

# Using Notebooks on the Path to Engineering Design

## Pathways to Engineering Design in the Elementary Classroom

Students engage in an engineering project to build understanding of engineering practices

Students learn science content through an engineering design project.

*Students apply learned science content to solve an engineering design challenge.*

# A Science Notebook

**A science notebook is a place to record the journey through an inquiry investigation.**

# Science Practices

- Asking questions.
- Developing and using models.
- Planning and carrying out investigations.
- Analyzing and interpreting data.
- Using mathematics.
- Constructing explanations.

# Essential Components of a Notebook and Inquiry

- Focus Question - Problem – Purpose
- Prediction (often based on a model)
- Planning or Procedures for an Investigation
- Observations, Data, Charts, Graphs, Drawings and Illustrations
- Claims and Evidence
- Drawing Conclusions
- **Next steps, New Questions (PM Design Challenge)**

| Science Practice   | Notebook entry  |
|--|---|
| Ask a question   | What change can be made to the pendulum to change the rate of swings?   |
| Make a prediction (while using a model)                            | <i>The Swinging Pendulum</i>  |
| Focus question for the investigation<br>Based on their prediction. | Example: How does the length of the pendulum affect the rate of swings? |
| Planning and carrying out an investigation                         | Data table with information from the investigation                      |
| Analyze and interpret data   | Claim and Evidence  |
| Conclusion   | Solution to the Grandfather Clock problem                               |

# Science Practices

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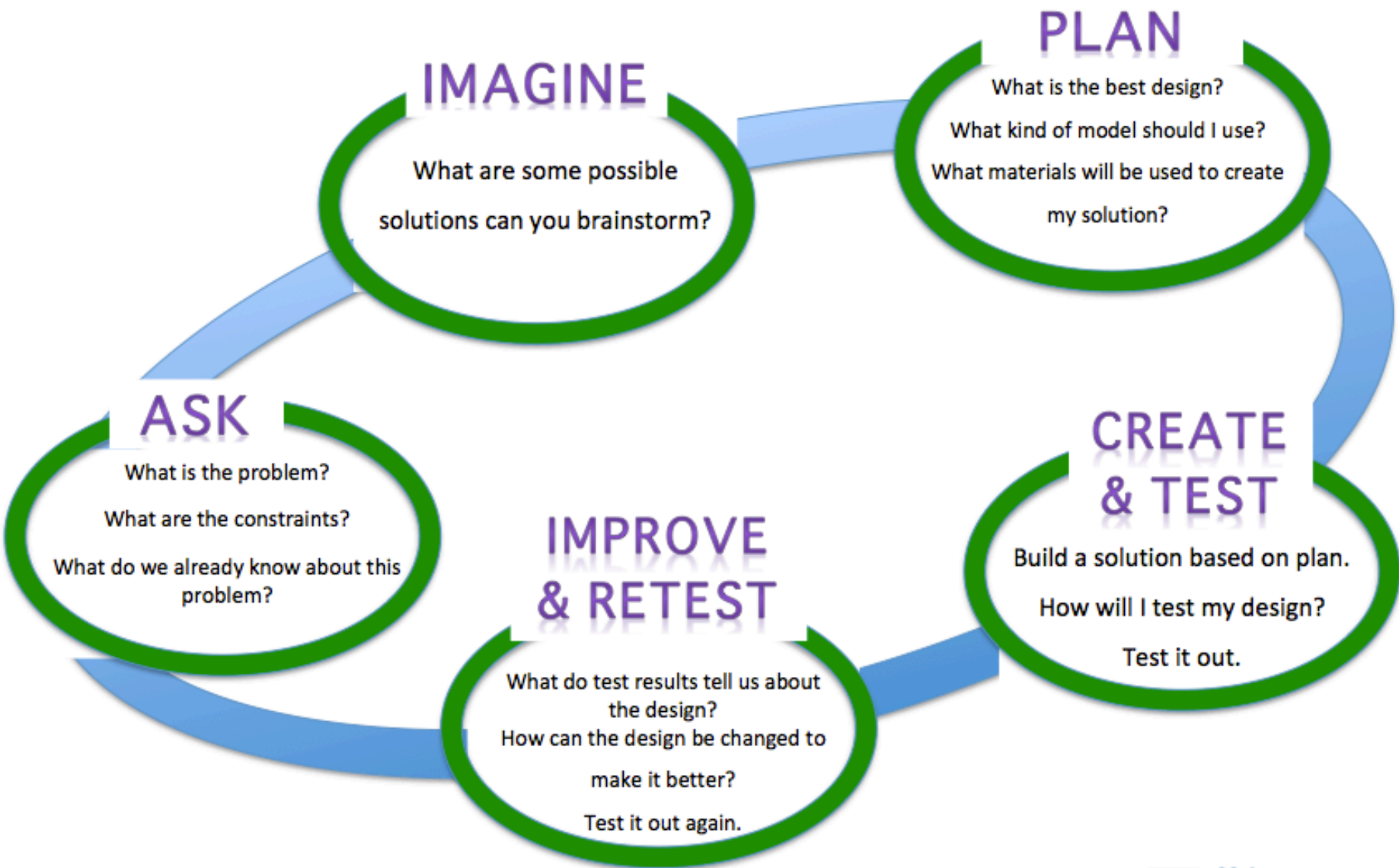
# Going from Inquiry to Engineering Design



# Design is a Process

- The solution to a design problem does not suddenly appear in a vacuum.
- A good solution requires a methodology or process.
- The process used in developing solutions is often described as various stages. These stages characterize various elements of the general process. There are probably as many depictions of design process as there are engineers!
- Caveat: Be cautious when presenting a particular process to students so that it is not interpreted as a rigid "cookbook" approach or as THE only pathway.

# Engineering Design Process



# The “What” and “Why” of Engineering Notebooks

- Used in industry to record **what** and **when** work was done
- Used to clarify and record thinking, communicate ideas to others (e.g. client, machinist, etc.)
- Permanent records therefore must be permanently bound; each page numbered consecutively, dated and entries written in permanent ink, no blank pages
- Entries may be supplemented (permanently attach documents) and describe these attachments in the bound notebook
- Many companies require someone besides the author to date and sign the notebook periodically (daily or weekly basis) as proof of when work was done
- Include narrative to describe sketches, diagrams, plots, and equations.

Factoid: In the U.S., patents are awarded based on evidence of "first to discover;" in most other countries, patents go to the "first to file."

# Engineering Practices

- Defining problems
- Developing and using models
- Planning and carrying out investigations
- Analyzing and interpreting data
- Using mathematics and computational thinking
- Designing solutions
- Engaging in argument from evidence
- Obtaining, evaluating, and communicating information

# Components of a Student Engineering Notebook

What is the *purpose* of student engineering notebooks?

- Statement of Problem
- Brainstorming of Solutions
- Planning of Design Solution
- Creating & Testing Results
- Record of Improvements (Iterations)

# ASK

- *What is the problem?*
- *What are the constraints?*
- *What do we already know about this problem?*

# ASK

- *What is the problem?*
  - Notebook Entry
    - *Draw a picture of the problem and/or*
    - *State what the problem is*
    - *Paste in the design brief*

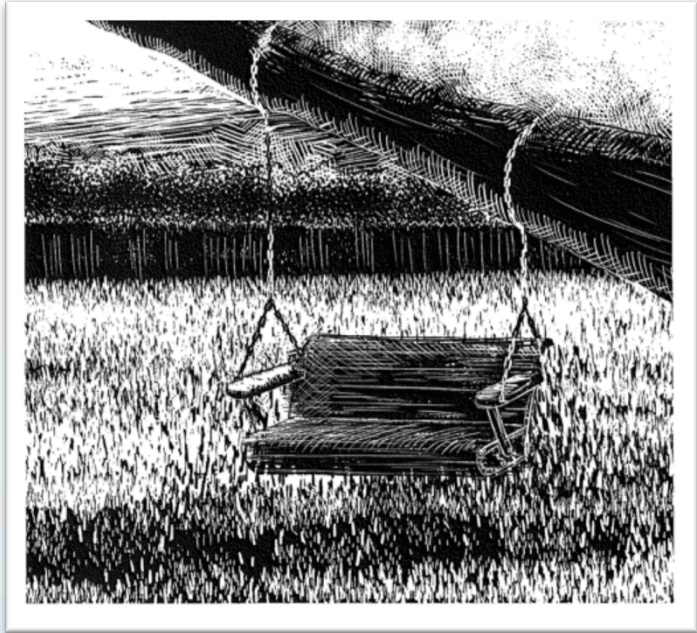
Note:

- Fix the swing is not sufficient statement for “defining the problem”
- Define the problem includes establishing the need and often acknowledges basic parameters of a sufficient solution

e.g. *Design a way to connect the porch swing to a crooked branch so that it swings straight.*

# ASK

- *What are the **constraints**?*



- Define constraints to students
- Notebook entry – clarify as a class / list constraints
  - e.g. “Crooked Swing” Problem Constraints
    - Swing must swing straight
    - Swing seat must be level so people can sit in it
    - Must hang the swing from the crooked branch
    - Solution cannot damage the swing OR the tree
    - Must be something that the (elderly) neighbor can do
    - Must be safe
  - COST / MATERIALS / TIMEFRAME / DIMENSIONS (often constraints)
- *How will we know when we’ve been successful?*  
(Our solution meets the **criteria**)

# ASK

- *What do we already know about this problem? (from the story - reread)*

Know the swing is connected by two chains on each side of a crooked branch – and when people use the swing it swings crooked.

Know when they added weight it didn't fix the problem

Know when they shortened both sides of the swing it didn't fix it

- *What science is needed to solve or fix the problem? (use inquiry findings recorded in notebook)*

Know that changing the length of the chain changes how fast the swing swings back and forth. Shorter length = quicker back and forth, longer string = longer time back and forth

# IMAGINE

- *What are some possible solutions you can brainstorm?*
- Engineers often spend time researching solutions of others
- Notebook entry
  - Students record drawings and write descriptions of their ideas
  - Work in small groups to brainstorm
  - Work as individuals to brainstorm
  - Review and sharing of brainstorming

# PLAN

- *What is the best design?*
- Evaluate designs
  - Justify why a particular design is the best
  - *I think this design will work the best because....*
- Develop a plan for creating a model for the chosen design
  - Select the most appropriate model (e.g. drawing, physical, mathematical, etc.)
  - Identify materials to build the physical models when appropriate

# CREATE & TEST

- Create the model based on the plan
- Test it out
  - Implies devise a test
  - Tests against the criteria (see list)
- Notebook entry
  - Collection of data from testing

# IMPROVE & RETEST

- Study test results.
  - Analyze – *What do test results tell us about the design?*
  - Share solutions - *How have others solved the problem?*
- Modify design to make it better.
  - *How can the design be changed to make it better?*
  - *Is there an alternative design that may be a better solution?*
- Test it out again.

# Communicate Solution

- Tie solution back to the original context.
- Question: How can the neighbor fix the swing so that it swings straight?

*Based on the model I build and tested, I would suggest that the neighbor can make a y-shaped harness that connects the porch swing chains to one central point and then to the crooked branch...*

# Challenges

- Students are reluctant to redesign.
  - Is redesign always required?
  - Suggestions for encouraging redesign (e.g. “up the ante” by adding constraints)
- Knowing how to evaluate solutions
- Develop a recognition that no solution is perfect - improvements can still be made
- Scaffolding for entries; developing genuine purpose for entries
- Connection E to Science and Math
- Others?

# Engineering Design ...Some First Steps

- Become familiar with engineering design (CTS, trade books)
- Examine your existing curriculum to identify opportunities for engineering design integration
- Select a process with identifiable stages for engineering design
- Review resources ([www.mmsa.org](http://www.mmsa.org))
- Start small – do one project; focus on one aspect of the design process; etc.