LAB-AIDS Correlations for

A FRAMEWORK FOR K-12 SCIENCE EDUCATION: PRACTICES, CROSSCUTTING CONCEPTS, AND CORE IDEAS[1]

Mark Koker, Ph D, Director of Curriculum & Professional Development, LAB-AIDS

This document intended to show how our curriculum products align with the new directions in the current Framework document, which should also give the reader an idea of how LAB-AIDS curriculum products will ultimately align with the "Next Generation" Science Standards, since these will be based heavily on this Framework.[2]

ABOUT OUR PROGRAMS

LAB-AIDS Core Science Programs are developed to support current knowledge on the teaching and learning of science. All materials support an inquiry-driven pedagogy, with support for literacy skill development and with assessment programs that clearly show what students know and are able to do from using the programs. All programs have extensive support for technology in the school science classrooms, and feature comprehensive teacher support. For more information, please visit www.lab-aids.com, and navigate to the program of interest.

Our middle and high school science programs support the intent of the next generation *Framework*—and will support the standards derived from them (expected public release in 2013)—as shown in this document.

Middle Level, Grades 6-8

SEPUP

Materials from the Science Education for Public Understanding Program (SEPUP) are developed at the Lawrence Hall of Science, at the University of California, Berkeley, and distributed nationally by LAB-AIDS, Inc. Development of SEPUP materials is supported by grants from the National Science Foundation.

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[1] Committee on Conceptual Framework for the New K-12 Science Education Standards; National Research Council

[2] It is not an exhaustive document, and does not purport to show every match between the *Framework* and our curricula.

Issues and Earth Science

- A. Studying Soils Scientifically, 1-11
- B. Rocks and Minerals, 12-23
- C. Erosion and Deposition, 24-35
- D. Plate Tectonics, 36-49
- E. Weather and Atmosphere, 50-70
- F. The Earth in Space, 71-84
- G. Earth and the Solar System, 85-98

Issues and Life Science

- Experimental Design: Studying People Scientifically, 1-10
- Body Works, 11-29
- Cell Biology and Disease, 30-53
- Genetics, 54-71
- Ecology, 72-88
- Evolution, 89-101
- Bioengineering, 102-108

Issues and Physical Science

- Studying Materials Scientifically, 1-11
- The Chemistry of Materials, 12-29
- Water, 30 – 52
- Energy, 53-72
- Force and Motion, 73-88

LAB-AIDS KITS and SEPUP Modules

- 211 Energy Transfer: Waves, Sound and Light
- P140 Investigating Light and Matter
- HC-2 Household Chemicals
- TT-2 Thresholds and Toxicity

High School

Environmental Science
Science and Sustainability is developed by the SEPUP group at the Lawrence Hall of Science, University of California Berkeley, under the direction of Dr Barbara Nagle, SEPUP Director. Development of *Science and Sustainability* was supported by grants from the National Science Foundation. There are four units in the course, as follows:

- Part 1 – Living on Earth
- Part 2 – Feeding the World
- Part 3 – Using Earth's Resources
- Part 4 – Feeding the World

Biology

Science and Global Issues: Biology (SGI Biology) was developed by the SEPUP group, at the Lawrence Hall of Science, University of California Berkeley, under the direction of Dr Barbara Nagle, SEPUP Director. Development of *SGI Biology* is supported by grants from the National Science Foundation. *SGI Biology* is published by, and available exclusively from, LAB-AIDS, Ronkonkoma NY. There are five units in *SGI Biology*, as follows:

•Sustainability, pp. 1-46
•Ecology: Living on Earth, pp. 43-154
•Cell Biology: World Health, pp. 155-258
•Genetics: Feeding the World, pp. 259-412
•Evolution: Maintaining Diversity, pp. 413-512

Chemistry

A Natural Approach to Chemistry (NAC) is written by Hsu, Chaniotakis, Carlisle, and Damelin, The course provides an integrated, 5E-based approach to the study of chemistry using examples from the chemistry of the human health and the environment to engage and motivate students. It features a student book, lab manual (59 labs), a specially-designed probeware system (the LAB-MASTER®), and full teacher support.

For more information on any of our programs, please visit us on the web at www.lab-aids.com.

ABOUT THE NEXT GENERATION FRAMEWORK

A Framework for K-12 Science Education Standards (released in July 2011) represents the first step in a process to create new standards in K-12 science education. This *Framework* builds on the strong foundation of previous studies that have sought to identify and describe the major ideas for K-12 science education. These include *Science for All Americans* and *Benchmarks for Science Literacy* (1993) developed by the American Association for the Advancement of Science (AAAS) and the *National Science Education Standards* (1996) developed by the National Research Council. The *Framework* highlights the power of integrating understanding the ideas of science with engagement in the practices of science and is designed to build students' proficiency and appreciation for science over multiple years of school. Of particular note is the prominent place given to the ideas and practices of engineering.

The Carnegie Corporation has taken a leadership role to ensure that the development of common science standards proceeds and is of the highest quality by funding a two-step process: first, the development of this framework by the National Research Council (NRC) and, second, the development of a next generation of science standards based on the framework by Achieve, Inc. The *Framework* highlights the power of integrating understanding the ideas of science with engagement in the practices of science and is designed to build students' proficiency and appreciation for science over multiple years of school. The *Framework* represents the first step in a process that should inform state-level decisions and provide a research-grounded basis for improving science teaching and learning across the country. It is intended to guide standards developers, curriculum designers, assessment developers, state and district science administrators, professionals responsible for science teacher education, and science educators working in informal settings.

OVERVIEW OF THE FRAMEWORK

A. Scientific and Engineering Practices

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

B. Crosscutting Concepts

1. Patterns
2. Cause and effect: Mechanism and explanation
3. Scale, proportion, and quantity
4. Systems and system models
5. Energy and matter: Flows, cycles, and conservation
6. Structure and function
7. Stability and change

C. Disciplinary Core Ideas

C1. Physical Sciences

PS 1: Matter and its interactions
PS 2: Motion and stability: Forces and interactions
PS 3: Energy
PS 4: Waves and their applications in technologies for information transfer

C2. Life Sciences

LS 1: From molecules to organisms: Structures and processes
LS 2: Ecosystems: Interactions, energy, and dynamics
LS 3: Heredity: Inheritance and variation of traits
LS 4: Biological evolution: Unity and diversity

C3. Earth and Space Sciences

ESS 1: Earth's place in the universe
ESS 2: Earth's systems
ESS 3: Earth and human activity

C4. Engineering, Technology, and the Applications of Science

ETS 1: Engineering design
ETS 2: Links among engineering, technology, science, and society

The following sections give examples from our middle level and high school programs that shows how the scientific and engineering practices in the *Framework* are addressed. Practice goals reference 12th grade exit outcomes.

A. SCIENTIFIC AND ENGINEERING PRACTICES

"Engaging in the practices of science helps students understand how scientific knowledge develops; such direct involvement gives them an appreciation of the wide range of approaches that are used to investigate, model, and explain the world. Engaging in the practices of engineering likewise helps students understand the work of engineers, as well as the links between engineering and science. Participation in these practices also helps students form an understanding of the crosscutting concepts and disciplinary ideas of science and engineering; moreover, it makes students' knowledge more meaningful and embeds it more deeply into their world view." [3]

LAB-AIDS curriculum materials in general, and SEPUP materials specifically, can be used to address the Practices component of the *Next Gen* Framework. The following table provides information on the SEPUP instructional design that support *Next Gen* practices.

Next Gen Framework Practice	SEPUP Design that supports this feature
1. Asking questions (for science) and defining problems (for engineering)	The 'Key Skills' section of the SEPUP TG provides detailed information on locations in the program that call for students to ask questions, control variables, make and revise predictions/hypotheses, and more

[3] A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas, p. 3-1.

Next Gen Framework Practice	SEPUP Design that supports this feature
2. Developing and using models	SEPUP features specific 'modeling' type activities and comment on the use of the model in understanding the concept
3. Planning and carrying out investigations	SEPUP features specific 'designing investigations' type activities and a 4-point rubric to assess student performance
4. Analyzing and interpreting data	SEPUP features specific 'analyzing data' type activities and a 4-point rubric to assess student performance
5. Using mathematics and computational thinking	The 'Key Skills' section of the SEPUP middle level TGs provides detailed information on locations in the program that call for students to use mathematics, calculate simple statistics, create/use graphs and tables, and more
6. Constructing explanations (for science) and designing solutions (for engineering)	The 'Key Skills' section of the SEPUP TG provides detailed information on locations in the program that call for students to write explanations, make presentations, and more
7. Engaging in argument from evidence information	SEPUP features specific 'evidence and tradeoffs' type activities, which focus on constructing arguments from evidence, and a 4-point rubric to assess student performance
8. Obtaining, evaluating, and communicating	SEPUP features specific 'communicating scientific information' type activities and a 4-point rubric to assess student performance

The tables below provide specific activity references and examples of how the scientific and engineering practices appear in our curriculum materials. It is not a complete, exhaustive listing, other examples appear that are not listed below.

Practice 1. Asking questions

Practice Goals	*SEPUP Middle Level*	*SEPUP SGI Biology*	*Natural Approach to Chemistry*
Ask questions about the natural and human-built worlds—for example: Why are there seasons? What do bees do? Why did that structure collapse? How is	IAES 16, 55, 67, 72 IAPS 3, 38, 39, 51, 54, 65, 68, 74, 77 IALS 5, 8, 14, 48,	Throughout, see for example: Eco 10-11 Cell 11	Throughout, see for example "Chemisry Connections" in each chapter, SB 1.3x, 2.3x, 3.3x, etc.

Practice Goals	*SEPUP Middle Level*	*SEPUP SGI Biology*	*Natural Approach to Chemistry*
electric power generated?	64, 81, 83		
Distinguish a scientific question (e.g., Why do helium balloons rise?) from a non-scientific question (Which of these colored balloons is the prettiest?)	SEPUP Module: TT-2, HC-2	Appendices H, I	SB 1.2 (also Florida lab manual)
Formulate and refine questions that can be answered empirically in a science classroom and use them to design an inquiry or construct a pragmatic solution.	IAES 16, 55, 67, 72 IAPS 3, 38, 39, 51, 54, 65, 68, 74, 77 IALS 5, 8, 14, 48, 64, 81, 83	Eco 10-11 Cell 11	Throughout, e.g., LM 15A (e.g., in a lemon battery, where does the energy come from, and how can this principle be used to design batteries?)
Ask probing questions that seek to identify the premises of an argument, request further elaboration, refine a research question or engineering problem, or challenge the interpretation of a data set—for example: How do you know? What evidence supports that argument?	IAES 2, 18, 23, 24, 36, 49, 50, 70, 71, 83, 98 IALS 10, 34, 67, 71, 72, 87, 89, 101 IAPS 11, 29, 33, 44, 47. 49, 52, 73, 87	Eco 1, 18 Cell1, 15, 17, 18 Gen 20 Evo 1, 14, 15	Throughout, e.g., LM 12A (Why are living organisms dependent on temperature?)
Note features, patterns, or contradictions in observations and ask questions about them.	IAES 76, 82, 95 IALS 14, 19, 22, 30, 39, 40, 47, 51, 60, 64, 66, 77 IAPS 6, 7, 10, 18, 35, 37, 38, 41, 63, 64, 67, 83, 87	Sus 5 Eco 2, 10, 14, 16 Cell 1, 7, 8, 11 Gen 4, 20	Throughout, e.g., SB 5.4x[4] (why do different elements give off different colors when heated?)

[4] Note, '5.4x' refers to the chemistry connections after section 5.4

Practice Goals	*SEPUP Middle Level*	*SEPUP SGI Biology*	*Natural Approach to Chemistry*
For engineering, ask questions about the need or desire to be met in order to define constraints and specifications for a solution.	IALS 104-105, 107 IAES 34 IAPS 85	Gen 2, 11, 13.1[5], 16.1, 17.1, 19	Throughout, e.g., SB 10.4x (What does it mean to manufacture chemical products, especially using "green" techniques

Practice 2. Making and Using Models

Practice Goals	*SEPUP Middle Level*	*SEPUP SGI Biology*	*Natural Approach to Chemistry*
Construct drawings or diagrams as representations of events or systems, or to represent a simple physical model of a real-world object and use it as the basis of an explanation or to make predictions about how the system will behave in specified circumstances.	IALS 12, 18, 21 IAES 73, 80, 90 IAPS 20, 49, 86	Eco 6 Cell 3 Gen 17 Evo 7	SB 12.1, 12.4 (reaction profiles, catalysts); 13A (calibration curves for pH measurement using spectrophotometry)
Represent and explain phenomena with multiple types of models—for example, represent molecules with 3-D models or with bond diagrams—and move flexibly between model types when different ones are most useful for different purposes.	IALS 12, 21, 40, 69 IAES 21, 28, 37 IAPS 20, 36, 65, 86	Eco 5 Cell 7 Gen 10, 12, 16, 17 Evo 12	LM 5A (atomic model), LM 5C (spectrum cards), 6C (valence, using atom model), 7B (molecular geometry using molecular models)
Discuss the limitations and precision of a model as the representation of a system, process, or design and suggest ways	IAPS 20, 36 IAES 37, 43 IALS 30, 51, 96	Eco 5 Cell 7 Evo 12	SB 2.2 (p. 51)

[5] Note, '13.1, 16.1, 17.1, hereinafter refer to the case studies following each activity cited

Practice Goals	*SEPUP Middle Level*	*SEPUP SGI Biology*	*Natural Approach to Chemistry*
in which the model might be improved to better fit available evidence or better reflect a design's specifications.			
Use (provided) computer simulations or simulations developed with simple simulation tools as a tool for understanding and investigating aspects of a system, particularly those not readily visible to the naked eye.	IAES 40, 44, 47, 48, 51, 64, 68, 76, 81 IAPS 55, 64, 71-72, 85 IALS 6, 12, 17, 21, 23, 26, 27, 28, 57, 61, 63	Eco 8, 9, 14 Cell 4, 5, 12, 16, Gen 3, 12, 16 Evo 11	Not addressed
Make and use a model to test a design, or aspects of a design, and to compare the effectiveness of different design solutions.	IAES 24, 31 IALS 104, 105, 107 IAPS 70, 85, 86	Eco 5 Cell 7 Gen 3, 7, 10, 16 Evo 12	LM 12A, procedure step 7

Practice 3. Planning and Carrying Out Investigations

Practice Goals	*SEPUP Middle Level*	*SEPUP SGI Biology*	*Natural Approach to Chemistry*
Formulate a question that can be investigated within the scope of the classroom, school laboratory, or field with available resources and, when appropriate, frame a hypothesis for an expected outcome based on a model or theory.	IAES 16, 55, 67, 72 IAPS 3, 38, 51, 54, 65, 68, 74, 77 IALS 5, 8, 14, 48, 64, 81, 83	Not addressed	LM 9A, 15A
Decide what data are to be gathered, what tools are needed to do the gathering, and how measurements will be recorded.			LM 4A, 17B

Practice Goals	*SEPUP Middle Level*	*SEPUP SGI Biology*	*Natural Approach to Chemistry*
Decide how much data are needed to produce reliable measurements and consider any limitations on the precision of the data.			LM 12A
Plan experimental or field-research procedures, identifying relevant independent and dependent variables and, when appropriate, the need for controls.	IAES 67, 69, 72 IALS 74, 83, 86 IAPS 59, 60, 67, 70	Sus 5 Eco 2, 10, 11 Cell 11 Gen 2, 18	SB 1.2
Consider possible confounding variables or effects and ensure that the investigation's design has controlled for them.	IAES 10, 28, 72 IALS 2, 8, 10, 14, 17 IAPS 3, 27-28, 51, 56	Not addressed	LM 11A (missing mass in the reaction is actually carbon dioxide gas)

Practice 4. Analyzing and Interpreting Data

Practice Goals	*SEPUP Middle Level*	*SEPUP SGI Biology*	*Natural Approach to Chemistry*
Analyze data systematically, either to look for salient patterns or to test whether the data are consistent with an initial hypothesis.	IAES 76, 82, 95 IALS 14, 19, 22, 30, 39, 40, 47, 51, 60, 64, 66, 77 IAPS 6, 7, 10, 18, 35, 37, 38, 41, 63, 64, 67, 83, 87	Sus 5 Eco 2, 10, 16 Cell 8, 11 Gen 4, 20	LM 4A
Recognize when the data are in conflict with expectations and consider what revisions in the initial model are needed.			LM 3B (mixing equal quantities of different substances does not result in a mixture with average temperature)
Use spreadsheets, databases, tables, charts, graphs, statistics, mathematics, and information technology to collate, summarize,	IALS 3, 14, 17, 19, 30, 51, 54, 72, 77, 78, 84, 85, 95, 96, 98 IAPS 12, 22, 40,	Eco 2, 3, 10, 12, 14, 18, 19 Gen 7, 11, 20	LM 9B (create a calibration curve for measurement vs. absorption)

Practice Goals	*SEPUP Middle Level*	*SEPUP SGI Biology*	*Natural Approach to Chemistry*
and display data and to explore relationships between variables, especially those representing input and output.	75, 78, 83 IAES 27, 51, 52, 55, 70, 75, 93, 95	Evo 1, 4 Note Appendix B, Bar graph checklist	
Evaluate the strength of a conclusion that can be inferred from any data set, using appropriate grade-level mathematical and statistical techniques.	IALS 17, 19, 77 IAES 27, 51, 54, 64, 90, 91 IAPS 56, 74, 76, 77	Sus 5 Cell 11 Gen 20	LM 3B (calculate specific heat by successive approximation)
Recognize patterns in data that suggest relationships worth investigating further. Distinguish between causal and correlational relationships.	IALS 17, 77 IAPS 54, 76, 77 IAES 51, 55, 56, 58, 70, 75	Sus 5 Eco 2, 10, 16 Cell 8, 11 Gen 4, 20 Sus 5 Eco 16	LM 12A (plot growth rate vs pH, salinity, sugar concentration); SB 19.1 (carbon dioxide and global climate change)
Collect data from physical models and analyze the performance of a design under a range of conditions.	IAPS 54, 76, 74, 77, 82 IAES 28, 31-32, 67, 72 IALS 17, 22, 24, 27, 48, 104-105	Sus 5 Eco 2, 10, 16 Cell 8, 11 Gen 4, 20	LM 20A (half-life simulation)

Practice 5. Using Mathematics, Information and Computer Technology, and Computational Thinking

Practice Goals	*SEPUP Middle Level*	*SEPUP SGI Biology*	*Natural Approach to Chemistry*
Recognize dimensional quantities and use appropriate units in scientific applications of mathematical formulas and graphs.	IAPS 74, 76, 78 IAES 67, 70	Sus 5 Eco 10, 11 Cell 11	SB 1.1 LM 1D
Express relationships and quantities in	IAPS 74, 76, 78	These standards not addressed but	SB 13.2

Practice Goals	*SEPUP Middle Level*	*SEPUP SGI Biology*	*Natural Approach to Chemistry*
appropriate mathematical or algorithmic forms for scientific modeling and investigations.		will be in upcoming SGI Physics units.	LM 13A
Recognize that computer simulations are built on mathematical models that incorporate underlying assumptions about the phenomena or systems being studied.	IAES 76, 81	Eco 8, 14 Evo 11	Not addressed
Use simple test cases of mathematical expressions, computer programs, or simulations—that is, compare their outcomes with what is known about the real world—to see if they "make sense."	IAES 68, 76, 81	Eco 8, 14 Gen 4, 7 Evo 11 (?)	Not addressed
Use grade-level appropriate understanding of mathematics and statistics in analyzing data.	IALS 17, 19, 77 IAES 27, 51, 54, 64, 90, 91 IAPS 56, 74	Standard not addressed	LM 3B (derivation of specific heat equation relating mass and temperature) SB 13.2 (pH scale derived from log of hydrogen ion concentration)

Practice 6: Constructing Explanations and Designing Solutions

Practice Goals	*SEPUP Middle Level*	*SEPUP SGI Biology*	*Natural Approach to Chemistry*
Construct their own explanations of phenomena using their knowledge of accepted scientific theory and	IAES 21, 28, 40-41, 47-48, 73, 76-77, 81 IALS 12, 21, 24,	Eco 5, 15 Cell 7 Gen 6,7, 10, 13, 16, 17 Evo 3, 11, 12	Throughout, see for example "conceptual questions" at end of each chapter,

Practice Goals	*SEPUP Middle Level*	*SEPUP SGI Biology*	*Natural Approach to Chemistry*
linking it to models and evidence.	40-41, 51 IAPS 17, 36, 49, 65		e.g., 5.1 (23, 24, 26); 5.2 (32); 5.3 (45, 50) etc.
Use primary or secondary scientific evidence and models to support or refute an explanatory account of a phenomenon.	IAES 42, 47, 52, 56, 63, 68, 69 IALS 21, 24, 27, 40, 77, 93 IAPS 18, 25, 33	Eco 5, 15 Cell 7 Gen 6,7, 10, 13, 16, 17 Evo 3, 11, 12	Throughout, see for example "conceptual questions" at end of each chapter, e.g., 5.2 (32, 37, 38), etc.
Offer causal explanations appropriate to their level of scientific knowledge.	IALS 2, 19 IAES 42, 58, 77	Sus 5	Throughout, see for example "conceptual questions" at end of each chapter, e.g., 3.3 (49), also SB 3.2, LM 3B, etc.
Identify gaps or weaknesses in explanatory accounts (their own or those of others).		Eco 9, 11, 14 Gen 3, 16	Not addressed

In their experience of engineering, students should have the opportunity to:

Practice Goals	*SEPUP Middle Level*	*SEPUP SGI Biology*	*Natural Approach to Chemistry*
Solve design problems by appropriately applying their scientific knowledge.	IAES 31 IALS 104, 105, 107 IAPS 85 HC-2	Not addressed in SGI Biology but will be in SGI Physics.	17A (how to clean up an oil spill)
Undertake design projects, engaging in all steps of the design cycle and producing a plan that meets specific design criteria.	IALS 104, 105, 107		SB 15.4, LM 15 (design, construct, and test, an electrochemical cell)
Construct a device or implement a design	IALS 104, 105, 107		SB 15.4, LM 15 (design, construct,

Practice Goals	*SEPUP Middle Level*	*SEPUP SGI Biology*	*Natural Approach to Chemistry*
solution.			and test, an electrochemical cell)
Evaluate and critique competing design solutions based on jointly developed and agreed-on design criteria.	IALS 104, 105, 107		Not addressed

Practice 7: Engaging in Argument from Evidence

Practice Goals	*SEPUP Middle Level*	*SEPUP SGI Biology*	*Natural Approach to Chemistry*
Construct a scientific argument showing how the data support the claim.	IAPS 11, 12, 27-29, 40, 51-52, 64, 88 IAES 11, 23, 34, 36, 49, 70, 83, 89, 98 IALS 9, 10, 29, 29, 32, 34, 49, 53, 67, 71, 87-88	Sus 6 Eco 4, 5, 19 Cell 18, Gen 1, 10 Evo 9, 15	LM 13C (explain the mechanism for how commercial antacids work)
Identify possible weaknesses in scientific arguments, appropriate to the students' level of knowledge, and discuss them using reasoning and evidence.			SB 21.3 (probability of extraterrestrial life)
Identify flaws in their own arguments and modify and improve them in response to criticism.			LM 3B
Recognize that the major features of scientific arguments are claims, data, and reasons and distinguish these elements in examples.			SB 1.2 (the scientific method)
Explain the nature of the controversy in the development of a given scientific idea, describe the debate that surrounded its inception, and indicate	IALS 37, 60, 94, 97 IAES 16, 40-42 IAPS 15-16, 80	Gen 12 Evo 4, 11, 14	Florida LM, extension D

Practice Goals	*SEPUP Middle Level*	*SEPUP SGI Biology*	*Natural Approach to Chemistry*
why one particular theory succeeded.			
Explain how claims to knowledge are judged by the scientific community today and articulate the merits and limitations of peer review and the need for independent replication of critical investigations.	IAES 42 IALS 2, 37, 94 IAPS 33,	Appendix I	SB 1.2 (the scientific method)
Read media reports of science or technology in a critical manner so as to identify their strengths and weaknesses.	There is online support for this standard at www.sepuplhs.org, on a course-by-course basis	Appendix H, and online at www.sepuplhs.org	Not addressed

Practice 8: Obtaining, Evaluating, and Communicating Information

Practice Goals	*SEPUP Middle Level*	*SEPUP SGI Biology*	*Natural Approach to Chemistry*
Use words, tables, diagrams, and graphs (whether in hard copy or electronic), as well as mathematical expressions, to communicate their understanding or to ask questions about a system under study.	IALS 3, 14, 17, 19, 30, 51, 54, 72, 77, 78, 84, 85, 95, 96, 98 IAES 27, 51, 52, 55, 70, 75, 93, 95 IAPS 12, 22, 40, 75, 78, 83	Sus 5, 6 Cell 10 Gen 15, 18 Evo 3, 14, 15	LM 3C, 4A, 5B, 5C, 7A-B, 9A-9B
Read scientific and engineering text, including tables, diagrams, and graphs, commensurate with their scientific knowledge and explain the key ideas being communicated.	IAPS 27, 28, 29, 52, 85, IAES 69, 84, 98 IALS 29, 31, 37, 67, 71, 73, 7483, 86, 88	Sus 5, 6 Cell 10 Gen 15, 18 Evo 3, 14, 15	LM 13D, 18A
Recognize the major	IAPS 27, 28, 29,	Sus 5, 6	LM 3C, 4A, 5B, 5C,

Practice Goals	*SEPUP Middle Level*	*SEPUP SGI Biology*	*Natural Approach to Chemistry*
features of scientific and engineering writing and speaking and be able to produce written and illustrated text or oral presentations that communicate their own ideas and accomplishments.	52, 85, IAES 69, 84, 98 IALS 29, 31, 37, 67, 71, 73, 7483, 86, 88	Cell 10 Gen 15, 18 Evo 3, 14, 15	7A-B, 9A-9B
Engage in a critical reading of primary scientific literature (adapted for classroom use) or of media reports of science and discuss the validity and reliability of the data, hypotheses, and conclusions.	IAPS 33 IALS 37, 60, 97 IAES 42	Not addressed	Not addressed

B. CROSS-CUTTING CONCEPTS

The crosscutting concepts were selected for their value across the sciences and in engineering. These concepts help provide students with an organizational framework for connecting knowledge from the various disciplines into a coherent and scientifically based view of the world.

> "Although crosscutting concepts are fundamental to an understanding of science and engineering, students have often been expected to build such knowledge without any explicit instructional support. Hence the purpose of highlighting them as Dimension 2 of the framework is to elevate their role in the development of standards, curricula, instruction, and assessments. These concepts should become common and familiar touchstones across the disciplines and grade levels. Explicit reference to the concepts, as well as their emergence in multiple disciplinary contexts, can help students develop a cumulative, coherent, and usable understanding of science and engineering." [6]

Reviewers of national science education documents will likely recognize content from this section as mapping to Chapters 1-3, and 11-12 of *Atlas of Scientific Literacy* (AAAS, 2001), and from the standards relating to Unifying Concepts and Processes, Science as Inquiry, Science and Technology, and History and Nature of Science from the *National Science Education Standards* (National Research Council, 1996).

Cross-cutting concepts	*SEPUP Middle Level*	*SEPUP SGI Biology*	*Natural Approach to Chemistry*
1. *Patterns.* Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them.	IALS 66, 75, 76, 90, 91 IAPS 15, 16, 58 IAES 40, 44, 56	Appendix G Gen 5, 8	SB 6.1-6.3 LM 6A-C
2. *Cause and effect: Mechanism and explanation*. Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and	IALS 19 IAES 42, 58, 77, 80 IAPS 34, 49	Sus 5 Cell 14 Gen 16, 17	SB 3.3, 4.1, 5.4, 6.2 6.3, 12.2-12.4. 14.1, 16.1, 17.3

[6] A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas, p 4-1.

Cross-cutting concepts	*SEPUP Middle Level*	*SEPUP SGI Biology*	*Natural Approach to Chemistry*
explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts.			
3. *Scale, proportion, and quantity.* In considering phenomena, it is critical to recognize what is relevant at different measures of size, time, and energy and to recognize how changes in scale, proportion, or quantity affect a system's structure or performance.	IAES 8, 42, 55, 68 IAPS 17, 20, 24, 58 IALS 12, 18, 77, 85, 87	Eco 14, 16 Cell 16.1 Gen 20 Evo 1, 2, 15	SB 2.2, 3.3, 4.2, 7.1, 8.3, 12.4, 18.1-18.5
4. *Systems and system models.* Defining the system under study—specifying its boundaries and making explicit a model of that system—provides tools for understanding and testing ideas that are applicable throughout science and engineering.	IALS 12, 40-41, 51, 53, 59, 63, 69-70 IAES 25, 28, 32, 40, 42, 47-48, 54, 68, 76, 77, 80-81 IAPS 31-34, 31, 44, 52	Eco 7, 8, 9, 16-17 Cell 3, 7, 8 Gen 10, 12 Eco 1, 15	SB 12.2-12.3, 14.2, 21.1-21.3
5. *Energy and matter: Flows, cycles, and conservation.* Tracking fluxes of energy and matter into, out of, and within systems helps one understand the systems' possibilities and limitations.	IALS 79, 80, 81 IAES 42, 55, 58, 62, 75 IAPS 58, 69, 70	Eco 7, 8, 9	SB 1.3, 3.2, 5.2, 8.3, 9.1, 10.4, 19.1-19.3, 20.4
6. *Structure and function.* The way in	IALS 16, 21, 24,	Cell 4, 5	SB 2.2, 4.1, 5.1-5.3,

Cross-cutting concepts	*SEPUP Middle Level*	*SEPUP SGI Biology*	*Natural Approach to Chemistry*
which an object or living thing is shaped and its substructure determine many of its properties and functions.	40, 43, 63, 104-105 IAPS 17, 20-21, 36-37, 48-49, IAES 15, 21, 29-30	Gen 10, 12, 14 Evo 5, 6, 7, 8	6.1-6.2, 7.3, 8.1-8.2, 16.2, 17.1-17.2, 18.1-18.5
7. *Stability and change*. For natural and built systems alike, conditions of stability and determinants of rates of change or evolution of the system are critical elements of study.	IALS 92, 93, 97, 98, 99 IAES 22, 28-29, 41-42, 62 IAPS 13	Eco 14, 16, 17 Cell 14, 16 Gen 12, 16 Evo 3, 8, 12	SB 12.1, 19.1-19.3, 20.3

C. CORE SCIENCE AND ENGINEERING CONCEPTS

PHYSICAL SCIENCE

The committee developed three core ideas in the physical sciences:

- PS1: Matter and Its Interactions;
- PS2: Motion and Stability: Forces and Interactions; and,
- PS3: Energy.

These three core ideas parallel those identified in previous documents, including the *National Science Education Standards* and *Benchmarks for Science Literacy*.

They also introduce a fourth core idea: PS4: Waves and Their Applications in Technologies for Information Transfer. The committee included this fourth idea to stress the interplay of physical science and technology, as well as to expand student's understanding of light and sound as mechanisms of both energy transfer and transfer of information between objects that are not in contact.

Modern communication, information and imaging technologies are applications of scientific understandings of light and sound and their interactions with matter, and modern science could not be done without it.

Core Idea	*LAB-AIDS Location*
Core Idea PS1: Matter and Its Interactions	
PS1.A: Structure and Properties of Matter	
By the end of grade 8. All substances are made from some 100 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. Pure substances are made from a single type of atom or molecule; each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it.	IAPS 14-16

Core Idea	LAB-AIDS Location
Gases and liquids are made of molecules or inert atoms that are moving about relative to each other. 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. Solids may be formed from molecules, or they may be extended structures with repeating subunits (e.g., crystals). The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter.	IAPS 35 IAPS 35-36
By the end of grade 12. Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states. The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. Stable forms of matter are those in which the electric and magnetic field energy is minimized. A stable molecule has less energy, by an amount known as the binding energy, than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart.	NAC 5.1 NAC 6.1, 6.2 NAC 7.1, 7.2 NAC 20.4
PS1.B: Chemical Reactions	
By the end of grade 8. 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. The total number of each type of atom is conserved, and thus the mass does not change. Some chemical reactions release energy, others capture or	IAPS 15-16 IAPS 25

Core Idea	*LAB-AIDS Location*
store energy.	
By the end of grade 12. Chemical processes, their rates, and whether or not energy is absorbed or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in total binding energy (i.e., the sum of all bond energies in the set of molecules) that are matched by changes in kinetic energy. In many situations, a dynamic and condition-dependent balance between a reaction and the reverse reaction determines the numbers of all types of molecules present. The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions. Chemical processes and properties of materials underlie many important biological and geophysical phenomena.	NAC 10.4 NAC 12.1, 12.2 NAC 10.3 NAC 2.3x[7], 4.3x, 5.4x, 6.3x, 7.3x, 8.4x,
PS1.C: Nuclear Processes	
By the end of grade 8. Nuclear fusion can result in the merging of two nuclei to form a larger one, along with the release of significantly more energy per atom than any chemical process. It occurs only under conditions of extremely high temperature and pressure. Nuclear fusion taking place in the cores of stars provides the energy released (as light) from those stars and produced all of the more massive atoms from primordial hydrogen. Thus the elements found on Earth and throughout the universe (other than hydrogen and most of helium which are primordial) were formed in the stars by this process.	IAPS 64 IAES 92 Not covered at middle level
By the end of grade 12. Nuclear processes, including fusion, fission, and radioactive decays of unstable nuclei, involve changes in nuclear binding energies. The total number	NAC 20.1-20.2

[7] Note, 2.3x refers to the 'Chemistry Connections' section, which follows 2.3, and similarly for other citations in the list

Core Idea	*LAB-AIDS Location*
of neutrons plus protons does not change in any nuclear process. Strong and weak nuclear interactions determine nuclear stability and processes. Spontaneous radioactive decays follow a characteristic exponential decay law. Nuclear lifetimes allow radiometric dating to be used to determine the ages of rocks and other materials from the isotope ratios present. Normal stars burn out after having converted all of the material in their cores to iron. Elements more massive than iron are formed by fusion processes only in the extreme conditions of supernova explosions, which explains why they are relatively rare.	NAC 20.1 NAC 20.2 NAC 20.3 NAC 21.1 NAC 21.1
Core Idea PS2: Motion and Stability: Forces and Interactions	
PS2.A: Forces and Motion	
By the end of grade 8. Any two interacting objects exert forces of equal magnitude on each other in opposite directions (Newton's third law). 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 heavier 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. Forces on an object can also change its shape or orientation. In order to share information with others all positions of objects and the directions of forces and motions must be described in an arbitrarily chosen reference system and arbitrarily chosen units of size.	IAPS 80 IAPS 81 IAPS 77 IAPS 77 Not addressed at middle level
By the end of grade 12. Newton's second law accurately predicts changes in the motion of macroscopic objects but it requires revision for subatomic scales or for speeds close to the speed of light. Momentum is a property of objects defined for a particular frame of reference that depends on their mass and speed. In any system total momentum is always conserved. If a system interacts with objects outside itself the total momentum of	These topics are not addressed in current LAB-AIDS programs, will be in *Ergopedia* physics program under development

Core Idea	*LAB-AIDS Location*
the system can change; however any such change is balanced by changes in momentum of objects outside the system.	
PS2.B: Types of Interactions	
By the end of grade 8. 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. 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. Long range gravitational interactions govern the evolution and maintenance of large scale systems in space, such as galaxies or the solar system, and determine the patterns of motion within those structures. Forces that act at a distance (gravitational, electric, and magnetic) involve fields that can be mapped by their effect on a test object (mass, charge, or magnet, respectively).	IAPS 66 IAES 95 IAES 95, 96 Not addressed at the middle level
By the end of grade 12. Newton's law of universal gravitation and Coulomb's law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects. Forces at a distance are mediated by fields that can transfer energy through space. Magnets or changing electric fields cause magnetic fields; electric charges or changing magnetic fields cause electric fields. Attraction and repulsion between electric charges at the atomic scale explain the structure properties and transformations of matter as well as the contact forces between material objects. The strong and weak nuclear interactions are important inside atomic nuclei—for example they determine the patterns of which nuclear isotopes are stable and what kind of decays occur for unstable ones.	These topics are not addressed in current LAB-AIDS programs, will be in physics program under development NAC 20.2, 20.4

Core Idea	*LAB-AIDS Location*
PS2.C: Stability and Instability in Physical Systems	
By the end of grade 8. A stable system is one in which any small change leads to forces that return the system to its prior state (e.g., a weight hanging from a string). A system can be static but unstable (e.g., a pencil standing on end). A system can be changing but have a stable repeating cycle of changes; such observed regular patterns allow predictions about the system's future (e.g., Earth orbiting the sun). Many systems, both natural and engineered, rely on feedback mechanisms to maintain stability, but they can function only within a limited range of conditions. With constant conditions, a system starting out in an unstable state will continue to change until it reaches a stable configuration (e.g., sand in an hourglass).	Not addressed in LAB-AIDS middle level programs IAES 77, 79, 84 Not addressed in LAB-AIDS middle level programs
By the end of grade 12. Systems often change in predictable ways; understanding the forces that drive the transformations and cycles within a system, as well as the forces imposed on the system from the outside, help to predict its behavior under a variety of conditions. When a system has a great number of component pieces, one may not be able to predict much about its precise future. For such systems (e.g., with very many colliding molecules), one can often predict average but not detailed properties and behaviors (e.g., average temperature, motion, and rates of chemical change but not the trajectories or other changes of particular molecules). Systems may evolve in unpredictable ways when the outcome depends sensitively on the starting condition and the starting condition cannot be specified precisely enough to distinguish between different possible outcomes.	NAC 12.1 NAC 3.1, 12.1 NAC 12.3
Core Idea PS3: Energy	
PS3.A: Definitions of Energy	
By the end of grade 8. Motion energy is properly called kinetic energy; it is	IAPS 55

Core Idea	*LAB-AIDS Location*
proportional to the mass of the moving object and grows with the square of its speed. A system of objects may also contain stored (potential) energy, depending on their relative positions. For example, energy is stored—in gravitational interaction with Earth—when an object is raised, and energy is released when the object falls or is lowered. Energy is also stored in the electric fields between charged particles and the magnetic fields between magnets, and it changes when these objects are moved relative to one another. Stored energy is decreased in some chemical reactions and increased in others.	IAPS 58 IAPS 66, 68 IAPS 19
The term "heat" as used in everyday language refers both to thermal motion (the motion of atoms or molecules within a substance) and radiation (particularly infrared and light). Temperature is not a measure of energy; the relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present.	IAPS 56, 59-62 IAPS 56

Core Idea	*LAB-AIDS Location*
By the end of grade 12. Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's *total* energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms. At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, electrical and magnetic fields, and heat. Terms for energy as viewed at this scale are seldom well defined; for example, "mechanical energy" generally refers to some combination of motion and stored energy in an operating machine. "Chemical energy" generally is used to mean the energy that can be released or stored in chemical processes, and "electrical energy" may mean energy stored in a battery or energy transmitted by electric currents. Historically, different units and names were used for the energy present in these different phenomena, and it took some time before the relationships between them were recognized. These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as either motions of particles or energy stored in fields (which mediate interactions between particles). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space. Electromagnetic radiation (such as light and X-rays) can be modeled as a wave or as particles.	NAC 1.3 NAC 1.3 NAC 1.3 NAC 1.3 NAC 3.1-3.3 NAC 20.1-20.2 NAC 5.2
PS3.B: Conservation of Energy and Energy Transfer	

Core Idea	*LAB-AIDS Location*
By the end of grade 8. When the motion energy of an object changes, there is inevitably some other change in energy at the same time. For example, the friction that causes a moving object to stop also heats the object and the surrounding environment. Similarly, to make an object start moving or to keep it moving when friction forces transfer energy away from it, energy must be provided from, say, chemical (e.g., burning fuel) or electrical (e.g., an electric motor and battery) processes. 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. Energy is transferred out of hotter regions or objects and into colder ones by the processes of conduction, convection, and radiation.	IAPS 58, 67 IAPS 83 IAPS 58 IAPS 62-63 IAPS 59-62
By the end of grade 12. Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system. Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. Mathematical expressions, which quantify how the stored energy in a system depends on relative particle positions and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior. The availability of energy limits what can occur in any system. Uncontrolled systems always evolve toward more stable states—that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than their surrounding environment cool down). Any object or system that can degrade with no added energy is unstable. Eventually it will do so, but if the energy releases throughout the transition are small, the process duration	NAC 1.3 NAC 1.3 NAC 3.1 (kinetic energy of molecules) NAC 10.4

Core Idea	*LAB-AIDS Location*
can be very long (e.g., long-lived radioactive isotopes).	NAC 20.2, 20.3
PS3.C: Relationship Between Energy and Forces	
By the end of grade 8. When two objects interact, each one exerts a force on the other, and these forces can transfer energy between them. For example, gravitational interactions between an object and Earth store energy as the object is raised and release energy as the object falls; magnetic and electric forces between two objects at a distance can transfer energy between the interacting objects.	IAPS 77, 81 IAES 95, 96 IAPS 66
By the end of grade 12. Force fields (gravitational, electric, and magnetic) contain energy and can transmit energy across space from one object to another. When two objects interacting through a force field change relative position, the energy stored in the force field is changed. Each force between the two interacting objects acts in the direction such that motion in that direction would reduce the energy in the force field between the objects. However, prior motion and other forces also affect the actual direction of motion.	NAC 5.1, 5.2 NAC 5.1, 5.2
PS3.D: Energy in Chemical Processes and Everyday Life	
By the end of grade 8. The chemical reaction by which plants produce complex food molecules (sugars) requires an energy input (i.e., from sunlight) to occur. In this reaction, carbon dioxide and water combine to form carbon-based organic molecules and release oxygen. Both the burning of fuel and cellular digestion in plants and animals involve chemical reactions with oxygen that release stored energy. In these processes, complex molecules containing carbon react with oxygen to produce carbon dioxide and other materials. Machines can be made more efficient, that is, require less fuel input to	IALS 80, 81 IAPS 58 IAPS 64 Not addressed in LAB-AIDS middle level

Core Idea	LAB-AIDS Location
perform a given task, by reducing friction between their moving parts and through aerodynamic design. Friction increases energy transfer to the surrounding environment by heating the affected materials.	program IAPS 56
By the end of grade 12. Nuclear fusion processes in the center of the sun release the energy that Earth receives through radiation. The main way in which that solar energy is captured and stored on Earth is through the complex chemical process known as photosynthesis. Solar cells are human-made devices that likewise capture the sun's energy and produce electrical energy. A variety of multistage physical and chemical processes in living organisms, particularly within their cells, account for the transport and transfer (release or uptake) of energy needed for life functions. All forms of electricity generation and transportation fuels have associated economic, social, and environmental costs and benefits, both short and long term. Although energy cannot be destroyed, it can be converted to less useful forms—for example, to heat in the surrounding environment. Machines are judged as efficient or inefficient based on the amount of energy input needed to perform a particular useful task. Inefficient machines are those that produce more waste heat while performing the task and thus require more energy input. It is therefore important to design for high efficiency so as to reduce costs, waste materials, and many environmental impacts.	NAC 20.4, 21.1 NAC 18.2 NAC 11.4 SGI BIO Eco 9, 10, 11; Cell , 23 NAC 1.3 NAC 1.3
Core Idea PS4: Waves and Their Applications in Technologies for Information Transfer	
PS4.A: Wave Properties	
By the end of grade 8. A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude. A sound wave needs a medium through which it is	LA 211, P140

Core Idea	*LAB-AIDS Location*
transmitted. Geologists use seismic waves and their reflection at interfaces between layers to probe structures deep in the planet.	IAES 43
By the end of grade 12. The wavelength and frequency of a wave are related to one another by the speed of travel of the wave, which depends on the type of wave and the medium through which it is passing. The reflection, refraction, and transmission of waves at an interface between two media can be modeled on the basis of these properties. Combining waves of different frequencies can make a wide variety of patterns and thereby encode and transmit information. Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses. Resonance is a phenomenon in which waves add up in phase in a structure, growing in amplitude due to some energy input. Structures have particular frequencies at which they resonate. This phenomenon (e.g., waves in a stretched string, vibrating air in a pipe) is used in speech and in the design of all musical instruments.	These topics are not addressed in current LAB-AIDS programs, will be addressed in physics program under development
PS4.B: Electromagnetic Radiation	
By the end of grade 8. When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object's material and the frequency (color) of the light. The path that light travels can be traced as straight lines, except at surfaces between different transparent materials (e.g., air and water, air and glass) where the light path bends. Lenses and prisms are applications of this effect. A wave model of light is useful for explaining brightness, color, and the frequency-dependent bending of light at a surface between media (prisms). However, because light can travel through space, it cannot be a	LA P140, 211 LA P140, 211 LA P140, 211 LA P140, 211

Core Idea	*LAB-AIDS Location*
matter wave, like sound or water waves.	
By the end of grade 12. Electromagnetic radiation (e.g., radio, microwaves, light) can be modeled as a wave of changing electric and magnetic fields or as particles called photons. The wave model is useful for explaining many features of electromagnetic radiation, and the particle model explains other features. Quantum theory relates the two models.	NAC 5.4 NAC 5.2, 5.4
Because a wave is not much disturbed by objects that are small compared with its wavelength, visible light cannot be used to see such objects as individual atoms. All electromagnetic radiation travels through a vacuum at the same speed, called the speed of light. Its speed in any other given medium depends on its wavelength and the properties of that medium.	NAC 5.4
When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat). Shorter wavelength electromagnetic radiation (ultraviolet, X-rays, gamma rays) can ionize atoms and cause damage to living cells. Photovoltaic materials emit electrons when they absorb light of a high-enough frequency. Atoms of each element emit and absorb characteristic frequencies of light, and nuclear transitions have distinctive gamma ray wavelengths. These characteristics allow identification of the presence of an element, even in microscopic quantities.	NAC 5.4 NAC 5.4 NAC 5.2, 5.4 NAC 5.4
PS4.C: Information Technologies and Instrumentation.	
By the end of grade 8. Appropriately designed technologies (e.g., radio, television, cell phones, wired and wireless computer networks) make it possible to detect and interpret many types of signals that cannot be sensed directly. Designers of such devices must understand both the signal and its interactions with matter.	This content not addressed in LAB-AIDS middle level programs

Core Idea	*LAB-AIDS Location*
By the end of grade 12. Multiple technologies based on the understanding of waves and their interactions with matter are part of everyday experience in the modern world (e.g., medical imaging, communications, scanners) and in scientific research. They are essential tools for producing, transmitting, and capturing signals and to storing and interpreting the information contained in them. Knowledge of quantum physics enabled the development of semiconductors, computer chips, and lasers, all of which are now essential components of modern imaging, communication, and information technologies.	NAC 20.5 (PET, CAT scans) These topics are not addressed in current LAB-AIDS programs, will be covered in physics program under development

LIFE SCIENCE

Just as the life sciences are anchored by core principles, the *Framework* is organized around four core ideas reflecting unifying principles in life sciences. These core ideas are:

- LS 1: From molecules to organisms: Structures and processes
- LS 2: Ecosystems: Interactions, energy, and dynamics
- LS 3: Heredity: Inheritance and variation of traits
- LS 4: Biological evolution: Unity and diversity

These core ideas are essential for a conceptual understanding of the life sciences and will enable students to make sense of emerging research findings. Furthermore, the *Framework* organizes knowledge of the life sciences in a sequence that matches the way children learn about life. Hence it begin at the level of organisms, delving into the many processes and structures, at scales ranging from components as small as individual atoms to organ systems that are necessary for life to be sustained. The focus then broadens to consider organisms in their environment—how they interact with the environment's living (biotic) and physical (abiotic) features. Next the *Framework* considers how organisms reproduce, passing genetic information to their offspring, and how these mechanisms lead to variability and hence diversity within species. Finally, the core ideas in the life sciences culminate with the principle that evolution can explain how the diversity that is observed within species has led to the diversity of life across species through a process of descent with adaptive modification. Evolution also accounts for the remarkable similarity of the fundamental characteristics of all species.

Core Idea	LAB-AIDS Location
Core Idea LS1: From Molecules to Organisms: Structures and Processes	
LS1.A: Structure and Function	
By the end of grade 8. All living things are made up of cells. They may consist of one single cell (unicellular) or many different numbers and types of cells (multicellular). Unicellular organisms (microorganisms), like multicellular organisms, need food, water, a way to dispose of waste, and an environment in which they can live. Within cells, special structures are responsible for particular functions, and the cell membrane forms the boundary that controls what enters and leaves the cell. In multicellular organisms, the body is a system of multiple interacting subsystems	IALS 42, 45 IALS 42 IALS 40, 42-43 IALS 12-18, 22-23

Core Idea	LAB-AIDS Location
and groups of cells that work together to form tissues and organs that are specialized for particular body functions.	
By the end of grade 12. Systems of specialized cells within organisms help them perform the essential functions of life, which involve chemical reactions that take place between different types of molecules, such as water, carbohydrates, lipids, and nucleic acids. All cells contain genetic information in the form of DNA, which is where genes are located. Genes contain the instructions that code for the configuration of molecules called proteins, which carry out the work of cells. Multicellular organisms have a hierarchical structural organization, in which any one system is made up of numerous parts and is itself a component of the next level. Feedback mechanisms maintain a living system's internal conditions within certain limits and mediate behaviors, allowing it to remain alive and functional even as external conditions change within some range. Outside that range (e.g., at a too high or too low external temperature, with too little food or water available), the organism cannot survive. Feedback mechanisms can encourage (through positive feedback) or discourage (negative feedback) what is going on inside the living system.	SGI BIO Cell 3-5 SGI BIO Gen 10 SGI BIO Gen 14, 16 SGI BIO Cell 6 SGI BIO Cell 6 SGI BIO Cell 6
LS1.B: Growth and Development of Organisms	
By the end of grade 8. Organisms reproduce, either sexually or asexually, and transfer their genetic information to their offspring. Animals engage in characteristic behaviors that increase the odds of reproduction. Plants reproduce in a variety of ways, sometimes depending on animal behavior and specialized features (such as attractively colored flowers) for reproduction. Plant growth can continue throughout the plant's life through production of plant matter in	IALS 57, 63 IALS 63 IALS 55 SEPUP web content (www.sepuplhs.org/middle/ials)

Core Idea	LAB-AIDS Location
photosynthesis. Genetic factors as well as local conditions affect the size of the adult plant. The growth of an animal is controlled by genetic factors, food intake, and interactions with other organisms, and each species has a typical adult size range.	SEPUP web content (www.sepuplhs.org/middle/ials)
By the end of grade 12. In multicellular organisms, growth occurs via a process called mitosis: a fertilized cell divides successively into many cells, with each parent cell passing identical genetic material to two daughter cells. As successive subdivisions of an embryo's cells occur, programmed genetic instructions and small differences in their immediate environments activate or inactivate different genes, which cause the cells to develop differently—a process called differentiation. Cellular division and differentiation produce and maintain a complex organism, composed of systems of tissues and organs that work together to meet the needs of the entire body. In sexual reproduction, a specialized type of cell division called meiosis occurs and results in the production of sex cells, such as gametes (sperm and eggs) or spores, which contain only one member from each chromosome pair in the parent cell.	SGI BIO Cell 13, Gen 17 SGI BIO Cell 14 SGI BIO Cell 13-14 SGI BIO Gen 13
LS1.C: Organization for Matter and Energy Flow in Organisms	
By the end of grade 8. Plants, algae (including phytoplankton), and many microorganisms use the energy from light to make sugars (food) from carbon dioxide from the atmosphere and water through the process of photosynthesis, which also releases oxygen. These sugars can be used immediately or stored for growth or later use. Animals obtain food from eating plants or eating other animals. Within individual organisms, food moves through a series of chemical reactions in which it is broken down and rearranged to form new molecules, to support growth, or to	IALS 80-81 IALS 79

Core Idea	LAB-AIDS Location
release energy. In most animals and plants, oxygen reacts with carbon- containing molecules (sugars) to provide energy and produce waste carbon dioxide; anaerobic bacteria achieve their energy needs in other chemical processes that do not require oxygen.	IALS 79 IALS 45
By the end of grade 12. The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen. The sugar molecules thus formed contain carbon, hydrogen, and oxygen, and some trace minerals that are used to make amino acids and other carbon-based molecules that can be assembled into larger molecules (such as proteins or DNA), used for example to form new cells. As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products. As a result of these chemical reactions, energy is transferred from one system of interacting molecules to another. For example, aerobic (in the presence of oxygen) cellular respiration is a chemical process in which the bonds of food molecules and oxygen molecules are broken and new compounds are formed that can transport energy to muscles. Anaerobic (without oxygen) cellular respiration follows a different and less efficient chemical pathway to provide energy in cells. Cellular respiration also releases the energy needed to maintain body temperature despite ongoing energy loss to the surrounding environment. Matter and energy are conserved in each change. This is true of all biological systems, from individual cells to ecosystems.	SGI BIO Cell 12 SGI BIO Eco 9 SGI BIO Cell 12 SAS 16 SGI BIO Eco 7-8, Cell 12 SAS 16 SGI BIO Eco 7-10, Cell 12 SGI BIO Cell 12 SGI BIO Eco 8
LS1.D: Information Processing	
By the end of grade 8. Each sense receptor responds to different inputs	IALS 5-6

Core Idea	LAB-AIDS Location
(electromagnetic, mechanical, chemical), transmitting them as signals that travel along nerve cells to the brain. The signals are then processed in the brain, resulting in immediate behaviors or memories. Changes in the structure and functioning of many millions of interconnected nerve cells allow combined inputs to be stored as memories for long periods of time.	IALS 5-6
By the end of grade 12. In complex animals, the brain is divided into several distinct regions and circuits, each of which primarily serves dedicated functions, such as visual perception, auditory perception, interpretation of perceptual information, guidance of motor movement, and decision making about actions to take in the event of certain inputs. In addition, some circuits give rise to emotions and memories that motivate organisms to seek rewards, avoid punishments, develop fears, or form attachments to members of their own species and, in some cases, to individuals of other species (e.g., mixed herds of mammals, mixed flocks of birds). The integrated functioning of all parts of the brain is important for successful interpretation of inputs and generation of behaviors in response to them.	Brain anatomy and behavior not addressed in current LAB-AIDS high school programs
Core Idea LS2: Ecosystems: Interactions, Energy, and Dynamics	
LS2.A: Interdependent Relationships in Ecosystems	
By the end of grade 8. Organisms and populations of organisms are dependent on their environmental interactions both with other living things and with nonliving factors. Growth of organisms and population increases are limited by access to resources. In any ecosystem, organisms and populations with similar requirements for food, water, oxygen, or other resources may compete with each other for limited resources, access to which consequently constrains their growth and reproduction. Similarly, predatory	IALS 72-74, 77, 79-80 IALS 77, 79 IALS 72, 73

Core Idea	LAB-AIDS Location
interactions may reduce the number of organisms or eliminate whole populations of organisms. Mutually beneficial interactions, in contrast, may become so interdependent that each organism requires the other for survival. Although the species involved in these competitive, predatory, and mutually beneficial interactions vary across ecosystems, the patterns of interactions of organisms with their environments, both living and nonliving, are shared.	IALS 72, 77, 85, 87 IALS 79 IALS 72, 77, 85, 87
By the end of grade 12. Ecosystems have carrying capacities, which are limits to the numbers of organisms and populations they can support. These limits result from such factors as the availability of living and nonliving resources and from such challenges as predation, competition, and disease. Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite. This fundamental tension affects the abundance (number of individuals) of species in any given ecosystem.	SGI BIO Eco 2, 14 SGI BIO Eco 15-16
LS2.B: Cycles of Matter and Energy Transfer in Ecosystems	
By the end of grade 8. Food webs are models that demonstrate how matter and energy is transferred between producers (generally plants and other organisms that engage in photosynthesis), consumers, and decomposers as the three groups interact—primarily for food— within an ecosystem. Transfers of matter into and out of the physical environment occur at every level, for example when molecules from food react with oxygen captured from the environment, the carbon dioxide and water thus produced are transferred back to the environment, and ultimately so are waste products, such as fecal material. Decomposers recycle nutrients from dead plant or animal matter back to the soil in	IALS 79 IALS 79 IALS 80

Core Idea	LAB-AIDS Location
terrestrial environments or to the water in aquatic environments. The atoms that make up the organisms in an ecosystem are cycled repeatedly between the living and nonliving parts of the ecosystem.	IALS 80
By the end of grade 12. Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes. Plants or algae form the lowest level of the food web. At each link upward in a food web, only a small fraction of the matter consumed at the lower level is transferred upward, to produce growth and release energy in cellular respiration at the higher level. Given this inefficiency, there are generally fewer organisms at higher levels of a food web, and there is a limit to the number of organisms that an ecosystem can sustain. The chemical elements that make up the molecules of organisms pass through food webs and into and out of the atmosphere and soil, and are combined and recombined in different ways. At each link in an ecosystem, matter and energy are conserved; some matter reacts to release energy for life functions, some matter is stored in newly made structures, and much is discarded. Competition among species is ultimately competition for the matter and energy needed for life. Photosynthesis and cellular respiration are important components of the carbon cycle, in which carbon is exchanged between the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes.	SGI BIO Eco 8-9, 10-11 SGI BIO Eco 7 SGI BIO Eco 7-8 SGI BIO Eco 8 SGI BIO Eco 7-8 SGI BIO Eco 7-8 SGI Bio Eco 8, 9
LS2.C: Ecosystems Dynamics, Functioning, and Resilience	
By the end of grade 8. Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations. Biodiversity describes the variety of species	IALS 83 IALS 73, 77 IALS 75-76

Core Idea	LAB-AIDS Location
found in Earth's terrestrial and oceanic ecosystems. The completeness or integrity of an ecosystem's biodiversity is often used as a measure of its health.	
By the end of grade 12. A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more-or-less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability. Moreover, anthropogenic changes (induced by human activity) in the environment—including habitat destruction, pollution, introduction of invasive species, overexploitation, and climate change—can disrupt an ecosystem and threaten the survival of some species.	SGI BIO Eco 14 SGI BIO Eco 15-16 SGI BIO Eco 15-16 SGI BIO Eco 1, 4, 16, Evo 1-2
LS2.D: Social Interactions and Group Behavior	
By the end of grade 8. Groups may form because of genetic relatedness, physical proximity, or other recognition mechanisms (which may be species-specific). They engage in a variety of signaling behaviors to maintain the group's integrity or to warn of threats. Groups often dissolve if they no longer function to meet individuals' needs, if dominant members lose their place, or if other key members are removed from the group through death, predation, or exclusion by other members.	This content not addressed in LAB-AIDS middle level programs
By the end of grade 12. Animals, including humans, having a strong drive for social affiliation with members of their own species and will suffer, behaviorally as well	This content not addressed in LAB-AIDS high school programs

Core Idea	LAB-AIDS Location
as physiologically, if reared in isolation, even if all their physical needs are met. Some forms of affiliation arise from the bonds between offspring and parents. Other groups form among peers. Group behavior has evolved because membership can increase the chances of survival for individuals and their genetic relatives.	
Core Idea LS3: Heredity: Inheritance and Variation of Traits	
LS3.A: Inheritance of Traits	
By the end of grade 8. Genes are located in the chromosomes of cells, with each chromosome pair containing two variants of each of many distinct genes. Each distinct gene chiefly controls the production of specific proteins, which in turn affect the traits of the individual (e.g., human skin color results from the actions of proteins that control the production of the pigment melanin). Changes (mutations) to genes can result in changes to proteins, which can affect the structures and functions of the organism and thereby change traits.	IALS 63 IALS 63
Sexual reproduction provides for transmission of genetic information to offspring through egg and sperm cells. These cells, which contain only one chromosome of each parent's chromosome pair, unite to form a new individual (offspring). Thus offspring possess one instance of each parent's chromosome pair (forming a new chromosome pair).	IALS 63 IALS 63
Variations of inherited traits between parent and offspring arise from genetic differences that result from the subset of chromosomes (and therefore genes) inherited or (more rarely) from mutations.	IALS 63
By the end of grade 12. In all organisms the genetic instructions for forming species characteristics are carried in the chromosomes. Each chromosome consists of a single very long DNA molecule, and each gene on the chromosome is a particular segment of that DNA. The	SGI BIO Gen 5, 13, 14 SGI BIO Gen 14 SGI BIO Gen 10

Core Idea	LAB-AIDS Location
instructions for forming species characteristics are carried in DNA. All cells in an organism have the same genetic content, but the genes used (expressed) by the cell may be regulated in different ways.	SGI BIO Gen 17
Not all DNA codes for a protein; some segments of DNA are involved in regulatory or structural functions, and some have no as-yet known function.	SGI BIO Gen 11, 16
LS3.B: Variation of Traits	
By the end of grade 8. In sexually reproducing organisms, each parent contributes half of the genes acquired (at random) by the offspring.	IALS 63
Individuals have two of each chromosome and hence two alleles of each gene, one acquired from each parent. These versions may be identical or may differ from each other.	IALS 63
In addition to variations that arise from sexual reproduction, genetic information can be altered because of mutations.	IALS 63
Though rare, mutations may result in changes to the structure and function of proteins. Some changes are beneficial, others harmful, and some neutral to the organism.	IALS 63
By the end of grade 12. The information passed from parents to offspring is coded in the DNA molecules that form the chromosomes.	SGI BIO Gen 13-14
In sexual reproduction, chromosomes can sometimes swap sections during the process of meiosis (cell division), thereby creating new genetic combinations and thus more genetic variation.	SGI BIO Gen 13-14
Although DNA replication is tightly regulated and remarkably accurate, errors do occur and result in mutations, which are also a source of genetic variation.	SGI BIO Gen 16
Environmental factors can cause mutations in genes, and viable mutations are inherited.	SGI BIO Gen 16
Environmental factors also affect expression of traits, and hence affect the probability of occurrences of traits in a population. Thus the variation and	SGI BIO Gen 11, 16

Core Idea	LAB-AIDS Location
distribution of traits observed depends on both genetic and environmental factors.	
Core Idea LS4: Biological Evolution: Unity and Diversity	
LS4.A: Evidence of Common Ancestry and Diversity	
By the end of grade 8. Fossils are mineral replacements, preserved remains, or traces of organisms that lived in the past. Thousands of layers of sedimentary rock not only provide evidence of the history of Earth itself but also of changes in organisms whose fossil remains have been found in those layers. The collection of fossils and their placement in chronological order (e.g., through the location of the sedimentary layers in which they are found or through radioactive dating) is known as the fossil record. It documents the existence, diversity, extinction, and change of many life forms throughout the history of life on Earth. Because of the conditions necessary for their preservation, not all types of organisms that existed in the past have left fossils that can be retrieved. Anatomical similarities and differences between various organisms living today and between them and organisms in the fossil record enable the reconstruction of evolutionary history and the inference of lines of evolutionary descent. Comparison of the embryological development of different species also reveals similarities that show relationships not evident in the fully formed anatomy.	IALS 90-92 IALS 93 IALS 93 IALS 93 IALS 98-99 Comparative embryological development not addressed in LAB-AIDS middle level programs
By the end of grade 12. Genetic information, like the fossil record, also provides evidence of evolution. DNA sequences vary among species, but there are many overlaps and common features; the ongoing branching that produces multiple lines of descent can be inferred from the DNA composition of organisms. Such information is also derivable from the similarities and differences in amino acid sequences and from anatomical and	SGI BIO Evo 5-8 SGI BIO Evo 8-9

Core Idea	LAB-AIDS Location
embryological evidence.	
LS4.B: Natural Selection	
By the end of grade 8. Genetic variations among individuals in a population give some individuals an advantage in surviving and reproducing in their environment. This is known as natural selection. It leads to the predominance of certain traits in a population and the suppression of others. In *artificial* selection, humans have the capacity to influence certain characteristics of organisms by selective breeding. One can choose desired parental traits determined by genes, which are then passed on to offspring.	IALS 94, 97 IALS 55
By the end of grade 12. Natural selection occurs only if there is both (1) variation in the genetic information between organisms in a population and (2) variation in the expression of that genetic information—that is, trait variation—that leads to differences in performance among individuals. The traits which positively affect survival are more likely to be reproduced and thus are more common in the population.	SGI BIO Evo 11-12, 13 SGI BIO Evo 11-12 SGI BIO Evo 11-12
LS4.C: Adaptation	
By the end of grade 8. Adaptation by natural selection acting over generations is one important process by which species change over time in response to changes in environmental conditions. Traits that support successful survival and reproduction in the new environment become more common; those that do not become less common. Thus, the distribution of traits in a population changes. In separated populations with different conditions, the changes can be large enough that the populations, provided they remain separated (a process called reproductive isolation), evolve to become separate species.	IALS 94, 97 IALS 95, 96, 100 IALS 95, 96 IALS 95, 96

Core Idea	LAB-AIDS Location
By the end of grade 12. Natural selection is the result of four factors: (1) the potential for a species to increase in number, (2) the genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for an environment's limited supply of the resources that individuals need in order to survive and reproduce, and (4) the ensuing proliferation of those organisms that are better able to survive and reproduce in that environment. Natural selection leads to adaptation, that is to a population dominated by organisms that are anatomically, behaviorally, and physiologically well suited to survive and reproduce in a specific environment. That is, the differential survival and reproduction of organisms in a population that have an advantageous heritable trait leads to an increase in the proportion of individuals in future generations that have the trait and to a decrease in the proportion of individuals that do not. Adaptation also means that the distribution of traits in a population can change when conditions change. Changes in the physical environment, whether naturally occurring or human-induced, have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline—and sometimes the extinction—of some species. Species become extinct because they can no longer survive and reproduce in their altered environment. If members cannot adjust to change that is too fast or too drastic, the opportunity for the species' evolution is lost.	SGI BIO Evo 10-13 SGI BIO Evo 12 SGI BIO Evo 12 SGI BIO Evo 12 SGI BIO Evo 1-2, 10 SGI BIO Evo10, 13
LS4.D: Biodiversity and Humans	
By the end of grade 8. Biodiversity is the wide range of existing life forms that have adapted to the variety of conditions on	Biodiversity is not covered in LAB-AIDS middle level programs

Core Idea	LAB-AIDS Location
Earth, from terrestrial to marine ecosystems. Biodiversity includes genetic variation within a species, in addition to species variation in different habitats and ecosystem types (e.g., forests, grasslands, wetlands). Changes in biodiversity can influence humans' resources, such as food, energy, and medicines, as well as ecosystem services that humans rely on—for example, water purification and recycling.	
By the end of grade 12. Biodiversity results from the formation of new species (speciation) minus the loss of species (extinction). Biological extinction, being irreversible, is a critical factor in reducing the planet's natural capital. Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. These problems have the potential to cause a major wave of biological extinctions—as many species or populations of a given species, unable to survive in changed environments, die out—and the effects may be harmful to humans and other living things. Thus sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. And sustaining biodiversity so that landscapes of recreational or inspirational value are preserved is essential to supporting and enhancing human life.	SGI BIO Eco 3, Evo 1-2, 13, 15 SGI BIO Evo 1-2 SGI BIO Evo 2 SGI BIO Evo 2, 15 SGI BIO Evo 1-2, 15 SGI BIO Evo 1-2, 15

EARTH SCIENCE

Because organizing earth and space sciences (ESS) content is complex, given its broad scope and interdisciplinary nature, past efforts to promote earth science literacy have presented this content in a wide variety of ways. To organize the ESS content, the *Framework* begins at the largest spatial scales of the universe and move toward increasingly smaller scales and a more anthropocentric focus.

- ESS 1: Earth's place in the universe
- ESS 2: Earth's systems
- ESS 3: Earth and human activity

Thus, the first core idea, ESS1: Earth's Place in the Universe, describes the universe as a whole and addresses its grand scale in both space and time. This idea includes the overall structure, composition, and history of the universe, the forces and processes by which the solar system operates, and Earth's planetary history.

The second core idea, ESS2: Earth's Systems, encompasses the processes that drive Earth's conditions and its continual evolution (i.e., change over time). It addresses the planet's large-scale structure and composition, describes its individual systems, and explains how they are interrelated. It also focuses on the mechanisms driving Earth's internal motions and on the vital role that water plays in all of the planet's systems and surface processes.

The third core idea, ESS3: Earth and Human Activity, addresses society's interactions with the planet. Connecting the earth and space sciences to the intimate scale of human life, this idea explains how Earth's processes affect people through natural resources and natural hazards, and it describes as well some of the ways in which humanity in turn affects Earth's processes.

Core Idea	*LAB-AIDS Location*
Core Idea ESS1: Earth's Place in the Universe	
ESS1.A: The Universe and Its Stars	
By the end of grade 8. Patterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted, and explained with models. The universe began with a period of extreme and rapid expansion known as the Big Bang. Earth and its solar system are part of the Milky Way galaxy, which is one of many galaxies in the universe.	IAES 73, 77, 80-81 (note: Big Bang not addressed) IAES 92
By the end of grade 12. The star called the	NAC 21.1

Core Idea	*LAB-AIDS Location*
sun is changing and will burn out over a life span of approximately 10 billion years. The sun is just one of a myriad of stars in the Milky Way galaxy, and the Milky Way is just one of hundreds of billions of galaxies in the universe. The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth.	NAC 21.1 NAC 21.1
ESS1.B: Earth and the Solar System	
By the end of grade 8. The solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them. This model of the solar system can explain tides, eclipses of the sun and the moon, and the motion of the planets in the sky relative to the stars. Earth's spin axis is fixed in direction but tilted relative to its orbit around the sun; the seasons are a result of that tilt, as is the differential intensity of sunlight on different areas of the earth across the year.	IAES 89-90, 92, 95-96 IAES 78-82 IAES 75-77
By the end of grade 12. Kepler's laws describe common features of the motions of orbiting objects, including their elliptical paths around the sun. Orbits may change due to the gravitational effects from, or collisions with, other bodies. Gradual changes in the shape of Earth's orbit around the sun, together with changes in the tilt of the planet's axis of rotation, both occurring over hundreds of thousands of years, have altered the intensity and distribution of sunlight falling on the earth. These phenomena cause a cycle of ice ages and other gradual climate changes.	This content is not yet addressed in LAB-AIDS high school programs, but is addressed in materials under development, with commercial availability in 2012-13

Core Idea	*LAB-AIDS Location*
ESS1.C: The History of Planet Earth	
By the end of grade 8. The geological time scale from rock strata provides a way to organize Earth's history. Major historical events include the formation of mountain chains and ocean basins, the evolution and extinction of particular living organisms, volcanic eruptions, periods of massive glaciation, and development of watersheds and rivers through glaciation and water erosion. Analyses of rock strata and the fossil record provide only relative dates, not an absolute scale.	IAES 38-39 IAES 29, 41-42, IALS 89-90 IAES 39, IALS 94
By the end of grade 12. Radioactive-decay lifetimes and isotopic content in rocks provide a way of dating rock formations and thereby fixing the scale of geological time. The continents' rocks (some as old as 4 billion years or more) are much older than rocks on the ocean floor (less than 200 million years), where tectonic processes continually generate new rocks and remove old ones. Although active geological processes, such as plate tectonics (link to ESS2.B) and erosion, have destroyed or altered most of the very early rock record on Earth, other objects in the solar system, such as lunar rocks, asteroids and meteorites, have changed little over billions of years. Studying these objects can provide information about Earth's formation and early history.	NAC 20.3 This content is not yet addressed in LAB-AIDS high school programs, but is addressed in materials under development, with commercial availability in 2012-13
Core Idea ESS2: Earth's Systems	
ESS2.A: Earth Materials and Systems	
By the end of grade 8 All earth processes are the result of energy flowing and matter cycling within and among the planet's systems. This energy is derived from the sun and the earth's hot interior. The energy that flows and matter that cycles produce chemical and physical changes in Earth's materials and living organisms. The planet's systems interact over scales that	IAES 38-39 IAES 22, 38-39

Core Idea	*LAB-AIDS Location*
range from microscopic to global in size, and they operate over fractions of a second to billions of years. These interactions have shaped Earth's history and will determine its future.	IAES 38-39
By the end of grade 12 Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes. A deep knowledge of how feedbacks work within and among Earth's systems is still lacking, thus limiting scientists' ability to predict some changes and their impacts. Evidence from deep probes and seismic waves, reconstructions of historical changes in the earth's surface and its magnetic field, and an understanding of physical and chemical processes lead to a model of Earth with a hot but solid inner core, a liquid outer core, a solid but plastic mantle, and a solid surface crust. The top part of the mantle, along with the crust, forms structures known as tectonic plates (link to ESS2.B). Motions of the mantle and its plates are driven by convection (i.e., the flow of matter due to the energy transfer from the interior outward and the gravitational movement of denser materials toward the interior). The geological record shows that changes to global and regional climate can be caused by interactions among changes in the sun's energy output or Earth's orbit, tectonic events, ocean circulation, volcanic activity, glaciers, vegetation, and human activities. These changes can occur on a variety of time scales from sudden (e.g., volcanic dust clouds) to intermediate (ice ages) to very-long-term tectonic cycles.	This content is not yet addressed in LAB-AIDS high school programs, but is addressed in materials under development, with commercial availability in 2012-13

Core Idea	*LAB-AIDS Location*
ESS2.B: Plate Tectonics and Large-Scale System Interactions	
By the end of grade 8 Plate tectonics is the unifying theory that explains the past and current movements of the rocks at Earth's surface and provides a framework for understanding its geological history. Plate movements are responsible for most continental and ocean floor features and for the distribution of most rocks and minerals within Earth's crust. Maps of ancient land and water patterns, based on investigations of rocks and fossils, make clear how Earth's plates have moved great distances, collided, and spread apart.	IAES 40-42 IAES 41-42 IAES 41-42 and web content at www.sepup.com/iaes
By the end of grade 12 The radioactive decay of unstable isotopes continually generates new energy within Earth's crust and mantle. This energy moves through and out of the planet's interior, primarily by mantle convection. Plate tectonics can be viewed as the surface expression of mantle convection.	This content is not yet addressed in LAB-AIDS high school programs, but is addressed in materials under development, with commercial availability in 2012-13
ESS2.C: The Roles of Water in Earth's Surface Processes	
By the end of grade 8 Water continually cycles among land, ocean, and atmosphere via transpiration, evaporation, condensation, and precipitation as well as downhill flows on land. The complex patterns of the changes and the movement of water in the atmosphere, determined by winds, landforms, and ocean temperatures and currents, are major determinants of local weather patterns. Global movements of water and its changes in form are propelled by sunlight and gravity. Variations in density due to variations in temperature and salinity drive a global pattern of interconnected ocean currents. Water's movements both on the land and underground cause weathering and erosion, which change the land's surface features and create underground formations.	IAES 60-62 IAES 62 IAES 51, 69 IAES 55-58 Density gradients not addressed in LAB-AIDS middle level programs IAES 29, 31, 33

Core Idea	*LAB-AIDS Location*
By the end of grade 12 The abundance of liquid water on Earth's surface and its unique combination of physical and chemical properties are central to the planet's dynamics. These properties include water's exceptional capacity to absorb, store, and release large amounts of energy; transmit sunlight; expand upon freezing; dissolve and transport materials; and lower the viscosities and melting points of rocks.	This content is not yet addressed in LAB-AIDS high school programs, but is addressed in materials under development, with commercial availability in 2012-13
ESS2.D: Weather and Climate	
By the end of grade 8 Weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. These interactions vary with latitude, altitude, and local and regional geography, all of which can affect oceanic and atmospheric flow patterns. Because these patterns are so complex, weather can be predicted only probabilistically. The ocean exerts a major influence on weather and climate by absorbing energy from the sun, releasing it over time, and globally redistributing it through ocean currents. Greenhouse gases in the atmosphere absorb and retain the energy radiated from land and ocean surfaces, thereby regulating Earth's average surface temperature and keeping it habitable.	IAES 51-53, 57-58, 69 IAES 51-52, 69 IAES 55-58 IAES 58 (note: greenhouse gases not introduced)
By the end of grade 12 Global climate is a dynamic balance on many different time scales among energy from the sun falling on Earth; the energy's reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems; and the energy's reradiation into space. Climate change can occur if any part of Earth's systems is altered. Geological evidence indicates that past climate changes were either sudden changes caused by alterations in the atmosphere; longer term changes (e.g., ice ages) due to variations in solar output, Earth's orbit, or the tilt of its	This content is not yet addressed in LAB-AIDS high school programs, but is addressed in materials under development, with commercial availability in 2012-13

Core Idea	*LAB-AIDS Location*
axis; or even more gradual atmospheric changes due to plants and other organisms that captured carbon dioxide and released oxygen. The time scales of these changes varied from a few to millions of years. Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate (link to ESS3.D). Global climate models incorporate scientists' best knowledge of physical and chemical processes and of the interactions of relevant systems. They are tested by their ability to fit past climate variations. Current models predict that, although future regional climate changes will be complex and varied, average global temperatures will continue to rise. The outcomes predicted by global climate models strongly depend on the amounts of human-generated greenhouse gases added to the atmosphere each year and by the ways in which these gases are absorbed by the ocean and the biosphere. Hence the outcomes depend on human behaviors (link to ESS3.D) as well as on natural factors that involve complex feedbacks among Earth's systems (link to ESS2.A).	
ESS2.E: Biogeology	
By the end of grade 8 Evolution is shaped by Earth's varying geological conditions. Sudden changes in conditions (e.g., meteor impacts, major volcanic eruptions) have caused mass extinctions, but these changes, as well as more gradual ones, have ultimately allowed other life forms to flourish. The evolution and proliferation of living things over geological time have in turn changed the rates of weathering and erosion of land surfaces, altered the composition of Earth's soils and atmosphere, and affected the distribution of water in the hydrosphere.	Biogeology not addressed in IAES (IAES addresses changes in fossil histories of fish, reptiles and mammals over time, but these are not related to specific external geological conditions)

Core Idea	*LAB-AIDS Location*
By the end of grade 12 The many dynamic and delicate feedbacks between the biosphere and other earth systems cause a continual co-evolution of Earth's surface and the life that exists on it.	SGI BIO Evo 1-2 (emphasis placed on human impact on biodiversity)
Core Idea ESS3: Earth and Human Activity	
ESS3.A: Natural Resources	
By the end of grade 8. Humans depend on Earth's land, ocean, atmosphere, and biosphere for many different resources. Minerals, fresh water, and biosphere resources are limited, and many are not renewable or replaceable over human lifetimes. These resources are distributed unevenly around the planet as a result of past geological processes (link to ESS2.B). Renewable energy resources, and the technologies to exploit them, are being rapidly developed.	This content not addressed in LAB-AIDS middle level programs
By the end of grade 12. Resource availability has guided the development of human society. All forms of energy production and other resource extraction have associated economic, social, environmental, and geopolitical costs and risks, as well as benefits. New technology and regulation can change the balance of these factors.	This content is not yet addressed in LAB-AIDS high school programs, but is addressed in materials under development, expected commercial availability in 2012-13
ESS3.B: Natural Hazards	
By the end of grade 8. Some natural hazards, such as volcanic eruptions and severe weather, are preceded by phenomena that allow for reliable predictions. Others, such as earthquakes, occur suddenly and with no notice, and thus they are not yet predictable. However, mapping the history of earthquakes in a region and an understanding of related geological forces can help forecast the locations and likelihoods of future events.	IAES 30, 37 IAES 43 IAES 43-45, 47-48
By the end of grade 12. Natural hazards and other geological events have shaped the course of human history by destroying	This content is not yet addressed in LAB-AIDS high school programs, but is addressed in materials under

Core Idea	*LAB-AIDS Location*
buildings and cities, eroding land, changing the course of rivers, and reducing the amount of arable land. These events have significantly altered the sizes of human populations and have driven human migrations. Natural hazards can be local, regional, or global in origin, and their risks increase as populations grow. Human activities can contribute to the frequency and intensity of some natural hazards.	development, expected commercial availability in 2012-13
ESS3.C: Human Impacts on Earth Systems	
By the end of grade 8. Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of many other species. But changes to Earth's environments can have different impacts (negative and positive) for different living things. Typically, as human populations and per-capita consumption of natural resources increase, so do the negative impacts on the earth unless the activities and technologies involved are engineered otherwise.	IALS 73, 85, 87, 101 IALS 98
By the end of grade 12. The sustainability of human societies and of the biodiversity that supports them require responsible management of natural resources not only to reduce existing adverse impacts but also to get things right in the first place. Scientists and engineers can make major contributions—for example, by developing technologies that produce less pollution and waste and that preclude ecosystem degradation. When the source of a problem is understood and international agreement can be reached, it has been possible to regulate activities to reverse or avoid some global impacts (e.g., acid rain, the ozone hole).	SGI BIO Eco 1, 4, 16, 18, 19 SGI BIO Sus 1, 3, 4 SGI BIO Eco 18-19 SGI BIO Evo 1, 2, 15
ESS3.D: Global Climate Change	
By the end of grade 8. Human activities, such as the release of carbon dioxide from burning fossil fuels, are major factors in	Global climate change is not addressed in LAB-AIDS middle level programs

Core Idea	*LAB-AIDS Location*
global warming. Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depend on the understanding of climate science, engineering capabilities, and other kinds of knowledge, such as understanding of human behavior and on applying that knowledge wisely in decisions and activities.	
By the end of grade 12. Because global climate changes usually happen too slowly for individuals to recognize them directly, scientific and engineering research—much of it based on studying and modeling past climate patterns—is essential. The current situation is novel, not only because the magnitudes of humans' impacts are significant on a global scale but also because humans' abilities to model, predict, and manage future impacts are greater than ever before. Through computer simulations and other studies, important discoveries are still being made about how the ocean, the atmosphere, and the biosphere interact and are modified in response to human activities, as well as to changes in human activities. Thus science and engineering will be essential both to understanding the possible impacts of global climate change and to informing decisions about how to slow its rate and consequences—for humanity as well as for the rest of the planet.	This content is not yet addressed in LAB-AIDS high school programs, but is addressed in materials under development, expected release in 2012-13 Note: SGI BIO Cell 2 examines changes in distribution of the mosquito responsible for transmitting malaria in response to global climate change, as predicted by computer models

CORE AND COMPONENT IDEAS IN ENGINEERING, TECHNOLOGY, AND APPLICATIONS OF SCIENCE

Early on, the *Framework* authors state that "…any [science] education that focuses predominantly on the detailed products of scientific labor—the facts of science—without developing an understanding of how those facts were established or that ignores the many important applications of science in the world misrepresents science and marginalizes the importance of engineering…" (see Chapter 3 of the *Framework*).

This statement has two implications for science education standards in general and for this report's framework in particular. The first is that students should learn how scientific knowledge is acquired and how scientific explanations are developed. The second is that students should learn how science is utilized, in particular through the engineering design process, and they should come to appreciate the distinctions and relationships between engineering, technology, and applications of science (ETS).

- ETS 1: Engineering design
- ETS 2: Links among engineering, technology, science, and society

In line with those conclusions and recommendations, the goal of this section of the *Framework* is not to replace current K-12 engineering and technology courses. The goal is rather to strengthen the science education provided to K-12 students by making the connections between engineering, technology, and the applications of science explicit, both for standards developers and curriculum developers, and to ensure that all students, whatever their path through K-12 education, gain an appreciation of these connections.

Core Idea ETS1: Engineering Design

Core Idea	*LAB-AIDS Location*
ETS1.A: Defining and Delimiting an Engineering Problem	
By the end of grade 8. The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that are likely to limit possible solutions (e.g., familiarity with the local climate may rule out certain plants for the school garden).	IAPS 84 IAES 32, 34-35 IALS 104-105

Core Idea	*LAB-AIDS Location*
By the end of grade 12. Design criteria and constraints, which typically reflect the needs of the end-user of a technology or process, address such things as the product's or system's function (what job it will perform and how), its durability, and limits on its size and cost. Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them.	SGI BIO Gen 17.1, 18.1, 19 NAC 3.3x[8], 8,4x, 10.4x, 15.4x, 19.3x, 20.3.x SAS 11.3, 20.1, 23.5, 24.2, 29.2, 29.4, 30.1, 32.1, 37.1
Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities. But whatever the scale, the first things that engineers do is define the problem and specify the criteria and constraints for potential solutions.	SGI BIO Gen 17.1, 18.1, 19 NAC 3.3x, 8,4x, 10.4x, 15.4x, 19.3x, 20.3.x SAS 11.3, 20.1, 23.5, 24.2, 29.2, 29.4, 30.1, 32.1, 37.1
ETS1.B: Developing Possible Solutions	
By the end of grade 8. A solution needs to be tested, and then modified on the basis of the test results, in order to improve it. There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors. In any case, it is important to be able to communicate and explain	IAPS 84 IAES 32, 34-35 IALS 104-105
solutions to others. Models of all kinds are important for testing solutions, and computers are a valuable tool for simulating systems. Simulations are useful for predicting what would happen if various parameters of the model were changed, as well as for making improvements to the	IAPS 84 IAES 32, 34-35, 47-48 IALS 104-105

[8] Note that "3.3x" refers to the "Chemistry Connections content for chapter 3, etc.

Core Idea	*LAB-AIDS Location*
model based on peer and leader (e.g., teacher) feedback.	
By the end of grade 12. Complicated problems may need to be broken down into simpler components in order to develop and test solutions. When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. Testing should lead to improvements in the design through an iterative procedure. Both physical models and computers can be used in various ways to aid in the engineering design process. Physical models, or prototypes, are helpful in testing product ideas or the properties of different materials.	SAS 25.1-25.3, 29.1-29.4 SAS 25.1-25.3, 29.1-29.4, 30.3,
Computers are useful for a variety of purposes, such as in representing a design in 3-D through CAD software; in troubleshooting to identify and describe a design problem; in running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs.	This standard is not addressed.
ETS1.C: Optimizing the Design Solution	
By the end of grade 8. There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. Comparing different designs could involve running them through the same kinds of tests and systematically recording the results to determine which design performs best. Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of those characteristics may be incorporated into	IAPS 84 IAES 32, 34-35 IALS 104-105 Note: Some of the content of these standards is implied but not explicitly addressed.

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the new design. This iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution. Once such a suitable solution is determined, it is important to describe that solution, explain how it was developed, and describe the features that make it successful.	
By the end of grade 12. The aim of engineering is not simply to find a solution to a problem but to design the best solution under the given constraints and criteria. Optimization can be complex, however, for a design problem with numerous desired qualities or outcomes. Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. The comparison of multiple designs can be aided by a trade-off matrix. Sometimes a numerical weighting system can help evaluate a design against multiple criteria. When evaluating solutions, all relevant considerations, including cost, safety, reliability, and aesthetic, social, cultural, and environmental impacts, should be included. Testing should lead to design improvements through an iterative process, and computer simulations are one useful way of running such tests.	SGI BIO Gen17.1, 18.1, 19 NAC 3.3x[9], 8,4x, 10.4x, 15.4x, 19.3x, 20.3.x SAS 11.3, 20.1, 23.5, 24.2, 29.2, 29.4, 30.1, 32.1, 37.1 Note: Some of the content of these standards is implied but not explicitly addressed. The SEPUP program materials do address trade-offs, but does not always use a formal matrix. Non-SEPUP programs do not necessarily address trade-offs.

Core Idea ETS2: Links Among Engineering, Technology, Science, and Society

Core Idea	*LAB-AIDS Location*
ETS2.A: Interdependence of Science, Engineering, and Technology	
By the end of grade 8. Engineering advances have led to important discoveries in virtually every field of science, and scientific discoveries have led to the development of entire industries and engineered systems. In	IAES 85, 87, 93-94, 98 IAPS 22-23, 68-70, 85 IALS 25, 26, 28, 52, 69, 103

[9] Note that "3.3x" refers to the "Chemistry Connections content for chapter 3, etc.

Core Idea	*LAB-AIDS Location*
order to design better technologies, new science may need to be explored (e.g., materials research prompted by desire for better batteries or solar cells, biological questions raised by medical problems). Technologies in turn extend the measurement, exploration, modeling, and computational capacity of scientific investigations.	
By the end of grade 12. Science and engineering complement each other in the cycle known as research and development (R&D). Many R&D projects may involve scientists, engineers, and others with wide ranges of expertise. For example, developing a means for safely and securely disposing of nuclear waste will require the participation of engineers with specialties in nuclear engineering, transportation, construction, and safety; it is likely to require as well the contributions of scientists and other professionals from such diverse fields as physics, geology, economics, psychology, and sociology.	SAS 10.1-10.3, 11.3-11.4, 20.1, 25.1-25.2, 29.2-29.4, 37.1 NAC 8.4x, 19.3x, 20.5x SGI BIO Gen 16.1, 17.1, 19
ETS2.B: Influence of Engineering, Technology and Science on Society and the Natural World	
By the end of grade 8. All human activity draws on natural resources and has both short- and long-term consequences, positive as well as negative, for the health of both people and the natural environment. The uses of technologies and any limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. Thus technology use varies from region to region and over time. Technologies that are beneficial for a certain purpose may later be seen to have impacts (e.g., health-related, environmental) that were not foreseen. In such cases, new regulations on use or new technologies (to mitigate the impacts or eliminate them) may be required.	IAES 12 IALS 72-73, 87-88, 89 IAPS 22, 24, 26-29, 42-43, 51, 64, 69-70

Core Idea	*LAB-AIDS Location*
By the end of grade 12. Modern civilization depends on major technological systems, including those related to agriculture, health, water, energy, transportation, manufacturing, construction, and communications. Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks. Widespread adoption of technological innovations often depends on market forces or other societal demands, but it may also be subject to evaluation by scientists and engineers and to eventual government regulation. New technologies can have deep impacts on society and the environment, including some that were not anticipated or that may build up over time to a level that requires attention or mitigation. Analysis of costs, environmental impacts, and risks, as well as of expected benefits, is a critical aspect of decisions about technology use.	SAS 10.1-10.3, 11.3-11.4, 20.1, 25.1-25.2, 29.2-29.4, 37.1 NAC 8.4x, 18.4x, 19.3x, SGI BIO Gen 16.1, 17.1, 19