Core Idea ETS1

Engineering Design

How do engineers solve problems?

- 6E process (an engineering specific variation on the 5E process)
- the "design process"
    - problem definition
    - model development
    - model use
    - investigation
    - analysis
    - interpretation of data
    - application of mathematics
    - application computational thinking
    - determination of solutions
- engineer(ing)
    - practices
    - specialized knowledge
    - criteria
    - constraints
    - modeling
    - analysis
    - optimization
    - trade-offs.
- problem solving

ETS1.A: DEFINING AND DELIMITING AN ENGINEERING PROBLEM

What is a design for?
What are the criteria and constraints of a successful solution?

- the engineering design process
    - identification of a problem to solve
    - specification of clear goals (or criteria, that the final product or system must meet)
        - criteria
            - (Typically reflect the needs of the expected end-user of a technology or process, address such things as how the product or system will function --what job it will perform and how-- its durability, and its cost)
            - (Needs to be quantifiable whenever possible and stated so that one can tell if a given design meets them.)

- engineering
    - limitations, or constraints
        - These frame the salient conditions under which the problem must be solved, may be physical, economic, legal, political, social, ethical, aesthetic, or related to time and place.
        - Quantitatively, measure and measurement constraints may include limits on cost, size, weight, or performance.
        - Place restrictions on a design, not all of them are permanent or absolute.

Grade Band End Points for ETS1.A

By the end of grade 2.

- design situation
- problem
- solution
- engineering(s)
    - ask questions
    - make observations
    - gather information
    - think about problems
    - see to understand problems
    - design solutions

By the end of grade 5.

- Problem solutions
    - limited by available materials and resources (constraints)
    - are determined by considering the desired features of a solution or criteria. (when successful)
    - can have many different proposed solutions
    - solutions are compared on the basis of
        - how well each one meets the specified criteria for success
        - how well each takes the constraints into account.

By the end of grade 8.

- A design task's criteria and constraints
    - Sequires rigorous definition if the design is to be successful.
    - Specification of constraints include
        - The consideration of scientific principles

        - The consideration of 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).

By the end of grade 12.

- design criteria
    - include satisfying any requirements set by society, such as taking issues of risk mitigation into account
    - are quantified to the extent possible and stated in such a way that one can tell if a given design meets them.
- design constraint(s)
    - typically reflect the needs of the end-user of a technology or process
    - address the product's or system's function (what job it will perform and how),
    - product durability
    - limits on the devices size and cost
- scale of design need

ETS1.B: DEVELOPING POSSIBLE SOLUTIONS

What is the process for developing potential design solutions?

- creative process
- design
- problem solving (finding solutions to design problems)
- open-ended
- brainstorming
- specification of solution(s)
- criteria
- constraint
- informal
- sketch(es)
- diagram(s)
- models (physical, graphical, and mathematical models)
- finished product (such as a machine, building, or any other working system)
- types of systems (e.g., mechanical, electrical, biotechnological)
- visualization of design elements (of a possible solution)
- design performance
- feasible solution(s)
- optimal solution
- parameters
- scale model
- prototype

- sketches and drawings (graphical models)
- input
- Mathematical models
    - Allow engineers to estimate the effects of a change in one feature of the design (e.g., material composition, ambient temperature) on other features, or on performance as a whole, before the designed product is actually built.
    - Are often embedded in computer-based simulations.
- computer-aided design (CAD)
- computer-aided manufacturing (CAM)
    - common modeling tools used in engineering.
- data
- experiment
- performance information

Grade Band Endpoints for ETS1.B

By the end of grade 2.

- design(s) (plan)
    - can be conveyed through sketches, drawings, or physical models
    - useful in communicating ideas for a problem's solutions to other people are complicated to make
    - may require the designer to break the problem into parts
    - may require the designer to attend to each part separately
    - requires the designer to bring the parts together to test the overall plan

By the end of grade 5.

- research
    - internet searche
    - market research
    - field observation
- brainstorm solutions
- test solutions
- refine possible solutions
- investigation
- failure points or difficulties
- models
    - simple physical models
    - computer models

By the end of grade 8.

- Solution(s)
    - needs to be tested
        - computers are a valuable tool for simulating systems
    - needs to be modified on the basis of the test results
    - needs to be improved
- systematic processes
- solution evaluation
- design/problem criteria
- design/problem constraints
- simulation
- prediction
- parameter
- peer or 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 solution
- evaluating solutions
    - by taking into account
        - a range of constraints, including
            - cost
            - safety
            - reliability
            - aesthetics
        - a range of impacts, including
            - social impacts
            - cultural impacts
            - environmental impacts
- testing solutions
    - an iterative procedure
- models (both physical models and computers)
- engineering design process
- Physical models (prototypes)
    - are helpful in testing
        - product ideas
        - properties of different materials
        - computers are useful
            - can help create files representing a design in 3-D through CAD software.
            - troubleshooting

- denitify design problems
- describe a design problem

- run simulations
  - test different solutions to see which one is most
    - efficient
    - economical

ETS1.C: OPTIMIZING THE DESIGN SOLUTION

How can the various proposed design solutions be compared and improved?

- multiple solutions
  - finding the
    - "best" solution or optimal solution
      - requires making
        - value judgments
- optimization
  - often requires making
    - trade-offs (among competing criteria)
      - that can be
        - devalued or traded off
        - trade-off matrix
          - to compare the overall
            - advantages
            - disadvantages
    - judgment (The decision as to which criteria are critical and which ones can be traded off)
      - based on
        - the situation
        - perceived needs
        - end-user of the product or system
        - many factors
          - environmental impacts
          - health impacts
          - available technologies
          - expectations of users
        - change over time and vary from place to place
      - design solution(s)
        - (that is considered optimal at one time and place may appear far from optimal at other times and places. Thus different designs, each of them optimized for different conditions, are often needed)

Grade Band Endpoints for ETS1.C

By the end of grade 2.

- solution
- problem
- design(s)
    - test them
    - discuss their strengths
    - discuss their weaknesses

By the end of grade 5.

- solution
- best
- problem
- criteria
- constraints

By the end of grade 8.

- systematic processes
- evaluating solutions
- criteria (of a problem)
- constraints (of a problem)
- recording the results
- tests
- redesign process
- iterative process
- modification
- refinement
- optimal solution
- suitable solution

By the end of grade 12.

- engineering
- constraints
- criteria
- optimization
- design problem
- qualities
- outcomes
- trade-offs (decisions about the priority of certain criteria over others)

- trade-off matrix
- numerical weighting system
- evaluate
- relevant considerations (cost, safety, reliability, and aesthetic, social, cultural, and environmental impacts)
- iterative process
- computer simulations