Engineering Design Workshop

for teachers and students

Quality Design Projects for Engineering Fairs

Sponsored by

Santa Clara Valley Science and Engineering Fair Association

Purpose

"…help teachers and students understand the engineering design process."

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Outline

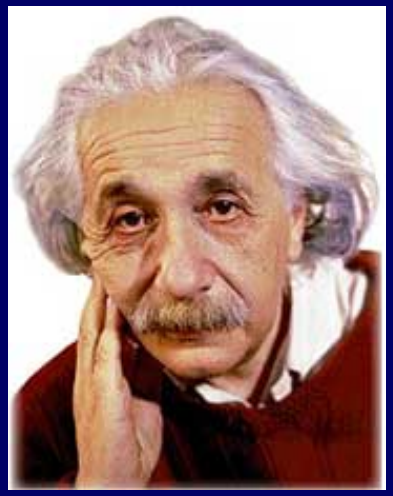
- Science Process vs. Engineering Design Process
- 7-Steps of the Engineering Design Process with Examples
- Pitfalls
- Summary

Science and Engineering Processes

Purpose and Nature

- Science is the search for knowledge and understanding
- Engineering is the application of scientific principles to satisfy human needs

They are both creative problem solving methods!



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SCIENCE & ENGINEERING

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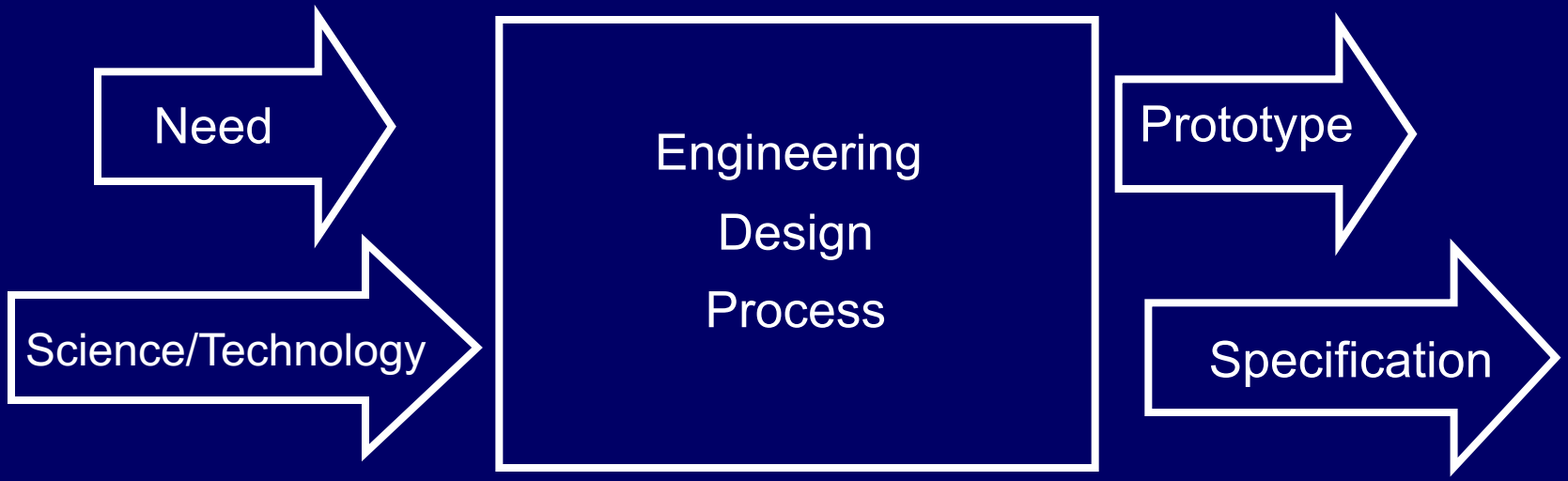
SCIENCE & ENGINEERING



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The 7 Steps to the Engineering Design Process

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Engineering Design Process

1. Define a need
2. Establish criteria and constraints
3. Research, evaluate alternatives, test plan
4. Construct a prototype
5. Test against established criteria
6. Failure analysis, tweak, and re-test
7. Final documentation

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Step #1 through #7 Record Everything in your Project Book

A complete record

All key decisions

Good drawings

Test plans

Results

Conclusions

Things learned

Step #1: DEFINE A NEED

- Have a need, a customer for the project
- Often stated as bigger (or smaller), cheaper, faster, lighter
- Engineering Goal template: *The design and construction of a* (engineering project) *for* (user) *to do* (some function).
- Project MUST have technical content

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GENERATING ENGINEERING PROJECT IDEAS

- Student interests
- Listening to other's complaints
- 'Cool' ideas or improvements
- ScienceBuddies.org 'Aptitude Test'

Helpful Links to Stimulate Project Ideas

- SCVSEFA website. Event dates and guidelines. Links to helpful sites. https://science-fair.org
- Science Buddies: https://sciencebuddies.org
- HowStuffWorks Science Channel. Good topics and research. http://science.howstuffworks.com
- Education Oriented sites:
  - https://educate.intel.com (More teacher oriented)
  - http://www.TryEngineering.org (General Engineering)
  - http://www.TryNano.org (Nanotechnology)
- Research sites:
  - https://www.asme.org (American Society of Mechanical Engineers)
  - https://www.asce.org (American Society of Civil Engineers)
  - https://www.ieee.org (Institute of Electronic and Electrical Engineers)
  - https://www.aiaa.org (American Institute of Aeronautics and Astronautics)

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ENGINEERING GOAL STATEMENT EXERCISE

The design and construction of a (project) *for* (user) *to* (function).

Project: solar powered scooter
User: children
Function: zip around the block

Technical Content:

solar energy, energy storage, motor torque, mechanical gear ratios, brake system

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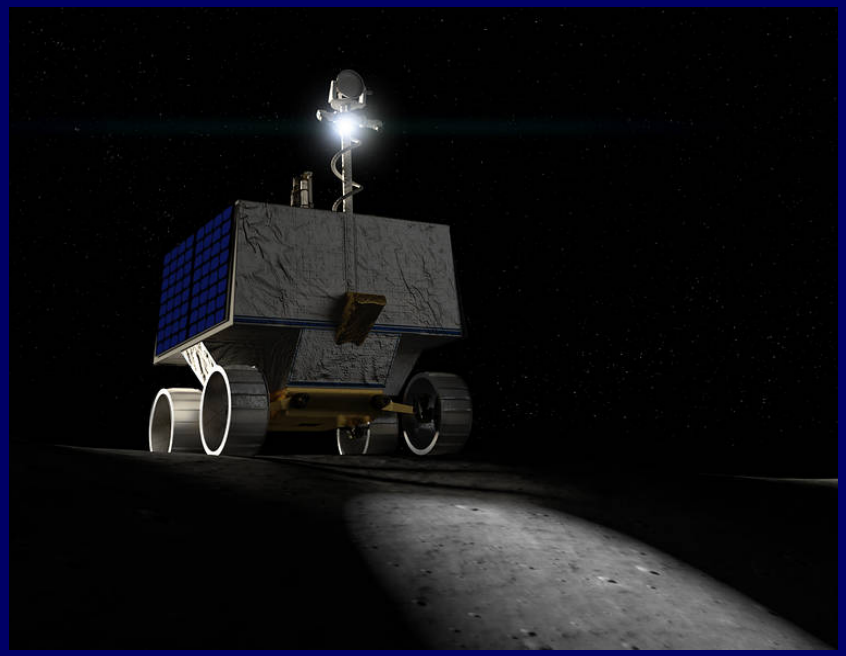
“The design and construction of a (*project*) for (*user*) to do (*function*).”

project	*user*	*function*
Hose powered hub cap cleaner	People who get cold feet	Communicate with Mandarin speakers
Electromagnetic padlock opened by a specific light sequence	English speaking tourists and businessmen	Automatically turn on when the feet cool down to a certain temperature.
BBQ temperature sensor	Homeowners	Know when their meat is cooked
Spoken English input to Mandarin text output translator	Car washers	Mow using cheap and easy lawn care
Automated lawn mower	Outdoor chefs	Lock valuables without carrying a key
Sock heater	Businessmen with a laser pointer	Clean small crevices in hub caps

Step #2: Criteria & Constraints

"Design criteria are requirements you specify for your design that will be used to make decisions about how to build the product"



VIPER Lunar Rover: Image courtesy of NASA

- Size
- Appearance
- Physical Features
- Performance
- Use Environment

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Some Design Constraints

- Cost
- Time

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Criteria & Constraints for Solar Powered Scooter

1. Transport up to 35 kg rider
2. Speed of at least 8 kph on level surfaces
3. Travels through 10 meters of shade
4. Material cost
5. Testing completed by Feb 28

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Step #3: List Alternatives

- Research reveals what has been done
- Likely to find good alternatives for cheapest, fastest, or lightest
- Create a test plan based on the design criteria from Step #2

Solar Powered Scooter Test Plan

1. Transport up to 35 kg rider

Test Plan: Transport a 35kg load

2. Speed of at least 8 kph on level surfaces

Test Plan: 100m distance should take less than 45 seconds

3.Travels through 10 meters of shade

Test Plan: Charge up battery. With 35kg rider, ride through 10m of shade

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Human Testing Considerations

The Science Fair IRB must **pre-approve** any projects using human Testing. Rules are here: https://societyforscience.org/isef/international-rules/human-participants

Fill out and attach the Human Participant Research Plan to your engineering template application: https://science-fair.org/wp/wp-content/uploads/2015/10/Research-Plan-Human-Participants.docx

Unless your project qualifies as Exempt….

Exempt Studies

- Exempt Studies do not require IRB pre-approval. They include:
  - A Student designed invention that does not pose a safety risk that is being tested only by the student.
    - Still advise filling out Risk Form 3: http://science-fair.org/wp/wp-content/uploads/2013/10/form3-2014.pdf
  - Data/Record analysis studies for pre-existing publicly available datasets.
  - Behavioral observations in unrestricted public settings.

Online application Process

Instructions are here:

https://science-fair.org/rules-and-registration/application-form-instructions

There is series of required forms to prepare:

https://science-fair.org/rules-and-registration/required-forms

For engineering projects, fill out:

https://science-fair.org/wp/wp-content/uploads/2017/09/2018-Engineering-Project-Word.doc

Template contains the topics we've discussed:

- Engineering Goal Statement
- Design criteria and constraints
- Project design including construction diagrams, electrical circuit diagrams and software flow charts
- Basic test plan for the design criteria
- Bibliography

When you have completed your forms, upload them to your Forms folder.

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Minimum Quality Requirements

- Common application problems:
  - Lack of measurable criteria
    - ‘fast’ instead of ‘…velocity > 12km/hr…’
    - ‘too heavy’ instead of ‘…mass of < 44kg…’
    - ‘high accuracy’ instead of ‘…< 17 errors per 1000 samples…’
  - Inadequate bibliography
  - Plagiarized experiments… go beyond what you find online

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Step #4: Construct Prototype

- Prototype is implementation of chosen design alternative
- It is a proof of design, production and suitability

Step #5: Test it Well

- Execute the developed Test Plan
- Learn beyond minimum requirements! Characterize the limits of your project.

Solar Powered Scooter Testing

1. Transport 35 kg rider. *Exceeds Test Plan:* Maximum mass transported
2. Speed. *Exceeds Test Plan:* Measure and plot speed vs. rider mass.
3. Travels through shade. *Exceeds Test Plan:* Measure and plot distance in shade travel vs. rider mass.

- *Extra Knowledge:* solar energy, storing energy, electric motor torque, gears

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Step #6: Failure Analysis and Tweak/Redesign Iterations

- Evaluate the test results. Do they satisfy design criteria?
- If not, can you tweak the process as opposed to a complete redesign?
- In reality, “Fail early, fail often!”
- This is the longest step….

Failure Analysis and Tweak/Redesign Examples

- Solar scooter cannot move 35kg ….
- Get a higher torque motor, increase gear ratio, reduce scooter weight
- Scooter speed only reaches 5kph…
- Get a motor with higher RPM, increase the wheel diameter, reduce scooter weight

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Step #7: Complete the Project Book (Started at project definition)

A complete record

All key decisions

Good drawings

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Results

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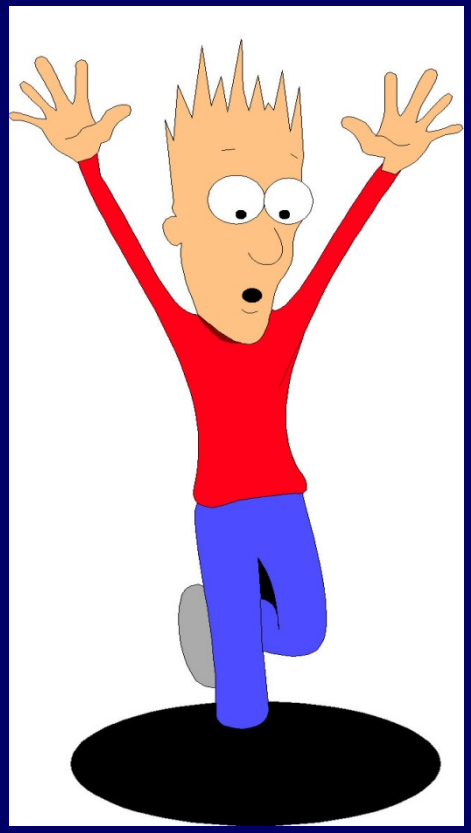
Avoid These Pitfalls



No need, no end product

Been done!

Analysis as a product

Ah ha!, gadgetry, kits

Testing without asking the user

Demonstrations (see next…)

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Demonstration projects revolve around

'How ____ works.'

A common demonstration is the Magnetic Levitated Train.

If faced with this….

determine the interest

- If magnetic fields: induced electrical currents, earth's magnetic field, …
- If transportation: safety equipment improvements (helmets, seat belts…)

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Summary

Design Features

1. Meets a need, has a “customer”
2. Design criteria and constraints
3. Evaluate alternatives and generate test plan
4. Build prototype
5. Test/evaluate against test plans
6. Analyze, “tweak” (☺), redesign (☹), retest
7. Project book: record, analyses, decisions, specs

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Best of Luck

Engineering is exciting!

Use creative problem solving!

Ignite your students' passion!

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