

Applied Mechanical Design

Fostering creativity

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Inspired by
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Conceptual Design Phase

- Consists in finding a viable and promising concept
- Idea is to fill morphological matrix with several working principles for each function
- A working principle represents physical effect and its embodiment
- Find maximum number of working principles by creativity, searches and analysis of known systems → Ideation tools

- It is all about guided idea generation
- Techniques provide systematic framework for generating ideas
- Systematic procedures force designers to explore alternatives
- Implementation of structure and experience build confidence in success of results

- “Ideation” is generation of ideas
- “Creativity” is ability to generate new ideas and concepts that are useful
- “Innovation” is application of creative output



<http://uncideation.tumblr.com/>

- Can creativity be enhanced?
 - Yes, through practice
 - Yes, through tools

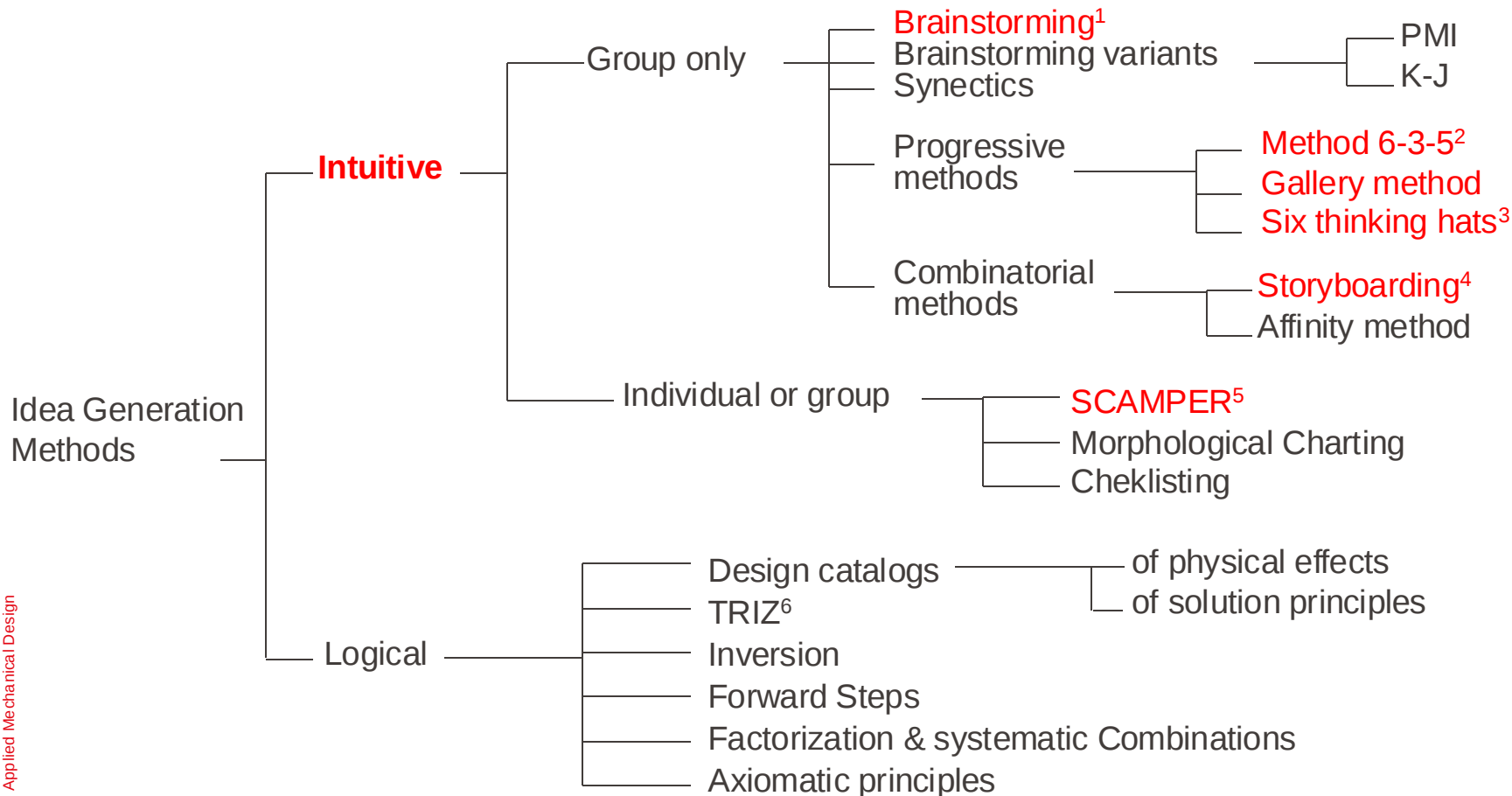
- Surrounding and mindset affect creativity
 - Environment
 - Concentration
 - Attitude
 - Independence of thought



<https://designschool.canva.com/blog/creative-learning/>

What we know about creativity

- Everyone, regardless of age, gender, education, possesses creative potential
- Creative performance is influenced by attitude, emotion, environment
- Some factors may present barriers that block creativity
- Creative ability can be taught, developed, and generally enhanced and encouraged



- Systematic, group-oriented technique for producing large number of ideas
- Rules & guidelines
 - No critique or judgment
 - Wild ideas are encouraged
 - Modifying, combining, and improving upon the ideas of others is promoted
- Quantity as opposed to quality of ideas is emphasized

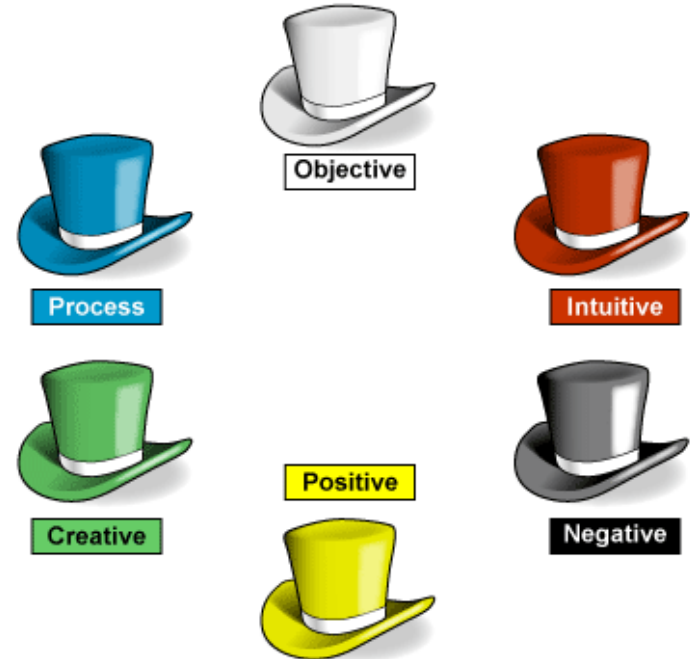
■ Methodology

- Identify ideation task
- Form group of six
- Each participant writes down three solution keywords
- Sheet with keywords are passed to neighbor, who records three further solutions or developments
- Ideas are passed a total of five times
- Often used after brainstorming session
- Clocking and rigid ruling might inhibit creativity

- Methodology
 - Identify ideation task
 - Form group
 - Individuals sketch solutions
 - Group reviews all sketches exposed in a gallery
 - Individuals further develop and refine ideas
 - Group finalizes ideas and selects promising ones
 - Extension to other methodologies
 - Requires significant amount of time
 - Graphical, ordered and iterative brainstorming

Six Thinking Hats³

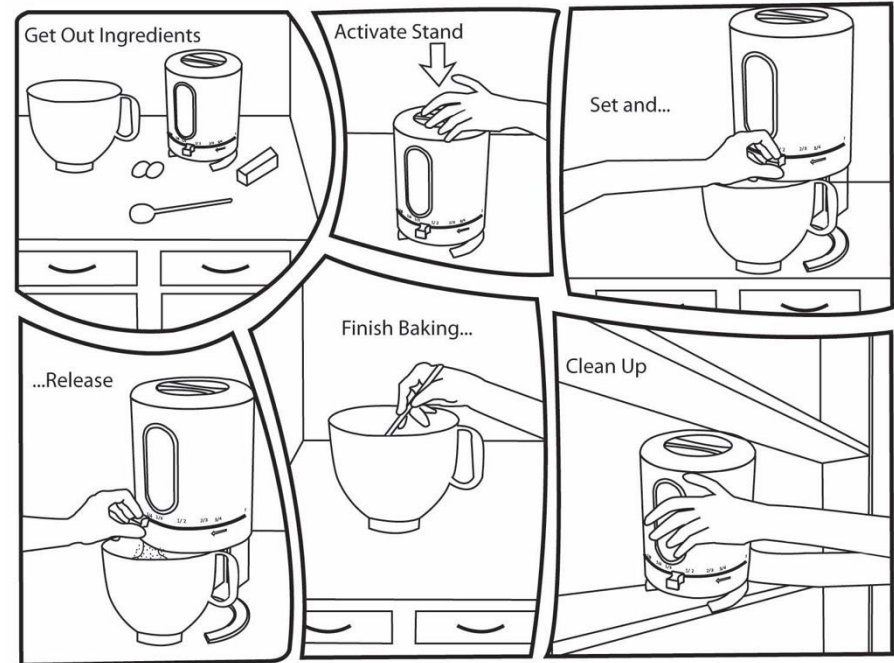
- Discussion in group with given roles
- All aspects / views of a problem are taken into account
- Efficient discourse on complex problem
- Role play may suppress individual creativity



Six Thinking Hats³

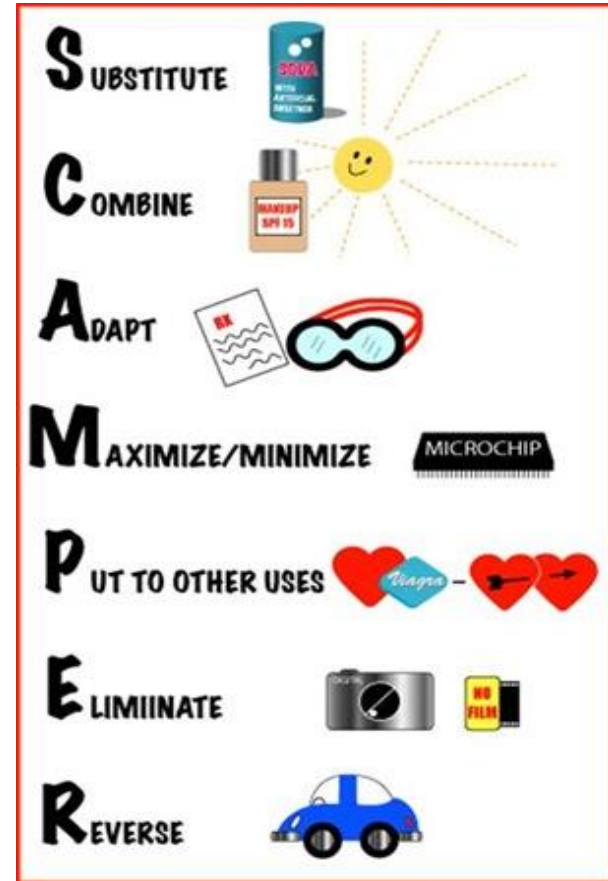
- White: Analytical thinking. Focus on facts, available information and data base. Objective assessment. Pursue constructive approaches and solutions
- Red: Intuition and emotional thinking. Focus on feelings and personal opinions. Little need for logic and rational justifications
- Black: Critical thinking, judgment, caution, constructive skepticism. Strictly logical, pointing out why a proposal does not fit the facts, experience or conditions; what could go wrong; what is the worst-case scenario, etc.
- Yellow: Optimistic thinking. Envisaging of what could be achieved; positive speculation about the best-case scenario, benefits, value-creation, etc.
- Green: Creative, associative thinking. Introducing novel and provocative ideas; creative, constructive, alternative and unorthodox approaches
- Blue: Keeps process overview, puts ideas into order, moderates discussion

- Extensively used in film industry
- Popularized by W. Disney
- Used in defense and aerospace industry
- Suited for identifying use cases of product
- May be used to identify hidden specifications
- Documentation is part of creative process



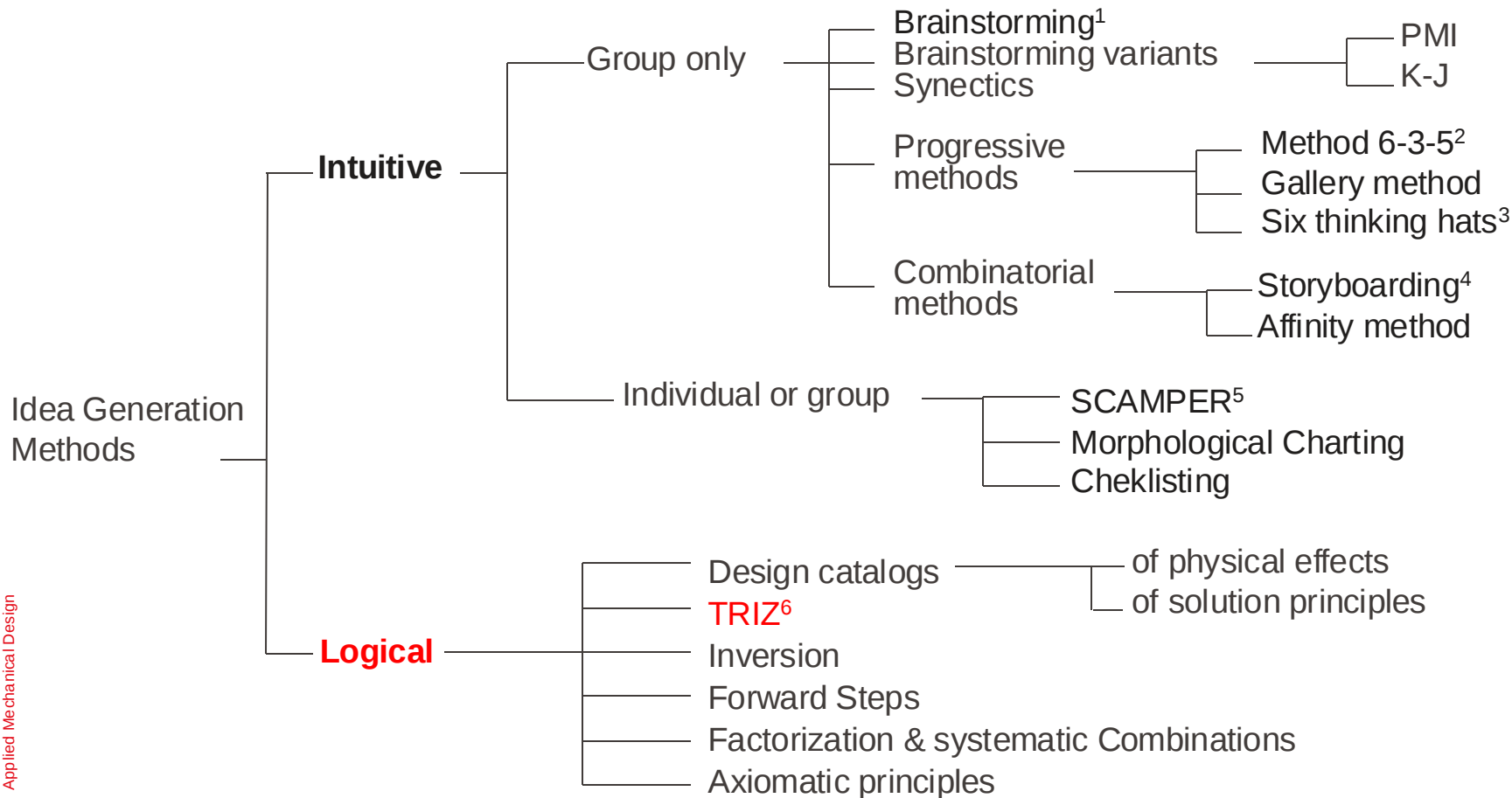
<http://web.mit.edu/2.009/www/resources/illustrator/crash-course/storyboard.html>

- Collection of useful techniques to unblock creative thinking
- Helps in shifting perspective
- A collection of successful creativity tools
- No systematics to cover full solution space

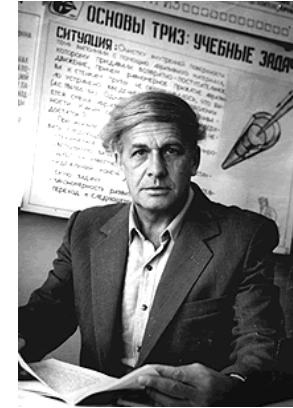


- Substitute
 - Components or sub-systems, objects/process/problem with others. Materials, people, time, use environment...
- Combine
 - Combine parts, by mixing functionality, materials, features, components, services to create synergies
- Adapt
 - Change functions, use parts of other component, vary characteristics and use, exchange sub-systems, vary haptics, adapt acoustics, exchange colors...

- Maximize / minimize
 - Change size, distort geometrical aspects, exaggerate properties or features of objects / processes / services / problems...
- Put to other use
 - Find other uses of current solution, identify different relationships with intended users or markets, to whom could your solution / product / process also of value...
- Eliminate
 - Remove parts from current solution, reduce functionality to the minimum, simplify use...
- Reverse
 - Turn problem upside-down, move it inside-out, find contrary uses, inverse sequences...



- Theory of inventive problem solving
- Introduced by G. Altshuller
- Objective is algorithmic approach to invention



Researchgate.net

- Research produced following findings
 - Problems and their solutions are repeated across industries and science
 - Patterns of technological evolution are repeated across industries and science
 - Most innovations are transpositions of known solutions into other fields
 - Same solutions often overcome similar dilemma or contradiction
- Analysis of patterns therefore lead to systematic innovation processes
 - 40 principles of invention

40 principles of invention

page A - 40 principles of invention in TRIZ method, sketches rendered into vector graphics

01) DIVISION a) ship built, removable/replaceable bulkheads b) multi-engine aircraft, multi-piston engine of internal combustion c) multi-blade centrifuge razor d) multi-lane aircraft, airflows of aircraft, or wind power plants e) multi-grip jokers f) a bladed piece of paper sheets	08) ANTI-WEIGHT (balance preserving) a) wind turbines, windmills b) low-inertia c) fish ladder (fish swimming in water) d) balloon filled with hot air e) floating hydrofoil f) concept of hovercrafts	15) DYNAMICS a) automatically extendable/contractible b) automatic gears in needed c) automatic gears in needed d) undercarriages in case of variable stiffness e) electronic controllers for carburetors f) electronically controlled fuel injection g) electronic controllers for carburetors in dependency of driving conditions during the driving
02) TAKING OUT a) taking of noisier noisy tower unit, or compressed out of the main body b) (engines, turbines, blades) combined with internal ducts for air ventilation system, taken out of the building, i.e. placed on the buildings elevations c) sound of bird's predator, previously registered on a tape, and played back, can be used scaring away the birds, notoriously flying near or around the airports	09) PRE-ELIMINARY ANTI-ACTION (COUNTER-ACTION) a) counter-acting sounds b) counter-acting sounds c) counter-acting sounds d) counter-acting sounds e) counter-acting sounds f) counter-acting sounds	16) EXCESSIVE (OR PARTIAL) ACTION a) in close fit of both piston and cylinder of the engine b) spray excessively paint, and then to remove the excess of the paint c) to fulfill the fuel tank, and then to remove the excess of fuel
03) LOCAL QUALITY a) dustless excavation of coal b) dust in captured by tiny droplets c) dust in captured by tiny droplets d) dust in captured by tiny droplets e) dust in captured by tiny droplets f) dust in captured by tiny droplets	10) PRE-ELIMINARY ACTION a) parking of hard disc reading/writing heads (when it is needed) b) blowing off of the (potentially choked) nozzles in striding cartridges c) blowing off of the (potentially choked) nozzles in striding cartridges d) blowing off of the (potentially choked) nozzles in striding cartridges e) blowing off of the (potentially choked) nozzles in striding cartridges f) blowing off of the (potentially choked) nozzles in striding cartridges	17) ANOTHER DIMENSION a) two coils in 1D b) two coils in 2D c) two coils in 3D d) two coils in 4D e) two coils in 5D f) two coils in 6D g) two coils in 7D h) two coils in 8D i) two coils in 9D j) two coils in 10D k) two coils in 11D l) two coils in 12D m) two coils in 13D n) two coils in 14D o) two coils in 15D p) two coils in 16D q) two coils in 17D r) two coils in 18D s) two coils in 19D t) two coils in 20D u) two coils in 21D v) two coils in 22D w) two coils in 23D x) two coils in 24D y) two coils in 25D z) two coils in 26D aa) two coils in 27D ab) two coils in 28D ac) two coils in 29D ad) two coils in 30D ae) two coils in 31D af) two coils in 32D ag) two coils in 33D ah) two coils in 34D ai) two coils in 35D aj) two coils in 36D ak) two coils in 37D al) two coils in 38D am) two coils in 39D an) two coils in 40D
04) ASYMMETRY a) pneumatic type asymmetrically reinforced from outside, due to contact with pavement b) left or right-handed rules of priority, in right of road c) asymmetrically reinforced from outside, due to contact with pavement d) asymmetrically reinforced from outside, due to contact with pavement e) asymmetrically reinforced from outside, due to contact with pavement f) asymmetrically reinforced from outside, due to contact with pavement	11) BEFOREHAND CUSHIONING a) for instance, a method of "treating" the cut tree branches b) actually forces a tree to beforehand reaction, in gathering healing substances c) beforehand reaction, in gathering healing substances d) beforehand reaction, in gathering healing substances e) beforehand reaction, in gathering healing substances f) beforehand reaction, in gathering healing substances	18) MECHANICAL SELF-INDUCED VIBRATIONS (IN RESONANCE) a) piezoelectric engine - a conceptual design b) electric circuit c) piezoelectric engine - a conceptual design d) piezoelectric engine - a conceptual design e) piezoelectric engine - a conceptual design f) piezoelectric engine - a conceptual design
05) MERGING a) several computers combined into functioning network b) a hedge made of pales c) bodies made of wood/plastication forces d) soffit lines combined into coverage of house roof e) mobile concrete mixer, mobile crane, refrigerator, merged into single mobile machine, etc. combining of the stationary machines with mobile undercarriages	12) EQUIPOTENTIALITY a) a sequence of movements b) a sequence of movements c) a sequence of movements d) a sequence of movements e) a sequence of movements f) a sequence of movements	19) PERIODICAL ACTION, OR PULSED ACTION a) pulsed laser, against bases b) pulsed laser, against bases c) pulsed laser, against bases d) pulsed laser, against bases e) pulsed laser, against bases f) pulsed laser, against bases
06) UNIVERSALITY a) a helmet in use, within field conditions, rendered as b) universal c) universal d) universal e) universal f) universal	13) INVERSION (UPSIDE DOWN) a) reversing the working mode of vacuum cleaner, in cleaning of carpets b) turn mounted object upside down, on assembling line c) turn mounted object upside down, on assembling line d) turn mounted object upside down, on assembling line e) turn mounted object upside down, on assembling line f) turn mounted object upside down, on assembling line	20) CONTINUITY ACTION OF USEFUL ACTION a) in both directions b) in both directions c) in both directions d) in both directions e) in both directions f) in both directions
07) EMBEDDED STRUCTURES (nested "Dolls" - Matryoshka) a) a) spade b) a2) frying pan c) sets of universal kitchen nooks, with operating actuators (rasps, juice extractors, etc.)	14) SPHEROIDALITY, CURVATURES a) applications of b) replacement of c) replacement of d) replacement of e) replacement of f) replacement of	21) SKIPPING, QUICK MODE, OR PACE OF REALIZATION a) quick b) quick c) quick d) quick e) quick f) quick

A technique of Engineering Creativity and Inventive Thinking in Problem Solving

page B - 40 principles of invention in TRIZ method, sketches rendered into vector graphics

22) "BLESSING IN DISGUISE" (CONVERT HARM INTO BENEFIT) a) burning out main inside/outside the blating fire b) burning out main inside/outside the blating fire c) burning out main inside/outside the blating fire d) burning out main inside/outside the blating fire e) burning out main inside/outside the blating fire f) burning out main inside/outside the blating fire	28B) SUBSTITUTING OF MECH. SYS. WITH ELECTRO-MAGN. SYSTEMS a) magnetic force instead of mechanical force b) magnetic force instead of mechanical force c) magnetic force instead of mechanical force d) magnetic force instead of mechanical force e) magnetic force instead of mechanical force f) magnetic force instead of mechanical force	34) DISCARDING & RECOVERING, (REJECT & PARTS REGENERATION) a) dissolving medication capsules made of biologically discarded (inert material) b) dissolving medication capsules made of biologically discarded (inert material) c) dissolving medication capsules made of biologically discarded (inert material) d) dissolving medication capsules made of biologically discarded (inert material) e) dissolving medication capsules made of biologically discarded (inert material) f) dissolving medication capsules made of biologically discarded (inert material)
23) FEEDBACK PRINCIPLE a) basically, as well as particularly b) object c) object d) object e) object f) object	29A) PNEUMATICS & HYDRAULICS a) pneumatic automobile tyre b) pneumatic (air-tight) dampers c) pneumatic (air-tight) dampers d) pneumatic (air-tight) dampers e) pneumatic (air-tight) dampers f) pneumatic (air-tight) dampers	35) CHANGING STATE, PARAMETERS, PROPERTIES OF MATERIALS 1) high temperature food processing 2) low temperature food processing 3) product ready for further processing (for example in liquid chocolate)
24) INTERMEDIATE MEANS, "FITTING" PRINCIPLE a) in electronic circuits b) fitting of input impedance to receiver's impedance c) fitting of input impedance to receiver's impedance d) fitting of input impedance to receiver's impedance e) fitting of input impedance to receiver's impedance f) fitting of input impedance to receiver's impedance	29B) PNEUMATICS & HYDRAULICS a) automobile brakes b) in driving of phase elevator, where the precision of driving is needed as well as enormous force transition c) in driving of phase elevator, where the precision of driving is needed as well as enormous force transition d) in driving of phase elevator, where the precision of driving is needed as well as enormous force transition e) in driving of phase elevator, where the precision of driving is needed as well as enormous force transition f) in driving of phase elevator, where the precision of driving is needed as well as enormous force transition	36) PHASE TRANSITION a) binary phase transition cycle for refrigerator construction b) binary phase transition cycle for refrigerator construction c) binary phase transition cycle for refrigerator construction d) binary phase transition cycle for refrigerator construction e) binary phase transition cycle for refrigerator construction f) binary phase transition cycle for refrigerator construction
25) SELF-SERVICING PRINCIPLE a) FOG b) FOG c) FOG d) FOG e) FOG f) FOG	29C) PNEUMATICS & HYDRAULICS a) flexible balloons, domes, barriers b) flexible balloons, domes, barriers c) flexible balloons, domes, barriers d) flexible balloons, domes, barriers e) flexible balloons, domes, barriers f) flexible balloons, domes, barriers	37) THERMAL EXPANSION 1) thermal shift fitting 2) state of thermal balance
26) COPYING, IMAGING PRINCIPLE a) use of ultrasonics b) use of ultrasonics c) use of ultrasonics d) use of ultrasonics e) use of ultrasonics f) use of ultrasonics	30) FLEXIBLE FILMS, FOILS, MEMBRANES a) flexible balloons, domes, barriers b) flexible balloons, domes, barriers c) flexible balloons, domes, barriers d) flexible balloons, domes, barriers e) flexible balloons, domes, barriers f) flexible balloons, domes, barriers	38) STRONG OXIDANTS a) oxygen b) ozone c) indirectly
27) INEXPENSIVE SHORT-LIVED OBJECTS (CHEAP CADUCITY, & DISPOSABLE MATERIALS) a) kitchen utensils, dishes, disposable supplies, cutlery made of plastic b) kitchen utensils, dishes, disposable supplies, cutlery made of plastic c) kitchen utensils, dishes, disposable supplies, cutlery made of plastic d) kitchen utensils, dishes, disposable supplies, cutlery made of plastic e) kitchen utensils, dishes, disposable supplies, cutlery made of plastic f) kitchen utensils, dishes, disposable supplies, cutlery made of plastic	31) POROUS MATERIALS a) porous, sponge materials b) porous, sponge materials c) porous, sponge materials d) porous, sponge materials e) porous, sponge materials f) porous, sponge materials	39) NEUTRAL ATMOSPHERES, INERT ENVIRONMENTS a) Co. extinguishers b) No or He: protection atmospheres in processing, and production c) No or He: protection atmospheres in storing of products, and materials, both raw and processed
28A) PRINCIPLE OF SUBSTITUTING OF MECHANICAL SYSTEM WITH FUNCTIONALLY EQUIVALENT ELECTRO-MAGNETIC SYSTEMS a) mechanical pressure b) magnetic fields c) magnetic fields d) magnetic fields e) magnetic fields f) magnetic fields	32) COLOUR CHANGING (ALTERNATING) a) in trapping process for inner surfaces of engine pistons & cylinders, the problem of photosensitive distribution can be solved b) in trapping process for inner surfaces of engine pistons & cylinders, the problem of photosensitive distribution can be solved c) in trapping process for inner surfaces of engine pistons & cylinders, the problem of photosensitive distribution can be solved d) in trapping process for inner surfaces of engine pistons & cylinders, the problem of photosensitive distribution can be solved e) in trapping process for inner surfaces of engine pistons & cylinders, the problem of photosensitive distribution can be solved f) in trapping process for inner surfaces of engine pistons & cylinders, the problem of photosensitive distribution can be solved	40) COMPOSITE MATERIALS a) elements of blades, rotors, airfoils b) elements of blades, rotors, airfoils c) elements of blades, rotors, airfoils d) elements of blades, rotors, airfoils e) elements of blades, rotors, airfoils f) elements of blades, rotors, airfoils

A technique of Engineering Creativity and Inventive Thinking in Problem Solving

- Analysis of contradictions and their solution principles allows to establish contradiction matrix and associate solution principles
- Methodology
 - Abstraction of issue to be solved
 - Identify contradiction(s)
 - Conflict between two effects
 - Conflict between properties
 - Introduce contradiction pairs into matrix

The image displays two key TRIZ tools. On the left is the 'Contradiction Matrix for Solving Technical Contradictions', a 39x39 matrix with a green diagonal. It lists 39 technical parameters on both the horizontal and vertical axes. A legend at the top left indicates that green cells represent solutions found 'without inventive principles' and red cells represent solutions found 'with inventive principles'. On the right is the '40 Inventive Principles' table, which lists 40 principles used to resolve physical contradictions. Below this is a smaller table titled 'Separation Principles for Solving Physical Contradictions'.

Principle	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
1. Segmentation																																							
2. Local Quality																																							
3. Local Inversion																																							
4. Asymmetry																																							
5. Separation in Time																																							
6. Separation in Space																																							
7. Separation by Condition																																							
8. Separation by State																																							
9. Separation by Scale																																							
10. Separation by Color																																							
11. Separation by Temperature																																							
12. Separation by Humidity																																							
13. Separation by Pressure																																							
14. Separation by Magnetic Field																																							
15. Separation by Electric Field																																							
16. Separation by Sound																																							
17. Separation by Light																																							
18. Separation by Smell																																							
19. Separation by Taste																																							
20. Separation by Weight																																							
21. Separation by Volume																																							
22. Separation by Shape																																							
23. Separation by Motion																																							
24. Separation by Position																																							
25. Separation by Orientation																																							
26. Separation by Quantity																																							
27. Separation by Quality																																							
28. Separation by Function																																							
29. Separation by Material																																							
30. Separation by Color																																							
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37. Separation by Light																																							
38. Separation by Smell																																							
39. Separation by Taste																																							

■ Example

- Static object needs to be longer without impacting its mass
- http://www.triz40.com/TRIZ_GB.php

The screenshot displays the TRIZ40 website interface. At the top left is the logo 'TRIZ40 by SolidCreativity'. At the top right are language options 'EN | DE | FR' and a 'Menu' button. The main text explains that TRIZ systems evolve towards ideality by overcoming contradictions and lists 40 principles. An example contradiction is provided: 'you need a static object to be longer without becoming heavier'. To the right, a step-by-step guide shows '1) Set the contradiction to solve' with two dropdowns: '4: Length of stationary' and '2: Weight of stationary'. Below this, a box titled 'The TRIZ Matrix proposes the following Principles to solve this contradiction:' lists four principles: '35: Parameter changes', '28: Mechanics substitution', '40: Composite materials', and '29: Pneumatics and hydraulics'.

TRIZ40
by SolidCreativity

EN | DE | FR

Menu

For TRIZ, systems evolve towards ideality by overcoming CONTRADICTIONS. TRIZ matrix gathers 40 Principles (known solutions) able to overcome these contradictions. E.g. you need a static object to be longer without becoming heavier: This is a contradiction. Browse the Matrix or use this interactive Matrix to discover possible ways of solutions: The PRINCIPLES.

1) Set the contradiction to solve

4: Length of stationary

2: Weight of stationary

The TRIZ Matrix proposes the following Principles to solve this contradiction:

- + 35: Parameter changes
- + 28: Mechanics substitution
- + 40: Composite materials
- + 29: Pneumatics and hydraulics

Some Comments on Ideation Tools

- There is no such thing as a best tool
- Outcome is dependent on individuals and team dynamics
- Test different tools and identify most suitable for your environment
- Combine different methodologies to maximize output
- The different methodologies need training

1. A. F. Osborn, *Applied Imagination*. Charles Scriber's Sons, New York 1953
2. B. Rohrbach, *Kreativ nach Regeln – Methode 635, eine neue Technik zum Lösen von Problemen*. Absatzwirtschaft 12, 73-76, Heft 19, 1969
3. E. de Bono, *Six Thinking Hats: An Essential Approach to Business Management*. Little, Brown, & Company 1985
4. W. S. Starkey, *The Beginnings of STOP Storyboarding and the Modular Proposal*. APMP Proposal Management, 2000
5. B. Eberle, *Help! In solving problems creatively at home and school*. Carthage: Good Apple, 1984
6. http://www.triz40.com/TRIZ_GB.php
http://www.triz40.com/aff_Principles_TRIZ.php

