

# Primary to Secondary Engineering Learning: A Framework for International Consideration

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## FRAMEWORK

### P-12 Engineering Learning

- Engineering Habits of Mind** that students should develop over time through repetition and conditioning,
- Engineering Practices** in which students should become competent, and
- Engineering Knowledge** that students should be able to recognize and access to inform their engineering practice.

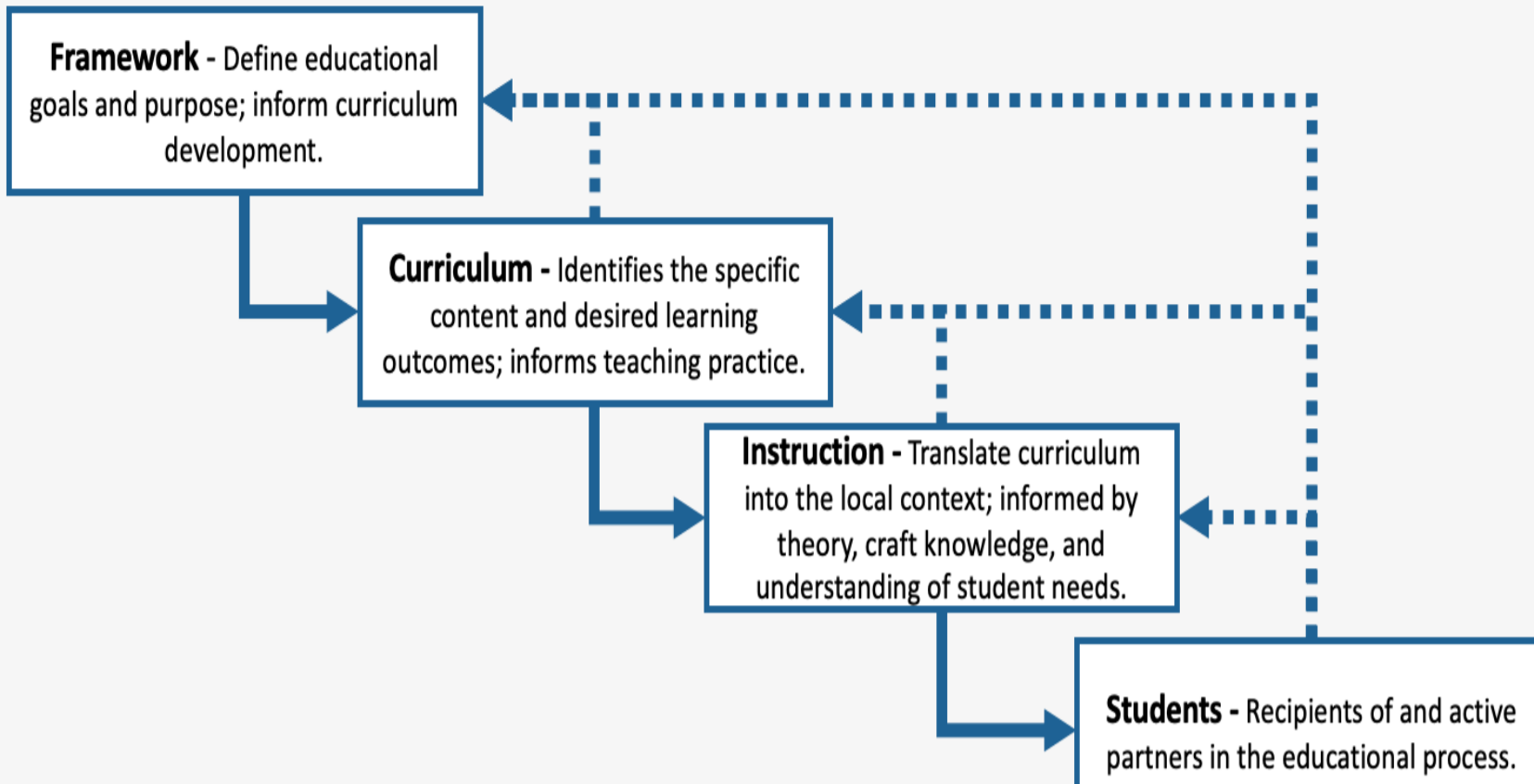


Literacy Dimensions	Main Components	
Engineering Habits of Mind	Optimism Persistence Conscientiousness	Systems Thinking Creativity Collaboration
Engineering Practices	Engineering Design Material Processing	Quantitative Analysis Professionalism
Engineering Knowledge Domains	Engineering Sciences Engineering Mathematics	Engineering Technical Applications

## SYNOPSIS

The teaching of engineering has made its entrance into the subject of *Design & Technology Education (DTE)* around the world over the past few decades. This inclusion has been particularly true for the United States which refers to its DTE-related subject as *Technology & Engineering Education*. The inclusion of engineering has likely been due to the closely aligned epistemologies and classroom practices between engineering and DTE. But, while engineering has been emphasized in primary and secondary schooling, there has also been limited guidance for articulating how engineering could/should be taught, both authentically and equitably, across the years of school and how it is connected with other school subjects. To aid in this effort, a *Framework for P-12 Engineering Learning* was formed through over 3 years of iterative research and development work and published by the American Society of Engineering Education (2020). This framework was created to help provide a unifying vision and guidebook to inform decisions for improving the coherency and equity of engineering teaching and learning across the country. In addition, throughout this process, *Engineering Performance Matrices (EPMs)* were generated to offer sample blueprints of how the engineering concepts and sub-concepts identified within the framework could build upon each other to support teachers in creating authentic learning experiences that increase in sophistication over time—enabling students to achieve any designated engineering-related performance tasks or achievement or any standards related to engineering/tech.

## RESEARCH & DEVELOPMENT



Primary (PK-2)	Habits
Elementary (3-5)	Practices
Middle (6-8)	Knowledge
High (9-12)	

### Engineering Performance Matrices

**A. Core or Auxiliary Concept** Identifies the domain or practice's concept of focus.

**B. Engineering Literacy Dimension Bar** Identifies Engineering Habits of Mind, Knowledge, or Practice (if applicable); and the Overview, which defines the concept and its importance to Engineering Literacy.

**C. Performance Goal for High School Learners** Indicates mastery of the domain through core concept application.

**D. Columns for Sub-Concepts**

**E. Basic Column** Denotes partial mastery of prerequisite knowledge and skills that are fundamental for proficient work.

**F. Proficient Column** Represents solid academic performance.

**G. Advanced Column** Demonstrates competency over challenging subject matter, including subject-matter knowledge, application of such knowledge to real-world situations, and analytical skills appropriate to the subject matter.

**Core Concept: Problem Framing**

**Engineering Literacy Dimension: Engineering Practices**  
**Practice: Engineering Design**  
**Overview:** Problem Framing is a process, which occurs early in and throughout the practice of Engineering Design that involves outlining one's mental interpretation of a problem situation by identifying the goals and essential issues related to developing a desired solution. This includes identifying design parameters to formulate a problem statement that (a) considers multiple perspectives, (b) removes perceived assumptions that unnecessarily limit the problem-solving process, and (c) frames the design scenario in such a manner that helps guide the problem-solving process. This core concept is important to the practice of Engineering Design as design problems are, by nature, ill-structured and open-ended.

**Performance Goal for High School Learners**  
 I can successfully construct, justified problem statements that highlight the key elements of a design scenario, including multiple perspectives (clients/end-users) to guide the evaluation of trade-offs between multiple, and sometimes conflicting, goals, criteria, and constraints during a design project.

Dimension	Basic	Proficient	Advanced
IDENTIFYING DESIGN PARAMETERS	I can analyze a provided description of a design situation in order to identify explicit design criteria and constraints.	I can infer design criteria and constraints that are not explicitly described in a provided description of a design situation.	I can evaluate the relationships between design criteria and constraints, prioritizing them within a specific context of a design in order to effectively balance trade-offs between any conflicting goals.
PROBLEM STATEMENT DEVELOPMENT	I can identify elements of a design situation, assessing "what the central issue is that requires a resolution," "who the issue affects," "when/where the issue occurs," and "why the issue needs a novel solution."	I can summarize elements of a design situation to write a concise problem statement that represents a clear description of a justifiable issue along with the main goals to be addressed by the problem-solving team.	I can evaluate a statement to determine if a vision or a design team is clearly stated with sufficient information that justifies the execution of a problem-solving process.
CONSIDERING ALTERNATIVES	I can identify the assumptions or perceived rules associated with a problem statement that are limitations for solution opportunities.	I can rephrase a problem from multiple perspectives to generate alternative problem frames/statements that remove assumptions limiting solution designs.	I can evaluate alternative problem frames/statements in an effort to select the ones which have the greatest opportunity to generate innovative solutions.

## IMPLEMENTATION EXAMPLES

**Core Concept: Computational Thinking**

**Engineering Literacy Dimension: Engineering Practices**  
**Practice: Quantitative Analysis**  
**Overview:** Computational Thinking is the process of dissecting complex problems in a manner to generate solutions that are expressed as a series of computational steps in which a computer can perform (Aho, 2002). Typically, this process is separated into four elements: (i) decomposition (the method of dissecting a problem into smaller more manageable tasks), (ii) pattern recognition (the method of searching for similarities within problems or solutions), (iii) abstraction (the method of synthesizing important information and filtering out irrelevant data while generating a solution), and (iv) algorithm design (the method of creating a step-by-step solution to be carried out by a computer program) (BBC, 2008). Computational Thinking also includes knowledge related to (a) the formation of algorithms (including flowcharting), (b) the translation of algorithms using appropriate programming languages, and (c) software design, implementation, and testing. Computational Thinking is important to the practice of Quantitative Analysis as engineering professionals systematically analyze and develop algorithms and programs to develop or optimize solutions to design problems. Furthermore, computational thinking is necessary to develop efficient and automated physical systems as well as visualizations of design concepts and computational scientific models (NRC, 2001).

**Performance Goal for High School Learners**  
 I can successfully design, develop, implement, and evaluate algorithms/programs that are used to visualize/control physical systems that address an engineering problem/task.

Dimension	Basic	Proficient	Advanced
ALGORITHM FORMATION (including flowcharting)	I can interpret a flowchart of a designed system and describe how the system may work with what algorithms.	I can develop algorithms in order to develop a part of my solution and communicate them using flowcharts.	I can develop and implement a program that incorporates a series of algorithms in order to optimize my solution in its entirety.
PROGRAMMING LANGUAGES	I can develop basic programs using correct syntax and logical organization.	I can develop programs using more advanced programming techniques, such as loops, conditional structures, and variables.	I can develop programs using highly advanced techniques, such as writing external functions and calling them from a program.
SOFTWARE DESIGN, IMPLEMENTATION, & TESTING	I can develop a solution to an engineering design problem using industry-grade software.	I can develop and implement a solution to an engineering design problem using a variety of industry-grade software.	I can evaluate and justify which software package, among a variety of industry-grade software, is optimal for solving a specific engineering design problem.

**SMART buoys:** Integrating data visualization and design to reduce ocean-life casualties

**engineering in action**

**engineering in the wild:** using current environmental concerns to teach engineering practices

**excellent in engineering**

**engineering the reduction of food waste:** teaching problem framing and project management through culturally situated learning

The ASEE project emphasizes the importance of student learning project management strategies and tools.

To develop a problem statement by identifying explicit goals, determining the core implicit goals, and considering multiple perspectives regarding the design scenario to help eliminate any perceived assumptions that unnecessarily limit the problem-solving process. Additionally, students will be able to learn and apply the fundamental core concepts of engineering design (define, analyze, design, build, test, and evaluate) to create a solution.