Problem Solving in STEM Subjects
Engineering Design

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Problem Solving

- The key to the problem solving process –
  - Asking the right questions and answering them in the most coherent manner is at the heart of any problem solving process.
- Problem solving skills can be incorporated into all academic disciplines.

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Comparisons of Problem-Solving Methods

Engineering Design	G. Polya, How to Solve It	Scientific Inquiry
1. Identify the need or problem	Understand the problem	1. Formulate the problem
2. Research the need of problem	↓	2. Information gathering
3. Develop possible solutions	Devise a plan	3. Make hypotheses
4. Select the best possible solution	↓	4. Plan the solution
5. Construct a prototype	Carry out the plan	5. Test solutions (perform experiments)
6. Test and evaluate the solution		6. Interpret data, Draw conclusions
7. Communicate the solution	↓	7. Presentation of results
8. Redesign	Looking Back	8. Develop new hypotheses

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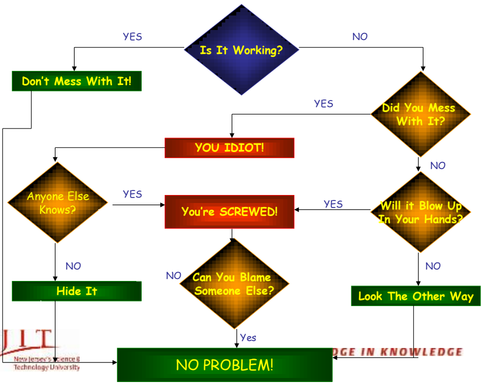
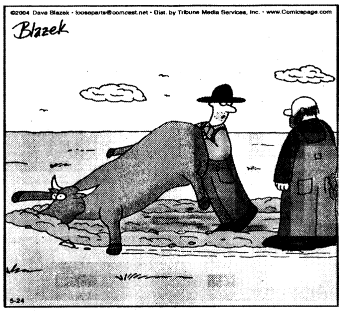
Flowchart For Problem Resolution



Loose Parts by Gilpin & Blazek



"I don't know what they're talkin' about. Gettin' me a steer ain't made plowin' no easier."

Engineering and Science

- Engineering is a mathematical and scientific endeavor that requires a good deal of reason about materials, structures, energy, etc.
- Mathematics and science help engineers analyze existing ideas and their embodiment in "things."

Engineering and Science

Engineers design and develop objects which are perceived as needed but do not occur naturally or where needed, Scientists concern themselves primarily with understanding the world and nature as it is.

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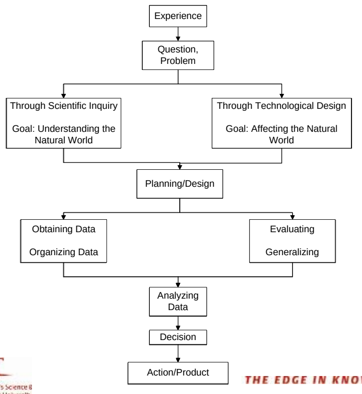

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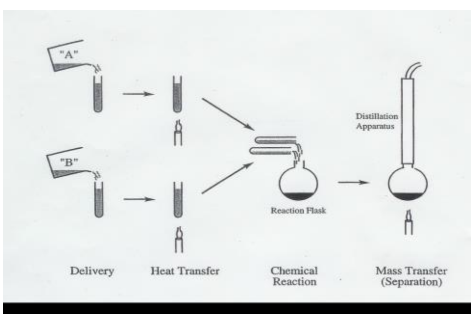
Chemist Approach to Problem Solving



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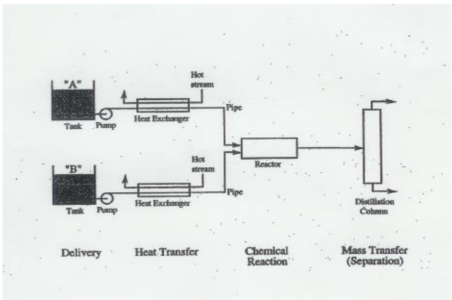
ChE Approach to Problem Solving



Next Generation Science Standards

- Content Standards - **"Conceptual Categories"**
- APPENDIX H – Understanding the Scientific Enterprise: The Nature of Science in the Next Generation Science Standards
- APPENDIX F – Science and Engineering Practices in the NGSS
- APPENDIX I – Engineering Design in the NGSS
- APPENDIX L – Connections to the Common Core State Standards for Mathematics
- APPENDIX M – Connections to the Common Core State Standards for Literacy in Science and Technical Subjects
- Appendix K – Model Course Mapping in Middle and High School for the Next Generation Science Standards

APPENDIX F – Science and Engineering Practices in the NGSS

In addition to the **"Conceptual Categories"**, NGSS includes **"Practices of Science and Engineering"**.

Use of the term "practices" is meant to emphasize that engaging in scientific investigation requires not only skill but also knowledge that is specific to each practice.

Eight Practices of Science and Engineering

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

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Engineers are basically problem solvers. It is the purpose and function of the engineer not only to design products, but to keep improving upon their design. The products of today contain many improvements over those first created by early engineers.

Engineers:

- Design things that meet the needs of people, the community, and society.
- Analyze existing objects for improvements.
- Re-think and re-engineer existing objects.

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ENGINEERING DESIGN PROCESS

Engineering design is …a collaborative process to investigate, create, plan, make, test, improve, and evaluate solutions to a problem.

- *Identification of the Problem*
- *Analysis of the Problem – Design Constraints*
- *Research the Problem – Information Gathering*
- *Brainstorm Alternative Design Solutions*
- *Modeling "Best" Solution*
- *Testing and Evaluating Model/Prototype*
- Refine and Retest Model/Prototype
- *Communicate Final Design (e.g. Presentation)*

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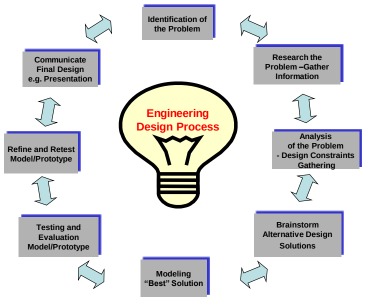
The Cyclic Design Process



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Engineering Design Process
“Defining and Understanding the Problem”

- Identify the Problem
  - What does the customer need?
  - What problem needs to be solved?
  - Not always clear
- Research the Problem – learn all you can
  - What background information is needed before we can start developing possible solutions?
  - What sources do we need to obtain that information
  - How reliable are those sources?
  - What previous work has been done on this or similar problems that could be used?

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Engineering Design Process
“Analyzing the Problem and Brainstorming”

- Design constraints
  - Technology, economic (pricing vs. market demand), human interface problems, government regulations, usability (i.e battery life)
- Develop initial specifications meeting constraints
- Discuss concept of brainstorming
- Design alternative solutions and analyze each to determine its fit within the requirements
  - Simulation vs. real product
  - Many times this is just feasibility, not final design

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Engineering Design Process
"Selecting the Best Solution"

- From previous step, determine best solution
  - Need constraints and initial specifications to determine why best solution
- Model solution, and determine if you were correct
  - Calculations, computer simulation
- Iterative step – might not have picked the best solution initially
  - Might not know this until next step

Engineering Design Process
"Testing, Evaluating, and Refining the Design"

- Develop more detailed specification and test protocol
  - Test for failure, not success
- Build prototype
  - May not be final production methodology
- Test prototype
  - Might not work (pick alternative solution) or cancel project
- Redesign and retest until satisfied
  - Need finite end
- Closer to real production product than early prototype
  - Alpha vs. beta testing

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Engineering Design Process
"Communicating the Final Design"

- Engineering Documentation
  - Requirements document, specifications document, testing documents
- Technical material
  - Schematics, blueprints, operating and technical manual
  - Service manual
- Marketing material
  - Why the product is terrific!
- Sales presentation material
  - Cost, distribution, availability

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Figure 2. Ads for Venus pencils (circa 1930) often employed engineering themes.

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Things to Consider: Product Attributes in Engineering Design

- **Power.** The amount the product produces or consumes.
- **Speed.** How fast does it operate? How long will it take to manufacture?
- **Cost.** The price to the consumer to purchase, the cost to the company to manufacture, and the cost its implementation will have on society in general.
- **Reliability.** How well does it operate? How long will it last? Is it a quality product?
- **Safety.** Are there any health risks?
- **Functionality.** Does it perform the desired tasks effectively?
- **Ease of use.** Can the customer operate it easily and intuitively?
- **Aesthetics.** Is it pleasing to see, feel, touch, or hear.
- **Ethics and social impact.** Will it benefit or harm people and the social or physical environments in which they live?
- **Maintainability.** How easily and cost-effectively can it be kept in good working order?
- **Testability.** How easily and effectively can it be tested by the manufacturer prior to volume production for the market?
- **Manufacturability.** What issues must be addressed in the manufacture of the product?

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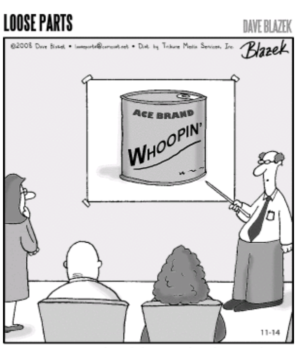
From http://www.micron.com/students/engineer/design.html



"Anyone explored the moral and societal implications of putting this in a new easy-open container?"

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More Things to Consider: Non-Product Attributes in Engineering Design

- Personal interests of the engineer
- Company interests and values
- Size of company
- Needs of the community
- Economics and marketability
- Political climate
- Familiarization with the technology

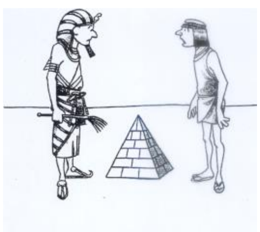
Loose Parts by Gilpin & Blazek

"I gotta believe this whole thing would go a lot better if one of us would just invent fire."

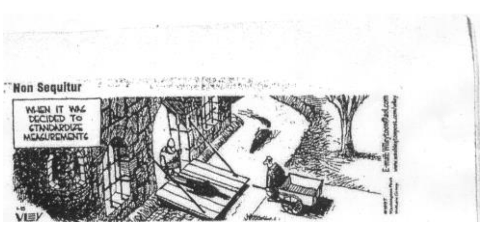
"My latest invention...It makes everything unseasonably warm."

Design Criteria

- How can failure occur?
- What design features can prevent that failure mode with introducing another one?



"We had a little problem with the decimal point."



THIS, BUD, 'S FOR YOU

Some years ago, in a popular commercial on television, a fellow smashed a beer can against his forehead. Did it hurt? Was the can closed or open, and would that make a difference? (This question requires only a theoretical answer. Do not attempt to investigate through investigative means.)

Although aluminum beverage cans must be designed primarily to withstand the internal pressure of their contents, most are designed to be strong enough (before being opened) to support a good-sized person standing on them. What would be the reasons for this design criterion?

DESIGN CHALLENGE

A large cosmetic company had a problem that some of the soap boxes coming off the production lines were empty. The problem was quickly isolated to the assembly line, which transported the packaged boxes of soap to the delivery department: some soap boxes went through the assembly line empty. The management is seeking a solution to the problem.

DESIGN CHALLENGE
Suggested solutions

1. Several engineers spent much time and money in devising an X-ray machine with high-res monitors manned by staff to watch all the boxes on the line to make sure they weren't empty.
2. A workman hearing about the problem came up with a different solution. He got a powerful industrial fan and pointed at the assembly line. As each soap box passed the fan, the empty boxes were blown off the line.

Moral: Sometimes the simplest solution is the best!

DESIGN CHALLENGE

Have students explore an everyday, well-known artifact such as a paper clip, pencil, paper cup, soda can, or other object. They can research the development of the artifact, and design an improved version of the artifact using the design process.

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Figure 1. Pencils and pencil leads made over several centuries by J. S. Staedtler demonstrate the variety of this deceptively simple implement.

Lesson: Pharmaceutical Research Design Problem

TeachEngineering

https://www.teachengineering.org/view_lesson.php?url=collection/mis_/lessons/mis_pharma/mis_pharma_lesson01.xml

Lesson Focus: Through this lesson and its associated activity, students explore the role of biomedical engineers working for pharmaceutical companies. Students participate in the research phase of the design process as it relates to improving the design of a new prescription medication. During the research phase, engineers learn about topics by reading scholarly articles written by others, and students experience this process. Students draw on their research findings to participate in discussion and draw conclusions about the impact of medications on the human body.

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Lesson: Can You Copperplate?

TryEngineering

http://tryengineering.org/lesson-plans/can-you-copperplate

Lesson Focus

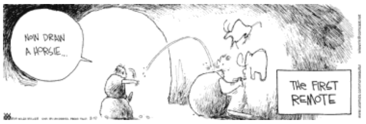
Lesson explores chemical engineering and explores how the processes of chemical plating and electroplating have impacted many industries. Students work in teams to copper plate a range of items using everyday materials. They develop a hypothesis about which materials and surface preparations will result in the best copper plate, present their plans to the class, test their process, evaluate their results and those of classmates, and share observations with their class

Re-Engineering: A Challenge

Ask students to explain how parts are related to other parts in systems.

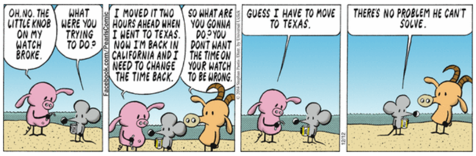
For example, a car, a household device, or a human being.

Estimate the effect of making a change in one part of a system on the system as a whole.



"I think maybe we should change our attack strategy."

NJSTA Newsletter - September 1998 page 2



There should be no problem that your students cannot solve!

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Questions

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