THREE DIMENSIONAL SCIENCE

SCIENCE & ENGINEERING PRACTICES

1. ASKING QUESTIONS AND DEFINING PROBLEMS

Science begins with a question about a phenomenon such as "Why is the sky blue?" or "What causes cancer?" A basic practice of the scientist is the ability to formulate empirically answerable questions about phenomena to establish what is already known, and to determine what questions have yet to be satisfactorily answered.

Engineering begins with a problem that needs to be solved, such as "How can we reduce the nation's dependence on fossil fuels? or "What can be done to reduce a particular disease? or "How can we improve the fuel efficiency of automobiles? A basic practice of engineers is to ask questions to clarify the problem, determine criteria for a successful solution, and identify constraints.

2. DEVELOPING AND USING MODELS

Science often involves the construction and use of models and simulations to help develop explanations about natural phenomena. Models make it possible to go beyond observables and simulate a world not yet seen. Models enable predictions of the form "if...then... therefore" to be made in order to test hypothetical explanations.

Engineering makes use of models and simulations to analyze extant systems to identify flaws that might occur, or to test possible solutions to a new problem. Engineers design and use models of various sorts to test proposed systems and to recognize the strengths and limitations of their designs.

3. PLANNING AND CARRYING OUT INVESTIGATIONS

Scientific investigations may be conducted in the field or in the laboratory. A major practice of scientists is planning and carrying out systematic investigations that require clarifying what counts as data and in experiments identifying variables.

Engineering investigations are conducted to gain data essential for specifying criteria or parameters and to test proposed designs. Like scientists, engineers must identify relevant variables, decide how they will be measured, and collect data for analysis. Their investigations help them to identify the effectiveness, efficiency, and durability of designs under different conditions.

4. ANALYZING AND INTERPRETING DATA

Scientific investigations produce data that must be analyzed in order to derive meaning. Because data usually do not speak for themselves, scientists use a range of tools—including tabulation, graphical interpretation, visualization, and statistical analysis—to identify the significant features and patterns in the data. Sources of error are identified and the degree of certainty calculated. Modern technology makes the collection of large data sets much easier providing secondary sources for analysis.

Engineering investigations include analysis of data collected in the tests of designs. This allows compari- son of different solutions and determines how well each meets specific design criteria—that is, which design best solves the problem within given constraints. Like scientists, the engineers require a range of tools to identify the major patterns and interpret the results. Advances in science make analysis of proposed solutions more efficient and effective.

5. MATHEMATICAL AND COMPUTATIONAL THINKING

In science, mathematics and computation are fundamental tools for representing physical variables and their relationships. They are used for a range of tasks such as constructing simulations; statistically analyzing data; and recognizing, expressing, and applying quantitative relationships. Mathematical and computational approaches enable prediction of the behavior of physical systems along with the testing of such predictions. Moreover, statistical techniques are also invaluable for identifying significant patterns and establishing correlational relationships.

In engineering, mathematical and computational representations of established relationships and principles are an integral part of the design process. For example, structural engineers create mathematical-based analysis of designs to calculate whether they can stand up to expected stresses of use and if they can be completed within acceptable budgets. Moreover, simulations provide an effective test bed for the development of designs as proposed solutions to problems and their improvement, if required.

6. CONSTRUCTING EXPLANATIONS AND DESIGNING SOLUTIONS

The goal of science is the construction of theories that provide explanatory accounts of the material world. A theory becomes accepted when it has multiple independent lines of empirical evidence, greater explanatory power, a breadth of phenomena it accounts for, and has explanatory coherence and parsimony.

The goal of engineering design is a systematic solution to problems that is based on scientific knowledge and models of the material world. Each proposed solution results from a process of balancing competing criteria of desired functions, technical feasibility, cost, safety, aesthetics, and compliance with legal requirements. Usually there is no one best solution, but rather a range of solutions. The optimal choice depends on how well the proposed solution meets criteria and constraints.

7. ENGAGING IN ARGUMENT FROM EVIDENCE

In science, reasoning and argument are essential for clarifying strengths and weaknesses of a line of evidence and for identifying the best explanation for a natural phenomenon. Scientists must defend their explanations, formulate evidence based on a solid foundation of data, examine their understanding in light of the evidence and comments by others, and collaborate with peers in searching for the best explanation for the phenomena being investigated.

In engineering, reasoning and argument are essential for finding the best solution to a problem. Engineers collaborate with their peers throughout the design process. With a critical stage being the selection of the most promising solution among a field of competing ideas. Engineers use systematic methods to compare alternatives, formulate evidence based on test data, make arguments to defend their conclusions, critically evaluate the ideas of others, and revise their designs in order to identify the best solution.

8. OBTAINING, EVALUATING, AND COMMUNICATING INFORMATION

Science cannot advance if scientists are unable to communicate their findings clearly and persuasively or learn about the findings of others. A major practice of science is thus to communicate ideas and the results of inquiry—orally; in writing; with the use of tables, diagrams, graphs and equations; and by engaging in extended discussions with peers. Science requires the ability to derive meaning from scientific texts such as papers, the internet, symposia, or lectures to evaluate the scientific validity of the information thus acquired and to integrate that information into proposed explanations.

Engineering cannot produce new or improved technologies if the advantages of their designs are not communicated clearly and persuasively. Engineers need to be able to express their ideas orally and in writing; with the use of tables, graphs, drawings or models; and by engaging in extended discussions with peers. Moreover, as with scientists, they need to be able to derive meaning from colleagues' texts, evaluate information, and apply it usefully.

Adapted from the National Research Council's "A Framework for K-12 Science Education." July, 2011. National Academies Press.

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SCIENCE AND ENGINEERING PRACTICES

DISCIPLINARY CORE IDEAS

CROSSCUTTING CONCEPTS

THREE DIMENSIONAL SCIENCE

CROSSCUTTING CONCEPTS

1. PATTERNS

Observed patterns of forms and events guide organization and classification, and they promptquestions about relationships and the factors that influence them.

2. CAUSE AND EFFECT: MECHANISM AND EXPLANATION

Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and 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.

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.

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.

6. STRUCTURE AND FUNCTION

The way in which an object or living thing is shaped and its substructure determine many of its properties and functions.

7. STABILTY AND CHANGE

For natural and built systems alike, conditions of stability and determinants of rates of change or evolution of a system are critical elements of study.

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SCIENCE AND ENGINEERING PRACTICES
DISCIPLINARY CORE IDEAS
CROSSCUTTING CONCEPTS

THREE DIMENSIONAL SCIENCE

DISCIPLINARY CORE IDEAS

1. DISCIPLINARY CORE IDEAS IN PHYSICAL SCIENCE

PS1: Matter and Its Interactions
PS1.A: Structure and Properties of Matter
PS1.B: Chemical Reactions
PS1.C: Nuclear Processes

PS2: Motion and Stability: Forces and Interactions
PS2.A: Forces and Motion
PS2.B: Types of Interactions
PS2.C: Stability and Instability in Physical Systems

PS3: Energy
PS3.A: Definitions of Energy
PS3.B: Conservation of Energy and Energy Transfer
PS3.C: Relationship Between Energy and Forces
PS3.D: Energy in Chemical Processes and Everyday Life

PS4: Waves and Their Applications in Technologies for Information Transfer
PS4.A: Wave Properties
PS4.B: Electromagnetic Radiation
PS4.C: Information Technologies and Instrumentation.

2. DISCIPLINARY CORE IDEAS IN LIFE SCIENCE

LS1: From Molecules to Organisms: Structures and Processes
LS1.A: Structure and Function
LS1.B: Growth and Development of Organisms
LS1.C: Organization for Matter and Energy Flow in Organisms
LS1.D: Information Processing

LS2: Ecosystems: Interactions, Energy, and Dynamics
LS2.A: Interdependent Relationships in Ecosystems
LS2.B: Cycles of Matter and Energy Transfer in Ecosystems
LS2.C: Ecosystem Dynamics, Functioning, and Resilience
LS2.D: Social Interactions and Group Behavior

LS3: Heredity: Inheritance and Variation of Traits
LS3.A: Inheritance of Traits
LS3.B: Variation of Traits

LS4: Biological Evolution: Unity and Diversity
LS4.A: Evidence of Common Ancestry and Diversity
LS4.B: Natural Selection
LS4.C: Adaptation
LS4.D: Biodiversity and Humans

3. DISCIPLINARY CORE IDEAS IN EARTH & SPACE SCIENCE

ESS1: Earth's Place in the Universe
ESS1.A: The Universe and Its Stars
ESS1.B: Earth and the Solar System
ESS1.C: The History of Planet Earth

ESS2: Earth's Systems
ESS2.A: Earth Materials and Systems
ESS2.B: Plate Tectonics and Large-Scale System Interactions
ESS2.C: The Roles of Water in Earth's Surface Processes
ESS2.D: Weather and Climate
ESS2.E: Biogeology

ESS3: Earth and Human Activity
ESS3.A: Natural Resources
ESS3.B: Natural Hazards
ESS3.C: Human Impacts on Earth Systems
ESS3.D: Global Climate Change

4. DISCIPLINARY CORE IDEAS IN ENGINEERING, TECHNOLOGY, AND THE APPLICATION OF SCIENCE

ETS1: Engineering Design
ETS1.A: Defining and Delimiting an Engineering Problem
ETS1.B: Developing Possible Solutions
ETS1.C: Optimizing the Design Solution

ETS2: Links Among Engineering, Technology, Science, and Society
ETS2.A: Interdependence of Science, Engineering, and Technology
ETS2.B: Influence of Engineering, Technology, and Science on Society and the Natural World

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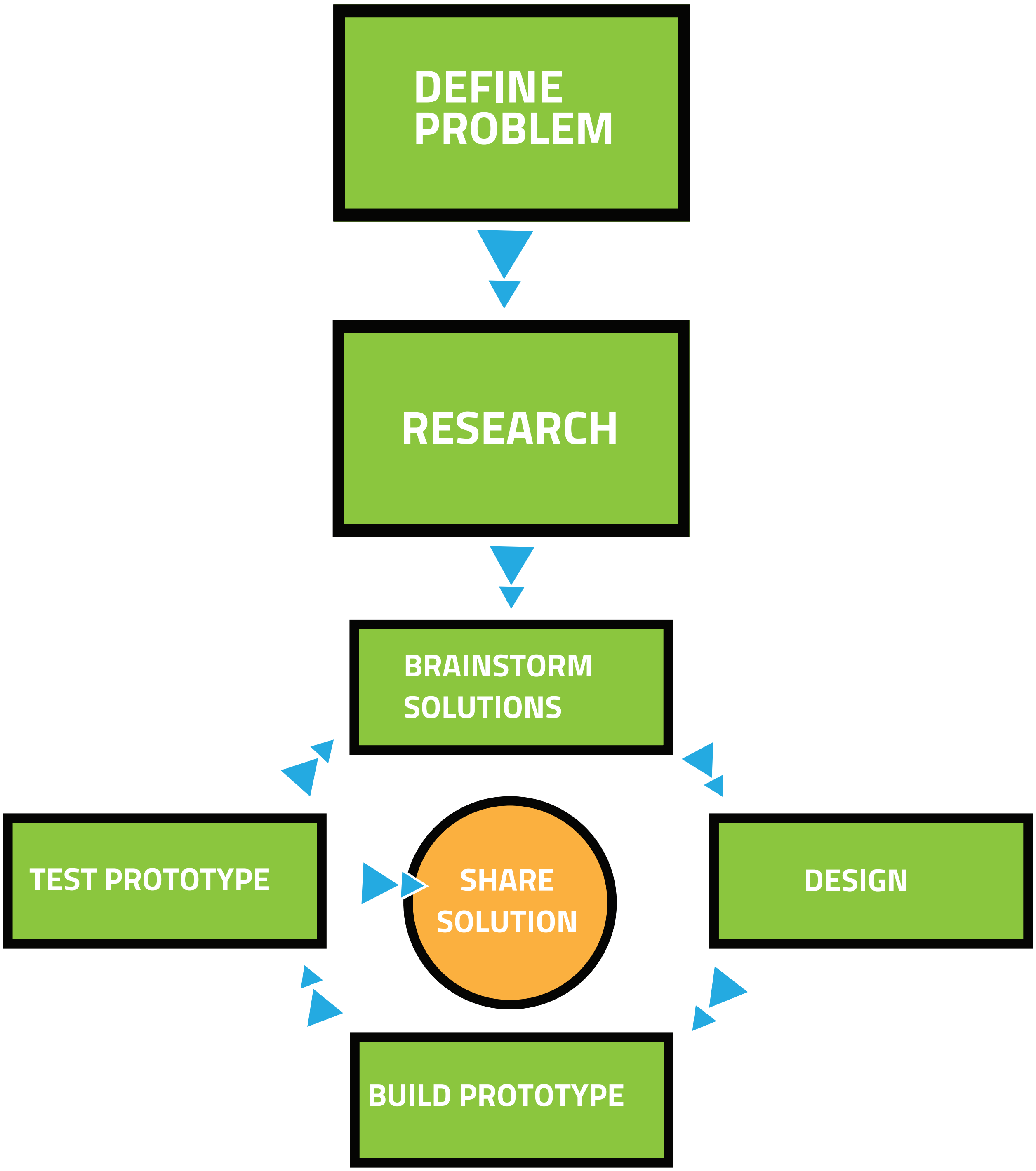
SCIENCE AND ENGINEERING PRACTICES
DISCIPLINARY CORE IDEAS
CROSSCUTTING CONCEPTS

THREE DIMENSIONAL SCIENCE

ENGINEERING DESIGN PROCESS



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SCIENCE AND ENGINEERING PRACTICES
DISCIPLINARY CORE IDEAS
CROSSCUTTING CONCEPTS

Claim (answers question)	
Evidence (must include data)	**Reasoning (the argument: how the evidence supports or does not support the claim)**
Revised Claim (if necessary to account for evidence that does not support original claim)	

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