



College of Engineering

GE106: Introduction to Engineering Design

Creativity and Creativity in Engineering Design

By

Matthew Amao

Outline



- **What is Creativity?**
- **Creativity as a Process**
- **Characteristics of Creative People**
- **Creativity in Engineering**
- **Characteristics of Creative Engineers**
- **Teams and Creativity**
- **Creative Methods in Engineering**
- **Engineering Creativity and Constraints**
- **Creativity Stimulation Techniques**
- **Idea Selection**
- **Final Thoughts**

Before We Start

“The best way to have a good idea is to have **a lot of ideas.**”

Linus Pauling (Nobel Laureate)



“Nothing is more dangerous than an idea when it is the **only one** you have.”

Emile Chartier (French Philosopher)

The bottom line is you need ideas, no matter how you look at it, either from artistic or scientific perspectives.

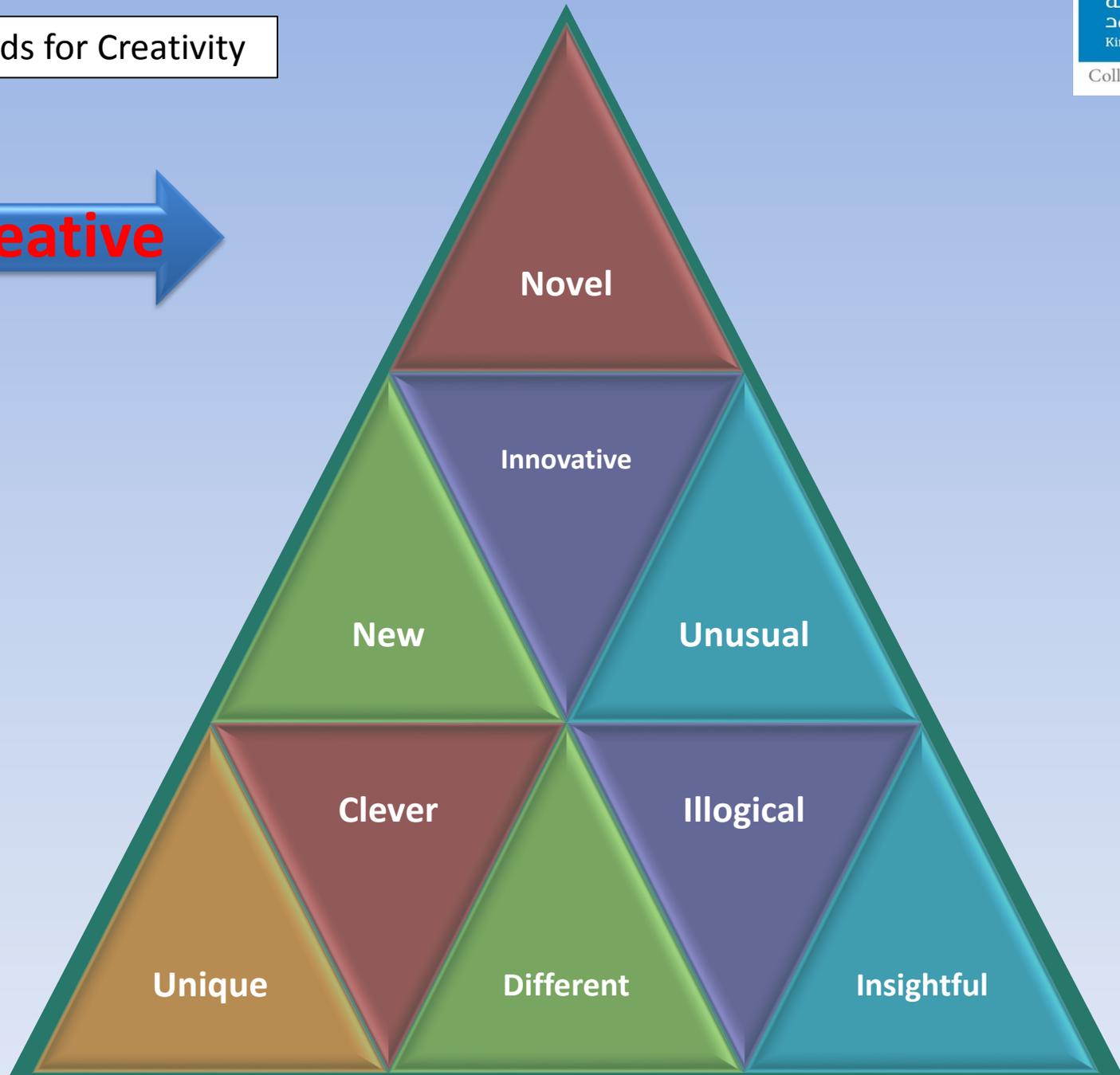
Creativity

- A mental process involving the generation of new ideas or concepts, or new relations between existing ideas or concepts.
- It is both: an art and a science.
- It is doing things in a “non-normal” way.



Other Words for Creativity

Creative



What is Creativity?



Creativity in Individuals

A Function of Resources, Motivation, & Creative Thinking

Creative Thinking Skills

– your capacity to think outside the box and put existing ideas together in a new combination



Resources

– your knowledge, expertise, and access to relevant information

CREATIVITY

Internal Motivation

– motivation from within; your need or passion to be creative

Creativity

Innovation

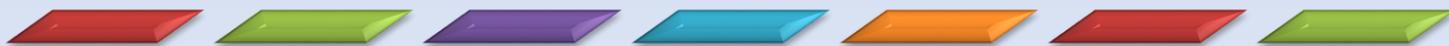
Invention

Creativity is the capability or act of conceiving something original or unusual.

Innovation is the implementation of something new.

Invention is the creation of something that has never been made before and is recognized as the product of some unique insight.

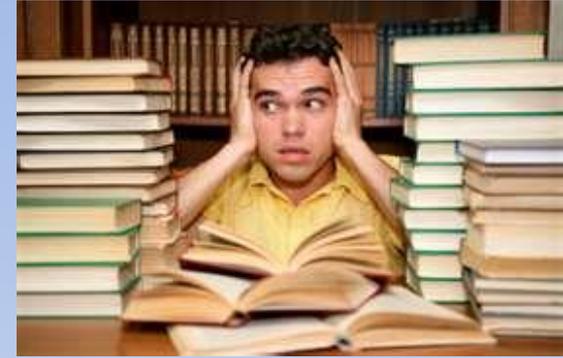
Creativity is a skill; innovation is a process



Creativity (Cont'd)

- **Advantages of being creative**
 - + generally able to cope
 - + develop new understanding
 - + become more adaptable
 - + able to survive

- ***Disadvantages of being creative***
 - + thought to be a societal (group) misfit
 - + often treated as being strange
 - + often misunderstood
 - + expression can often be suppressed

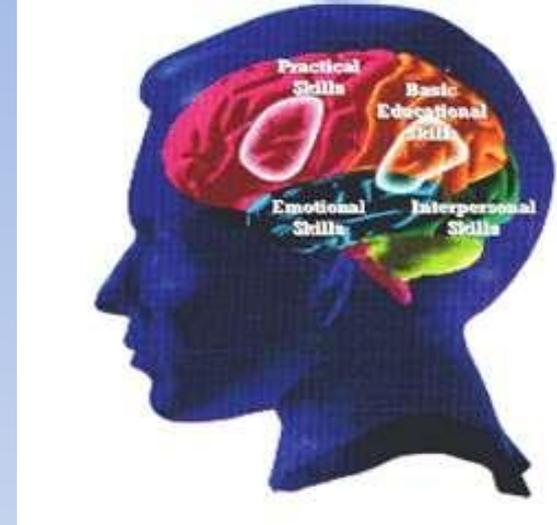


Coping



Creativity (Cont'd)

- **Humor is an indicator of creativity**
 - + Intersection of several planes of experience
 - + Thoughts jump from one context to another
 - + Related to intelligence
- **Sources of creativity**
 - + a new look at an old problem
 - + asking questions that are difficult to answer
 - + preparing for the unexpected
 - + “thinking outside the box”



Intelligence Centers



Outside the Box Thinking

To be creative* you need to be able to view things from different perspectives; you must have flexibility and a tolerance of ambiguity!

Mental locks



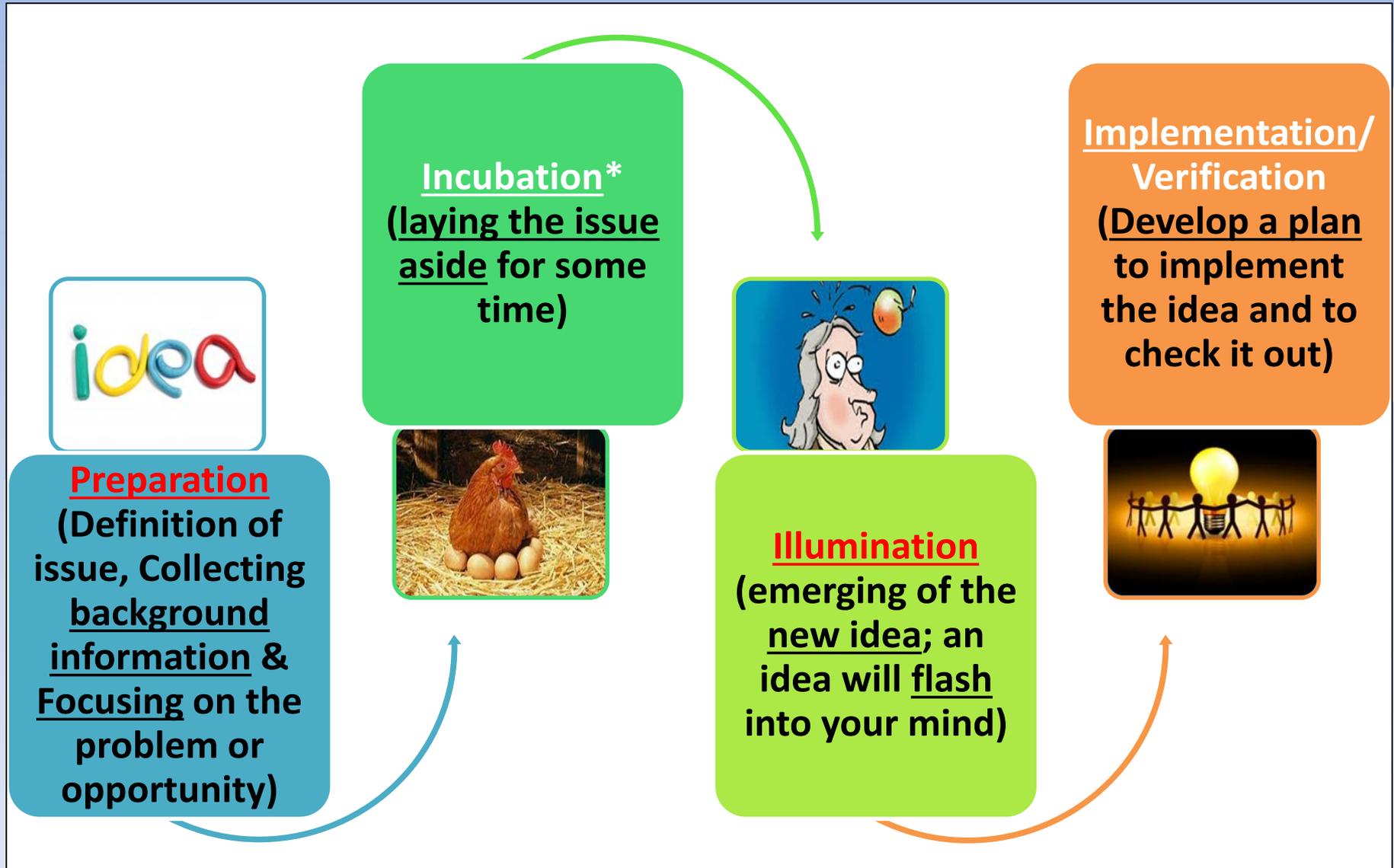
- There is one right answer
- That is not logical
- Follow the rules
- That is not my area
- Don't be foolish
- To err is wrong
- I am not creative
- Premature Judgment

Mental Unlocks



- Think Laterally
- Don't impose assumptions
- Work when your mind is fresh
- Work fast and short periods
- Focus
- Push hard
- Have fun
- No fear

Creativity as a Process



Creative People

- **Are flexible**
 - variety of approaches
- **Are able to visualize**
 - not limited to just words and symbols
- **Are curious and humorous**
 - continually ask questions and express emotions through humor
- **Are comfortable with complexity**
 - not easily overwhelmed (affect someone's emotions in very powerful way)



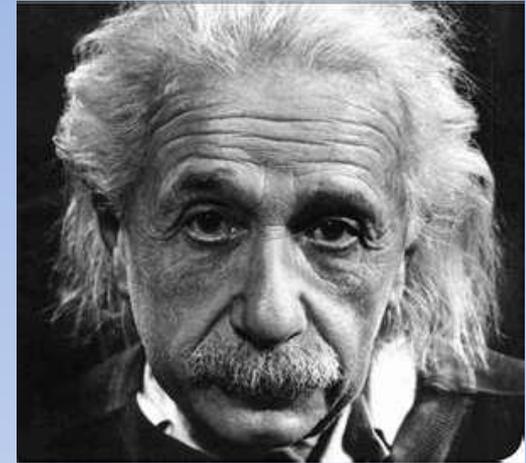
Creative People

- **Are aware**
 - Aware of the important aspects around them
- **Can conceptualize and recall**
 - Interested in concepts rather than details
- **Have discipline and self-confidence**
 - self-motivated and unwavering
(strong and steady despite opposition)
- **Are adaptable and resilient**
 - undaunted **(determined and not afraid to continue)** by defeat

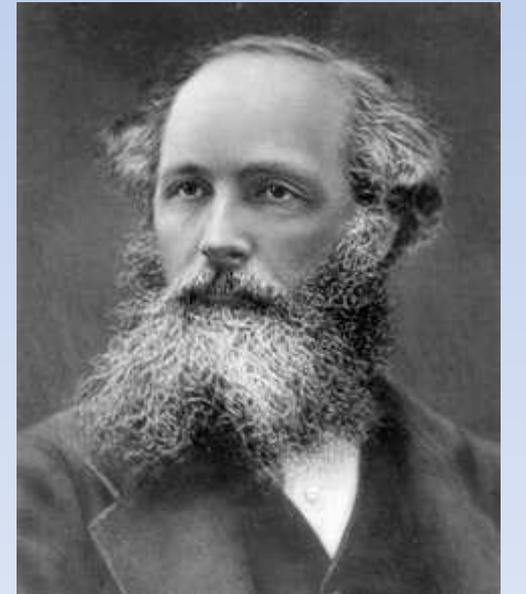


Creative People

- **Have mental agility** (able to move quickly and easily)
 - can fantasize and are intellectually playful
- **Are skeptical** (having doubts about something that other people think is true or right) of accepted ideas
 - less conservative than the average
- **Are informal** (relaxed and friendly)
 - are able to work anywhere
- **Achieve fulfillment**
 - recognition and honor/not driven by money



Albert Einstein



James Clerk Maxwell

Characteristics of Creative People

Achiever

Flexible

Motivated

Humorous

Persistent

Confident

Independent



Knowledgeable

Energetic

Skeptical

Adaptable

Open-minded

Dreamer

Tolerant

Some Thoughts on Creativity

Creativity must be experienced, to be understood

Hints to becoming more creative:

- Hangout with creative people
- Practice mental drawing*
- Keep a journal**
- Keep an open mind
- Maintain a positive attitude
- Try new things
- “Think Outside the Box”
- Practice creativity-enhancing exercises
- Stay alert for opportunities



Creativity and Engineering

- The professional life of engineers is devoted to the creative solution of problems.
- Technology is the result of **creativity with a purpose**, or engineering design*.

- Sending someone to the moon and to bringing him back to earth in 1968 required a number of technologies created by Engineers.



Creative Engineers* Have:

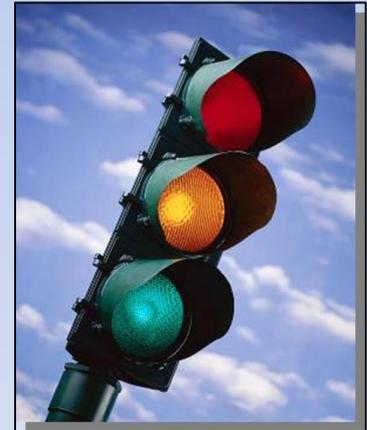
- Curiosity and tolerance of unknown
- Openness to new experiences
- Willingness to take risks
- Ability to observe details and see the “whole picture”
- No fear of problems
- Ability to concentrate and focus on the problem until it is solved.



What someone once said:

- This 'telephone' has too many shortcomings to be seriously considered as a means of communication. The device is inherently of no value to us. (Western Union internal memo, 1876)

- I think there is a world market for maybe five computers. (Thomas Watson*, 1943)
- 640K [memory] ought to be enough for anybody (Bill Gates, 1981)**



* Thomas John Watson Sr. (February 17, 1874 – June 19, 1956) was an American businessman. He served as the chairman and CEO of International Business Machines (IBM)

** Here a link describing more about this statement by Bill Gates: <https://www.computerworld.com/article/2534312/operating-systems/the--640k--quote-won-t-go-away---but-did-gates-really-say-it-.html>

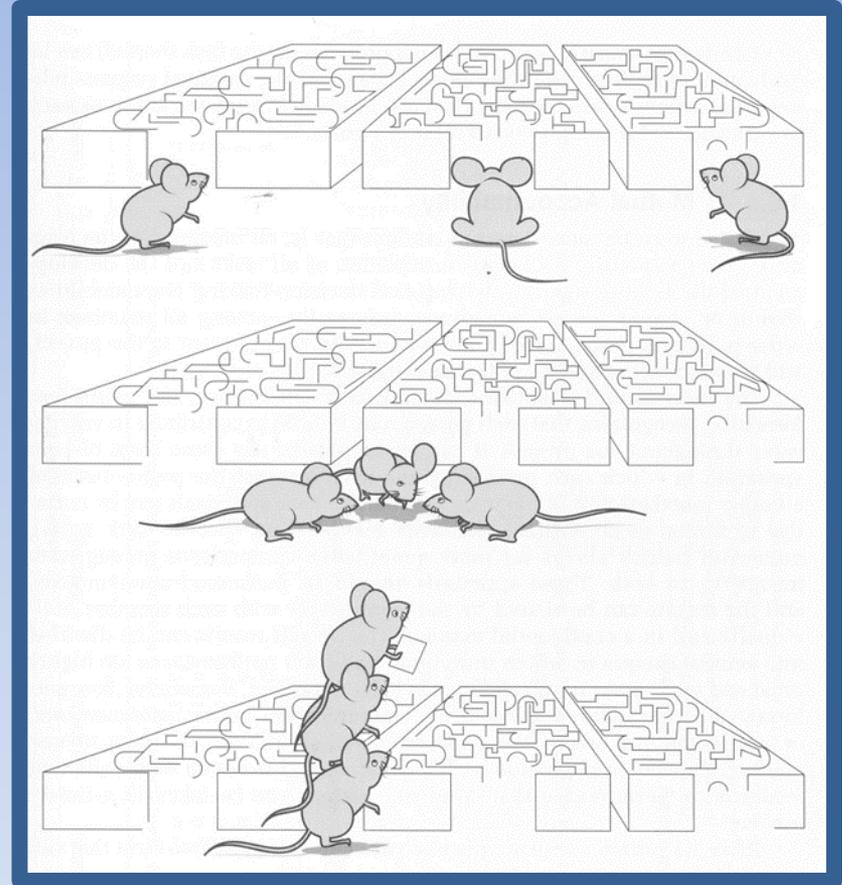
What you should hear:

- Great spirits have always encountered violent opposition from mediocre minds.- *Albert Einstein*
- The person who says it cannot be done should not interrupt the person doing it.- *Chinese Proverb*
- Every really new idea looks crazy at first.
- *Alfred North Whitehead**



Teams and Creativity

- Teams combine* the different backgrounds, experiences and thinking preferences of individuals
- Interaction among team members – other's ideas are used as stepping-stones to more creative ideas
- Willingness on the part of a team to take greater risks



By working in a well structured team you can combine differing backgrounds and experiences resulting in a much greater resource. You can also combine different thinking preferences to end up with a “whole brain.”

There are numerous methods that can be used to promote interaction among team members (i.e. brainstorming).

Engineering Creative Methods

- **Evolution**: Incremental improvement; *Every problem that has been solved can be solved again in a better way.*
- **Synthesis**: Two or more existing ideas are combined into a third, new idea.
- **Revolution**: Completely different, new idea.
- **Reapplication**: Look at something old, in a new way.
- **Changing Direction**: Attention is shifted from one angle of a problem to another.

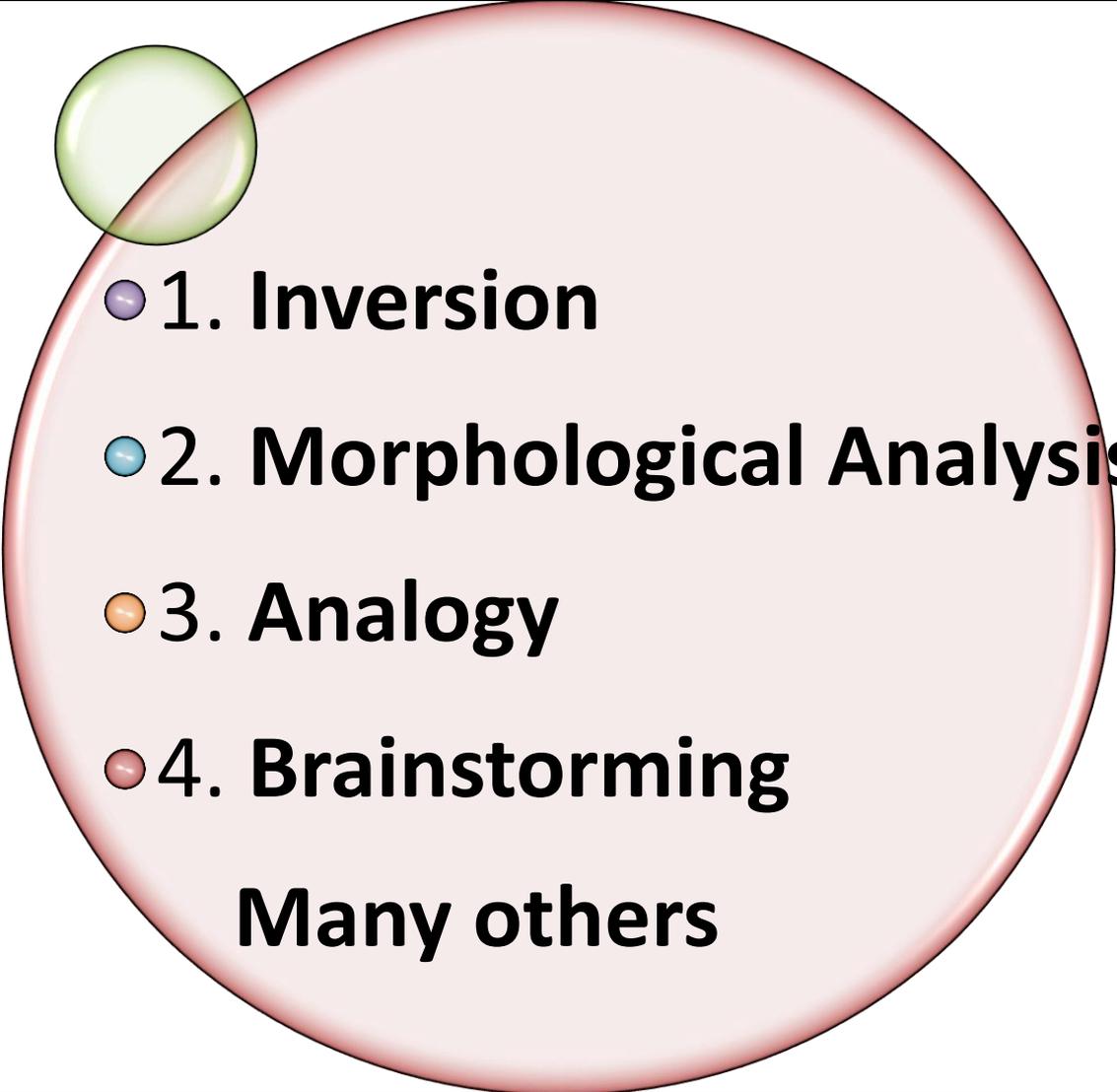
Introduction to Creative Thinking, Robert Harris. Version Date: July 1, 1998

Engineering Creativity and Constraints

- In engineering, creativity is useful only if it fits into the realities* of the physical world
 - A creative idea in engineering must conform to the established physical laws.
 - A creative idea in engineering must conform to our present knowledge of the nature of matter, unless we invent or find a new form of matter.
- Creativity in engineering is constrained by feasibility and practicality.



Creativity Stimulation* Techniques

- 
- 1. **Inversion**
 - 2. **Morphological Analysis**
 - 3. **Analogy**
 - 4. **Brainstorming**

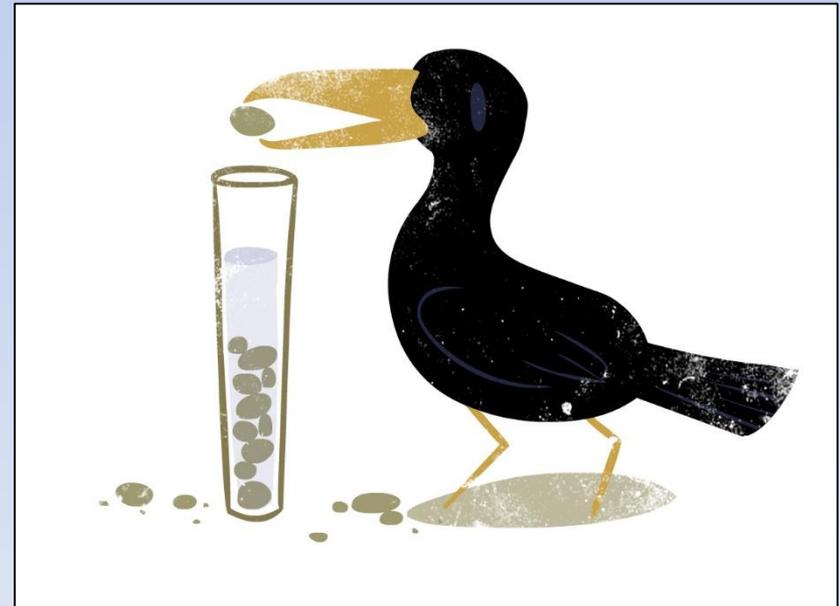
Many others

Creativity Techniques: Inversion

- Inverting the problem to view it from a different angle
- If you would like to save energy, explore wasting energy and see how that can give you tools to solve the “how to save energy” problem.

- The crow example: Water too low in the jug. Instead of trying to explore how to go to the water, explore how the water can get to the crow.

Solution; put stones!



Creativity Techniques: Morphological Analysis

- The **problem** is divided into smaller **sub-problems**. Its basic forms or units (individual functional units of the problem). This is also called functional decomposition.
- Concepts are then generated to satisfy each smaller sub-problem or functional unit.

1. List the functions and features required (each of the sub-problems)
2. Identify as many ways (i.e. solution concepts) as possible to satisfy each feature or function. (*Concepts are alternative solutions for each sub-problem*)
3. Draw a table with features/functions listed vertically and concepts listed horizontally.
4. Identify all practical combinations, these will form the solution concepts (design concepts).

Morphological Analysis

Organizing Functions/Key Features and Means to Generate Designs that Work

- Morphological Analysis - **Important Alternative Development tool**
 - Chart or Matrix
 - **Functions** or Key Features are listed in the **first column**
 - Alternate **Means (solutions)** of achieving each function are given **in that function's row**
 - Generating the Means for each function **can be a highly creative process**
 - **Means do not have to be words** – some designers use **sketches or thumbnails** to show some alternative means

Morphological Analysis ...

- The Morphological Analysis **can be used to generate Complete Alternatives**
 - Leftmost column lists **ALL functions/key features**.
 - **Selecting a means from EACH row guarantees that the solution satisfies all required functionality.**
- **Will NOT, however, guarantee that**
 - Alternatives will **WORK**
 - Or even be **internally consistent**
 - Judgement is still required
- This approach can result in a **HUGE number of alternatives.**

Morphological Analysis – Example 1

- Design a means of transportation for disabled persons.

Feature	Possible Concepts
Body Support	<u>armchair</u> , under arm , leg support, hanging basket, sofa
Ground Support	<u>wheels</u> , air cushion , caterpillar, tracks, rollers, castors, skids
Structure	space frame , plate, <u>flat platform</u>
Power Supply	<u>Battery</u> , compressed air, human , spring, fly wheel, solar, nuclear
Propulsion	jet, <u>wheel</u> , propeller
Speed Control	automatic , <u>manual</u> , on-off
Direction Control	<u>Steering</u> , one side lock , reverse , side thrust
Stability	automatic balance , wheel base, <u>low c.g.</u>

Morphological Analysis (Example)

Design a means of transportation for disabled persons*

Feature	Concept 1	Concept 2	Concept 3	Concept 4
Body Support	armchair	under arm	leg support	sofa
Ground Support	rollers**	tracks	wheels**	skids
Power Supply	Battery	solar	human	air
Speed Control	automatic	manual	on-off	-
Direction Control	side thrust	one side lock	reverse	steering

Design 1: Armchair + Rollers + Solar + Automatic + Side-thrust

Design 2: Armchair + Wheels + Human + Manual + Steering***

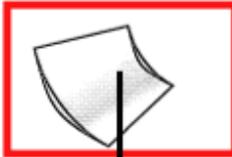
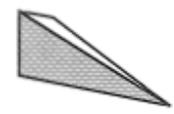
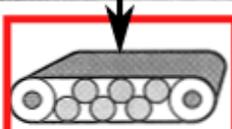
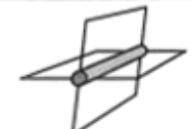
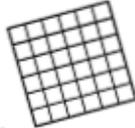
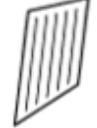
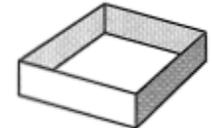
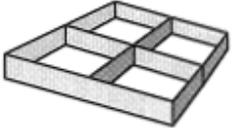
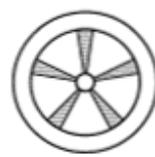
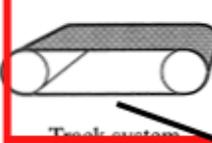
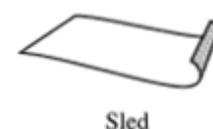
* This is the Problem Statement.

** **Rollers** move only back and forth, while **Wheels** move in all directions

***These are called design scenarios (or just scenarios)

Morphological Analysis- Example 2

Design a device for picking, packaging, and transporting vegetables.

	Option 1	Option 2	Option 3	Option 4
Vegetable picking device		 Triangular plow	 Tubular grabber	 Mechanical picker
Vegetable placing device	 Conveyor belt	 Rake	 Rotating mover	 Force from vegetable accumulation
Dirt sifting device	 Square mesh	 Water from well	 Slits in plow or carrier	
Packaging device			 Bowl	
Method of transportation		 Track system	 Sled	
Power source	Hand pushed	Horse drawn	Wind blown	Pedal driven

↓
Concept 1

Morphological Analysis – Example 3

Design of a beverage container.

- Morphological Chart/Matrix showing **one means for each function** which can be **combined to form one complete alternative** that **looks feasible**

MEANS FEATURE/ FUNCTION	1	2	3	4	5	6
Contain Beverage	Can	Bottle	Bag		Box
Material for Drink Container	Aluminum	Plastic	Glass	Waxed Cardboard	Lined Cardboard	Mylar Films
Mechanism to Provide Access to Juice	Pull Tab	Inserted Straw	Twist Top	Tear Corner	Unfold Container	Zipper
Display of Product Information	Shape of Container	Labels	Color of Material
Sequence Manufacture of Juice, Container	Concurrent	Serial

Steps for Morphological Brain-storming

Seeds for Morphological Brain-storming

Functionality;

Operational Method;

Power Source (Gasoline, Diesel, Electrical (battery), Electrical (mains), Chemical);

Components;

Areas of Use;

Capacity (by function, units of capacity, range of function, by performance indicators)

Material (Steel, Iron, Wood, Plastic, Ceramics, Nano-material, Fibers);

Styling and Finishing;

Systems Included;

Method of Transportation (if applicable).

Variations Generation

- For each seed generated, provide various design options.

Remaining Steps

Remaining Process

- Create a grid (matrix) of all the possibilities.
- **Begin eliminating impossible combinations.**
- Then eliminate un-reasonable combinations.
- **Eliminate useless combinations.**
- Then eliminate expensive combinations.
- **What is left should give you a number of design features and alternatives.**
- Morph these designs. This is done by creating a combination of these working features with one another to produce, say, three or more concepts.
- **Weight and Rate these various concepts using good criteria to reach an optimal design!**

During Eliminations, Remember:

- Some ideas are crazy and un-applicable for various reasons.
- **Some combinations are a must.**
- Some combinations are impossible.
- **Some ideas are expensive.**
- **Some ideas are just not available for implementation at this day and age.**

Morphological Analysis (cont'd)

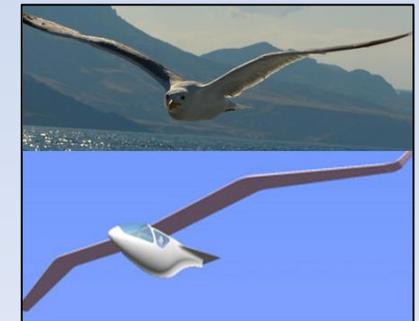
- This approach is *very powerful*
- It generates “so many” combinations of possible solution concepts.
- Many obviously will not make sense and can be quickly eliminated.
- However, you often find a new idea by looking at the possible combinations* of concept pieces.
- Remember, this is an iterative process, you may have to go back to the beginning until you find the right solution.

Creativity Techniques : Analogy

- **Personal analogy** (imagine yourself in the situation, e.g., if designing a product, imagine yourself as the product itself or one of its functions)
- **Direct analogy*** (copy ideas from nature, wild life) (*Biomimicry*)



<https://youtu.be/iMtXqTmfta0>



Creativity Techniques: Brainstorming*

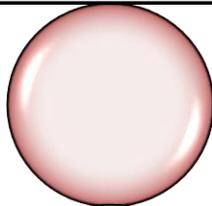
Rules (within a comfortable/friendly environment):

- Define the problem to be solved
- No criticism allowed during the session
- Large quantity of ideas wanted (quantity over quality)
- Crazy ideas are welcome
- Keep ideas short and snappy
- Combine and improve on others' ideas “laterally” (new categories) and “vertically” (new ideas in categories)

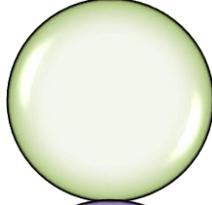


Idea Selection

- Creative sessions lead to many ideas, how do you select the best one?
- Do some clustering first (merge similar ideas under one heading).
- Then, apply one or more of the following options:



1. Questions Options Criteria (QOC)



2. Voting



3. SWOT Analysis

Idea Selection: Questions Options Criteria (QOC)

- Determine important criteria beforehand
- Judge each option (idea) based on the criteria
- Criteria may have a different weighting!

	Criteria 1	Criteria 2	Criteria 3
Option 1			
Option 2			
Option 3			
Option 4			

Idea Selection: Voting

- Members are given a fixed number of colored stickers (virtual money)
- Voting for good ideas (criteria) is by putting a sticker next to it
- For very good ideas, multiple stickers can be put
- This could be used to reduce the list of alternative ideas



Idea Selection: SWOT Analysis

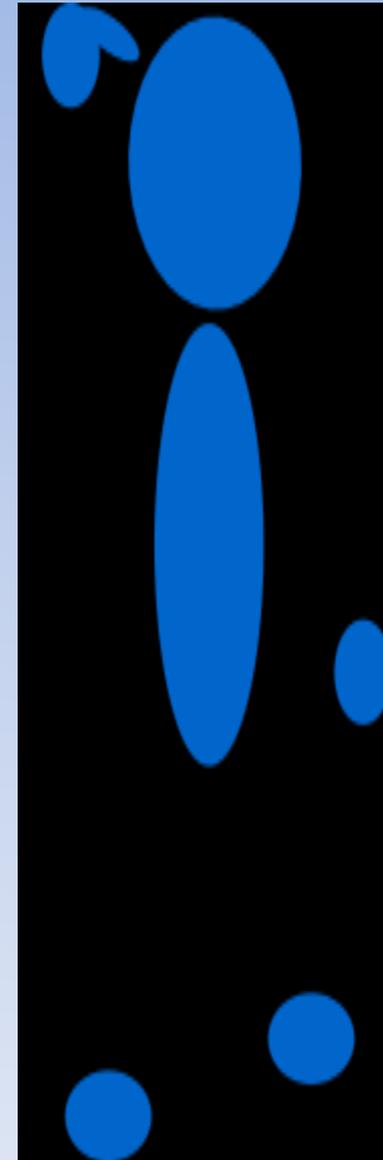
Strengths Weaknesses Opportunities Threats

- Often used to analyze business but can also be used to select ideas.
- Specify each of these for each idea
- Can be applied to a reduced list of ideas.
- Better suited to modify/improve existing designs.



Final Thoughts

- For every good **idea**, expect to have tens of bad or wrong or useless ideas.
- You don't have to be a **mathematical** genius. But you should be competent in mathematics.
- Evaluate and improve the extent of your hands-on and **laboratory** skills.
- **Visualize** how the work could be accomplished (spreadsheets, flowcharts, drawing).
- **Imagination** is also crucial. Begin at the science fiction level, then apply the constraints gradually.
- Keep a design **notebook (log book)**.*





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