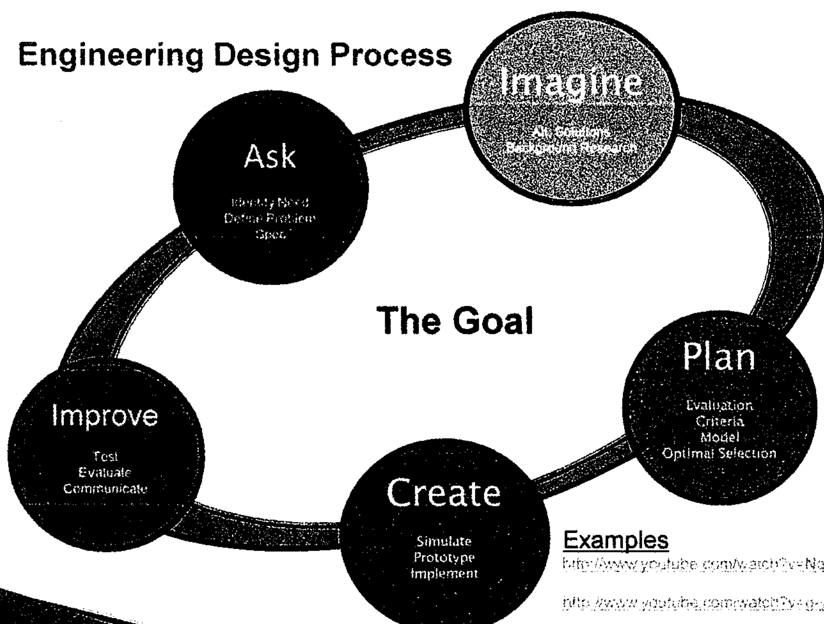
# ENGINEERING DESIGN PROCESS REVIEW

- Problem Definition
- Background Research
- Specifications
- Develop Solutions
- Evaluate for optimal solution with Pugh Chart (Evaluation Matrix)
- Gantt Chart
- Modeling and Prototyping
- Test Plan

## Engineering Design Process

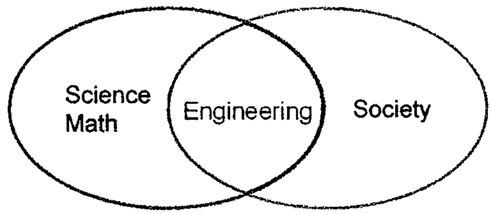



Examples

http://www.youtube.com/watch?v=k6qTwqiHnAM

## ASK: Identify the need. / What's the problem?!

- Remember that engineers are around to solve people's problems by meeting their needs




- Identify a need by thinking about what could make your & others' lives better
  - An easy, safe, and economic way to light your house when it is dark
  - To be able to feed your pet twice a day at specific times even if you can't be at home
  - A faster, cheaper, and reliable delivery service
  - A cheap and better binder for middle school students that won't destroy papers

## ASK: Why is there a need? Why is it a problem? Defining the problem

- We came up with some problem that needs fixing
  - This preliminarily answers the questions of "what is wrong?"
- To understand the root of the problem, we ask "why does the problem exist?"
  - If we don't know why it is a problem then we may only solve some of its symptoms
  - We need to get to the root of the problem to come up with the best solution
- Now that we understand the real problem we can define a problem statement
  - Clear and concise description of the client's need/problem.
  - Does not necessarily include the form of the solution.
  - Leave some room for creativity and innovation!

## ASK: Why is there a need? Why is it a problem? Defining the problem

- **Identify the need. What is wrong?**
  Middle school students think that it would be really great if they had cheap binders that wouldn't destroy or lose their papers.
- **Why are their binders destroying their papers?**
  The binder rings become offset and their papers get caught on the gap.
- **Why are their binder rings becoming offset?**
  Pulling the rings instead of using the tabs causes the rings to become offset.
- **Why are they pulling the rings instead of using the tabs?**
  It is faster and easier to pull the rings than use the tabs
- **Clear and concise description of the client's need/problem.**
  **Problem Statement:** Middle school students are losing and ripping their papers a gap forms between the binders rings due to incorrect operation of the binder. They do not use the tabs to open the binder because they are difficult/inconvenient. The students need a cost-effective way to store and retrieve their papers safely.

## ASK: Specifications

- **List of preliminary goals that will be used to verify the solution meets the needs**
- **Clearly defines the client's needs and expectations for the design**
  - Necessary
    - Needed to satisfy the client's needs and expectations
    - Design constraints
  - Traceable
    - Justify the specification (why are we requiring this ) back to the client's need
  - Verifiable
    - Inspection: measures by the senses
    - Analysis: mathematical or scientific models/principles, or simulations
    - Test: conduct experiment
    - Demonstration: situational operation
  - Implementation-free
    - State what is needed but keep it flexible to allow for a variety of innovative solutions
    - Quantifiable design constraints can include numerical values with tolerances

# Ask: Specifications

**Problem Statement:** Middle school students are losing and ripping their papers by opening their binders incorrectly because the tabs are difficult/inconvenient to open. They need a cost-effective way to store and retrieve their papers safely.

| Specification | Weight | Justification |
|---|---|---|
| Cost Effective<br>> $3 more per student | 5 | Students do not have a lot of money to spend on binders. Cost should be no more than $3 more than the current cost of binders. |
| Durability<br>Survive a school year's worth of use | 5 | Students do not have a lot of money to spend on replacing their binders so the solution should make the binder last for a whole school year. |
| Must fit a 2 inch binder | 5 | The standard school binder is 2 inch. |
| Look should be appealing<br>>70% of student find it appealing | 3 | Students are more likely to use something that is aesthetically appealing. |
| Fast production time<br>> 2 days | 2 | It would be better to be able to get quickly in case the school runs out unexpectedly. |
| Easy to use<br>Less effort to open than tabs | 4 | The main problem stems from inconvenience so the solution should be easy to use. |
| Material must be safe | 5 | Student safety is very important. |

# Imagine: Background Research

- Ask questions
- Find out what exists and what works and what doesn't
  - Gap-free and single release binders do exist but cost too much
- Collect data and information
  - Survey the importance of looks and ease of use
- Look for patterns and similarities with other problems or solutions
  - Levers make things to easier to open. Can we use a lever here?
- Decompose the problem into smaller, more manageable pieces
  - We could focus on the ring gap, the incovenient tabs, or correct the way students open their binders
- Figure out what fields of knowledge that you need to learn more about
  - We need to learn more about the physics of levers
  - Find resources that can help with that (such as tutorials, books, papers, experts)
- Figure out the kinds of materials, tools and equipment that you might need

# Imagine: Develop Solutions

- Eliminate the need
  - Can we do anything to eliminate the need?
  - Teach students the correct way to open the binder and why it benefits them
- Challenge the basic assumptions
  - Instead of trying to improve on existing solutions approach it from a totally new angle
  - Binder rings meet head-on what if we had them meet side-side
- Employ analogies
  - Compare to other solutions in nature or things that already exist
  - Nuts and bolts are an example of existing fastener tech. that closely tightly without gaps

# Imagine: Develop Solutions

- Personalize the problem
  - Gain insight by putting yourself into the problem situation
- Reverse the problem
  - Try to design a solution opposite of what you need to gain insight into identifying important parameters
  - If we made the tabs really tiny it would be even more difficult to open
- Repeat components or process steps
  - Add more because often two is better than one
  - What if we make the tab length longer or increased the number of rings?
- Combine or Separate functions
  - Can we somehow change the existing design so that the rings function also includes opening the binder?

# Imagine: Brainstorming Solutions

- **Minimal Solution**
  - Create a sticker and a campaign to teach students how to open a binder correctly
  - If opened correctly, binder rings will not offset and papers will not fall out or get ripped in the gap
  - Sticker can be placed inside the binder so students are reminded each time they open it
  - Campaign will inform students about the benefits of opening their binder correctly
    Ex. No more losing papers, No more ripped paper, Save money, etc.
- **Optimal Solution**
  - Create an add on sleeve for the binder rings
  - Sleeve will sit permanently on one side of the ring and the other side will slide into when closed
  - Even if they open incorrectly and a gap forms, the sleeve will cover it so papers will not fall out or get ripped
  - Sleeves can be made cheaply and quickly
- **Extravagant Solution**
  - Create a lever add on for the binder tabs
  - Extra leverage will make the binder easier to open
  - Lever will need to fold open and closed to stay out of the way of the papers
  - Lever must be made of material strong enough to withstand the force needed to open the binder

# Plan: Pugh Chart/Evaluation Matrix

- Compares possible solutions based on how well they meet the specifications (evaluation criteria)
- Weights are scaled by importance (highest = most important) and help to give more importance to certain specifications
- Scores are also usually scaled (highest = best)
- If no weighting involved score with -1 (worst) , 0 (neutral), 1 (best)

| Specifications | Weight | Solution A | | Solution B | | Solution C | |
|---|---|---|---|---|---|---|---|
| | | Score | Weighted Score | Score | Weighted Score | Score | Weighted Score |
| Spec 1 | $W_1$ | 5 | $W_1$ x 5 | 3 | $W_1$ x 3 | 2 | $W_1$ x 2 |
| Spec 2 | $W_2$ | 3 | $W_2$ x 3 | 4 | $W_2$ x 4 | 5 | $W_2$ x5 |
| Spec 3 | $W_3$ | 1 | $W_3$ x 1 | 5 | $W_3$ x 5 | 5 | $W_3$ x 5 |
| | Total | | | | | | |

Scale of 1 – 5 (best)

Scale of 1 – 5 (best)

## Evaluate Solutions: Pugh Chart/Evaluation Matrix

| Specifications | Weight | Solution A "teach them!" | | Solution B "sleeves" | | Solution C "folding levers" | |
|---|---|---|---|---|---|---|---|
| | | Score | Weighted Score | Score | Weighted Score | Score | Weighted Score |
| **Cost Effective** **> $3 more per student** | 5 | 5 | 25 | 3 | 15 | 1 | 5 |
| **Durability** **Survive a school year's worth of use** | 5 | 5 | 25 | 3 | 12 | 5 | 25 |
| **Must fit a 2 inch binder** | 5 | 5 | 25 | 5 | 20 | 5 | 25 |
| **Look should be appealing** **>70% of student sample group rates as appealing** | 3 | 4 | 12 | 1 | 3 | 3 | 9 |
| **Fast production time** **> 2 days** | 2 | 5 | 10 | 4 | 8 | 2 | 4 |
| **Easy to use** **Less effort to open than tabs** | 4 | 1 | 4 | 4 | 16 | 5 | 20 |
| **Material and mechanisms must be safe** | 5 | 5 | 25 | 5 | 25 | 4 | 20 |
| | **Total** | **30/35** | **126/145** | **26/35** | **99/145** | **25/30** | **108/145** |

## Plan: Gantt Chart

- A bar chart that graphically represents what needs to be done when and who will do it for the entire project
- Identify the tasks
- Assemble the teams of engineers
- Assign the identified tasks to each team or individual
- Order of Tasks (dependencies)
  - Parallel
  - Upon completion
- Gantt Project (open source software)
  - http://www.ganttproject.biz/
- Gantt Project Tutorial Videos
  - https://www.youtube.com/watch?v=OX-Iz3DxSdw
  - http://www.teachertube.com/viewVideo.php?video_id=10418

# Plan: Gantt Chart

Relationships between tasks

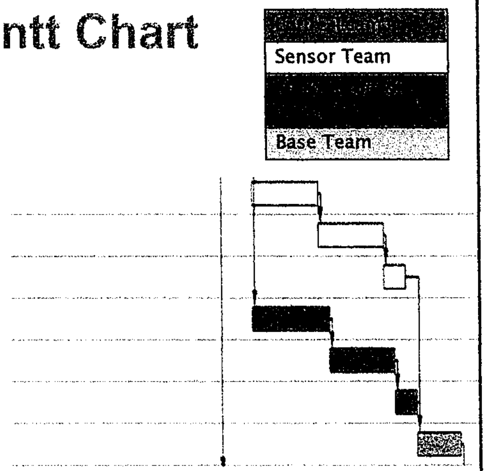
- Start – Start (SS)
  - Task cannot start until the dependent task is starting
  - Tasks must start at the same time and will run parallel to each other
- Finish – Start (FS)
  - Task cannot start until the dependent task is completed
  - Task must start only after the other is done and will not run parallel
- Finish – Finish (FF)
  - Task cannot finish before the dependent task is completed
  - Tasks will run in parallel until one of them finishes (may or may not finish at same time)
- Start – Finish (SF)
  - Task cannot end before the dependent task starts but may end later (not often used)

# Robotic Cat Toy Example

- **Identify the teams**
  - Motor Control Group (MG)
  - Sensor Group (SG)
- Identify the tasks, how long they will take, and responsible party
  1. Order sensors – 5 days- SG
  2. Order motors – 8 days - MG
  3. Develop sensor circuit – 7 days - SG
  4. Develop motor control circuit – 7 days - MG
  5. Test sensor circuit – 2 days - SG
  6. Test motors – 2 days - MG
  7. Combine motor and sensor circuits – 5 days – SG/MG
- Identify relationships between tasks
  - Finish-Start
  - 3-1, 5-3, 4-2, 6-4, 7-5&6

# Plan: Gantt Chart

| | | |
|---|---|---|
| Order and ship sensor parts | 11/21/13 | 11/26/13 |
| Sensor circuity | 11/27/13 | 12/2/13 |
| Sensor testing | 12/3/13 | 12/4/13 |
| Order and ship motor parts | 11/21/13 | 11/27/13 |
| Motor control circuitry | 11/25/13 | 12/3/13 |
| Motor testing | 12/4/13 | 12/5/13 |
| Connecting sensor and motor circuitry | 12/6/13 | 12/9/13 |

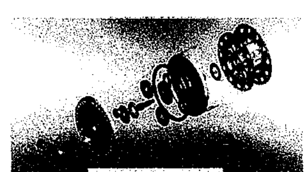



Shows the interdependencies between tasks and responsible groups

# Create: Modeling

www.ansys.com

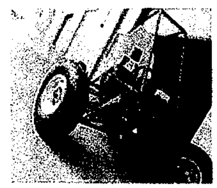
- Models are typically used when it is
  - Impossible or impractical to create experimental conditions to directly measure
  - More cost effective to model before prototyping
- Models are representations of concepts (with graphics and/or physics)
- Simulations are the implementation of a model
- Types of modelling:
  - Mathematical
  - CAD (computer aided design)
- Ex. Lever for the binder
  - Different designs can be drawn in solidworks
  - Simulated to show that it can withstand the correct forces and will work before we actually spend money to build one (prototype)

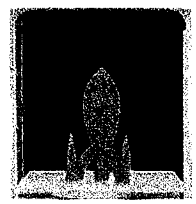


www.solidworks.com

## Create: Prototyping

- Prototypes are products built to test a concept or a process and verify that the performance meets the specifications
- Usually created in iterations as they are tested and redesigned to meet specs
  - Proof of concept – test that the concept works as intended without all final looks, materials, etc. implemented
  - Form – test the ergonomics and user interface
  - Visual – evaluate the design aesthetic (may not function)
  - Functional – closest to the final product design
- Usually involves some kind of fabrication
  - Breadboards and/or soldering for circuit prototypes
  - CNC machining or metal/wood/plastic work
  - Rapid prototyping using 3D printers
- Ex. Visual prototype for the binder sticker can be the paper printed on online posted graphics that can be tested for its educational effectiveness without the adhesive functionality





www.cubify.com

## Improve: Test Plan

- Test the model or prototype to verify that specifications are met though :
  - Inspection: measures by the senses
  - Analysis: mathematical or scientific models/principles, or simulations
  - Test: conduct experiment
  - Demonstration: situational operation
- Test plans should include :
  - Test coverage – what specification are we verifying for which stages of the product' s life
  - Test method – how will we implementing the test
    - Procedure or steps to implementing the test
    - List of materials and equipment need for the test
    - The pass and fail criteria of the test
  - Validity of the test – justification that the test is truly verifying the what we want it to