Reviewing the Alignment of *IPS* with *NGSS*

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Introductory Physical Science (*IPS*) was developed long before the release of the *Next Generation Science Standards* (*NGSS*); nevertheless, *IPS* does address much of what is called for in the new standards. Since no one program, *IPS* included, should be expected to support instruction in all of the standards for a given grade band (e.g. grades 6 through 8), this report will focus on the three dimensions (science and engineering practices, disciplinary core ideas for physical science, and crosscutting concepts) where *IPS* supports students in meeting the middle school expectations of the *NGSS*.

Although the *NGSS* calls for the three dimensions to be integrated during instruction, this review will parse them out in order to provide some level of analysis of the three dimensions.

The Science and Engineering Practices, Disciplinary Core Ideas, and Crosscutting Concepts listed in the tables are active links. Clicking on them will open your web browser and take you to the description of that item as it appears in *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (2012).

Science and Engineering Practices

The *NGSS* Appendix points out that student proficiency in the use of the practices is accomplished through repeated use in the context of a variety of disciplinary core ideas (i.e. the science and engineering practices are used at all grade levels and are not related to any specific discipline). More information about the practices and a discussion of each one is available in the *NGSS* Appendix. With this in mind, the following analysis of *IPS* content documents the practices that are included in the course as a whole while citing specific chapters when a detailed example is available.

Science and Engineering Practices	Where Included in *IPS*
Asking questions and defining problems	Virtually every experiment in every chapter begins by asking a question that is used as a guide to design the experiment. Students learn the importance and purpose of asking questions during the pre-lab discussion and while performing experiments. In addition, questions raised during the post-lab discussion aid in the process of reaching conclusions.

Developing and using models	The first seven chapters provide the experimental basis for developing the atomic model of matter in Chapter 8. The nature of the experimental design that can produce a model for matter is also modeled in Experiment 8.2, A Black Box. Based on experimental evidence from earlier in the course, the atomic model is expanded in Sections 8.3 through 8.5 to include molecules. In Chapter 9, the molecular model is expanded to include motion, pressure, temperature, and the relative masses of molecules. Chapter 11 uses experimental evidence to determine the mass and size of an atom.
Planning and carrying out investigations	The design, planning, and carrying out of investigations (experiments) is integral to the *IPS* approach and storyline. The disciplinary content of the entire course depends on the results of 50 experiments in 16 chapters. In each experiment, only general instructions are provided, requiring students to make a number of procedural decisions in planning and conducting the experiment.
Analyzing and interpreting data	Because the results of the experiments are not provided in the student text, students work in small groups and subsequently as a class to answer the guiding questions, analyze data, reach conclusions, and construct more generalizable explanations or models.
Using mathematics and computational thinking	Of the 50 experiments, 37 (74%) contain quantitative data and analysis. In addition, every section is followed by a number of questions related to the content and/or experiment included in that section. Many of these questions require mathematical computations. There is an additional set of questions at the end of each chapter, many of which require quantitative reasoning.
Constructing explanations and designing solutions	As indicated for "Analyzing and interpreting data," *IPS* involves a consistent pattern in which students design and carry out investigations, collect data, analyze that data, and interpret the data to construct explanations.

Engaging in argument from evidence	*IPS* students engage in argumentation in virtually every experiment as they analyze and interpret the data from their experiment with the other members of their small experiment group and then with the entire class during the post-lab discussion where the data for the entire class is compiled and graphed or displayed.
Obtaining, evaluating, and communicating information	As a natural element in the strongly experiment-oriented *IPS* program, students blend the comprehension of the written text, the information gained from experiments, and an exchange of ideas with the entire class during post-lab discussions to develop and understand the disciplinary core ideas, the contribution of the practices, and crosscutting concepts. This ability to obtain and communicate information is enhanced by record-keeping in laboratory notebooks and frequent lab reports.

Disciplinary Core Ideas

In the following chart, the Disciplinary Core Ideas cited in *NGSS* are addressed by reference to where they occur in experiments and reading sections within *Introductory Physical Science*. Not referenced are the numerous questions and problems in *IPS* that also support these core ideas.

Disciplinary Core Ideas	Where Included in *IPS*
PS1.A: Structure and Properties of Matter • Substances are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms.	The first 7 chapters of *IPS* build the evidence for this statement, with the 8th chapter then devoted to the atomic model of matter. Section 6.5 addresses the Law of Constant Proportions, and monatomic and diatomic molecules are introduced along with Avogadro's Law in Section 9.6. Sizes and masses of molecules are addressed in Chapters 8 through 11, as well as in Table A on pages 194-195 of the *IPS Teacher's Guide and Resource Book*.

• Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it.	Characteristic properties such as density, freezing/melting point, boiling point, and solubility are studied in Chapters 3 through 5, including 14 experiments. In particular, Chapter 3 provides emphasis on the use of characteristic properties to distinguish among substances, while Chapter 5 introduces mixtures and pure substances, and the utilization of characteristic properties to separate mixtures.
• Gases and liquids are made of molecules or inert atoms that are moving about relative to each other.	Molecular motion and diffusion are discussed and illustrated in Chapter 9.
• In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations.)	The relative densities of various materials are studied in Sections 3.5 through 3.8, including 3 experiments. The movement and resultant collisions of gas molecules are discussed along with diffusion in Section 9.1. These ideas are then used in Section 9.3, where the atomic model is used to predict the relation between volume and pressure of a gas. A parallel is drawn in Section 9.8 between the behavior of gas molecules in a sample at high pressure and the behavior of molecules in a liquid. The densities and compressibilities of liquids and solids are also compared to those of a high-pressure gas. An assumption about the near incompressibility of solids is revisited in a problem at the end of Chapter 11. Table A in Chapter 8 of the *Teacher's Guide and Resource Book* (pp. 194-195) summarizes the links between observations and the atomic model, including the distance between centers of atoms within a molecule and the distance between molecules.
• Solids may be formed from molecules, or they may be extended structures with repeating subunits (e.g., crystals).	Section 8.5, in addressing constant proportions and the atomic model, points out possible arrangements for extended structures of atoms.
• The changes of state that occur with variations in temperature or pressure can be described and predicted (qualitatively) using these models of matter.	The amount of energy (latent heat) involved in a change of state is studied in Experiment 12.6, Melting Ice, as well as Section 12.7, Heat of Fusion and Heat of Vaporization. The behavior of gases under high pressure comprises Section 9.8.

PS1.B: Chemical Reactions • Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants.	 While not specifically making connections between arrangements of atoms and chemical reactions, both decomposition and synthesis reactions are studied in Chapter 6: Compounds and Elements. Sections 6.1 through 6.4, including two experiments, provide the basis for the Law of Constant Proportions introduced in Section 6.5. Experiment 6.6, A Reaction with Copper, and Experiment 6.7, The Separation of a Mixture of Copper Oxide and Copper, involve an incomplete reaction and the fact that products of a reaction may be different from the original reactants. This idea has been foreshadowed by the investigations earlier in the chapter.
• The total number of each type of atom is conserved, and thus the mass does not change.	The Law of Conservation of Mass is addressed in Section 2.7, following the series of experiments earlier in the chapter that provide the basis for arriving at that law. The constancy of the number of atoms and the law of constant proportions are illustrated by "Experiment" 8.4: Constant Composition Using Fasteners and Rings. Table A in Chapter 8 of the *Teacher's Guide and Resource Book* (pp. 194-195) specifically addresses this core idea.
• Some chemical reactions release energy, others store energy.	Heats of reaction for various reactions are discussed in Sections 12.8 and 12.9.
PS1.C: Nuclear Processes	*IPS* strives to achieve student understanding based on students' laboratory and everyday experiences. At this level, nuclear forces, fission, and fusion cannot be addressed experimentally in the classroom. Consequently, nuclear processes were not included in the 9th edition of *IPS*.
PS2.A: Forces and Motion • For any pair of interacting objects, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first, but in the opposite direction (Newton's third law).	 Newton's third law is discussed in Section 14.7, following an introduction to forces in general. In this explanation, the experience gained from an earlier experiment (Experiment 14.5 Sliding Friction) is used to develop the third law, and it is emphasized that Newton's third law involves only the forces that objects exert on each other, not the effects of those forces.

• The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change. The greater the mass of the object, the greater the force needed to achieve the same change in motion. For any given object, a larger force causes a larger change in motion.	The relation between a force on an object and the motion of the object is addressed qualitatively in Section 14.1. Then, after studying single forces and developing the tools to combine forces acting in different directions, the net force is introduced in Section 15.4. Changes in motion due to the application of an unbalanced net force are the subject of Chapter 16, which culminates with a statement of Newton's second law.
• All positions of objects and the directions of forces and motions must be described in an arbitrarily chosen reference frame and arbitrarily chosen units of size. In order to share information with other people, these choices must also be shared.	Measurement skills, the choice of measurement devices, and measurement units are addressed in Chapter 1: Volume and Mass. Additional useful measurement units are introduced as the need arises. For example, the Joule is introduced in Chapter 12, early in the study of energy. The positions of objects and directions of forces and motion are addressed in Chapter 15: Forces Acting in Different Directions, and Chapter 16: Force and Motion in a Straight Line.
PS2.B: Types of Interactions • Electric and magnetic (electromagnetic) forces can be attractive or repulsive, and their sizes depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects.	Experiment 14.4, The Magnetic Force, and Chapter 14, in general, introduce attractive and repulsive forces, including the relation between the magnetic force and distances between magnets.
• Gravitational forces are always attractive. There is a gravitational force between any two masses, but it is very small except when one or both of the objects have large mass—e.g., Earth and the sun.	Section 14.2, Weight: The Gravitational Force, looks at the proportionality between weight and mass, as well as variations in the proportionality constant at different points on Earth's surface.
• Forces that act at a distance (electric, magnetic, and gravitational) can be explained by fields that extend through space and can be mapped by their effect on a test object (a charged object, or a ball, respectively).	The 9th edition of *IPS* was published before the release of *NGSS*. Although weight (Section 14.2) and magnetic force (Experiment 14.4) were included in this edition, the authors consciously omitted the concept of a field, thinking it more appropriate in a high school physics class.

PS3.A: Definitions of Energy	
• The term “heat” as used in everyday language refers both to thermal energy (the motion of atoms or molecules within a substance) and the transfer of that thermal energy from one object to another. In science, heat is used only for this second meaning; it refers to the energy transferred due to the temperature difference between two objects.	Heating and cooling are studied as processes involving the transfer of thermal energy. Section 12.1 introduces changes in thermal energy and establishes the basis for all subsequent energy studies in *IPS*; all energy changes are referred back to a change in thermal energy. The transfer of thermal energy (heating and cooling) is studied through the experiments in Chapter 12 that lead to the idea of specific heat. Experiment 12.6, Melting Ice, then provides the basis for understanding heats of fusion and vaporization in Section 12.7.
• The temperature of a system is proportional to the average internal kinetic energy and potential energy per atom or molecule (whichever is the appropriate building block for the system’s material). The details of that relationship depend on the type of atom or molecule and the interactions among the atoms in the material. Temperature is not a direct measure of a system's total thermal energy. The total thermal energy (sometimes called the total internal energy) of a system depends jointly on the temperature, the total number of atoms in the system, and the state of the material.	This bullet for PS3.A is cited in the elaboration of MS-PS1-4 within *NGSS* as “secondary to MS-PS1-4.” However, it is inaccurate in its definitions of *temperature* and *total thermal energy*. Consequently, no correlation exists with *IPS*. *(Compare to a restatement of the bullet, included in the PS3.A portion of NGSS, which appears 3 rows down in this chart.)*
• Motion energy is properly called kinetic energy; it is proportional to the mass of the moving object and grows with the square of its speed.	Kinetic energy and its relation to speed are addressed in Section 13.3, Kinetic Energy, and Section 13.4, Kinetic Energy as a Function of Speed. Experiment 13.5, Changing Gravitational Potential Energy to Kinetic Energy, as its name suggests, then looks at the increase in kinetic energy provided by a slowly falling object.
• A system of objects may also contain stored (potential) energy, depending on their relative positions.	Potential energy and gravitational potential energy, in particular, are introduced in Experiment 13.1, Heating Produced by a Slowly Falling Object, and Section 13.2, Gravitational Potential Energy. Changes in gravitational potential energy are then used to gather data about energy conversions. Elastic potential energy is introduced later in the chapter.

• Temperature is a measure of the average kinetic energy of particles of matter. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present.	The connection between temperature and the average kinetic energy of the molecules in a sample is established in Section 9.5, Temperature and Molecular Speed. An increase or decrease in temperature is then used as an indicator of a change in thermal energy in Chapter 12.
PS3.B: Conservation of Energy and Energy Transfer • When the motion energy of an object changes, there is inevitably some other change in energy at the same time.	The idea that changes in energy do not occur in isolation is introduced in Section 12.1, at the very beginning of the study of energy. In this way, the groundwork is laid for the eventual introduction of conservation of energy.
• The amount of energy transfer needed to change the temperature of a matter sample by a given amount depends on the nature of the matter, the size of the sample, and the environment.	This idea is built from Experiments 12.2, Mixing Warm and Cool Water, and 12.4, Cooling a Warm Solid in Cool Water. Experiment 12.2 addresses the masses of the samples, while 12.4 studies specific heat. Section 12.5 then compares the specific heats of different substances. Experiment 12.6, Melting Ice, introduces latent heat, which must be considered when the addition or loss of thermal energy causes a change of state.
• Energy is spontaneously transferred out of hotter regions or objects and into colder ones.	This is treated through a question about experimental procedure in Experiment 12.2. Students are asked "Why is this procedure better than putting the cool water (room temperature) in the calorimeter and the warm water in the test tube?"
PS3.C: Relationship Between Energy and Forces • When two objects interact, each one exerts a force on the other that can cause energy to be transferred to or from the object.	This disciplinary core idea is fairly complex, involving Newton's second and third laws, as well as the relationship between energy and forces. The third law is treated in Section 14.7, the second law is addressed in Chapter 16, and the effects of force on motion are spread throughout Chapters 14 through 16.

PS3.D: Energy in Chemical Processes and Everyday Life **PS4.A: Wave Properties** **PS4.B: Electromagnetic Radiation** **PS4.C: Information Technologies and Instrumentation**	Since *NGSS* was released after the 9th edition of *IPS*, the emphasis on these disciplinary core ideas was not anticipated in the context of a physical science course. Consequently, they are not treated within the experiments and reading sections of *IPS*.

Crosscutting Concepts

Much the same repetition and distribution throughout the curriculum that is called for with the Science and Engineering Practices is also required for understanding the value and being able to use the Crosscutting Concepts. As with the practices, crosscutting concepts are ideas that support learning in all science disciplines and provide links between the disciplines. More information about crosscutting concepts can be found in the *NGSS* Appendix. The following analysis of the *IPS* content identifies the crosscutting concepts that are included in the various chapters of *IPS.*

Crosscutting Concepts	Where Included in *IPS*
Patterns	In each experiment students search for patterns in data in order to explain their observations. This crosscutting concept is used in virtually every one of the 37 quantitative experiments. The use of histograms as a means of identifying patterns in data is introduced in Chapter 2 and used throughout the course.
Cause and Effect	In the process of planning and designing experiments throughout the course students create a "cause" and observe the "effect." Their task in the follow-up post-lab discussion is to establish an explanation or generalization based on evidence from the experiment.
Scale, Proportion, and Quantity	The quantitative nature of most of the experiments ensures that the concept of quantity is constantly in use. Proportional thinking is inherent in many of the experiments and concepts introduced, including density, solubility, Boyle's Law, Avogadro's Law, Hooke's Law, specific heat, changes in energy, heat of reaction, kinetic energy, potential energy, velocity, and Newton's Second Law. The concept of scale is introduced in estimating the sizes and masses of atoms and molecules.

Systems and System Models	The experiments dealing with heating and cooling in Chapter 12 require creating and maintaining systems that do not lose thermal energy. Experiments involving thermal, kinetic, and potential energies require students to understand the various parts of a system and the transfer of energy from one part of the system to another. An understanding of systems is also necessary to understand the experiments leading to the Law of Conservation of Mass and Conservation of Energy.
Energy and Matter	While not always explicitly stated, the ideas in this crosscutting concept are present in every experiment in every chapter.
Structure and Function	An entire chapter (Chapter 9: Molecular Motion) is devoted to the development of the nature and behavior of molecules based on the evidence collected from a series of experiments illustrating diffusion and the relationship of pressure, temperature and volume of a gas.
Stability and Change	Chapter 7: Radioactivity illustrates an example of change that is random on the micro scale while being both regular and predictable on the macro scale. Changes in temperature and energy are addressed in Chapters 12–16 through a number of experiments.