%	2.94	492
9. Improve the standards for Science and Technology. (n = 482)	4.8%	12.7%	**49.4%**	33.2%	3.11	482
10. Develop standards to address Science in Personal and Social Perspectives. (n = 468)	9.0%	20.7%	**43.2%**	27.1%	2.88	468
11. The Washington science standards should reflect the balance and depth of content found in the National Science Education Standards. (n = 503)	4.0%	4.4%	44.9%	**46.7%**	3.34	503
					answered question	526
					skipped question	90

Note. 526 respondents answered this set of items. Respondents who selected "no opinion" for an item were excluded from the analysis for that item.

As described earlier, many educators do not want to see a wholesale re-write of the document, but rather revisions that make the document more user-friendly and the standards more clearly defined. The focus group discussions and responses to the survey overwhelmingly endorsed the recommendations to reorganize and clarify the standards. This input suggests that the current standards require a considerable investment of time to develop educator competence in navigating the document. In addition, comments from the focus group members and survey respondents suggest that the standards are not written with enough clarity and specificity to ensure that educators interpret them consistently.

> ***The top priority should be making the standards clear so that teachers know what they should be teaching their students. They are so vague now and can be interpreted in so many different ways that each teacher may be teaching something different for the same standard.*** **– Survey Respondent**
>
> ***There needs to be some congruency among all of these documents – reading, writing, math, and science.*** **– Educator Focus Group Member**

Many stakeholder comments reflect concerns about creating standards that require such breadth of knowledge that depth of understanding is lost. The open-ended survey comments suggest that the higher levels of disagreement observed with regard to Recommendation 7, which addresses increasing the rigor of the standards, is in large part due to respondents who associated increased rigor with an increase in the amount of content that is required. While a number of stakeholders noted the importance of aligning the Washington Standards to the *NSES* and of ensuring that students meet standards for Science in Personal and Social Perspectives, some respondents are concerned that these additions will add to the overall breadth of content required by the standards.

> ***Do not add to what we have. Rigor does not mean more.*** **– Survey Respondent**
>
> ***Depth of understanding should be emphasized as opposed to coverage.*** **– Survey Respondent**
>
> ***I am concerned that the Science in Personal and Social Perspectives standards will add standards to a document that we are trying to focus more sharply.*** **– Survey Respondent**
>
> ***I'm hoping that the result of the review is to reduce the total number of objectives and show teachers what to teach in depth.*** **– Educator Focus Group participant**

Although stakeholders sometimes differed in their opinions about priorities for revisions to the science standards and about which approaches to curricula and instructional strategies will best allow students to achieve the standards, fundamentally, most stakeholders highly value science education as a mechanism for ensuring that Washington has an informed citizenry and the workforce necessary to keep the state globally completive. Local employers who participated in the focus groups pointed to the important role that science education plays in developing the critical thinking skills that are needed in the workplace and educators, students, and recent graduates pointed to the importance of showing students the real-world relevance of science education to motivate them to achieve the standards.

> ***Effective citizens will realize the cause and effect relationships that exist in all parts of our world and understand that all the skills and knowledge they gain in school work together to prepare them to participate effectively as adults, parents, consumers, voters...*** **– Survey Respondent**
>
> ***We need to be competitive with the rest of the world in all areas of science education.*** **– Survey Respondent**
>
> ***I can't imagine not [teaching applications of science] when you look at the headlines and you read about Microsoft's need for engineers.*** **– Educator Focus Group participant**
>
> ***Having science skills is good if you want to do science, but science teaches you how to solve problems… how to learn better… It prepares you for courses beyond science.*** **– General Public Focus Group participant, recent high school graduate**

Final Recommendations

The following recommendations are intended to guide the state of Washington in their efforts to develop and implement new science standards. Although the recommendations are based on a disciplined review of the current science standards, they provide a vision for a new set of science standards for the state of Washington. While the current science standards for the state of Washington rated relatively well when compared to the benchmark states and nations in this review, Washington faces the critical challenge of moving from a “good” set of science standards to an “excellent” set of science standards for the future.

The following recommendations are intended to guide the state of Washington in their efforts to develop and implement new science standards. The first section, *Recommendations to Inform Policy and Implementation Decisions* contains four broad recommendations and the second section, *Recommendations to Inform the Design and Writing of a New Science Standards Document*, contains seven more specific recommendations.

Recommendations to Inform Policy and Implementation Decisions

Science standards are central to a coherent science education system. Ultimately, though, it is the curriculum and teaching that matter most when improving science learning across the system. Science standards must effectively inform curriculum development, selection of instructional materials, professional development, and assessment. To this end, the policy decisions governing the use of science standards are fundamental to ensuring that they best serve the education system as a whole. The following four recommendations inform policy decisions with regard to science standards for the state of Washington.

I Based on our review and analysis of the current science standards for the state of Washington, we recommend the development of a new science standards document.

- Washington should assemble a Science Standards Revision Team to incorporate the changes detailed in this report.
- The new science standards document should build on the strengths of the current science standards document.
- The Science Standards Revision Team should include teachers, content specialists, a curriculum specialist, an assessment specialist, a university science educator, scientists from each of the three major disciplines, a professional with experience developing standards at the state or national level, a math educator who worked on the development of the math standards, and a professional editor.

At the conclusion of the review process, we recommend that the state of Washington convene a Science Standards Revision Team to develop a new set of science standards that reflects the recommendations provided in this report. The new set of science standards should build on the strengths of the current science standards by reorganizing existing content to make the document more user-friendly, by improving the specificity and clarity with which existing standards are described, by ensuring that existing and new content is assigned to appropriate grade levels based on current research on learning progressions, by strengthening existing standards for inquiry and science and technology, by eliminating areas of redundancy, and by focusing on the fundamental concepts and abilities presented in the *NSES*.

We recommend that this interdisciplinary team include at least two teachers at each grade span; a scientist who has extensive experience working with K-12 teachers in each of the three disciplines; at least one science curriculum specialist from a school district; at least one science assessment specialist; at least one university science educator; at least one person from any of the above categories who has developed standards at the state or national levels; a math educator who has worked on the development of the Washington math standards; and a professional editor. As they develop the new Washington science standards, this team should review the recently released Washington State K-12 Mathematics Standards to create important linkages between the two documents.

2 The new science standards should be a comprehensive K-12 document that sets high expectations for all students.

- The document should be expanded to include grades 11 and 12.
- The document should describe the knowledge, skills, and abilities that all students need to be prepared for post-secondary education.

Our recommendation to extend the Washington science standards to include grades 11 and 12 is firmly rooted in the vision that Washington is already, and will be in the future, a global leader in science and technology. *Washington Learns* was created by the 2005 Washington legislature and tasked with conducting a review of the state's entire education system. The *Washington Learns* committees reviewed the Washington education system with the goal of determining how to provide high-quality lifelong learning in the 21^{st} century. The *2006 Washington Learns* report highlights the need for Washington to educate it's citizens to achieve higher levels of educational attainment if the state is to meet its workforce demands and remain competitive in a challenging global economy. To this end, the report provides ten 10-year goals for a world-class education in the state of Washington. Goal number 7 from this report states:

> *All students will complete a rigorous high school course of study and demonstrate the abilities needed to enter a post-secondary education program or career path.* – Washington Learns (2006)

The report further emphasizes the importance of ensuring that the education system support math and science education to maintain it's competitive advantage:

> *In specific industries where Washington has a competitive advantage – global health, aerospace, advanced manufacturing and technology, and other research-intensive industries – the demands on our education system are even greater… Washington has a constitutional duty to provide a basic education for all children from kindergarten through twelfth grade.* – Washington Learns (2006)

If Washington is to maintain its position as a global leader in science-based industries, the state must make a clear and strong commitment to science standards that reflect what all students must know and be able to do by the completion of 12^{th} grade so they will be prepared for a post-secondary education.

Hereafter, this report will reference K-12 standards for the state of Washington. In particular, Recommendation 7, which addresses the rigor of the science standards, provides a detailed discussion of the implications of extending the science standards to grades 11 and 12.

3 The science standards should create a vision for the science content, methods of science, and applications appropriate for all K-12 students in the state of Washington.

- The new science standards should be clear on their purpose, audience, and voice.
- The document's purpose should reflect the values of the stakeholders in the state of Washington.

The front matter to the Washington GLEs provides an introduction to the standards as "a vision for all students" and notes guiding principles for teaching science in the state of Washington. Although this narrative is useful for setting expectations for what instruction should look like in the state of Washington, the document lacks a clear statement of expectations for how the science standards should be used in Washington.

If the science standards are to provide a vision of the content, methods, and applications for all students in the state of Washington, then the document itself must clearly articulate both its purpose and audience in order to achieve this vision. To this end, the front matter should include a discussion of how the new science standards are intended to be used in the state of Washington. We recommend that this statement clarify the role of science standards as:

1) defining the understanding and abilities of science that all students, without regard to background, future aspirations, or prior interest in science should develop;
2) providing a foundation for the development of materials, programs, and activities that support student achievement; and
3) guiding the development and use of assessments that are appropriately aligned with expectations for student achievement.

In describing this role of the standards in the state of Washington, pains must be taken to address prevalent misconceptions about the purpose of the standards. Discussions with the Washington Science Advisory Panel revealed that many teachers are provided with copies of the Washington Science GLEs and instructed to use the standards as their curriculum. Although the standards should inform curricular decisions and the selection of instructional materials, the standards themselves are not intended to provide a curriculum.

The *NSES* make the position on content standards and the school science curriculum clear. As shown in Figure 2, science content standards are not intended to serve as a science curriculum. Science standards specify what students should know and be able to do in science. The content described in science standards can be organized into many different curricula, which often integrate topics from different subject matter areas and content standards.

Figure 2	NSES Definitions
Science Content Standards	Includes specific capacities, understandings, and abilities in science. The content standards are not curriculum.
Science Curriculum The way content is delivered.	Includes the structure, organization, balance, and presentation of the content in the classroom.

Source. *National Science Education Standards* (1996), pg 22.

In describing how the standards are to be used in the state of Washington, the purpose should reflect the values of the state's educational stakeholders. Members of the Expert Review Panel, members of the Washington Science Advisory Panel, and participants in the pubic input process articulated a number of values that they believe should inform the vision for the Washington science standards:

The standards should:

- empower educators to work towards improving science education.
- support the use of well-designed curricula.
- set high expectations for students.
- allow teachers the flexibility to use a variety of instructional strategies.

The standards should not:

- preclude educators from making local decisions about the instructional strategies that will help their students to achieve the standards.
- be used to limit educational opportunities and course offerings for students who can achieve higher expectations in science.

Ultimately, the state of Washington must determine what values the document will reflect. What is essential is that these values be positive, challenging, and achievable. The values should be explicitly stated in the standards document itself and effectively communicated to all stakeholders in the education system. It is only through the development of this shared vision of education in the state of Washington that the science education system can begin to develop coherence among curriculum, instruction, assessments, teacher education, and professional development within the system.

The purpose of the science standards document must also address the intended audience for the science standards document. Although the science standards must serve educators working throughout the education system, a single document cannot meet all the needs of these diverse audiences. Instead, we recommend that the document be crafted for the primary audiences of curriculum and assessment specialists. We will elaborate on the appropriate use of the document by these and other audiences in Recommendation 4.

4	**Implementation of the science standards should result in greater coherence across the full spectrum of the education system - including curriculum development, selection of instructional materials, professional development, and assessment.**

- The standards must not be presented as the curriculum.
- Supporting documents are necessary to ensure reliable alignment between science standards, development and selection of instructional materials, professional development, classroom instruction, and assessment.
- Supporting documents should provide guidance on development and selection of standards-based instructional materials, professional development, instructional strategies, and assessment that support student achievement of the science standards and the measurement of that achievement.

This recommendation addresses what Washington State should do now to assure that the standards constructively influence the education system. Although no individual or organization can guarantee success, Washington State can establish a process that will increase the probability of fulfilling the promise of state standards.

We recommend that the state of Washington implement the *Strategic Framework for Standards-Based Reform* developed by the project on *National Science Education Standards* and described in *Improving Student Learning in Mathmatics and Science: The Role of National Standards in State Policy* (National Research Council, 1997). Such a framework helps leaders anticipate problems so they can realize the potential of standards to improve science education. Figure 3 summarizes that framework.

Figure 3	A Strategic Framework for Standards-based Reform	
Dissemination	Goal: Developing Awareness	"Getting the word out"
Interpretation	Goal: Increasing Understanding and Support	"Getting the idea"
Implementation	Goal: Changing Policies, Programs, and Practices	"Getting the job done"
Evaluation	Goal: Monitoring and Adjusting Policies, Programs, and Practice	"Getting it right"
Revision	Goal: Improving the Efficacy and Influence of Standards	"Doing it all again"

Actions by many individuals and organizations are needed if meaningful and lasting changes are to occur in science education. And, the larger the system the more coordinated the effort needs to be. The framework provided in this section is intended as an organizing tool for those responsible for standards-based reforms in education.

Similar to many models for change and improvement, the *Strategic Framework for Standards-Based Reform* (see Figure 3) has several different dimensions, each with particular goals. In the framework, the developer of the standards plays a role, as do other participants in the education system. State organizations, such as the Washington Science Teachers Association, play a major part in initial dissemination of the standards, but they do not implement the standards. The framework helps organize thinking about what strategies are needed and clarifies where responsibility and authority lie for making changes in the various components of the education system.

Although the framework is designed as a means of thinking about state standards, it is equally appropriate as a means of thinking about decisions at local levels.

Dissemination involves developing a general awareness of the existence of the standards document among those responsible for policy making, programs, and teaching, and providing support and encouragement for the changes that will be required.

Dissemination includes addressing the questions, "What are the science standards?" "Why are they needed?" and "How could they be used to shape policies, programs, and practice?" Although the current Washington science standards have been widely disseminated, what has been lacking during this process is clarity with regard to the message about what the standards can do (and cannot do), and why they are worth supporting. Being clear in the dissemination phase will help neutralize some criticisms and build support for the changes implied by the standards. As a final note on dissemination, leaders will need support from both the educational community and the general public.

Interpretation is about increasing understanding of and support for standards.

Interpretation involves careful analysis, dialogue, and the difficult educational task of challenging current conceptions and establishing a knowledge base that helps the community respond to critics. Deeper and richer understanding of standards is the goal.

Implementation involves changing policies, programs, and practices to be consistent with standards.

People modify the district and school science curriculum, revise criteria for the selection of instructional materials, change teacher credentialing and recertification, and develop new assessments. Enacting new policies, programs, and practices builds understandings that can feed back into interpretation.

In the evaluation dimension, information gathered about impact can contribute directly to improvement.

Monitoring of and feedback to various parts of the system results in modification and adjustment of policies, programs, and practices.

At some point, as a planned element of the process, revision of standards occurs, incorporating the new knowledge developed through implementation and evaluation and drawing heavily on input and discussion generated in the field by the original documents.

There exists some logical sequence to the dimensions. For example, people need to become aware of standards before they deepen their understanding through interpretation activities. Likewise, implementation without understanding can lead to change that is mechanical, superficial, and, in the extreme, can imperil reform with the dismissal that "it doesn't work." Effective implementation requires interpretation and understanding. Revision without adequate evaluation will not reflect what is learned from the original effort. Note, however, that while the framework may seem linear, its dimensions are intertwined. For example, because practice informs understanding, implementation can lead to a new or deeper interpretation of the standards or elements of them. Evaluation and reflection pervade all other dimensions.

The different dimensions of the framework are played out with different audiences, as shown in Figure 4. These audiences are organized into four categories that reflect each audience's primary role in the system: policy, program, practice, and political and public support.

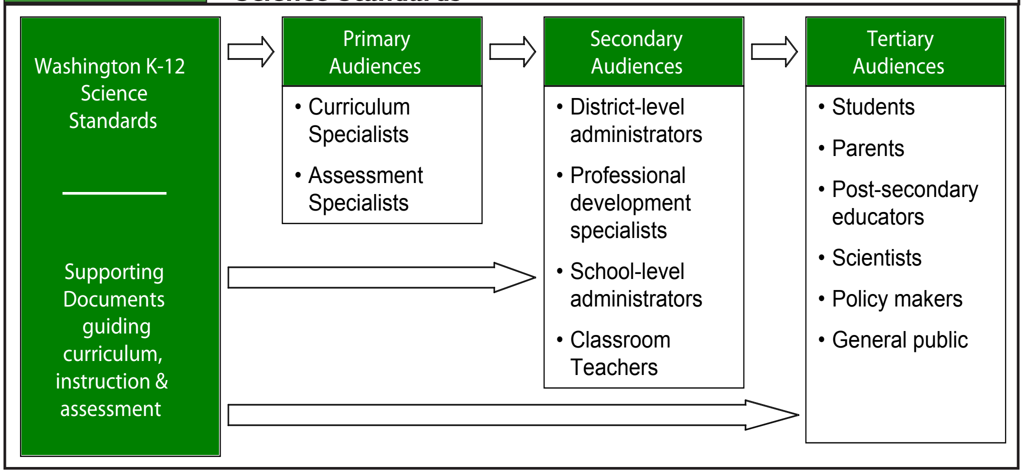
Figure 4	Participants in Standards-Based Education
Policy	Governors and State Legislators State Education Departments State and Local School Boards School Districts School Personnel
Programs	Colleges and Universities Publishers Curriculum and Assessment Developers School Districts Business and Industry Informal Educators Professional Organizations
Practices	Teachers Students
Political Support	Scientists and Engineers Business and Industry Federal, State, and Local Governments Parents General Public Teacher Unions

Although the developers of standards will likely have major responsibility for dissemination, they can be assisted by state agencies, special coalitions, or cadres of leaders. Responsibility and authority for implementation do not necessarily lie with the organizations that developed standards. The organizations or agencies can provide support and expertise, as well as help in networking various implementers, but they are not always positioned to change policies and practices directly. State supervisors, curriculum developers, teacher educators, and classroom teachers assume major responsibility for implementation.

As discussed in Recommendation 3, we recommend that the state of Washington recognize all of the diverse groups outlined above as important audiences of the sciences standards but also acknowledge that a single document cannot meet the varied needs of these groups. To ensure that implementation of the standards is coordinated across the components of the education system, Washington must establish the science standards as a central set of tenets that guide curriculum development, instructional practices, professional development, and assessment for science education; but the State must also provide appropriate avenues by which the professionals within these components of the education system can appropriately interface with the science standards. In some cases this may require the assistance of curriculum or assessment specialists who are the primary audiences of the science standards, and in other cases it may require supporting documents, developed by these primary audiences, that are supplements to the science standards.

To support this effort, we propose the implementation model shown in Figure 5.

Figure 5 **Implementation Model for the Washington K-12 Science Standards**



As shown in the model above, we envision the Washington science standards as central to guiding efforts across the education system, and we recognize primary, secondary, and tertiary audiences for the science standards. Although we refer to specific professionals in discussing these audiences (e.g. curriculum specialists), we acknowledge that other professionals may perform the functions typically associated with these specialists. For example, teachers often serve as curriculum developers. When acting in the role of a curriculum or assessment specialist, an individual is considered to be a member of the primary audience, regardless of his or her profession. Each audience interfaces with the Washington science standards in a unique manner:

1. The **primary audience** of the science standards includes curriculum and assessment specialists. The standards must serve the needs of both of these audiences equally well. Although the document itself does not serve as a curriculum or as test specifications, it should facilitate the development or selection of curricula by curriculum specialists and the development of test specifications by assessment specialists.

   Curriculum specialists should develop or select curricula that are based on the standards for use by classroom teachers. In addition, curriculum specialists should provide guidance on instructional strategies that integrate concepts and enable students to meet more than one standard in a unit or series of lessons. For example, inquiry standards and content standards can often be included in the same series of lessons. This is an instructional strategy that not only reduces the amount of instructional time necessary to cover the standards, but also reflects best practices within the field.

   Assessment specialists should develop assessment specifications or select assessment items that are also based on the standards. The Science WASL Specifications serve as a core supplemental document that assessment specialists use both in their work to develop test items and to communicate assessment strategies to teachers and educational administrators.

2. The **secondary audience** of the science standards includes other professionals working within the science education system such as educational administrators at the school and district levels, professional development specialists, and teachers. Although these audiences must be familiar with the science standards, they should rely on the work of curriculum and assessment specialists to facilitate interpretation of the standards for their needs.

3. The **tertiary audience** of the science standards includes the stakeholders in the education system and the general public, such as parents, scientists, and post-secondary educators. These audiences must be able to reference the science standards as documentation of what the students in the state of Washington are expected to know and be able to do, but they require guidance from the primary and secondary audiences to ensure that they understand the purpose of the document and how it informs curricular and assessment decisions.

Establishing a set of comprehensive science standards is central to ensuring coherence across the science education system in the state of Washington. However, the development of the science standards document alone cannot ensure this coherence. The education system must support the use of the science standards to ensure that educators across the system are applying the best practices within curriculum development, professional development, assessment, and classroom teaching so that students across the state of Washington achieve these standards.

Recommendations to Inform the Design and Writing of a New Washington Science Standards Document

OSPI is tasked with revising the science standards for the state of Washington, based on the recommendations of the SBE. The next set of seven recommendations are directed at the Science Standards Revision Team that OPSI will assemble. These recommendations are based on the findings from the Expert Panel's review and informed by the input of the Washington Science Advisory Panel. Where appropriate, we have provided examples to illustrate both strengths and weaknesses of the current set of standards and to provide examples from other states and nations that serve as useful references for the revision process.

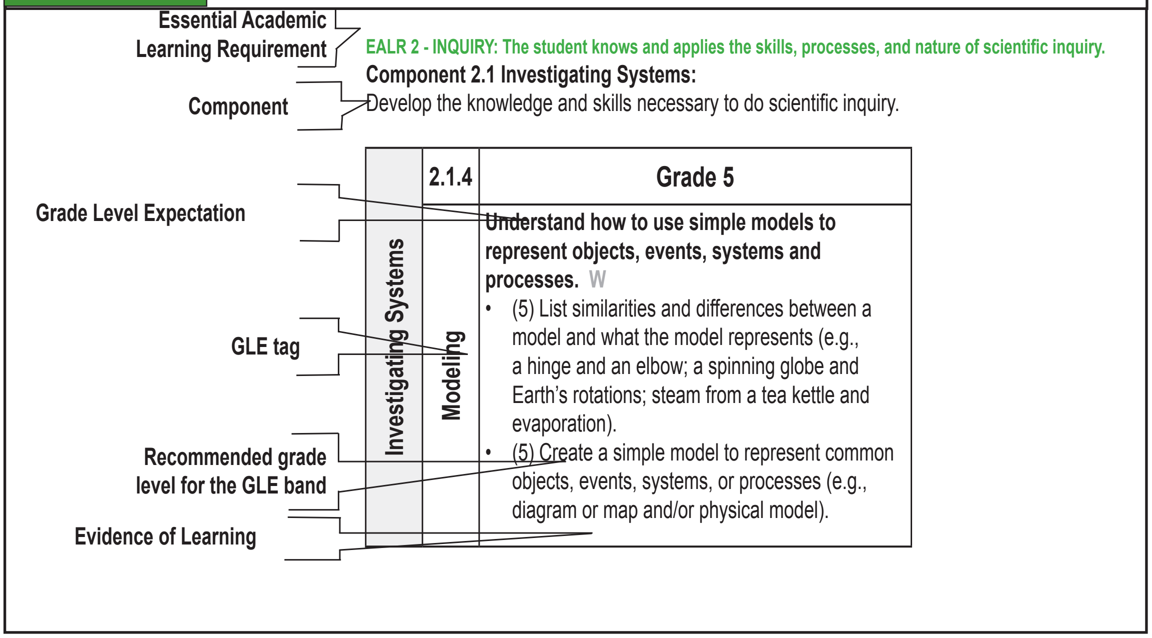
5 Simplify the organization of the Washington science standards document.

- Reduce the number of organizing elements to improve user navigation of the document.
- Organize the discipline content, currently provided in EALR 1, by life sciences, earth and space sciences, and physical sciences.
- Include the same clear delineation of science content, methods of science, and applications that is provided in the current document.
- Continue to provide standards for grade spans rather than for grade levels, including expanding the high school span to integrate grades 11 and 12.

When compared to Finland, Singapore, and Massachusetts, Washington received a low rating for Accessibility/Navigability (2 out of a possible 4). Although reviewers found that the format of the document supports coherence across grades spans, they noted that the presentation is overly complex, making it difficult for the reader to understand and locate needed information.

Figure 6 below displays the current organizing structure of the Washington science standards. The standards are organized into a complex hierarchy that includes an EALR, a Component, a GLE, a GLE tag, and a bulleted list of Evidence of Learning statements. For EALR 1, the Component statement organizes the EALR into GLEs that are related to properties and characteristics, structures, and changes. Standards for Physical Systems, Earth and Space Systems, and Living Systems are provided for each of these three components, thus producing a document in which the discipline content occurs in multiple places within the EALR. For example, life sciences content is included under Component 1.1: Properties, then separated by three pages of earth and space and physical sciences content before being presented again under Component 1.2: Structures.

Figure 6 **Structure of the Washington Grade Level Expectations**



Adapted from Science K-10 Grade Level Expectations: A New Level of Specificity, page 9.

Expert Panelists found that the Component feature in the current Washington document imposes an artificial structure that does not support the overall organization of the document. The component statements force the reader to read through too many layers to achieve an adequate depth of understanding of the standards, and result in an organization of content that is of little value to most users.

In contrast to the current Washington standards, both the Massachusetts and the Finland standards, which received the highest rating from reviewers, along with the *NSES*, are clearly organized by discipline content. Although the Singapore document rated higher than the Washington document, it was the lowest among the three. Like the ambitious approach that the Washington document takes by organizing the document by systems, the Singapore document uses a series of themes (diversity, cycles, systems, interactions, and energy) as the central organizer for the document. While these novel approaches are laudable because they provide a framework that encourages the integration of content across disciplines, the trade-off is a document that is challenging to navigate and contrary to the needs of most users.

In spite of the poor navigability of the current document, we find that there are helpful organizational and formatting elements in the current document that should be retained in the new Washington science standards document. For example, we favor the clear delineation of the science content, methods of science, and applications that is provided by the three EALRs over alternative presentations, by documents such as the Massachusetts standards, which present standards for inquiry within the context of the science disciplinary content. The clear delineation of these standards ensures that the standards for inquiry do not become "buried" within the individual discipline content standards. We also find that the presentation of the standards by grade span and content area in the current document facilitates an understanding of the learning progression of the content.

As shown in the figure below, the current grade span groups reflect those used in the national *Benchmarks*. Although there continues to be debate in the field over whether science standards are most appropriately presented by grade level or by grade span, our reviewers found that the grade span configuration provided in the current document appropriately balances the need to allow for flexibility with the need to articulate the learning progression in the achievement benchmarks. We therefore recommend that the new science standards document continue to organize standards by the grade spans used in the current document.

Figure 7 **Grade Span Organization of State and National Science Standards Documents**

Standards	Grade Span Groups
Washington (2005)	K-2, 3-5, 6-8, 9-10
National Science Education Standards	K-4, 5-8, 9-12
Benchmarks for Science Literacy	K-2, 3-5, 6-8, 9-12
California	K,1,2,3,4,5,6,7,8, 9-12
Colorado	K-4, 5-8, 9-12
Massachusetts	PreK-2, 3-5, 6-8, High School

6 Increase the clarity and specificity of the Washington science standards document.

- The science standards should not depend on scientific vocabulary alone to convey the meaning of an outcome statement of what students should understand or be able to do. Scientific vocabulary within the content statements is acceptable if the term is explained as part of the standard.
- The science standards should provide a more complete, detailed, and specific description of the content to be learned, with special attention to the Life Science content. Minimize the use of external references for defining the science content that is to be learned.
- The verbs used in the standards should specifically delineate what students are to understand/know or be able to do.
- The science standards should use content statements to detail the science content that is to be learned. Model the format of these statements after statements provided in reference documents such as the 2009 National Assessment of Educational Progress and the National Science Education Standards.

The current Washington science standards for the physical sciences, the earth and space sciences, inquiry, the nature of science, and science and technology rated well for specificity, with reviewers finding that they provide a description that is only slightly less detailed than the reference concepts in the *NSES*. The life sciences were found to be considerably less detailed and specific than the reference concepts. However, reviewers found it important to note that all of the content areas would have received significantly lower ratings had they not considered the ELs in their review. In addition, they found that a lack of specificity sometimes leads to a vagueness that compromises the clarity of the current Washington science standards.

In the current document, the GLE statements considered by themselves are generally of a very large grain size with little detail or specificity. It is necessary to read to the EL statements to obtain sufficient specificity to provide direction for assessment or to guide curriculum development. Unlike Washington, Massachusetts and the *NSES* provide a more detailed description of the content within the statement of the standard itself. The figure below provides examples of Washington GLEs and corresponding Massachusetts statements for similar content. Notice that the Massachusetts standards provide significantly more detail than the broad GLE statements. For example, in the last example (GLE 1.3.8) the reader is expected to fill in how organisms obtain matter and energy. The specific details are missing.

Figure 8 **Comparison of Washington and Massachusetts Statements of Science Content**

Washington	Massachusetts
GLE 1.3.3, K-2: Know that water can exist in different states: solid and liquid.	**Physical Sciences, Grades PreK-2, #2:** Identify objects and materials as solid, liquid, or gas. Recognize that solids have a definite shape and that liquids and gases take the shape of their container.
GLE 1.2.5, 3-5: Know how the Sun, Moon, and stars appear from Earth.	**Earth & Space Science, Grade 3-5, #13:** Recognize that the earth is part of a system called the "solar system" that includes the sun (a star), planets, and many moons. The earth is the third planet from the sun in our solar system.
GLE 1.3.8, 6-8: Understand how individual organisms, including cells, obtain matter and energy for life processes.	**Life Science, Grades 6-8, #16**: Recognize that producers (plants that contain chlorophyll) use the energy from sunlight to make sugars from carbon dioxide and water through a process called photosynthesis. This food can be used immediately, stored for later use, or used by other organisms.

Although the level of specificity was rated on par with the Massachusetts standards by using the ELs to add more details, once the Washington ELs were considered, reviewers noted several problems with using the EL statements as the primary source for providing needed detail.

1) ELs are not intended to be comprehensive. The *K-10 Grade Level Expectations: A New Level of Specificity* describe the ELs as:

> *A bulleted list of student demonstrations that provide educators with common illustrations of the learning. Because the bulleted list is not exhaustive, educators are encouraged to seek additional evidence of student learning from the* National Science Education Standards (NSES) *and the* American Association for the Advancement of Science (AAAS) Benchmarks*. These statements serve as the basis for the development of the WASL in science.*

Members of the Washington Science Advisory Panel also noted that the new Washington science standards should be more complete and comprehensive so that the reader is not reliant on external sources, and, in cases where external sources are referenced, specific citations should be provided to facilitate locating applicable material.

2) The selection of verbs in the ELs diminishes the specificity of the content being articulated. Verbs such as "analyze" and "explain" present the reader with an unspecified and unmeasureable outcome, thus reducing the specificity. The verbs "describe" and "identify," which are frequently used in the ELs, usually are not followed by a specified outcome, rendering the statement vague and low in specificity.

   For example, in GLE 1.1.3 for grade span 9-10, shown below, it is clear that the student should be able to provide a comparison of different wave types. However, the EL does not specify what the properties are, or what specifically students should know about them.

Figure 9	Washington GLE 1.1.3 (9-10)
Analyze sound waves, water waves, and light waves using wave properties, including frequency and energy. Understand wave interference. ▪ **EL:** Compare the properties of light waves, sound waves, and water waves.	

3) The ELs are not always appropriately aligned with the GLEs. As shown in Figure 10, in some cases it is difficult to judge the level of alignment because the GLE is not written with sufficient specificity. In other cases, the EL simply does not represent a concept or level of cognitive demand that is consistent with the one articulated in the GLE.

Figure 10 **Examples of Alignment Concerns for Washington GLEs and ELs**

Washington GLE & EL	Alignment Concern
GLE 1.2.5 (6-8) Understand the structure of the Solar System. ▪ **EL:** Describe the Sun (i.e., a medium-size star, the largest body in our solar system, major source of energy for phenomena on Earth's surface).	The GLE implies that students' descriptions of the sun should be in relation to the structure of the solar system. However, the parenthetical example indicates that they must be able to describe the role of the sun as "the major source of energy for phenomena on Earth's surface."
GLE 1.2.4 (3-5) Understand that the Earth's system includes a mostly solid interior, landforms, bodies of water, and an atmosphere. ▪ **EL:** Describe how one part of the Earth's system depends on or connects to another part of Earth's system (e.g., Puget Sound water affects the air over Seattle).	While the GLE indicates that students should know what the components of the Earth's system are, the EL implies an understanding of how the parts of the system relate to one another.

Based on these findings, we recommend that the new Washington science standards include more comprehensive content statements that detail the science content that students are expected to learn. Content statements express scientific principles and concepts and, unlike the EL statements, they are inclusive of the science content that students are expected to learn. For example, a content statement from the *NAEP Framework* for the Grade 8 content related to GLE 1.2.5 shown in the table above is:

> *In contrast to earlier theory that Earth is the center of the universe, it is now known that the sun, an average star, is the central and largest body in the solar system. Earth is the third planet from the sun in a system that includes seven other planets and their moons, as well as smaller objects, such as asteroids and comets.* – Science Framework for the 2009 NAEP, page 54.

Notice that this content statement provides detail about the science content that is to be learned that is lacking from both the GLE and the ELs in the current Washington document. Both the *NAEP Framework* and the *NSES* provide good examples of content statements.

The weakness in the current standards is that they lack sufficient specificity with regard to the science content to guide the development and selection of curricula. We believe that the inclusion of content statements will greatly enhance the usability of the Washington science standards by both curriculum and assessment specialists and ultimately support the development of a more coherent science education system in the state of Washington.

7 Increase the rigor of the Washington science standards document.

- Some concepts currently introduced in grades 3-5 should be introduced earlier.
- Increase the levels of cognitive demand of the standards at all grade spans.
- With the addition of grades 11 and 12, the learning progression across grade spans for each standard should be revisited and content redistributed, with special attention to grade spans 6-8 and 9-12.
- Use the most current research on learning progressions within disciplines to establish what students should know and be able to do at each grade span.

Reviewers found that the current standards for grade span 3-5 will probably support the proficient achievement level in the *NAEP Framework*; they were unsure whether the GLEs for grade span K-2 would support the proficient achievement level; and they found that the GLEs for grade spans 6-8 and 9-10 probably will not support the proficient achievement level.

In the current document, reviewers found that the application of the verbs in Bloom's Taxonomy, with a progression in the verbs from the taxonomy across grade spans, results in confusion and in some cases lowered expectations. Although Bloom's Taxonomy provides a useful framework for cognitive demand, the application of increasing levels of cognitive demand at increasing grade spans is inappropriate. Students at lower grade spans are are capable of some, if not many of the higher levels of cognitive demand in the Taxonomy. As a result of the application of Bloom's Taxonomy in the current standards, the levels of cognitive demand required for the Washington GLEs do not support proficiency for the Using Scientific Principles category of items in the *NAEP Framework*. We recommend that the new Washington science standards adopt a framework for cognitive demand that increases the levels of cognitive demand of the standards at all grade levels.

The question of rigor will be particularly important as the Science Standards Revision Team undertakes the development of a set of K-12 science standards. We recommend that the development the new K-12 document not be undertaken as merely an effort to add-on content for two additional grade levels. Instead, it should be used as an opportunity to set new expectations for what students should accomplish by grade 12 and to review what is currently understood about learning progressions within disciplinary areas to strengthen the rigor and the progression of content in the Washington science standards so that it provides a foundation for expectations at grade 12.

The Science Framework for the 2009 NAEP *divides science content expectations into Identifying Science Principles and Using Science Principles. The Identifying Science Principles category "focuses on students' ability to recognize, recall, define, relate, and represent basic science principles specified in the Physical Science, Life Science and Earth and Space Science content statements, while the Using Science Principles category "draws on 'schematic knowledge,' or 'knowing why' in addition to 'declarative knowledge.'" The* NAEP *is designed to include more Using Science Principles items than Identifying Science Principles items.*

Washington's Higher Education Coordinating Board has developed a *Preliminary set of Science College Readiness Definitions* that are intended to "articulate the relationship between Washington's K-10 learning standards and the knowledge and skills students need to develop throughout high school, particularly during the last two years of high school." The Expert Review Panel reviewed these definitions with an eye for how they might inform the development of science standards that extend through grade 12 in the state of Washington. The Panel concluded that the definitions cannot be easily adapted for use as science standards.

However, the document does provide a broad reference for the Science Standards Revision Team, particularly with regard to developing rigorous standards for students in grades 9 through 12. For example, College Readiness Definition A indicates that "students will demonstrate facility in the core science concepts at cognitive demand levels beyond those described in the Washington State Science EALR 1. The emphasis will move from primarily knowing and understanding towards synthesizing, evaluating and transferring knowledge and skills across disciplines to solve problems and generate explanations." Clearly, the *College Readiness Definitions* document reinforces the assertion that the Washington science standards must set higher expectations for the levels of cognitive demand with which students approach science content if students are to be prepared for post-secondary education by the completion of grade 12.

Reviewers of the current science standards noted that although the document is clearly attentive to progression between grade spans, this progression often appears to be based on "what kids could do next," rather than based on current research about learning progressions within each discipline. We recommend that the Revision Team reference the most current research on learning progressions to ensure that the Washington K-12 science standards are consistent with best practices.

The recent National Research Council publication Taking Science To Schools *(2007), provides a useful starting place for incorporating the latest research on learning progressions. The publication clearly articulates the need for standards that are "deeply informed by research on children's learning such that the sequences are grounded also in what we know about the ideas children bring to the classroom that can form the foundation for developing understanding of scientific ideas."*

All three of the comparison states, the *NSES*, and the *Benchmarks* use a "high school" or single 9-12 grade span configuration of science standards. Members of the Washington Science Advisory Panel voiced a preference for standards that clearly identify what students are expected to know and be able to do by grade 10 because the WASL is administered at this grade level. They also raised questions about the implication of a set of 9-12 science standards that may appear inconsistent with Washington's current requirements for two years of high school science.

We recommend that the state of Washington develop standards that reflect what students are expected to know and be able to do by grade 12, and then establish graduation requirements and assessment strategies to align with these standards. Fundamentally, the standards should provide direction to the education system rather than being constrained by the artifacts of the current system. With this in mind, we recommend a single grade span for grades 9-12 that clearly articulates what students should know and be able to by the time they complete their K-12 education. This approach provides flexibility to districts, schools, and teachers to determine what strategies and courses of study will help their students to achieve these standards.

8 Strengthen the standards for inquiry in the state of Washington.

- Devote more attention to the "abilities" of inquiry in addition to the "understandings" of inquiry. Students at all grade levels should be expected to demonstrate the abilities of inquiry.
- Incorporate linkages to the Washington State K-12 Mathematics Standards.
- Provide guidance to clarify the purpose of the inquiry standards as defining learning outcomes for students rather than outlining instructional strategies.

Reviewers found that compared to other states, Washington has a better than average inclusion of inquiry in the science standards. As a result, some members of the Washington Science Advisory Panel questioned the necessity of including a recommendation related to the inquiry standards. We elected to include this recommendation because, as other Advisory Panel members noted, if students in the state of Washington are to be appropriately prepared to be members of the 21st century workforce, then it is essential they graduate with critical thinking skills that allow them to conceptualize, apply, analyze, synthesize, and evaluate information based on their observations and experiences. We therefore recommend that Washington strengthen the standards for inquiry to create standards that serve as a model for those in other states.

The *NSES* emphasize that students at all grade levels should "develop the ability to think and act in ways associated with inquiry," rather than merely understanding the nature of scientific inquiry. As discussed in the Content findings for EALR 2, the current Washington inquiry standards overemphasize the "understandings" of inquiry and give too little attention to the "abilities" of inquiry. Few of the grade span 6-8 or 9-10 GLEs for inquiry address the abilities of inquiry, and none of the K-2 or 3-5 GLEs do so.

The inquiry standards provide an opportunity to develop linkages to the Washington math standards. The Science Standards Revision Team should review the recently released Washington State K-12 Mathematics Standards with particular attention to the core content area of *Summary and Analysis of Data Sets*. Where appropriate, the Revision Team should incorporate references to the mathematics standards into the inquiry standards to ensure coherence between the science and math standards. The *Massachusetts Technology/Engineering* standards provide a useful model for including these references.

As described in the *NSES*, it is reasonable to expect all students, even those at the early grade levels, to demonstrate the abilities of inquiry. Limiting the expectations for early grade levels to those of "understanding" undermines the development of appropriate expectations for students. This weakness in the inquiry standards relates to the problematic application of Bloom's Taxonomy described in Recommendation 7. We recommend that in developing the new science standards, the Revision Team be particularly attentive to including the abilities of inquiry.

In addition to re-crafting the inquiry standards themselves, we recommend that the Revision Team develop a clear orientation that the inquiry standards serve as learning outcomes for students and not as instructional strategies for teachers. The inquiry standards define expectations for what students should know and be able to do. They do not document best practices for how teachers help students to achieve these expectations. In fact, current best practices for instruction in inquiry promote the integration of inquiry techniques with conceptual content.

Participants in both the Washington Science Advisory Panel and the Expert Review Panel reported that many teachers approach the Washington standards as an outline of what they are to teach for the year. As a result, they cover the EALR 1 content for the Physical, Earth and Space, and Life Sciences first, and sometimes "run out of time" for the inquiry content that is presented in EALR 2. We recommend that the Washington science standards and supporting documents provide explicit guidance to 1) clarify the nature of the inquiry standards as learning outcomes and 2) promote instructional strategies that integrate disciplinary content and inquiry in the classroom to help students attain these learning outcomes.

The Washington science standards should provide guidance to ensure that the use of inquiry standards as learning outcomes for students does not perpetuate the problem of poor instructional practices related to the teaching of inquiry:

> *Many textbooks and curriculum documents still have separate sections on scientific inquiry, science processes, or "the scientific method." Many classroom teachers follow the lead of these resources, teaching skills and inquiry techniques separately from the conceptual content of their courses.*
> – Taking Science to Schools (2007, page 216).

9 Improve the standards for Science and Technology.

- In addition to the "understandings" of technological design, increase focus on the "abilities" of technological design.
- Provide relevant, "real-world" examples to illustrate the concepts that are articulated in the standards.

The current science and technology standards for the state of Washington reviewed well, receiving ratings of 3's for the criteria of content, specificity, coherence, and depth, and in all cases meeting or exceeding the ratings of the comparison states. Like the standards for inquiry, student achievement of the standards for science and technology is fundamental to efforts to develop a 21st century workforce for the state of Washington. We therefore recommend that the Science Standards Revision Team devote attention to improving these already strong standards.

Like the current inquiry standards, the current science and technology standards provide too little attention to the "abilities" of technological design. The current GLEs for science and technology focus almost exclusively on the understanding of science and technology in the K-2 and 3-5 grade spans.

Reviewers found that examples are essential for illustrating the concepts in the science and technology standards. Without the inclusion of "real-world" examples, the learning outcomes that are articulated in the standards are often unclear to the reader. For example, GLE 3.1.3, shown below with two ELs, provides very little context for understanding the types of problems that students are expected to explore. As a result, the reader does not have a clear understanding of the learning outcome. We recommend that the Science Standards Revision Team reference the examples provided in the *NSES* and the *Massachusetts Technology/Engineering Standards* to provide "real world" examples of the science and technology standards to facilitate an understanding of the intended learning outcome.

> *The science and technology standards establish connections between the natural and designed worlds and provide students with opportunities to develop decision-making abilities. They are not standards for technology education; rather, these standards emphasize abilities associated with the process of design and fundamental understandings about the enterprise of science and its various linkages with technology.* – NSES, page 106.

Figure 11	Washington GLE 3.1.3 (6-8)
Analyze multiple solutions to a problem or challenge. ▪ Describe the criteria to evaluate an acceptable solution to the problem or challenge. ▪ Describe the reason(s) for the effectiveness of a solution to a problem or challenge using scientific concepts and principles.	

10	Develop standards to address Science in Personal and Social Perspectives.

- Include the Science in Personal and Social Perspectives content found in the NSES.

The *NSES* standards for science in personal and social perspectives outline learning outcomes for students with regard to personal and community health; population characteristics; natural hazards and resources; environmental change and quality; natural and human-induced hazards; and science and technology challenges. These standards set expectations that students understand science and its connection to contemporary social issues. A sample of the fundamental concepts underlying these standard for the 9-12 grade span are provided below.

Figure 12	Sample of Concepts Underlying the *NSES* 9-12 Grade Span Standard for Science in Personal and Social Perspectives
Population Growth	Populations grow or decline through the combined effects of births and deaths, and through emigration and immigration. Populations can increase through linear or exponential growth, with effects on resource use and environmental pollution.
Natural Resources	The earth does not have infinite resources; increasing human consumption places severe stress on the natural processes that renew some resources, and it depletes those resources that cannot be renewed.
Environmental Quality	Natural ecosystems provide an array of basic processes that affect humans. Those processes include maintenance of the quality of the atmosphere, generation of soils, control of the hydrologic cycle, disposal of wastes, and recycling of nutrients. Humans are changing many of these basic processes, and the changes may be detrimental to humans.

Like the comparison states, the current Washington science standards provide very little content related to science in personal and social perspectives. Some members of the Washington Science Advisory Panel questioned whether it is necessary to include this content in the Washington science standards because it is not present in the standards that were selected as benchmarks for the state of Washington. We contend that the science in personal and social perspectives content, like the inquiry and science and technology content, is fundamental to Washington's effort to prepare a 21st century workforce. We therefore recommend that the Science Standards Revision Team develop science standards for the science in personal and social perspectives content outlined in the *NSES*.

Although we recognize that the addition of the science in personal and social perspectives content adds to the volume of expectations required of students in the state of Washington, we believe that we would be remiss in not recommending the addition of this material. In consideration of the concerns expressed by the Washington Science Advisory Panel that the current standards already include too much information to be covered during the school year, in Recommendation 11 we provide suggestions for developing an overall set of science standards that can be reasonably accomplished during the course of a school year.

11 The Washington science standards should reflect the balance and depth of content found in the National Science Education Standards.

- Focus on fundamental concepts and abilities presented in the NSES.
- With the development of the new K-12 document, ensure that the Washington Standards contain all of the content from the NSES, with particular attention to Life Sciences.
- Eliminate areas of redundancy found in the current Washington science standards.

We recommend that the new Washington science standards focus on covering those concepts included in the *NSES*. The *NSES*, along with the *AAAS Benchmarks* informed the development of the current Washington science standards. The *NSES*, along with the *Benchmarks*, remain the primary science standards reference in the field because they were subjected to extensive internal and external reviews during development, and they are still considered to reflect the nation's best thinking on what students should know and be able to do in science. Indeed, the *NSES* are cited in the *NAEP Framework* as a primary reference for the development of the framework.

As the Science Standards Revision Team undertakes the development of the new K-12 science standards document, the team should ensure that the science standards reflect the content of the *NSES*. In some cases this development will entail redistributing existing content from grade levels prior to 11 and 12, particularly for the 9-10 grade span, and in other cases it will be necessary to add additional content from the *NSES*. In the current standards, the cell receives limited treatment (GLE 1.2.6) as compared to the description provided in the *NSES*. The *High School Biology Standards for Massachusetts* for example, provide a more comprehensive coverage of the cell that more closely follows the *NSES*.

The Expert Review Panel, the Washington Science Advisory Panel, and participants in the public input process expressed the concern that the science standards should not suffer from being "a mile wide and an inch deep." Panelists in both groups cautioned against sacrificing depth of content by adding to the breadth of the science standards to be covered. We recommend that the Science Standards Revision Team work to create a new science standards document that presents standards that can be reasonably accomplished during the K-12 progression by being attentive to the following during the revision process:

1) **Focus on the fundamental concepts and abilities presented in the *NSES*.** For example, the current science standards devote considerably more attention to Human Biology and fossil evidence than do the *NSES*, so these are areas that could receive less attention in the new science standards.

2) **Eliminate areas of redundancy.** For example, the life sciences content was found to contain redundancies between grade spans in the standards related to classification (GLE 1.1.6). Retention of fundamental content from one grade-level to the next should be assumed and therefore, it is not necessary to repeat content between grade-levels.

3) **Use introductory material and appendices of the science standards to point educators to supporting documents that highlight best practices in curriculum development and instructional strategies, specifically those that provide guidance for integrating multiple concepts into a unit or series of lessons.** As an example, inquiry standards and content standards can often be included in the same series of lessons. In a similar way, content and abilities of technological design can be met in the same unit. These strategies not only represent best practices in the field but also reduce the amount of instructional time necessary to cover the standards.

Conclusion

The recommendations presented in this report are based on the analysis and findings of an Expert Review Panel, public input from a preliminary set of recommendations, input from the Washington Science Advisory Panel, and the collective experience of the DHA project team developing and implementing national and state-level science standards. The recommendations provide a foundation for the development of a set of science standards that set high expectations for all students in Kindergarten through 12th grade in the state of Washington. They also provide guidance for the policies and practices that must be in place to ensure the science standards support a coherent science education system. The state of Washington will be well served by SBE and OSPI undertaking this effort to develop a new set of science standards and guidelines for implementation of those standards. This effort today will help provide Washington with the educated citizenry necessary to meet the workforce needs of tomorrow, positioning the state to realize its full potential as a global leader in science and technology, as well as the diverse economies dependent on science and technology to thrive.

Appendices

Appendix A: Reports for Reference

An important first step in the process of reviewing the Washington Science Standards is to review the established national and international reports that inform current thinking on the format, content, and appropriate use of science standards. This section provides a description of two landmark publications of science standards: *Benchmarks for Science Literacy* (American Association for the Advancement of Science, 1993) and the *National Science Education Standards* (National Research Council, 1996). It also describes the most recent frameworks available for three assessment systems that are currently used to measure student achievement in science: *National Assessment of Educational Progress (NAEP), Trends in International Mathematics and Science Study (TIMSS)*, and *Programme for International Student Assessment (PISA)*. Finally, descriptions of the two Washington state science documents that will serve as the basis of the review are provided: *K-10 Grade Level Expectations: A New Level of Specificity* (2005) and *Preliminary Science College Readiness Definitions* (2007).

National Science Education Standards and Benchmarks for Science Literacy

National Science Education Standards

The *National Science Education Standards* (*NSES)* were developed by the National Resource Council under the guidance and review of the National Academies of Science and published in 1996. As stated in the *NSES*:

> The National Science Education Standards present a vision of a scientifically literate populace. They outline what students need to know, understand, and be able to do to be scientifically literate at different grade levels… The standards apply to all students regardless of age, gender, cultural or ethnic background, disabilities, aspirations, or interest and motivation in science. They describe the science content that students should learn.

The content of *NSES* is unique among standards in that it contains more than content standards. The content standards are arranged by grade level spans (K-4, 5-8, 9-12). With the exception of Unifying Concepts and Processes, all eight content standards are included at each grade level span. The document contains the following standards:

- Standards for science teaching
- Standards for professional development
- Standards for assessment in science education
- Standards for science content
    - o Unifying Concepts and Processes K-12
    - o Science as Inquiry
    - o Physical Science

    - Life Science
    - Earth and Space Science
    - Science and Technology
    - Science in Personal and Social Perspectives
    - History and Nature of Science
- Standards for science education programs
- Standards for science education systems

Each of the nine science content standards is organized into three to five "categories" or broad conceptual topics. As an example the Physical Science Standards for grade span 5-8 contain three categories, "properties and changes in properties of matter, motions and forces, and transfer of energy." The standards are followed by a few pages of narrative that discuss the progression of learning through the grade levels and what is known about research on how students learn the content. A variety of classroom vignettes illustrating what the learning of the standards looks like in schools are inserted at various places in the document.

Within these standards a number of "evidences of understanding" are listed. These evidences of understanding are what are often considered the standards by the casual reader. These statements of understanding or abilities represent fairly large "grain size" amount of content and are often three or four sentences long at the upper grade spans making it possible to indicate the substance of what is to be learned and how extensive or elaborate the learning is to be. The stem of each standard reads; "As a result of their activities in grades (K-4, 5-8, or 9-12), all students should develop an understanding of …" The evidences of understanding are written as statements of major scientific ideas or concepts. The abilities of inquiry standards and the abilities of technological design standards are preceded with the stem "As a result of their activities in grades (K-4, 5-8, or 9-12), all students should develop abilities necessary to do…"

The standards were drafted by a working group of 18 volunteers made up of approximately equal numbers of classroom teachers, scientists, and university and K-12 science educators. The drafts were reviewed and edited by a small staff before being reviewed by the National Committee on Science Education Standards and Assessment, a large oversight group consisting of members of the National Academy of Sciences, and experts from a number of educational disciplines. After a thorough review of initial drafts the final document was reviewed using the National Research Council's rigorous Report Review Process.

Insights from the *NSES* include the manner in which inquiry and technology are handled and the use of the verb "understand." Both the abilities of inquiry and the understanding of inquiry are included in the content standards. In a similar fashion, the Science and Technology Standards include both the abilities of technological design and the understanding of science and technology. The use of the verb "understand" in the *NSES* and "know" in the *Benchmarks for Science Literacy*, discussed below, are considered to have the same level of depth and rigor.

Benchmarks for Science Literacy

The *Benchmarks for Science Literacy (BMfSL)* were developed by Project 2061 at the American Association for the Advancement of Science and published in 1993. The content in the *Benchmarks* was derived from an early report, *Science for All Americans (SFAA)*. The Introduction to the *Benchmarks* states that:

> *SFAA* answers the question of what constitutes adult science literacy, recommending what all students should know and be able to do in science, mathematics, and technology by the time they graduate from high school. *Benchmarks* specifies how students should progress toward science literacy, recommending what they should know and be able to

> do by the time they reach certain grade levels. Together the two publications can help guide the reform in science, mathematics, and technology education.

Benchmarks is divided into 12 chapters. Each chapter contains the benchmarks for all four grade level spans (K-2, 3-5, 6-8, 9-12):

- The Nature of Science
- The Nature of Mathematics
- The Nature of Technology
- The Physical Setting
- The Living Environment
- The Human Organism
- Human Society
- The Designed World
- The Mathematical World
- Historical Perspectives
- Common Themes
- Habits of Mind

Each chapter opens with a short quote from *SFAA* and a few overall comments about the ideas to be learned and, in very general terms the kinds of student experiences that would foster learning. The chapters are divided into a small number (usually 4 to 6) of sections containing the benchmarks by grade level span. Each section has an introduction with comments on common difficulties in learning the ideas, on pacing over grade levels, and on clarification of the ideas in the benchmarks. Each grade span also has a few comments to clarify what “knowing” entails and suggestions of what students’ experiences might include and what difficulties students might have. These comments are followed by the grade span benchmarks.

According to *Benchmark*s (page XII):

> In 1989, six school districts teams were formed in different parts of the nation to rethink the K-12 curriculum and outline alternative ways of achieving the literacy goals of *SFAA*. Each team, backed by consultants from and Project 2061 staff, was made up of 25 teachers and administrators and cut across grade levels and subjects. Working together over four summers and three academic years, the teams developed a common set of benchmarks. Drafts of *Benchmarks* were critiqued in detail by hundreds of elementary-, middle-, and high-school teachers, as well as by administrators, scientists, mathematicians, engineers, historians, and experts on learning curriculum design.

Important insights from this document include the manner in which learning is specified for each grade span. The “grain size” of *Benchmarks* is comparable to that in *NSES* each one containing enough information to indicate the substance of what is to be learned and how extensive or elaborate the learning is to be. The authors note that “*Benchmark* statements, whenever possible, are cast in language that approximates the intended level of sophistication.” According to the authors of *Benchmarks,* “know” implies that students can explain ideas in their own words, relate ideas to other benchmarks, and apply the ideas in novel contexts.

Assessment Frameworks

Unlike the *Benchmarks* and the *NSES*, which provide standards that can be used to support the development of curricula and assessment tools, the following documents provide guidance on the science content to be assessed, the types of assessment questions, and the administration of the assessment for three systems for assessing student achievement in science: *NAEP*, *PISA*, and *TIMSS.*

National Assessment of Educational Progress (NAEP) Science—2009-2019

The National Assessment of Educational Progress measures student science achievement nationally, state-by-state, and most recently across selected urban school districts. Periodically, the framework underlying the science assessment is revised or updated. The *Science Framework for the 2009 NAEP* (hereafter referred to as *Framework*) contains recommendations for the *NAEP Science Assessment* to be administered in 2009 and beyond. The *Framework* provides guidance on the science content to be assessed, the types of assessment questions, and the administration of the assessment.

Any *NAEP* framework must be guided by *NAEP* purposes as well as the policies and procedures of the National Assessment Governing Board (NAGB), which oversees *NAEP*. For the *NAEP Science Assessment*, the main purpose of the *Framework* is to establish what students should know and be able to do in science for the 2009 and future assessments. Meeting this purpose requires a framework built on what communities involved in science and science education consider as a rigorous body of science knowledge and skills that are most important for *NAEP* to assess.

In prioritizing the content, the *Framework* developers used two national documents, *National Science Education Standards* (NRC, 1996) and *Benchmarks for Scientific Literacy* (AAAS, 1993), as representative of the leading science communities and their expectations for what students should know and be able to do in science. As curriculum frameworks, however, these documents cover a very wide range of science content and performance. The inclusive nature of both these documents demonstrates the difficulty of identifying a key body of knowledge for students to learn in science and, therefore, what should be assessed. Neither document limits or prioritizes content as is necessary for developing an assessment, posing a considerable challenge to the *Framework* developers and those using the *Standards* and *Benchmarks* for curriculum reform. The development of the *Framework* also was informed by research in science and science education, best practices, international assessment frameworks, and state standards.

Development of the *NAEP 2009* was directed by a number of criteria. We include summaries of several criteria as they should inform decisions about the development of Washington science education standards and subsequent use of those standards for curriculum, instruction, assessment, and teacher education and professional development.

- **The NAEP 2009 Framework is informed by the National Standards and Benchmarks.** The *Framework* reflects the nation's best thinking about the importance and age-appropriateness of science principles and thus is informed by two national documents that were subject to extensive internal and external reviews during their development.
- **The NAEP 2009 Framework reflects the nature and practice of science.** The *National Standards* and *Benchmarks* include standards addressing science as inquiry, nature of science, history of science, and the human-made world. The *Framework* emphasizes the importance of these aspects of science education and should include the expectation that students will understand the nature and practice of science.
- **The NAEP 2009 Framework uses assessment content, formats, and accommodations consistent with the objectives being assessed.** The best available research guides assessment item design and delivery. The *Framework* is inclusive of student diversity as reflected in gender, geographic location, language proficiency, race/ethnicity, socio-economic status, and disability.
- **The NAEP 2009 Framework uses a variety of assessment formats.** These include well-constructed selected response and open-ended responses as well as performance tasks. In addition, multiple methods of assessment delivery should be considered, including the appropriate uses of computer technology.

- **Each achievement level—Basic, Proficient, and Advanced—includes a range of items assessing various levels of cognitive knowledge that is broad enough to ensure each knowledge level is measured with the same degree of accuracy.** Descriptions of Basic, Proficient, and Advanced are clear.

The design of the *NAEP 2009 Science Assessment* is guided by the *Framework's* descriptions of the science content and practices to be assessed. Figure 2 illustrates how content and practices are combined ("crossed") to generate performance expectations. The columns contain the science content (defined by content statements in three broad areas), and the rows contain the four science practices. A double dashed line distinguishes Identifying Science Principles and Using Science Principles from Using Scientific Inquiry and Using Technological Design. The former two practices can be generally considered as "knowing science," and the latter two practices can be considered as the application of that knowledge to "doing science" and "using science to solve real-world problems."

Figure 2. Crossing Content and Practices to Generate Performance Expectations

		SCIENCE CONTENT		
		Physical Science content statements	**Life Science** content statements	**Earth and Space Science** content statements
SCIENCE PRACTICES	**Identifying Science Principles**	*Performance Expectations*	*Performance Expectations*	*Performance Expectations*
	Using Science Principles	*Performance Expectations*	*Performance Expectations*	*Performance Expectations*
	Using Scientific Inquiry	*Performance Expectations*	*Performance Expectations*	*Performance Expectations*
	Using Technological Design	*Performance Expectations*	*Performance Expectations*	*Performance Expectations*

The content statements are organized according to the three broad content areas that generally comprise the K-12 school science curriculum:

- Physical Science
- Life Science
- Earth and Space Science

The content statements are derived from *National Standards* and *Benchmarks*, as well as informed by international frameworks and state standards. The selection of science content statements to be assessed at each grade level focuses on principles central to each discipline, tracks related ideas across grade levels, and limits the breadth of science knowledge to be assessed.

The following science practices were found in the major sources used to develop the *Framework*. The practices to be assessed at grades 4, 8, and 12 are organized into four categories:

- Identifying Science Principles
- Using Science Principles
- Using Scientific Inquiry
- Using Technological Design

Selection and vetting of content was based on the thorough review of both the *National Standards* and *Benchmarks*. In addition, the document was reviewed by the committees responsible for development of the framework.

Insights gained from this review include:

- Basing science content and processes on the *National Standards, Benchmarks, TIMSS,* and *PISA;*
- Incorporating technological design;
- Structuring the document based on learning progressions; and
- Using clear and unambiguous statements of content (i.e., they are not behavioral statements).

The Program for International Student Assessment (PISA) Science 2006

PISA measures 15-year-olds' capabilities in reading literacy, mathematics literacy, and science literacy every three years. *PISA* was first implemented in 2000, and the most recent results are for the 2003 assessment.

Each three-year cycle assesses one subject in depth. The other two subjects also are assessed, but not in the same breadth and depth as the primary domain. In 2003, mathematics was the primary subject assessed, and in 2006 science was the primary domain. Results from *PISA Science 2006* were released in December 2007. *PISA* also measures cross-curricular competencies. In 2003, for example, *PISA* assessed problem solving. Finally, each assessment includes questionnaires for students, school personnel, and parents.

PISA is sponsored by the Paris-based Organisation for Economic Cooperation and Development (OECD), an intergovernmental organization of 30+ industrialized nations. In 2003, 41 countries participated in *PISA*, including 30 OECD countries and 11 non-OECD countries. Data from 39 countries—29 OECD countries and 10 non-OECD countries—were used for the final analysis.

PISA uses the term *literacy* within each subject area to indicate a focus on the application of knowledge and abilities. Literacy refers to a continuum of knowledge and abilities; it is not a typological classification of a condition that one individual has or does not have. For the 2003 assessment, *scientific literacy* was defined as having the "capacity to use scientific knowledge, to identify questions, and to draw evidence-based conclusions in order to understand and help make decisions about the natural world and the changes made to it through human activity" (OECD 2003, p. 286). (Note: This definition was further clarified and elaborated for *PISA Science 2006* [OECD 2006].) "Domains or curricular areas that might be applicable are not isolated within the single domain of mathematics, science, or reading" (OECD 2003, p. 156).

Compared to the curricular orientation of *TIMSS* (discussed in the next section), *PISA* provides a unique and complementary perspective by focusing on the application of knowledge in reading, mathematics, and science for problems and issues in real-life contexts. *PISA's* goal is to answer the question: Considering schooling and other factors, what knowledge and skills do students have at age 15? The achievement scores from *PISA* represent a "yield" of learning at age 15, rather than a measure of the attained curriculum at grades 4 or 8, as is the case with *TIMSS*. The framework for assessment is based on content, processes, and life situations. For example, in 2003 the content for mathematical literacy consisted of major mathematical ideas such as space and shape, change and relationships, quantity, and uncertainty. The processes describe what strategies students use to solve problems, and the situations consist of personal contexts in which students might encounter mathematical problems.

In *PISA*, a situation may be presented and several questions asked about it. Although some items are answered by selected response, the majority of items require a constructed response. The typical *PISA* item makes more complex cognitive demands on the student than the typical item from *TIMSS* or the *National Assessment of Educational Progress* (NAEP) (Neidorf et al., 2004).

Trends in International Mathematics and Science Study (TIMSS) Science 2003

TIMSS 2003 is the third comparison of mathematics and science achievement completed since 1995. *TIMSS* combines science and mathematics in one assessment and assesses student learning at different grades; in 2003, *TIMSS* evaluated grades 4 and 8.

Since 1995, *TIMSS* has been coordinated by the International Association for the Evaluation of Educational Achievement (IEA), an international organization of national research institutions and governmental research agencies. *TIMSS* is funded by the U.S. Department of Education, the National Science Foundation, the World Bank, the United Nations Development Project, and participating countries. IEA is located in Boston, Massachusetts. In 2003, a total of 49 countries participated in *TIMSS* at the fourth-grade level, the eighth-grade level, or both levels.

While *PISA* uses a contextual applications orientation, *TIMSS* provides a complementary perspective by linking assessments to the curricula of cooperating countries. Thus, *TIMSS* provides an indication of the degree to which students have learned concepts in the mathematics and science they have had the opportunity to learn in school programs. *TIMSS* answers the question: Based on school curricula, what knowledge and skills have students attained by grade 4? By grade 8? The achievement scores from *TIMSS* represent the “learned” curriculum at different grade levels, specifically grades 4 and 8. The following figure summarizes essential information about *PISA* and *TIMSS*.

Table 1. Comparing the 2003 PISA and 2003 TIMSS.

	PISA: Programme for International Student Assessment	TIMSS: Trends in International Mathematics and Science Study
Organization sponsor	Organisation for Economic Co-operation and Development (OECD)	International Association for the Evaluation of Educational Achievement (IEA)
Location	Paris, France	Boston, Massachusettes, USA
Countries	41 participating countries in 2003	25 countries participated in grade 4 46 countries participated in grade 8
Content	Reading, mathematics, science	Mathematics and science
Emphasis	Knowledge and abilities as applied to real-world issues	Knowledge and abilities as attained based on countries' curriculum
Age or grade	15-year-olds (mostly grade 10)	Grade 4 (9-year-olds) and grade 8 (13-year-olds)
Assessment cycle	Every three years, with one content area emphasized in each assessment. 2003 emphasis: mathematics; 2006 emphasis: science	Every four years with variation of grades

Perhaps the most educationally significant insight to be gained from the two international assessments emerges from the difference between *TIMSS* and *PISA*. *TIMSS* is grounded in the curriculum and provides feedback for how students are attaining what is intended and enacted vis-à-vis a country's curriculum. While not ignoring school curriculum, *PISA* asks how students can apply their knowledge in real-world situations. Lower U.S. scores on *PISA* suggest that students do not do as well as the majority of economic competitors when they have to demonstrate basic skills in contextual situations.

The evidence from international assessments indicates that U.S. students achieve reasonably well on curriculum-based assessments. But U.S. students do not do very well on context-based assessments, especially on content and basic skills associated with economic productivity. *PISA* provides a beneficial perspective, one that complements that of *NAEP* and *TIMSS*.

Washington State Science Standards Documents

Although this review will reference a number of documents related to the Washington state science standards, the team will utilize the documents *Science K-10 Grade Level Expectations: A New Level of Specificity* (2005) and *Preliminary Science College Readiness Definitions* (2007) as the basis of their review. Descriptions of each of these documents are provided below:

Science K-10 Grade Level Expectations: A New Level of Specificity

The Washington Science Standards, also referred to as the Essential Academic Learning Requirements (*EALRs*), were developed in 1997 and a set of Grade Level Expectations (GLEs) added in 2005. The Science EALRs were developed as a result of Washington's Basic Education Act of 1993 which spelled out the goal: "Provide students with the opportunity to become responsible citizens, to contribute to their own economic well-being and to that of their families and communities, and to enjoy productive and satisfying lives."

The K-10 EALR statements are based on the three overriding themes of Inquiry, Systems, and Application. Under each of these three statements are a small number of K-10 components. The GLEs and their respective Evidences of Learning are placed under the components by grade level spans (K-2, 3-5, 6-8, 9-10). The three EALRs are:

EALR 1: SYSTEMS	EALR 2: INQUIRY	EALR 3: APPLICATION
The student knows and applies concepts and principles to understand properties, structures, and changes in physical, earth/ space, and living systems.	The student knows and applies the skills, processes, and nature of scientific inquiry.	The student knows and applies science concepts and skills.

The GLEs are written as short sentences beginning with a verb intended to identify Bloom's level of cognitive demand using the general progression of "know," "understand," and "analyze." A few of the K-3 GLE's are written with active verbs such as "observe" indicating the form of instruction involved. Many of the GLE's refer to a concept or idea but do not specify or elaborate on what is to be learned. The following is an example of a GLE of this nature. "Describe how a population of organisms responds to a change in its environment." (1.3.10)

The 2005 document, *K-10 Grade Level Expectations: A New Level of Specificity* indicates that "GLEs were developed from the 1997 EALRs through a process involving science educators, school administrators, university scientists, and representatives of prominent businesses from across Washington State. The Science Curriculum Instructional Framework (SCIF) team used material from the *Benchmarks for Science Literacy*, *Atlas of Science Literacy,* and the *National Science Education Standards* to clarify and give specificity to the EALRs by adding Grade Level Expectations and Evidences of Learning."

Preliminary Science College Readiness Definitions

College Readiness is a key educational strategy included in Section 8, Helping Students Make the Transition to College, of the state's *2004 Strategic Master Plan for Higher Education*. In 2006 under the auspices of the Higher Education Coordinating Board (HCEB) the science content development team began work on the *Science College Readiness Definitions*. A small team of six to seven high school and university personnel developed the definitions and attributes that were then reviewed by a group of 80 teachers and faculty.

The College Readiness Definitions and Attributes are designed to define what is needed for students to be able to successfully complete entry-level college coursework, without remediation, in two- and four-year colleges and universities. The college attributes reflect *how to learn*, while the college readiness definitions reflect *what to learn*. Student attributes include: demonstrate intellectual engagement; take responsibility for own learning; persevere through the learning process; pay attention to detail; demonstrate ethical behavior; communicate effectively; effectively read, parse and organize information presented questions/problems in order to formulate solutions.

The college readiness definitions include the follow six content areas and foundational skills: Big Ideas in Science (Physical Science, Life Science, and Earth and Space Science), Scientific Inquiry and the Nature of Science, Science and Society, Quantitative Analysis, Technology, and Communication.

The big ideas of science list the broad areas of science and do not define any specific ideas or concepts. The readiness document comments on this in the following way:

> The field of science is so broad that it does not allow for an exhaustive list of all that can or should be covered or considered important in the various science disciplines. Thus, Definition A emphasizes a student's proficiency with core science concepts—"big ideas" in science—at cognitive levels beyond those described in Washington State's grade 10 science EALR 1. Emphasis on learning moves from primarily knowing and understanding towards synthesizing and evaluating big ideas into a coherent and useful picture of the natural world, including physical, life and earth/space sciences.

The document consists largely of attributes and broad academic skills and does not attempt to assume the qualities of a standards document leading to an assessment. As the document states:

> Finally, in proposing English and science college readiness, the development teams emphasized that the intent is not to add another assessment layer or requirement to the K-12 system. While development of measures to determine whether individual students are "college ready" is viewed as valuable for both teacher and learner, additional statewide testing is considered unnecessary and, perhaps, counterproductive at this time.

Appendix B: Selected States and Nations for Benchmarking

The project team used independent comparison studies and published reviews of state and international standards to inform the selection of states and nations to serve as appropriate benchmarks for the review of the Washington science standards. This includes comparison studies of state standards reviews (such as reports prepared by Education Week, the Thomas B. Fordham Institute and the American Federation of Teachers) and findings from national and international assessments (such as *NAEP*, *TIMSS* and *PISA*). In addition to these reports, states' performance on the 2002 State New Economy Index was used to provide additional context for selecting appropriate benchmarks. *Washington Learns*, described in more detail below, identified states that performed well on this index as important benchmarks for the state of Washington in the new economy.

Based on the team's review of these documents, the following states and nations were selected as benchmarks for the review of the Washington Science Standards:

- California
- Colorado
- Massachusetts
- Finland
- Singapore

Below are summaries of the documents that were reviewed to inform the selection of these states and nations, followed by a presentation of key results from these documents for the top-ten performing states on the *2002 New Economy Index* and comparison results for nations that were considered as potential benchmarks.

Washington Learns (2006)

Washington Learns was created by the 2005 Washington legislature and tasked with conducting a review of the state's entire education system. The *Washington Learns* committees reviewed the Washington education system with the goal of determining how to provide high-quality lifelong learning in the 21st century. The reviewers proposed using the Global Challenge States as benchmarks against which to measure themselves. The Global Challenge States are the top eight performers on the 2002 New Economy Index (Progressive Policy Institute, 2002).

The New Economy Index ranks states on 21 indicators of their potential to compete in the new economy, grouped into the following 5 categories: knowledge jobs, globalization, economic dynamism and competition, transformation to a digital economy, and technological innovation capacity. Washington ranked second on the *2002 New Economy Index*, and the states that were selected as benchmarks ranked first (MA), third (CA), and fourth (CO).

Quality Counts 2007 and Quality Counts 2006

Education Week provides an annual publication tracking state policies for improving K-12 education. Each publication includes a State of the States report which tracks education information and grades states on their policy efforts in areas such as K-12 standards, assessments and accountability systems. Much of the data included in the State of the States report is gathered through an annual policy survey, results of which are verified with documentation from the state.

The *Quality Counts* report provides overall grades for state performance in the area of standards and accountability that is based on the following indicators: 1) the adoption of standards in four core subject areas (english, mathematics, science, and social studies/history) and ratings of the standard's clarity and specificity; 2) the usage of five types of assessment instruments; and 3) the implementation of an accountability system that includes report cards, ratings (based on adequate yearly progress or state criteria), assistance, sanctions, and rewards. In the 2006 report Washington received a B for standards and accountability; Massachusetts received an A; California received a B+; and Colorado received a B.

The State of State Science Standards (2005)

The 2005 report is the latest in a series of three reports by that Thomas B. Fordham Institute that review state science standards (previous reports were in 1998 and 2000). The findings from this 2005 review are also reported in the *2006 The State of State Standards* (Thomas B. Fordham Institute, 2006).

The members of the Fordham evaluation team rated the science standards for each state on a 4-point scale based on 21 criteria in the areas of: Expectations, Purpose, and Audience; Organization; Science Content and Approach; Quality; and Seriousness. In addition to the 21 criteria within these categories, two additional criteria were given special attention by the reviewers: Inquiry and Evolution.The reviewers indicate that they include inquiry as an additional criterion because "these subjects are now treated in most standards documents as independent content or even as skills the students are expected to acquire." However, the reviewers caution against the overemphasis of inquiry in science standards, and state that in order to earn the highest rating "a state that gives the now-customary prominence to Inquiry had also to offer substantive, correct, and grade-appropriate material – subject matter – on the processes of scientific inquiry or on history or philosophy of science rather than empty encouragement toward good behavior." With regard to the treatment of evolution, the document states that in order to receive the highest rating the standards must introduce the main lines of evidence, including the fossil record, genetics, molecular biology, and development and connect these lines of evidence with Earth history.

Washington received a C for science standards based on the 2005 review. Massachusetts and California received A's, and Colorado received a B.

Smart Testing, Let's Get it Right (2007)

The American Federation of Teachers (AFT) conducted a review of state standards and reported on the strength of the content standards and the state's alignment of the science standards to the state's assessment system. To meet the AFT criteria for having state tests aligned to the standards, the state must: 1) have strong content standards; 2) provide evidence of alignment of the tests to the standards (e.g. item specifications, test blueprints, etc.); and 3) post the alignment evidence on the Web in a transparent manner. The majority of states met the AFT criteria for strong content standards in science. However, only 23 fully met the criteria for alignment between the science tests and the science standards. Washington, Massachusetts, and California met the AFT criteria for alignment at the elementary, middle school and high school levels. Colorado only met the criteria at the high school level.

Table 2 provides a summary of results of these reviews for the top-ten performing states on the *2002 New Economy Index*, which were considered as potential benchmark states. In addition to findings from the New Economy Index, the Quality Counts 2006 and 2007 reports, the State of the State Science Standards 2005 report, and the AFT 2007 review, the table displays *NAEP* grade 4 and grade 8 results for 2005 and indicates the change in these results from 2000 to 2005. These results are included because they were another important indicator used in the selection of the benchmark states.

Following Table 2, Table 3 displays comparison results for nations that were considered as potential benchmarks. In addition to results from *TIMSS* and *PISA*, this table includes comparison information on the percentage of the population enrolled in secondary education and expenditures on education. The assessment results and additional contextual information, such as Finland's innovative means of implementing science standards, informed the selection of Singapore and Finland as benchmark nations.

Table 2: State Comparisons for Top-10 Ranking States on the New Economy Index

State/Nation	2002 New Economy Rank	Most Recent Year Updated[1]	College Readiness Defined[1]	Regular Timeline for Revising[1]	Quality Counts 2006 Overall grade	Fordham Science	Levels Mtg AFT Criteria for Science Alignment[2]	2005 NAEP Grade 4 (Average Score)[3]	Direction of Change from 2000 to 2005[3]	2005 NAEP Grade 8 (Average Score)[3]	Direction of Change from 2000 to 2005[3]
Massachusetts	1	2006-07	NO	NO	A	A	e, ms, hs	160		161	+
Washington	2	2005-06	NO	YES	B	C	e, ms, hs	153	N/A	154	N/A
California	3	1998-99	YES	NO	B+	A	e, ms, hs	137	+	136	+
Colorado	4	2005-06	NO	YES	B	B	hs	155	N/A	155	N/A
Maryland	5	2000-01	NO	YES	A-	B	e, ms, hs	149	+	145	
New Jersey	6	2002-03	YES	NO	B+	B	e, ms, hs	154	N/A	153	N/A
Connecticut	7	2004-05	NO	NO	B-	C	NONE	155		152	
Virginia	8	2002-03	NO	YES	B	A	e, ms, hs	161	+	155	+
Delaware	9	1994-95	NO	NO	B+	C	NONE	152	N/A	152	N/A
New York	10	1995-96	YES	YES	A	A	e, ms, hs	N/A	N/A	N/A	N/A

[1] Source. *Quality Counts 2007*.

[2] Source. American Federation of Teachers. elementary = e; middle school = ms; high school = hs

[3] Source. *The Nation's Report Card*, Science 2005. Direction of change is shown only for those states for which the change was statistically significant.

N/A indicates that *NAEP* results for at least one time-point are unavailable

Table 3: National Comparisons for Nations Considered as Potential Benchmarks

State/Nation	TIMSS 2003 Grade 4 Avg. Science Scale Score	TIMSS 2003 Grade 8 Avg Science Scale Score	PISA 15 yr olds Average Science Scale Score	Education Expectancy 2004*	Percent of Population in Enrolled Secondary Education*	Expenditures on Education as a percent of GDP*
Singapore	565	578	no data	N/A	N/A	N/A
Chinese Taipei	551	571	no data	N/A	N/A	N/A
Hong Kong	542	556	539	N/A	N/A	N/A
Japan	543	552	548	N/A	n/a	n/a
Australia	521	527	525	20.7	85%	3.7%
United States	536	527	491	16.9	82%	5.7%
New Zealand	520	520	521	19.1	95%	6.8%
Finland	n/a	n/a	548	20	94%	6.5%
Intl Ave	489	473		17.4 (OECD)		5.5% (OECD)

*Source. *Quality Counts 2007*.

Appendix C: Preliminary Recommendations

Recommendations to Inform Policy and Implementation Decisions

1 **Based on our review and analysis of the current science standards for the state of Washington we recommend the development of a new science standards document.**

- Washington should assemble a Science Standards Revision Team to incorporate the changes detailed in this report.
- The Science Standards Revision Team should include teachers, a curriculum specialist, an assessment specialist, a university science educator, scientists from each of the three major disciplines, a professional with experience developing standards at the state or national level, a math educator who worked on the development of the math standards, and a professional editor.

2 **The new science standards should be a comprehensive K-12 document that sets high expectations for all students.**

- The document should be expanded to include grades 11 and 12.
- The document should describe the knowledge, skills, and abilities that all students need to be prepared for post-secondary education.

3 **The science standards should create a vision for the science content, methods of science, and applications appropriate for all K-12 students in the state of Washington.**

- The new science standards should be clear on their purpose, audience, and vision.
- The document's purpose should reflect the values of the stakeholders in the state of Washington.

4 **Implementation of the science standards should result in greater coherence across the full spectrum of the education system - including curriculum development, selection of instructional materials, professional development, and assessment.**

- The standards must not be presented as the curriculum.
- Supporting documents are necessary to ensure reliable alignment between the science standards, development and selection of instructional materials, professional development, classroom instruction, and assessment.

Recommendations to Inform the Design and Writing of a New Washington Science Standards Document

5 Simplify the organization of the Washington science standards document.

- Reduce the number of organizing elements to improve user navigation of the document.
- Organize the discipline content, currently provided in EALR 1, by life sciences, earth and space sciences, and physical sciences.
- Include the same clear delineation of science content, methods of science, and applications that is provided in the current document.
- Continue to provide standards for grade spans rather than for grade levels, including expanding the high school span to integrate grades 11 and 12.

6 Increase the clarity and specificity of the Washington science standards document.

- The science standards should not depend on scientific vocabulary alone to convey the meaning of an outcome statement of what students should understand or be able to do. Scientific vocabulary within the content statements is acceptable if the term is explained as part of the standard.
- The science standards should provide a more complete, detailed, and specific description of the content to be learned, with special attention to the Life Science content. Minimize the use of external references for defining the science content that is to be learned.
- The verbs used in the standards should specifically delineate what students are to understand/know or be able to do.
- The science standards should use content statements to detail the science content that is to be learned. Model the format of these statements after statements provided in reference documents such as the *2009 National Assessment of Educational Progress* and the *National Science Education Standards*.

7 Increase the rigor of the Washington science standards document.

- Some concepts currently introduced in grades 3-5 could be introduced earlier.
- Increase the level of cognitive demand of the standards at all grade spans.
- With the addition of grades 11 and 12, the learning progression across grade spans for each standard should be revisited and content redistributed, with special attention to grade spans 6-8 and 9-12.
- Use the most current research on learning progressions within disciplines to establish what students should know and be able to do at each grade span.
- With the development of the new K-12 document, ensure that the Washington Standards contain all of the content from the *NSES*, with particular attention to Life Sciences.

8 Strengthen the standards for inquiry in the state of Washington.

- Devote more attention to the "abilities" of inquiry in addition to the "understandings" of inquiry. Students at all grade levels should be expected to demonstrate the abilities of inquiry.
- Incorporate linkages to the Washington State K-12 Mathematics Standards (March, 2008).
- Provide guidance to clarify the purpose of the inquiry standards as defining learning outcomes for students rather than outlining instructional strategies.
- Provide guidance to promote instructional strategies that integrate disciplinary content and inquiry in the classroom.

9 Improve the standards for Science and Technology.

- In addition to the "understandings" of technological design, increase focus on the "abilities" of technological design.
- Provide relevant "real world" examples to illustrate the concepts that are articulated in the standards.

10 Develop standards to address Science in Personal and Social Perspectives

- Include the Science in Personal and Social Perspectives content found in the *NSES*.

11 The Washington science standards should reflect the balance and depth of content found in the National Science Education Standards.

- Focus on fundamental concepts and abilities presented in the *NSES*.
- Eliminate areas of redundancy found in the current Washington science standards.
- Provide guidance for instructional strategies that integrate concepts and enable students to meet more than one standard in a unit or series of lessons.

This interim report presents the above recommendations based on the analysis and findings of the Expert Review Panel, input from the Washington Science Advisory Panel, as well as the collective experience of the DHA project team developing and implementing national- and state-level science standards. Following the presentation of this report to the Washington SBE, the document will be posted on the SBE website to facilitate public review and comment. The DHA project team will seek additional public comment through a series of focus groups in three locations across the state of Washington. A summary of the public comment will be prepared by the DHA project team, reviewed with the Washington Science Advisory Panel, and included in a separate section of the Final Report to the SBE.

Appendix D: Project Team and Expert Review Panel Biographies

David Heil, Co-Director and Expert Review Panel Facilitator

David Heil, President of DHA, is well known throughout the country as an innovative science educator, new enterprise developer, lecturer, author and host of the Emmy Award-winning PBS science series, Newton's Apple. He was the lead author of the award winning elementary science curriculum, *Discover The Wonder;* has produced innovative PreK -12 curricula for the National Science Foundation, PBS, and numerous corporate and government agency clients. He is the editor of the popular book *Family Science* and was the founding chair of the Foundation for Family Science supporting parent and child science learning worldwide. He has also been a leader in the informal science teaching and learning community providing expert consulting services to many of the nation's leading science and technology centers and organizations including the NSF, the National Academy of Sciences, the California Science Center, The National Science Center, the Smithsonian, the Denver Museum of Nature and Science, the Great Lakes Science Center, and currently, the Pacific Science Center in Washington State. Mr. Heil is frequently invited to speak at conferences and public events on science, technology, and the rewards of experiential learning.

Prior to establishing DHA, David was affiliated with the Oregon Museum of Science & Industry (OMSI) for 13 years, serving as associate director from 1988–1996. While at OMSI, David initiated and administered many of the museum's nationally recognized education and outreach programs, and also developed hands-on exhibits for national tour. David has also taught science and enrichment programs in grades 7-12, conducted research in plant biochemistry and radiochemistry, and worked for five years with the U.S. Fish and Wildlife Service. A native Oregonian, he is active in numerous scientific and educational organizations nationwide, is a past President of the Oregon Science Teachers Association, Director of Informal Science Education for the National Science Teachers Association (NSTA), served on the Board of Directors of the Biological Sciences Curriculum Study (BSCS), and currently serves on the Board of Directors for the Aspen Science Center and the Keystone Center.

Kasey McCracken, Project Manager

Kasey McCracken specializes in both internal and external evaluation at DHA. Using both qualitative and quantitative methodologies she plans and conducts baseline, formative, and summative evaluations as well as market research studies for a variety of non-profit entities, corporations, and government agencies, including the National Science Teachers Association, and NSF and NIH funded projects for a range of science and technology initiatives. Most recently, Ms. McCracken designed and conducted statewide surveys and focus groups on behalf of Washington's Pacific Science Center to provide public, member, school educator and administrator, and other key stakeholder input into the development of a comprehensive strategic business plan for Pacific Science Center. Prior to joining DHA, Kasey was an evaluation analyst for the Austin Independent School District (AISD) where she supported a variety of Department of Education-funded initiatives, including AISD's after-school program. As an independent evaluation consultant, she served a range of clients, including the Virginia Department of Mental Health, Mental Retardation, and Substance Abuse Services; the Partnership for People with Disabilities at Virginia Commonwealth University; and the Portsmouth (VA) Community Services Board. Kasey holds an MPH from the Johns Hopkins School of Public Health and a BA in Biology and Anthropology from the University of Pennsylvania.

Expert Review Panelists

Rodger W. Bybee, Co-Director and Expert Review Panel Chair

Rodger W. Bybee is one of the nation's leading science education scholars and has been an active leader in the development and implementation of national and state-level science standards. Most recently he served for 8 years as Executive Director of the Biological Sciences Curriculum Study (BSCS), a non-profit organization that develops curriculum materials, provides professional development, and conducts research and evaluation for the science education community. Prior to joining BSCS, he was executive director of the National Research Council's Center for Science, Mathematics, and Engineering Education (CSMEE), in Washington, D.C. Between 1985 and 1995 he was associate director of BSCS. From 1972 to 1985, Dr. Bybee was a professor of education at Carleton College in Northfield, Minnesota.

Dr. Bybee was a leader in the development of the National Science Education Standards. From 1993-1995, he chaired the content working group of that National Research Council project. At BSCS, he was principal investigator for five new National Science Foundation (NSF) programs; an elementary school program, *Science for Life and Living: Integrating Science, Technology, and Health*; a middle school program, *Middle School Science & Technology*; two high school programs, *BSCS Biology: A Human Approach* and *BSCS Science: An Inquiry Approach*; and a college program, *Biological Perspectives*. His work at BSCS also included serving as a principal investigator for programs to develop curriculum frameworks for teaching about the history and nature of science and technology for biology education at high schools, community colleges, and four-year colleges, and curriculum reform based on national standards. Dr. Bybee has served as chair of the Science Forum for PISA 2006 Science and chair of the Science Expert Group for that prestigious international entity.

Dr. Bybee has been active in education for forty years, having taught science at the elementary, junior and senior high school, and college levels. He has written widely, publishing in both education and psychology. He is co-author of a leading textbook titled *Teaching Secondary School Science: Strategies for Developing Scientific Literacy*. His recent books include *Achieving Scientific Literacy: From Purposes to Practices* and *Learning Science and the Science of Learning*. Over the years, he has received awards as a Leader of American Education and an Outstanding Educator in America and in 1979 was Outstanding Science Educator of the Year. He has received the National Science Teachers Association (NSTA) Distinguished Service to Science Education Award. The American Institute of Biological Science presented him the first annual AIBS Education Award, the Keystone Center presented him the Keystone Leadership in Education Award, and the University of Northern Colorado recognized him as the Outstanding Alumni for 2006. This year (2007) Dr. Bybee was the first recipient of the Public Understanding of Technology Award presented by the International Technology Education Association (ITEA). And most recently, Dr. Bybee was presented the National Science Teachers Association's (NSTA) most prestigious award, the Robert H. Carleton award presented to individuals who have made outstanding contributions to and provided leadership in science education at the national level and to NSTA in particular.

Harold Pratt, Co-Director and Panelist

Harold Pratt is a private consultant working in all areas of science education and has just completed a three-year term as is a Disciplinary Literacy Fellow in Science at the Learning Research and Development Center at the University of Pittsburgh. He also is the president of Science Curriculum Inc., the publishers of *Introductory Physical Science* and *Force Motion and Energy*. From May 1996 until July 1999, he was the Director of Science Projects in the Center for Science, Mathematics, and Engineering Education at the National Research Council (NRC). He has had extensive administrative and curriculum development experience at the local and national levels. Prior to joining NRC, he directed the revision of *Science for Life and Living*, at the Biological Sciences Curriculum Study in Colorado Springs, Colorado. From October 1992 to December 1994, he served as a Senior Program Officer at the NRC for the National Science Education Standards Project. From 1986 to 1991 he was the Executive Director of Curriculum for the Jefferson County (CO) Public Schools, the largest district in Colorado with an enrollment of over 80,000 students. Prior to that, he served the district as the Science Coordinator for 23 years. He has co-authored or directed the development of three science textbooks, a book on educational leadership, and published numerous articles and book chapters. He is a Fellow of the American Association for the Advancement of Science and was selected by the National Science Education Leadership Association (formerly the National Science Supervisors Association) as the first recipient of the Nation's Outstanding Science Supervisor Award. He was president of the National Science Teachers Association (NSTA) from 2001-2002. NSTA honored him with the Distinguished Service to Science Education Award in 1999 and their highest recognition, The Carlton Award in 2005. In December, 2005 he received the Susan Loucks-Horsley Award from the National Staff Development Council.

Harold's contributions to the National Science Education Standards have resulted in his consulting and advising numerous states in the development and implementation of their own science education standards, including Ohio, Georgia, Utah, Colorado, Arkansas, South Carolina, and Minnesota.

Bonnie Brunkhorst, Panelist

Bonnie Brunkhorst is Past Chair of the National Council of Scientific Society Presidents (CSSP), Past President of the National Science Teachers Association (NSTA), and served as a member of the National Research Council's National Committee on Science Education Standards and Assessment, and the Standards Executive Editorial Committee for the National Academy of Sciences. She was a member of the NRC Committee on Undergraduate Science Education (CUSE).

Dr. Brunkhorst is a professor at California State University, San Bernardino, with a joint appointment in the College of Natural Sciences in Geological Sciences and the College of Education in Science, Mathematics and Technology Education. She serves on the Graduate Faculty for the Ed.D Program in Educational Leadership. She also taught secondary science for 15 years and supervised the science program, K-8, in the Lexington, Massachusetts Public Schools before receiving her Ph.D. She received her Bachelor's and Master's degrees in Geology from Boston University, and her Ph.D. from the University of Iowa in science education with geology.

Her areas of expertise, research, and publication include K-university Earth science teaching, undergraduate science (geology and science and technology), public understanding of science, science in public policy, science education reform, professional development of science teachers, and science standards development and implementation Dr. Brunkhorst has extensive experience in building coalitions and cooperation among various constituencies with stakes in science and science education, nationally, state-wide and regionally. She initiated and developed the coalition of science and science education national professional societies in support of the development of the national science education standards while president of NSTA and coordinated the transfer of the standards development to the National Academy of Sciences from NSTA. She served as the coordinator and was co-founder for the national Salish Consortium for the Improvement of Science Teacher Preparation Through Research. She continues to be a strong supporter for science teachers' professionalism and leadership.

She served as a science consultant to the state Commission for Developing Academic Content and Performance Standards, which prepared the California Science Education Standards, and on the state Commission on Teacher Credentialing (CCTC) Panel for the development of California's science teacher preparation standards.

Herb Brunkhorst, Panelist
Herb Brunkhorst is Professor of Science Education and Biology at California State University, San Bernardino, and is currently Chair of the Department of Science, Mathematics, and Technology Education in the College of Education. He carries a joint appointment in the Department of Biology in the College of Natural Sciences. Dr. Brunkhorst earned a Ph.D. with majors in science education and plant physiology at the University of Iowa. He has been a science educator for the past 40 years; 17 years at the pre-college level and the past 23 years at the university level. Dr. Brunkhorst was co-principle investigator of a university system-wide collaboration to improve science teacher preparation. He served as a senior faculty researcher on a national multidimensional collaborative research effort for improving science and mathematics teacher education. Dr. Brunkhorst was selected as a California State University Chancellor's Teacher Preparation Scholar. He is a past president of the Association for Science Teacher Education (formerly the Association for the Education of Teachers of Science), Director of Pre-service Teacher Preparation for the National Science Teachers Association, a Fellow of the American Association for the Advancement of Science, and a lifetime National Associate of the National Academies (Science, Engineering and Medicine).

Arthur Eisenkraft, Panelist
Arthur Eisenkraft is a Distinguished Professor of Science Education and Director of the Center of Science and Math in Context (COSMIC) at the University of Massachusetts, Boston.

Before arriving at University of Massachusetts Boston, Dr. Eisenkraft taught high school physics for over 25 years. He is a past president of the National Science Teachers Association. He is project director of the NSF-supported Active Physics Curriculum Project that is introducing physics instruction for the first time to all students; leading a similar effort with Active Chemistry; and chair and co-creator of the Toshiba/NSTA ExploraVision Awards, involving 15,000 students annually. In 1993, he was Executive Director for the XXIV International Physics Olympiad after initiating the U.S. involvement in the program and serving as the academic director of the United States team for six years. He is a consultant for the award-winning ESPN SportsFigures. Eisenkraft has received numerous teaching awards. He is a fellow of the AAAS.

Anne Kennedy, Panelist
Anne Kennedy is the founding Director of the Science and Mathematics Education Resource Center (SMERC), a partnership of Educational Service District 112, Washington State University Vancouver, Hewlett Packard, and 30 SW Washington School Districts. Since 1992, SMERC has supported strategic and long-term growth and development of K-20 science and mathematics education programs locally, regionally, and statewide. Activities have included: teacher and principal leader institutes; courses and workshops in K-12 science and/or mathematics; construction of regional science materials centers; development and statewide dissemination of classroom-based assessments for elementary science; technical assistance to schools and teachers adopting and implementing standards-based curriculum; and recruitment and training of scientists and engineers in the service of K-12 education.

Kennedy is currently working on a doctorate in Educational Leadership at Lewis and Clark College in Portland, Oregon. Prior to joining ESD 112, she spent 10 years as a science teacher in both the public and private sectors specializing in astronomy, design and technology, environmental education, and inquiry learning. Her current teaching and research interests include school change, leader development, sustainable program development in science and mathematics education, and K-12 / Higher Education Partnerships.

Mark St. John, Panelist

Dr. Mark St. John, founder and president of Inverness Research Associates, has a background in evaluation, policy analysis, and science and mathematics education at all levels. He was trained in aeronautical engineering at Princeton, served as a high school physics teacher at Phillips Academy and then was a graduate student in physics at the University of New Mexico. This led to a doctoral degree and subsequent faculty position at UC Berkeley in an interdisciplinary math and science education program. Dr. St. John has hybrid expertise that combines a knowledge of science, deep experience in the teaching and learning of the science disciplines, and a broad understanding of educational reform efforts. For over 15 years, he has been involved in the evaluation and study of public and private initiatives aimed at improving science and mathematics education. For nearly two decades Dr. St. John and his colleagues at Inverness Research Associates have been involved in studies and evaluations of reform initiatives in education, including a study of the impact of National Standards. Most recently, Dr. St. John and his group have assisted foundations and state agencies in planning and refining the design of their reform initiatives, as well as helping them to think about the overall evaluation designs most appropriate to their goals and needs.

Jo Anne Vasquez, Panelist

Jo Anne Vasquez is an experienced elementary science educator and supervisor who has taught primary through college level science education courses. She is presently the Director of Professional Development and Outreach at the Center for Research on Education in Science, Math, Engineering and Technology (CRESMET) on the campus of Arizona State University. She is the Past President of the National Science Teachers Association, and the National Science Education Leadership Association. She is a Presidential Appointee to the *National Science Board*, the governing board of the *National Science Foundation***,** the first K-12 Educator to become a sitting member of this prestigious board. Jo Anne's distinguished service and extraordinary contributions to the advancement of science education at the local, state, and national levels has won her numerous awards including National Science Teachers Association's most prestigious honor the 2006 "Robert H. Carlton Award" for Leadership in Science Education. She has also received the *"Distinguished Service to Science Education Award"* the "*Search for Excellence in Elementary Science Education and Supervision Award*" the 2007 New York Academy of Science's "Willard Jacobson Award" for major contribution to the field of science education and was the 2004 NALEO (National Association of Latino Elected and Appointed Officials) honoree for her contributions to improving education.

Appendix E: Washington Advisory Panel Biographies

The Washington Science Advisory Panel, chaired by Jeff Vincent, an SBE board member and chair of the Science Committee, provided input into the review process and the development of recommendations. The Washington SBE appointed the Science Advisory Panel after publicly soliciting applications. The SBE received 68 applications and selected 19 panelists based on an effort to ensure representation of key stakeholders such as educators, parents, and practicing scientists. The SBE also worked to provide broad geographic representation within the state of Washington. Brief biographies for the 19 members of the Washington Science Advisory Panel are provided below.

Jeff Vincent, Chair, a member of the Washington State Board of Education, is the Chief Executive Officer and President of the Laird Norton Company LLC. He leads the Laird Norton investment team in the oversight of current investments, the development of new investment opportunities, and in the day-to-day management of Company activities. Jeff joined the Laird Norton Company LLC in January of 2001. Jeff has more than 20 years of business experience in such roles as CEO, CFO, corporate development officer, and strategy consultant. During 15 years of this experience, he worked with privately held family companies where he developed a fundamental understanding of how to successfully manage these types of entities. Jeff received his BSBA from Drake University, *summa cum laude*, and received his MBA from the Harvard Business School where he was a Baker Scholar.

Len Adams is a Health Promotion Specialist for the Tacoma/Pierce County Health Department, where he has worked for two years. Len worked for 27 years at Pacific Science Center, where he held a variety of positions related to informal science education.

Jeffrey Bierman has been a physics professor at Gonzaga University for 12 years, and is a scientist with undergraduate degrees in mathematics and physics and a Ph.D. in experimental nuclear physics. He is the parent of three children in Washington public schools.

Georgia Boatman teaches at Amistad Elementary School in Kennewick and is a National Board Certified elementary teacher with 31 years of teaching experience in grades 1-6 and Special Education.

Theresa Britschgi is in her third year as BioQuest Director at the Seattle Biomedical Research Institute. Theresa Britschgi earned her MS in Microbiology at Oregon State University prior to her work experience as a twelve-year veteran of the biotechnology/pharmaceutical industry.

Chris Carlson is a genetic epidemiologist at the Fred Hutchinson Cancer Research Center, and holds a Ph.D. from Stanford University in Genetics. He is a parent of three children, legislative chair in his local PTA, and school board member.

Grant Fjermedal is the father of three children attending Seattle's North Beach Elementary School, where he serves as a member of the PTA Board and teaches science as a parent volunteer. A former science and medical writer for the Associated Press, Fjermedal is the author of four nonfiction books.

Jen Fox currently serves as a high school science coach in the Seattle School District. She taught biology, marine biology, and botany at Roosevelt High School in Seattle for six years, and has worked on science teams at the state level.

Mario Godoy-Gonzalez has been teaching Physical Science and Biology/Biotechnology to English Language Learners (ELL) at Royal High School in Royal City since 1994. He began his teaching career in Chile in 1984.

Judy Kjellman has taught biology at Yakima Valley Community College for 39 years. She worked with a team of K-12 and college instructors to draft the preliminary Science College Readiness Definitions.

Sheldon Levias is a Learning Sciences Ph.D. student in the University of Washington's College of Education. He taught math and science for three years at Meany Middle School in Seattle and served for three years as a middle school science resource teacher in the Seattle School District.

Michael McCaw is a Senior Scientific Specialist in the Cellulose Fibers Technology group of Weyerhaeuser where he works on developing new uses and markets for cellulose fibers. He has worked in applied science for the company for over 20 years.

Brian MacNevin is currently a Teacher on Special Assignment with the North Cascades and Olympic Science Partnership, where he supports reform efforts of teacher leaders. He teaches at Shuksan Middle School in Bellingham and has 13 years of experience in science reform.

Judy Morrison is an Assistant Professor of Science Education at Washington State University TriCities, working with both preservice and in-service teachers. She has also taught chemistry, biology, and physical science at both the middle and high school levels.

George (Pinky) Nelson is the Director of the Science, Mathematics, and Technology Education program at Western Washington University. He holds a Ph.D. in astronomy, and has served on or directed many state and national science initiatives, including the AAAS Project 2061.

Kimberly Olson taught $6^{th}/7^{th}$ grade science for four years at Giaudrone Middle School in Tacoma and is now currently an Instructional Facilitator at Baker Middle School in Tacoma. She has been teaching for five years.

Steve Olson has been teaching physical science, chemistry, physics, and mathematics for six years at Lakeside High School in the Nine Mile Falls School District. He also serves as chair of the science department.

Ethan Smith has taught at Tahoma High School in Covington for ten years and is currently serving as the Instructional Technology Coach for the Tahoma School District.

Barbara Taylor has taught in the Othello School District for 14 years: three years teaching 9^{th} grade science and 10^{th} grade biology, and 11 years teaching 8^{th} grade science, math, and other subjects.

Kristen White has been teaching at Shahala Middle School in the Evergreen School District, Vancouver since 2001, and has over 15 years of teaching experience. She also served in the district office for two years as a Staff Development Specialist focusing on math, science, and technology.

Appendix F: References for Reports Used in Review and Other Resources

Reports and Documents Used to Support the Expert Panel Review

National Assessment Governing Board. (2007). *Science framework for the 2009 national assessment of educational progress*. Prepublication Edition. Developed by WestEd and the Council of Chief State School Officers. Washington, D.C.: U.S. Department of Education. Also available: http://www.nagb.org/frameworks/fw.html [accessed November 2007].

National Center for Education Statistics. (2004). *Highlights from the trends in international mathematics and science study (TIMSS) 2003.* (NCES #2005-005). P. Gonzales, J.C. Guzman, L. Partelow, E. Pahlke, L. Jocelyn, D. Kastberg, and T. Williams. Washington, D.C.: U.S. Department of Education. Also available: http://nces.ed.gov/pubsearch/pubsinfo.asp?pubid=2005005 [accessed November 2007].

International Association for the Evaluation of Educational Achievement. (2005). *TIMSS 2007 assessment frameworks.* I.V.S. Mullis, M.O. Martin, G.J. Ruddock, C.Y. O'Sullivan, A. Arora, and E. Erberber. Chestnut Hill, MA: TIMSS & PIRLS International Study Center, Lynch School of Education, Boston College. Available: http://timss.bc.edu/TIMSS2007/frameworks.html [accessed September 2007].

Organisation for Economic Co-operation and Development. (2004). *Learning for tomorrow's world first results from PISA 2003.* Programme for International Student Assessment. Paris: OECD Publishing. Also available: http://www.pisa.oecd.org/document/55/0,3343,en_32252351_32236173_33917303_1_1_1_1,00.html. [accessed November 2007].

Organisation for Economic Co-operation and Development. *Assessing scientific, reading and mathematical literacy: a framework for PISA 2006.* Programme for International Student Assessment. Paris: OECD Publishing. Also available: http://www.pisa.oecd.org/document/55/0,3343,en_32252351_32236173_33917303_1_1_1_1,00.html. [accessed November 2007].

National Research Council. (1996). *National science education standards*. National Committee on Science Education Standards and Assessment. Washington, DC: National Academy Press.

American Association for the Advancement of Science. (1993). *Benchmarks for science literacy*. New York: Oxford University Press.

Washington Higher Education Coordinating Board. (2006). *Status report on english and science college readiness.* College Readiness Project. Des Moines, WA: Author. Also available: http://www.hecb.wa.gov/collegeprep/CollegeReadinessProject.asp [accessed November 2007].

Edwards, V.B. (Ed.) (2007, January 4). From cradle to career: connecting american education from birth through adulthood. *Education Week*, *26*.

Edwards, V.B. (Ed.) (2006, January 5). Quality counts at 10: a decade of standards based education. *Education Week, 25*.

Thomas B. Fordham Foundation. (2006). *The state of state standards*. C.E. Finn, L. Julian, and M.J. Petrilli. Washington, DC: The Thomas B. Fordham Institute.

American Federation of Teachers. (2006). *Smart testing: let's get it right*. (Policy Brief 19). Washington, DC: Author. Also available: http://www.aft.org/presscenter/releases/2006/smarttesting/ [accessed November 2007].

Washington State Legislature. (2006). *Washington learns.* Washington Learns Steering Committee. Olympia, WA: state of Washington. Also available: http://www.washingtonlearns.wa.gov/default.htm. [accessed November 2007].

Progressive Policy Institute. (2002). *The 2002 state new economy index.* Technology & New Economy Project. Washington, DC: Author. Also available: http://www.neweconomyindex.org/ [accessed November 2007].

Comparison State and Nation Science Standards Documents

California State Board of Education. (Adopted 1998.) Science: academic content standards for kindergarten through grade twelve. Retrieved January 18, 2008 from http://www.cde.ca.gov/be/st/ss/scmain.asp.

Colorado Department of Education. (1995.) *Colorado Model Content Standards: Science.* Denver, CO: Author. Available: http://www.cde.state.co.us/coloradoscience/Standards_and_Assessment.htm [accessed December 2007].

Finnish National Board of Education. (2004) *National core curriculum for upper secondary schools 2003.* Helsinki: Author. Available: http://www.oph.fi/english/page.asp?path=447,27598,37840,72101,72105 [accessed January 2008].

Finnish National Board of Education. (2004) *National core curriculum for basic education 2004.* Helsinki: Author. Available: http://www.oph.fi/english/page.asp?path=447,27598,37840,72101,72106 [accessed January 2008].

Massachusetts Department of Education. (2006). *Massachusetts science and technology/engineering curriculum framework.* Malden, MA: Author. Available: http://www.doe.mass.edu/frameworks/current.html [accessed January 2008].

Ministry of Education, Singapore. (2007). *Science syllabus primary 2008.* Singapore: Curriculum Planning & Development Division. Available at: http://www.moe.gov.sg/cpdd/pri_science_links.htm [accessed December 2007].

Ministry of Education, Singapore. (2007). *Science syllabus lower secondary: normal (technical).* Singapore: Curriculum Planning & Development Division. Available at: http://www.moe.gov.sg/cpdd/lower_sec_science_links.htm [accessed December 2007].

Ministry of Education, Singapore. (2007). *Science syllabus lower secondary: express/normal (academic).* Singapore: Curriculum Planning & Development Division. Available at: http://www.moe.gov.sg/cpdd/lower_sec_science_links.htm [accessed December 2007].

Other References

National Research Council. (1997). *Improving student learning in mathematics and science: the role of national standards in state policy*. National Council of Teachers of Mathematics & the Center for Science, Mathematics, and Engineering Education. Washington, DC: National Academy Press.

National Research Council. (2007). *Taking science to school: learning and teaching science in grades K-8.* Committee on Science Learning, Kindergarten through Eighth Grade, R.A. Duschl, H.A. Schweingruber, and A.W. Shouse (Eds.). Washington, DC: The National Academies Press.