Specifications for Science Expectations

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This document contains the specifications that we agreed on in the January 20 meeting, with additional details. A separate document has the NAEP DRAFT content boundaries, which you can use as a resource (and also critique, since the boundaries are currently being revised). At the end of this document you will find a template for content statements, performances, and boundaries for a strand.

Before we meet again in mid-February, each content group (physics, chemistry, life science, earth and space science) needs to accomplish at least the following:

1. Essential and advanced content statements for ALL strands in your area.
2. Performances and boundaries for AT LEAST TWO strands in your area.
3. Informal notes about essential content from other strands, foundational knowledge, introductory essays, and critique of the NAEP boundaries.
4. A summary of issues or concerns that need to be resolved in the February meeting.

Website with resources for our writing

http://www.michigan.gov/mde/0,1607,7-140-28753_28760-133592--,00.html

Conceptual content: How do we decide what's included?

Three levels of expectations:

1. *Basic mathematics and language skills*. These are non-science content. We might describe them in an appendix but not include them in the main body of the document.
2. *Essential science content* that all high school graduates should master. Possible criteria:
    a. Included in NAEP middle school or high school content statements (other possible reference documents: Benchmarks, NSES, Michigan curriculum framework, Massachusetts framework), OR
    b. Necessary for essential content in another content area (e.g., understanding of chemical change is needed for life science content), OR
    c. Essential for all citizens to fulfill their basic responsibilities as learners, consumers, voters
3. *Advanced science content* (we need a better word, since this is not necessarily very advanced) that high school graduates need for college or some kinds of work. Possible criteria:
    a. Prerequisite knowledge for AP
    b. Included in undergraduate specifications
    c. Included in Understanding University Success
    d. Necessary for specific kinds of work

Biology	**Chemistry**	**Physics**	**Earth/Space Science**
Advanced Knowledge and Skills ▪ …. ▪ …. ▪ ….	Advanced Knowledge and Skills ▪ …. ▪ …. ▪ ….	Advanced Knowledge and Skills ▪ …. ▪ …. ▪ ….	Advanced Knowledge and Skills ▪ …. ▪ …. ▪ ….
Essential Knowledge and Skills ▪ …. ▪ …. ▪ ….	Essential Knowledge and Skills ▪ …. ▪ …. ▪ ….	Essential Knowledge and Skills ▪ …. ▪ …. ▪ ….	Essential Knowledge and Skills ▪ …. ▪ …. ▪ ….
Foundation Knowledge and Skills Basic Knowledge Thinking About Science Solving Problems Asking Questions Reading, Writing, Communication Orientation Towards Learning Scientific Method Basic Mathematics Conventions, Probability, Statistics, Measurement			

Practice dimension: How do we define useful and connected understanding?

Use NAEP practice dimension: Understanding a content statement involves mastery of all four kinds of practices:

← Communicate accurately and effectively →					
	Identifying Science Principles	Describe, measure, or classify observations	State or recognize correct science principles	Demonstrate relationships among closely related science principles	Demonstrate relationships among different representations of principles
	Using Science Principles	Explain observations of phenomena	Predict observations of phenomena	Suggest examples of observations that illustrate a science principle	Propose, analyze, and evaluate alternative explanations or predictions
	Using Scientific Inquiry	Design and critique aspects of scientific investigations	Conduct scientific investigations using appropriate tools and techniques	Identify patterns in data and/or relate patterns in data to theoretical models.	Use empirical evidence to validate or criticize conclusions about explanations and predictions
	Using Techno-logical Design	Propose or critique solutions to problems given criteria and scientific constraints	Identify scientific tradeoffs in design decisions and choose among alternative solutions	Apply science principles or data to anticipate effects of technological design decisions	

Question: Do we want the last category of practice to focus just on technology? What about social participation or personal decision-making, for example? (We decided to address this question by starting to write expectations and deciding what kinds of important practices were missing.)

Language of content expectations: Conceptual or performance?

NAEP solution: Cross conceptual content statements with practices:

		Science Content		
		Physical Science content statements	**Life Science content statements**	**Earth and Space Science content statements**
Science Practices	**Identifying Science Principles**	Identify the units that might be used to measure the speed of an ant and the speed of an airplane (see P8.14).[1]	Identify the raw materials that plants use to make sugars (see L8.4).	Identify wind as the movement of air from higher to lower pressure regions (see E8.11).
	Using Science Principles	An object (such as a toy car) moves with a constant speed along a straight line. Predict (with justification) what might happen to this object's speed as it rolls downhill (see P8.16).	Explain why sugars are found to move primarily down the stem of a growing plant (e.g., potato, carrot) (see L8.4).	Explain why mountain soils are generally thinner than floodplain soils (see E8.6).
	Using Scientific Inquiry	Design an experiment to determine how the speed of a battery-operated toy car changes as a result of added mass (see P8.16).	Criticize conclusions about likely consequences of consuming various diets based on flawed premises or flaws in logic of reasoning (see L8.5).	Given data (indexed by month) on annual trends of incoming solar radiation for five cities, determine whether the location is in the Northern or Southern Hemisphere (see E8.12).
	Using Technological Design	Design a car that will maintain a constant speed as it goes down a hill (see P8.16).	Identify possible ecological side effects of agricultural fertilizer runoff into a lake (see L8.7).	Describe the consequences (e.g., erosion) of undercutting a steep slope for a road cut (see E8.4).

Note: Text in red seems to me to be overly specific. It would be better to identify a more general class of examples, perhaps with specific examples in parentheses.

[1] In order to identify the science content statement on which each performance expectation is based, the content statement's unique code (from Tables 5, 7, and 9 in Chapter Two) is provided.

How to produce expectations in performance language

We can't write specific performances for all practices for every content expectation. Perhaps the solution is to write performances at the strand level. The NAEP Framework has "strands" identified by separate tables. There are:

6 physical science strands
5 life science strands
7 earth science strands

Possible outline for each content area:

1. General introduction to the content area, perhaps modeled on NAEP introductions (see pages 32, 45, 56). This could be a section where we can be more original than in the specific content statements.
2. Sections for each strand, each having three parts
    a. Essential and advanced content statements (see criteria above)
    b. Performances associated with content statements. NOTE: We need to develop a complete list of performances to be assessed (and therefore a list of performances that is representative of the curriculum as a whole). Possible criteria:
        i. At least one identifying or using performance for each content statement
        ii. At least two inquiry performances and two technology performances for each strand
        iii. Performance statements designate classes of performances, as opposed to specific individual activities (e.g., "Explain how plants (e.g., bean plants, oak trees, algae) make their food" rather than "Explain the process of photosynthesis in a bean plant")
    c. Boundaries for the strand. Following NAEP, we will try to specify boundaries in five categories:
        i. phenomena, examples, or observations;
        ii. representations;
        iii. instruments, units of measurement, and categories for classification;
        iv. technical vocabulary;
        v. clarification/other.

Example draft: Essential expectations for a properties of matter strand

Content Statements	
Essential **P8.1:** Properties of solids, liquids, and gases are explained by a model of matter that is composed of tiny particles in motion. **P8.4:** Elements are a class of substances composed of a single kind of atom. Compounds are a class of substances made up of molecules composed of two or more atoms of two or more different elements. Each element and compound has physical and chemical properties, such as boiling point, density, color, and conductivity, which are independent of the amount of the sample.[2] **P12.1:** Differences in the physical properties of solids, liquids, and gases are explained by the ways in which the molecules of the substances are arranged and the strength of the forces of attraction between the molecules. **P12.2:** Electrons, protons, and neutrons are parts of the atom and have measurable properties including mass and, in the case of protons and electrons, charge. The nuclei of atoms are composed of protons and neutrons. Forces that hold all the particles in the nucleus together are stronger than the electrical forces between the positively charged protons. **P12.3:** In the Periodic Table, elements are arranged according to the number of protons (called the atomic number). This organization illustrates commonality and patterns of physical and chemical properties among the elements. **P12.4:** In a neutral atom, the positively charged nucleus is surrounded by the same number of negatively charged electrons. Atoms of an element whose nuclei have different numbers of neutrons are called isotopes.	**Advanced**
Performances or Expectations (Not yet a complete list)	
Essential: Identifying and Using **P8.1:** Use positions and motions of atoms and molecules to explain the physical properties of solids, liquids, and gases (e.g., ice, liquid alcohol, air)	**Advanced: Identifying and Using** **Advanced: Inquiry and Technology**

[2] While this content statement generally holds, there are some compounds that decompose before boiling.

P8.4: Describe or measure physical and chemical properties of different elements and compounds. **P8.4:** Classify substances as elements or compounds based on their physical and chemical properties and information about their atomic-molecular composition. **P12.1:** Predict differences in melting points of different solids based on information about their chemical composition. **P12.2:** Draw pictures showing the arrangement of protons, neutrons, and electrons in common elements. **P12.3:** Predict properties of common elements based on their position in the Periodic Table. **P12.3:** Locate common elements in the Periodic Table based on descriptions of their physical and chemical properties. **P12.4:** Define the differences between elements and isotopes in terms of the numbers of protons and neutrons in their nuclei **Essential: Inquiry and Technology** **P8.4:** Investigate the physical and chemical properties of unknown substances and use the results of the investigation to make reasonable inferences about their chemical composition. **P12.3:** Identify elements or compounds whose properties make them appropriate for particular uses (e.g., electrical conductors, thermal insulators)	
Boundaries	
Essential technical vocabulary Generally limited to vocabulary in content statements, with the addition of Elements 1-20 and other common elements: iron, gold, silver, mercury, iodine. Common compounds of those elements Physical and chemical properties of substances or samples of substances: state of matter, color, density, mass, volume, pressure, temperature, melting point, boiling point, electrical conductivity, thermal conductivity, metallic character, solubility, flammability, acid/base/salt **Essential examples or observations**	**Advanced technical vocabulary** **Advanced examples or observations** **Advanced instruments and units of measure** **Advanced representations**

Elements and compounds listed above Mixtures of those elements and compounds, including solutions **Essential instruments and units of measure** Quantitative measures of linear dimensions, mass, volume, density, melting point, boiling point using standard laboratory instruments Qualitative descriptions of other chemical and physical properties: conductivity of heat and electricity, solubility Classification of elements as metals or non-metals **Essential representations** Chemical formulas and equations involving elements and compounds listed above Drawings of atoms and molecules Graphs and tables	

Appendix: NAEP Definitions of Boundary Categories

Phenomena, Examples, or Observations

There may be limits to the phenomena, examples, or observations that should be used in assessment items. For example, students may or may not be asked to apply laws of motion to electrons, or answer questions about a detritus-based food chain. In general, the following criteria should be followed in developing and reviewing items:

Students' reasoning and experience at each grade level (4, 8, or 12}

Probability that phenomena related to the topic are:

- experienced in daily life
- experienced in the science curriculum

Research on children's learning

This parameter refers to the breadth and depth of topic coverage in the assessment for grades 4, 8, and 12. Using Physical Science as an example, if the science principle to be assessed is the particulate nature of matter, phenomena that constitute empirical evidence for the this model of matter and the canonical version of the model are appropriate for items, including but not limited to physical properties of solids, liquids, and gases; compressibility; changes of state; thermal expansion and thermal conductivity; electrical conductivity; Brownian motion; solution of solid (sugar) in a liquid (water); diffusion. Taking grade 4 as a further example, it is fair to expect that all children at this level will have experienced most or all of these phenomena, either in their daily lives or as a part of the science curriculum, will be able to make simple predictions on the basis of these experiences, and be able to relate these observations to a model of matter as tiny particles in motion. Items can also ask students to explain that the prediction and other observations they have made are consistent with the idea that matter is composed of particles in motion.

Another guideline concerns boundary statements that may, in the first instance, pertain to a particular subtopic but are applicable across several topics or even across the *Framework* as a whole. One such example is "states of matter." Defining the boundary for the pertinent content statements occurs under the Physical Science subtopic Changes in Matter: only solid, liquid, and gas should be dealt with in the assessment (not states having unusual properties such as plasma, colloids, gels, or superfluid matter); however, this boundary applies across the whole *Framework*, not just in Physical Science.

Representations

Scientific information can be represented in different forms. Data are contained in tables and represented graphically and pictorially. Science principles can be represented verbally and in mathematical equations. Concept maps represent principles as nodes and arrows illustrating relationships between and among concepts. Students can be expected both to interpret and to produce these types of representations, as appropriate to their grade level. Diagrams and pictures of objects, including scientific instruments (rulers, graduated cylinders, thermometers); of particles (atoms, molecules, electrons); and of forces between and among particles also are appropriate for assessment items. Further, boundaries will attend to the kinds of mathematical

operations or equations and chemical formulas that should appear on assessment items. Only representations that students have had the opportunity to use should be a part of assessment items; this may include representations not explicitly mentioned in a content statement but subsumed by it, such as Punnett squares for the Life Science subtopic Heredity and Reproduction.

Mathematics required for understanding and responding to assessment items should not be so complex that an item is assessing mathematical understanding and facility rather than science understanding. Students should have been exposed to the mathematics required for an item one or two years prior to its use on a science assessment item. Computations should be simple so that computation time required is small.

Instruments, Units of Measurement, and Categories for Classification

In some cases, boundaries will describe the instruments students are expected to be able to use and the level of precision expected of students in measuring or classifying phenomena, or in interpreting measurements. All measurements will use the metric system. Properties to be measured are specified at the subtopic level, e.g., for Properties of Matter: mass (weight in grade 4), volume, density.

Technical Vocabulary

Vocabulary is important to science communication. Consequently, knowing definitions of science terms has a place in the science assessment. Students should know the meanings and be able to use science vocabulary associated with the topics to which they have been exposed. Boundaries will deal with technical terms beyond those that appear in the content statements that could be included in assessment items; conversely, some technical vocabulary terms may be considered off-limits.

Assessing the ability to define or use a science term is distinct from assessing knowledge of a principle with which the term is associated. Some items are designed to assess knowledge of the meaning of science vocabulary, others to assess understanding of science principles. If the intent of the item is to assess the understanding of a principle, then science vocabulary should not impede a student's ability to respond to the item. The items below illustrate this guideline. The following item is designed to measure a student's knowledge of the definition of a science term.

Clarification/Other

In addition to the four boundary parameters described above, boundary statements contain a fifth row allowing for clarifying commentary, for example, to restate the "big idea" encompassed by the boundary statement(s), for specifying further the intent of a boundary statement, or for elaborating on suitable types of representation.

Strand Template

Content Statements	
Essential Content Statements	**Advanced Content Statements**
Performances or Expectations (Not yet a complete list)	
Essential: Identifying and Using **Essential: Inquiry and Technology**	**Advanced: Identifying and Using** **Advanced: Inquiry and Technology**
Boundaries	
Essential examples or observations **Essential representations** **Essential instruments and units of measure** **Essential technical vocabulary** **Essential clarification/other**	**Advanced examples or observations** **Advanced representations** **Advanced instruments and units of measure** **Advanced technical vocabulary** **Advanced clarification/other**

Notes on Essential Science Knowledge from Other Content Areas

Note knowledge from other content areas that is needed for the essential or advanced performances in this strand:

Notes on Foundational Knowledge and Skills

Note foundations or general knowledge and skills that are needed for the essential or advanced performances in this strand:

Notes on Introductory Essay

Note ideas or points you might want to make in the essay that introduces your content area:

Comments for NAEP Revision (Optional)

The boundary statements (NOT the essays or content statements) are currently being revised, so your comments would be helpful. In providing your feedback on the content boundary tables and chains, please focus on the following questions:

1. Are the NAEP boundary statements consistent with the content statements? If no, please suggest revisions to the boundary statements.
2. Are the boundary statements appropriate to the grade level? If no, please suggest revisions to the boundary statements.
3. What inconsistences among the boundaries for different topics need to be resolved?
4. What about the boundaries is most important for the audiences of the Michigan Content Expectations: assessment developers, curriculum developers, teachers, and administrators?