ME 213 S2023:
Introduction to Engineering Design

Lecture 03:
Concept Generation Techniques
Outline

1. Where We Are
2. What is an Engineering Concept?
3. Alternating Modes of Thought
4. Ideation Best Practices
5. Brainstorming 101
6. Morphological Analysis
7. Design Heuristics
8. General Rules of Thumb
9. Presenting Your Idea
1. Where We Are

We Are Here

- Define the Problem
- Do Background Research
- Specify Requirements
- Brainstorm, Evaluate, and Choose Solution
- Develop and Prototype Solution
- Test Solution
- Based on results and data, make design changes, prototype, test again, and review new data.
- Solution Meets Requirements
- Solution Meets Requirements Partially or Not at All
- Communicate Results
2. What is an Engineering Concept?

• A sketch of a full or partial solution to a design problem.

• As we are mechanical engineers, our engineering concepts focus on potential forms of physical products.

• Includes few details on dimensions, components, materials etc.

• Includes just enough information to get across an idea and allow for its assessment of functionality and feasibility.
3. Alternating Modes of Thought

Divergent Thinking: Create Choices
Convergent Thinking: Make Choices
3. Alternating Modes of Thought

Keep these Separate!

Concept Generation

Concept Selection

DIVERGE

CREATE CHOICES

CONVERGE

MAKE CHOICES
4. Ideation Best Practices

1. Generate **multiple** and **diverse** ideas.
4. Ideation Best Practices

Key Questions to Answer:

How many ideas Are enough?

What does diverse mean?

How can you tell if the ideas are diverse?
4. Ideation Best Practices

1. Generate multiple and diverse ideas.
2. Don’t evaluate.

This is one of the hardest things to do.
You will have plenty of time to evaluate later.
4. Ideation Best Practices

1. Generate multiple and diverse ideas.
2. Don’t evaluate.
3. Think alone first.

Studies show that independent thought and preparation before group ideation produces more successful outcomes.
4. Ideation Best Practices

1. Generate multiple and diverse ideas.
2. Don’t evaluate.
3. Think alone first.
4. Avoid fixation.

What is fixation?

- Premature commitment to your first idea or an existing idea
- Barriers to new solutions based on real and perceived constraints
4. Ideation Best Practices

Idea Scarcity vs. Idea Fluency

<table>
<thead>
<tr>
<th>What Beginning Designers Do</th>
<th>What Informed Designers Do</th>
</tr>
</thead>
<tbody>
<tr>
<td>Work with few or just one idea, which they can get fixated or stuck on, and may not want to change or discard.</td>
<td>Practice idea fluency in order to work with lots of ideas by doing divergent thinking, brainstorming, etc.</td>
</tr>
</tbody>
</table>

Crismond & Adams, 2012
4. Ideation Best Practices

Fixation With Existing Solution
4. Ideation Best Practices

1. Generate multiple and diverse ideas.
2. Don’t evaluate.
3. Think alone first.
4. Avoid fixation.
5. Make the goal clear.

- Write a goal statement.
- When you or your team gets off-track, you can refocus.
4. Ideation Best Practices

Making the Goal Clear

• Project requirements guide your concept generation goal statement

• Remember: Some constraints are flexible; others are not

Requirements and physical laws create the bounds of your solution space
4. Ideation Best Practices

1. Generate multiple and diverse ideas
2. Don’t evaluate
3. Think alone first.
4. Avoid fixation
5. Make the goal clear
6. Use idea generation strategies

- Brainstorming
- Brainwriting
- SCAMPER
- Design Heuristics
- Synectics
- TRIZ

- Morphological Analysis
- Analogical Thinking
- Lateral Thinking
- IDEO Method Cards
- Whack Pack
4. Ideation Best Practices

1. Generate multiple and diverse ideas.
2. Don’t evaluate.
3. Think alone first.
4. Avoid fixation.
5. Make the goal clear.
6. Use Idea generation strategies.

Do all of these things to set yourself up for success!
5. Brainstorming 101

1. Postpone all judgment
2. Encourage wild ideas
3. Quantity over quality
4. Build on each other’s ideas
5. Every person and every idea has equal value

Challenges

1. Dominating personalities dominate
2. Quiet members don’t get heard
3. “Group process loss”
4. Failure to implement brainstorming “rules” including individual preparation results in poor outcomes
5. Brainstorming 101

More Techniques:

- **Analogy**
  How are similar problems solved in other fields? Are there biological or electrical analogs?

- **Inversion**
  Look at known solutions to similar design problems and work backward from the solution to the “inputs”.

- **Property & Constraint Adjustments**
  Look at known solutions to similar design problems and assume the extremes of select properties (e.g. zero, infinity). What if physical, economic, or other design constraints could be relaxed or removed?

- **Simplification**
  Delete as many complications in the problem as possible; reduce it to its “essence”.

More Techniques:

- Brainstorming 101
6. Morphological Analysis

<table>
<thead>
<tr>
<th>Parameter a</th>
<th>Parameter b</th>
<th>Means f</th>
<th>Means g</th>
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<tbody>
<tr>
<td>Parameter b</td>
<td>Parameter c</td>
<td>Means h</td>
<td>Means i</td>
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<td>Parameter a</td>
<td>Parameter c</td>
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<td>Means k</td>
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<td>Parameter d</td>
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<td>Means l</td>
<td>Means m</td>
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<tr>
<td>Parameter d</td>
<td></td>
<td>Means p</td>
<td>Means q</td>
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**Step 1**
Identify all parameters (functions and attributes)

**Step 2**
Make each parameter a row in a matrix

**Step 3**
Identify all possible means to implement each parameter, and list in columns

**Step 4**
Create solutions by combining different means
6. Morphological Analysis

<table>
<thead>
<tr>
<th>Contain beverage</th>
<th>cube</th>
<th>sphere</th>
<th>bag</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanism to Access juice</td>
<td>straw</td>
<td>lid</td>
<td>Sippy cup</td>
</tr>
<tr>
<td>Contain beverage</td>
<td>Bright colors</td>
<td>Makes sounds</td>
<td>Slender middle</td>
</tr>
<tr>
<td>Easy to hold</td>
<td>Rubber grip</td>
<td>handle</td>
<td>Slender middle</td>
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6. Morphological Analysis

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<thead>
<tr>
<th>Functional Requirements</th>
<th>Design Embodyments</th>
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<tbody>
<tr>
<td><strong>SLIDE SWIFTLY</strong></td>
<td>WD40</td>
</tr>
<tr>
<td><strong>STEER</strong></td>
<td>Steering Wheel</td>
</tr>
<tr>
<td><strong>SAFETY SURROUNDING</strong></td>
<td>Safety Helmet</td>
</tr>
<tr>
<td><strong>SKIS</strong></td>
<td>Snowboard</td>
</tr>
<tr>
<td><strong>REINS</strong></td>
<td>Botchhee Balls</td>
</tr>
<tr>
<td><strong>RAIN JACKET</strong></td>
<td>Car</td>
</tr>
<tr>
<td><strong>HOME</strong></td>
<td></td>
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**MORPHOLOGICAL ANALYSIS MATRIX**

- The sled
- Sphere/Globe
- Water proof material
- Butter stick
7. Design Heuristics

Cognitive Heuristics
Reasoning processes that do not guarantee the best solution, but often lead to potential solutions by providing a short-cut.

Design Heuristics
Concept modifiers that quickly lead to a potential solution, providing the opportunity for a novel design to occur.
DESIGN TASK
Design products that utilize sunlight for heating and cooking food.

CONVERT 2-D MATERIAL TO 3-D OBJECT

TWIST

METAL SHEET TWISTED INTO A SPIRAL

CONVERT FOR SECOND FUNCTION

MIMIC NATURAL MECHANISMS

UTILIZE OPPOSITE SURFACE

FOLD

FLAT REFLECTIVE SHEET

TELESCOPE

ADJUSTABLE LEGS

BEND

SHEET BENDS INTO PARABOLIC REFLECTOR

USE REPURPOSED OR RECYCLED MATERIALS

REPEAT

SMALL PIECES OF RECYCLED GLASS MIRROR TO MAKE PARABOLA

OPENS LIKE A FLOWER TO CAPTURE SUNLIGHT

SOLAR PANELS

MIRRORS

Daly, Yilmaz, Seifert, Christian, Gonzalez
7. Design Heuristics

Examples

Fold AND Make Multifunctional - this satellite includes solar cells that unfold to power on board devices and increase stability.

Slide - Triboelectric Generator produces electricity from friction when two plastics or metals rub against each other.
7. Design Heuristics

Examples

Information Display

Card #76
Utilize Opposite Surface

Card #7
Align components around center
8. General Rules of Thumb

• **More is Better**
  Go *beyond* what is asked in the individual assignment!

• **Seek Inspiration, not Duplication**
  Use benchmarks, analogous objects, and your own experience.

• **Make Freehand Sketches**
  The goal is to have just enough detail for you to show and remember your idea.

• **Partial Solutions are OK**
  You can combine multiple ideas into your final solution later.

• **Don’t Judge!... That Comes Later**
  Don’t let your brain instantly start shooting down ideas before you even write them down.
9. Presenting Your Idea

What NOT to do...

Clamp and Cut

Circular knife track
In this design, two cases holding battery and circuit board are connected using a hinge in the middle. Each case is a metal enclosure with one end (which is connected to hinge) open. A hasp [11] is used to lock the two cases together. Polymer seals can be added in the middle also to prevent water entering into the entire enclosure.