CPE/EE 322
Engineering Design VI
Lesson 3: Structuring the Search for the Problem

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2023-02-13

Outline

1. Focus on function
2. Formulating the real problem
3. Kepner-Tregoe situation analysis
4. Kepner-Tregoe problem analysis

Objectives

G. Voland, Engineering by Design, Chapter 3

- Explain why formulation of a problem statement is a critical step in the engineering design process
- Generate problem statements that focus on the function to be achieved by any viable design solution
- Identify the hazards associated with misdefining a problem
- Apply a number of techniques and strategies to define the real problem to be solved, including the statement-restatement technique, the source/cause approach, the revision method, present state-desired state (PS-DS) strategy, and Duncker diagrams
- Perform Kepner-Tregoe (KT) situation analysis to evaluate various aspects of a situation in terms of three criteria (timing, trend, and impact), thereby determining what is known, which tasks should be performed, and in what order these tasks should be completed
- Perform KT problem analysis to determine possible causes of a problem

Lab 3 — Python

- Study the GitHub [repository]() Lesson 3 labs
- Install required Python packages such as jdcal, astral, and geopy

```
$ cd ~/iot
$ cd *3
$ python3 julian.py
$ python3 date_example.py
$ python3 datetime_example.py
$ python3 time_example.py
$ python3 sun.py 'New York'
$ python3 moon.py
$ python3 coordinates.py 'SC Williams Library'
$ python3 address.py '40.74480675, -74.0253286203l404'
$ python3 cpu.py
$ python3 battery.py
$ python3 documentstats.py document.txt
```

Assignment 3 — Problem Formulation

- Generate problem statements that focus on the function to be achieved by any viable design solution
- Apply a number of techniques and strategies such as the statement-restatement technique, the source/cause approach, the revision method, present state-desired state (PS-DS) strategy, and Duncker diagrams
- Perform Kepner-Tregoe (KT) situation analysis to evaluate various aspects of a situation in terms of three criteria (timing, trend, and impact), thereby determining what is known, which tasks should be performed, and in what order these tasks should be completed
- Perform KT problem analysis to determine possible causes of a problem

Program Outcome 2: Design

2.4 (Design assessment) Students will be able to critically evaluate the impact of cost, features, and performance on the useful functionality of a project "product" from the perspective of a non-technical customer and will understand the importance of critically challenging his/her design and use assumptions to ensure exploration of alternative designs & features from the perspective of a final customer product.

Focus on Function

- Engineers should formulate a specific problem to develop a specific solution
- Describing the problem in terms of a particular solution can limit creativity and can often lead to simple modifications in the existing solutions rather than a breakthrough design
- A problem statement should focus on the functions to be perform by any viable solution, e.g., bridges perform the function of providing access across water

Formulating the Real Problem

1. The dangers of misdirected search
2. The statement-restatement technique
3. Determine the source and the cause: Why-Why diagrams
4. The revision method
5. Present state and desired state via Duncker diagrams
6. What's wrong with it?
7. Benchmarking and best practices: investigate existing solutions
8. Fresh eye approach

Dangers of Misdirected Search

- Properly formulating a problem is the most critical step in the engineering design process
- A problem statement can be incorrect, leading to a misdirected search for solutions
- To determine the real problem to solve, one can use heuristics that seem promising through numerous problem-solving efforts and trials
- Nevertheless, a heuristic that led to success in the past does not guarantee success in the future

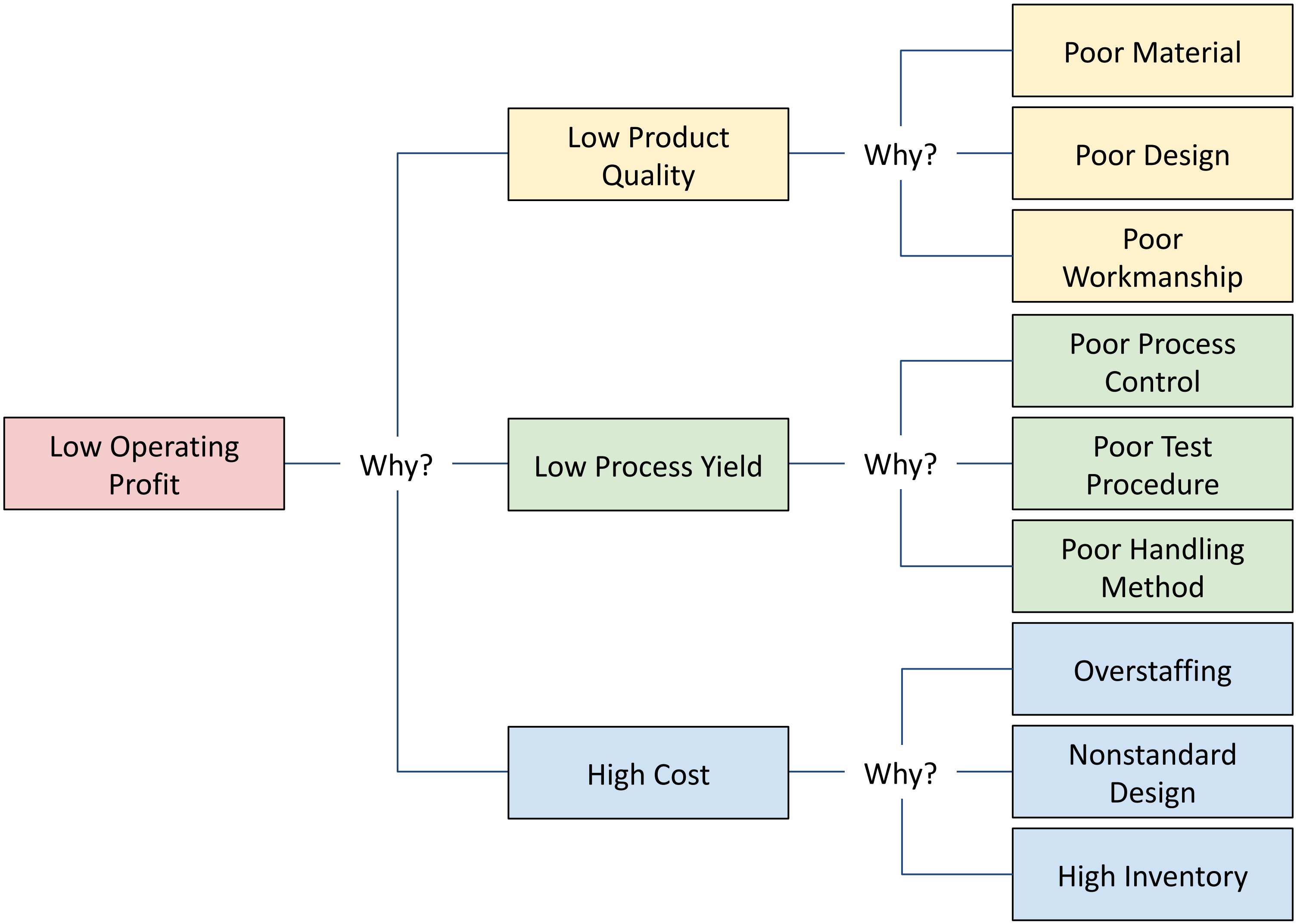
Statement-Restatement Technique

1. Determine the real problem in contrast to the stated problem
2. Determine the actual constraints or boundaries in contrast to the given or inferred boundaries
3. Identify meaningful goals in contrast to a set of given or inferred goals
4. Identify relationships between inputs, outputs, and any unknowns

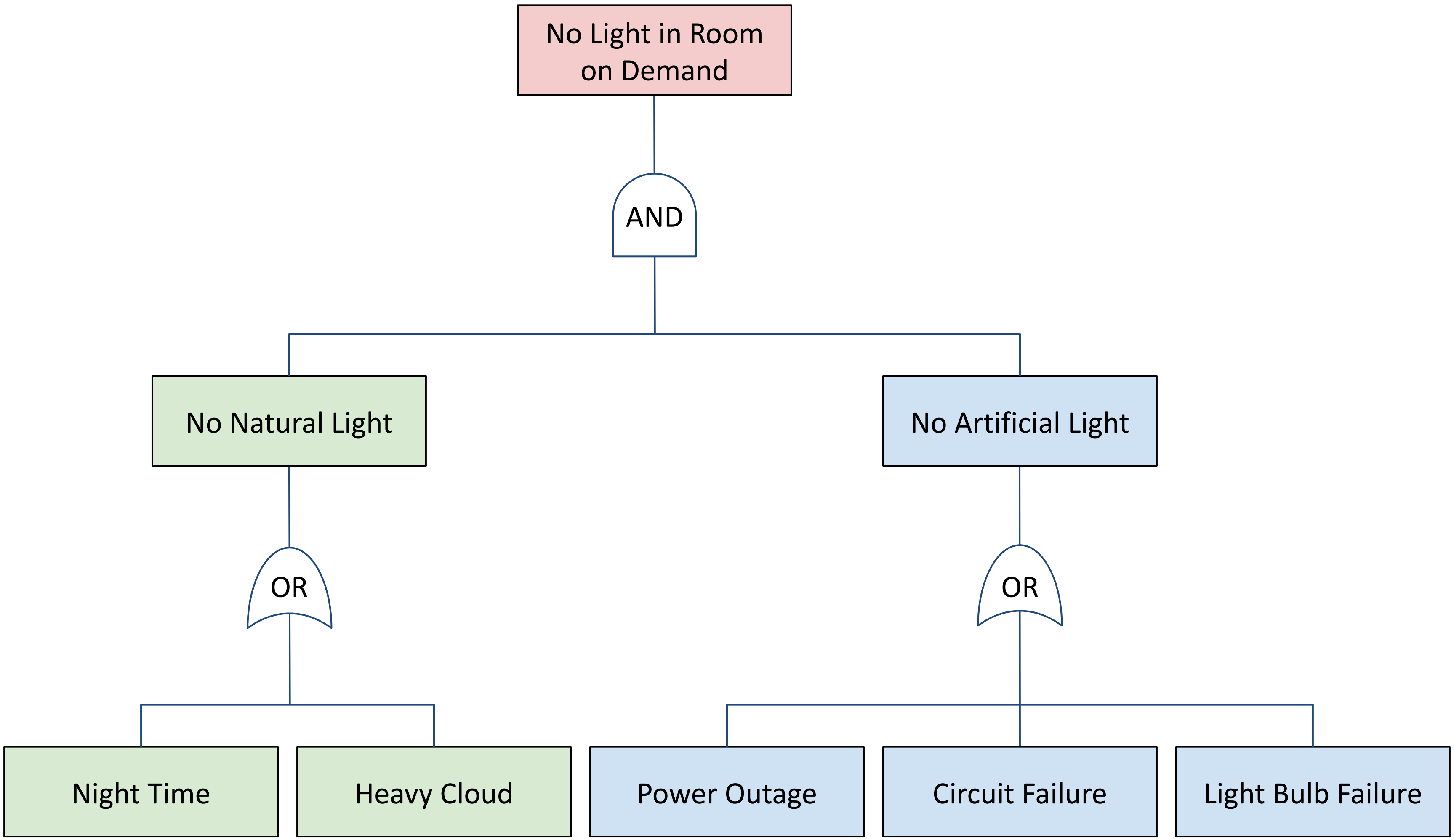
Source/Cause Approach

- Engineers need to focus on the source or cause of the problem, just as physicians need to treat the cause of an infection and not simply its symptoms
- A Why-Why diagram consists of the problem or situation under consideration on the left and branches to the right each with a possible underlying source of the problem, then repeatedly to the right identifying more specific causes
- Alternatively, a top-down fault tree diagram using Boolean logic breaks the potential underlying causes for a problem into specific possibilities

Why-Why Diagram



Fault Tree Diagram



Revision Method

The focus of the design effort can occasionally revert to the product or solution rather than the specific function to be achieved by the solution if

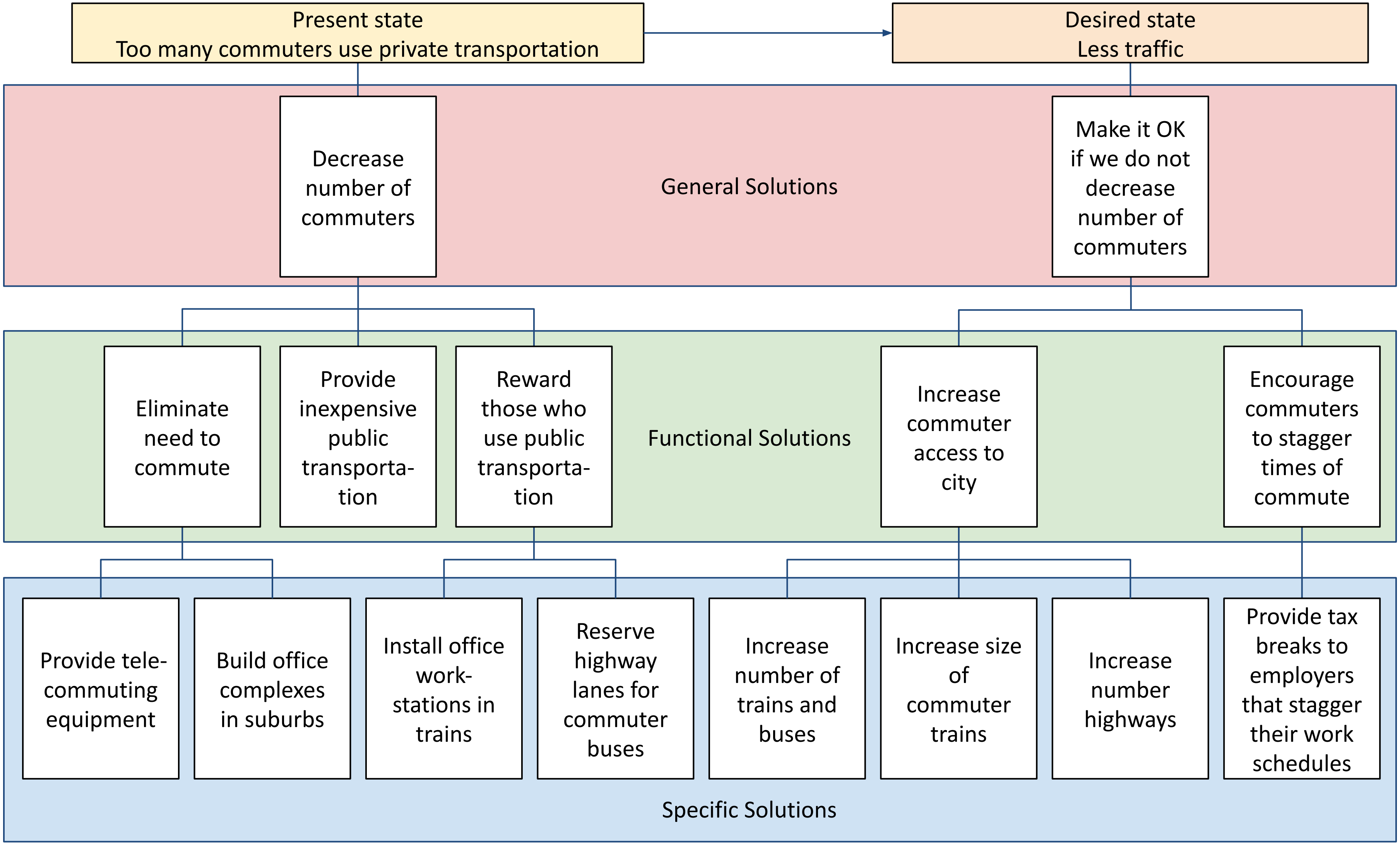
- The product is expected to face increased competition from similar products in the near future, e.g., patent protection on the design is about to expire
- One has exhausted all efforts in reformulating the problem
- One needs to stimulate creative thinking to generate new design concepts

By changing to a focus on the product, one can recognize additional needs of the customer and develop a revision of the existing design

The Duncker Diagram

- One can specify the present state (PS) and the desired state (DS) of the process or system under development
- Then modify the PS statement, the DS statement, or both until there is a satisfactory correlation between the two
- The Duncker diagram is a graphical tool that can be used to develop a set of matching PS and DS statements
- Duncker diagrams focus on developing solution at three different levels: general, functional, and specific solutions

Duncker Diagram Example



What's Wrong With It?

- Checklisting is one the techniques to develop creative solutions to a problem
- "What's wrong with it?" is a particularly effective checklisting question to ask during problem formulation and both the abstraction and synthesis phases of the design process
- "It" refers to an existing situation or product, or a proposed design solution

Benchmarking and Best Practices

- In benchmarking, a company compares its performance against competitors or other groups to identify areas for possible improvement
- In best practice, a more focused form of benchmarking, one identifies the finest methods and performance techniques within an industry
- Using benchmarking or best practice, one investigate if there are similar problems that have been solved by others
  - Why were earlier solutions successful or not?
  - How or why does your problem differ from others?
  - Could any existing solutions be adapted to solve your problem?

Fresh Eye Approach

- Using the "Fresh Eye" approach, one explains the problem to another person who is not on the design team
- Such a discussion may lead to a deeper understanding of underlying aspects of the problem, or may provide a new perspective of the situation that will lead to a more precise and correct formulation of the problem

Kepner-Tregoe (KT) Analysis

In 1981, Charles Kepner and Benjamin Tregoe developed a four-step problem-solving method that can be used for engineering design

- Situation analysis (SA) — timing, trend, and impact in high, moderate, or low level of concern/urgency
  Determine what we know, which tasks should be performed, and in what order
- Problem analysis (PA) — identity, location, timing, and magnitude
  Determine the cause of the problem or subproblem
- Decision analysis (DA)
  Determine the actions needed to correct the the subproblem and/or eliminate the cause of a current subproblem
- Potential problem analysis (PPA)
  Determine the actions needed to prevent any recurrences of the subproblem and/or the development of new problems

KT Problem Analysis — What

Is	Is not
What is known?	What is NOT known?
What was observed?	What was NOT observed?
What are the constraints?	What are NOT constraints?
What is important?	What is NOT important?
What are the goals/objectives?	What are NOT goals?
What can be expected?	What is NOT expected?

KT Problem Analysis — When

Is	Is not
When did the problem occur?	When did the problem NOT occur?
When must solution be implemented?	When is solution NOT needed?
When did changes occur?	When did changes NOT occur?
When were instruments calibrated?	When were instruments NOT calibrated?

KT Problem Analysis — Who

Is	Is not
Who can provide more information?	Who can NOT provide information?
Who is the customer?	Who is NOT the customer?
Who performed (each) task?	Who did NOT perform (each) task?
Who is source of information?	Who is NOT source of information?
Who is affected by problem?	Who is NOT affected by problem?

KT Problem Analysis — Where

Is	Is not
Where did problem occur?	Where did problem NOT occur?
Where are input sources located?	Where are input sources NOT located?
Where is equipment located?	Where is equipment NOT located?
Where are products shipped?	Where are products NOT shipped?
Where is customer located?	Where is customer NOT located?

KT Problem Analysis — Why

Is	Is not
Why is problem important?	Why is problem NOT important?
Why does solution work?	Why does solution NOT work?
Why is there a problem?	Why is there NOT a problem?

KT Problem Analysis — How

Is	Is not
How is problem related to other problems?	How is problem NOT related to other problems?
How can a task be performed?	How can a task NOT be performed?
How did problem develop?	How did problem NOT develop?

Lesson 3 Summary

- Technical problems can be classified into three basic categories: problems of prediction, problems of explanation, and problems of invention (or some combination thereof)
- Incorrect formulation of a problem may result in a final design that is of little value or that may even be hazardous
- Problem statement should focus on the functions to be achieved by the desired design solutions
- Use statement-restatement technique, source/cause approach, revision method, and present state-desired state strategy via Duncker diagrams to define the real problem to be solved
- Perform Kepner-Tregoe situation analysis to evaluate the level of concern/urgency in terms of timing, trend, and impact
- Perform Kepner-Tregoe problem analysis to determine the cause of the problem or subproblem in terms of its characteristics, location, timing, and magnitude by asking both positive and negative questions (what? when? who? where? why? how?)

Three Basic Types of Problems

Sidney Parnes 1922—2013, President (1967—1984) of the Creative Education Foundation (CEF), defined three basic types of problems in 1967

- **Problems of prediction**
  Calculate a result or predict system behavior by applying equations, physical laws, tools of data analysis, *etc*.
- **Problems of explanation**
  Seek the causes for a phenomenon or observed behavior
- **Problems of invention**
  Develop a new and effective solution to a problem

Engineers should consider if a problem is a combination of these problem types

George Boole 1815—1864

- George Boole was an English mathematician from Lincoln, U.K.
- As the first professor of mathematics at Queen's College, Cork (now University College Cork) in Ireland, he published *The Laws of Thought* in 1854
- The full title of the book was *An Investigation of the Laws of Thought on which are founded the Mathematical Theories of Logic and Probabilities*

Original and New Models

$249 Nest Thermostat
Metal
2.08-inch 480×480 display
10 Wire Terminals

$169 Nest Thermostat E
Polycarbonate
1.76-inch 320×320 Frosted Display
6 Wire Terminals

Suffering or Happiness

- Suffering refers to physical pain in the narrow sense, or includes psychological pain in the broad sense
- The opposite of suffering is pleasure or happiness
- Boman Irani, "You're only as happy as you choose to be," Instagram, 2019-02-03
- Frank Crane 1861—1928 attributed to Abraham Lincoln 1809—1865, "Folks are usually about as happy as they make up their minds to be," the *Syracuse Herald*, 1914-01-01
- Gretchen Rubin authored the *New York Times* bestsellers *Better Than Before*, *Happier at Home*, and *The Happiness Project*

Emotional Intelligence

Emotional intelligence (EI), also known as emotional quotient (EQ), is the capability of individuals to

- Recognize their own emotions and those of others
- Discern between different feelings and label them appropriately
- Use emotional information to guide thinking and behavior
- Manage and/or adjust emotions to adapt to environments or achieve one's goal(s)

	Others' suffering	Others' happiness
Bring us suffering	Empathy	Envy
Bring us happiness	Schadenfreude	Mudita

Karl Duncker 1903—1940

- Karl Duncker was a Gestalt psychologist
- He coined the term functional fixedness for describing the difficulties in visual perception and in problem solving
- Functional fixedness arises from the fact that one element of a whole situation already has a fixed function
- The fixed function has to be changed for making the correct perception or for finding the solution to the problem
- Duncker's candle problem is a cognitive performance test that measures the influence of functional fixedness on a participant's problem solving capabilities

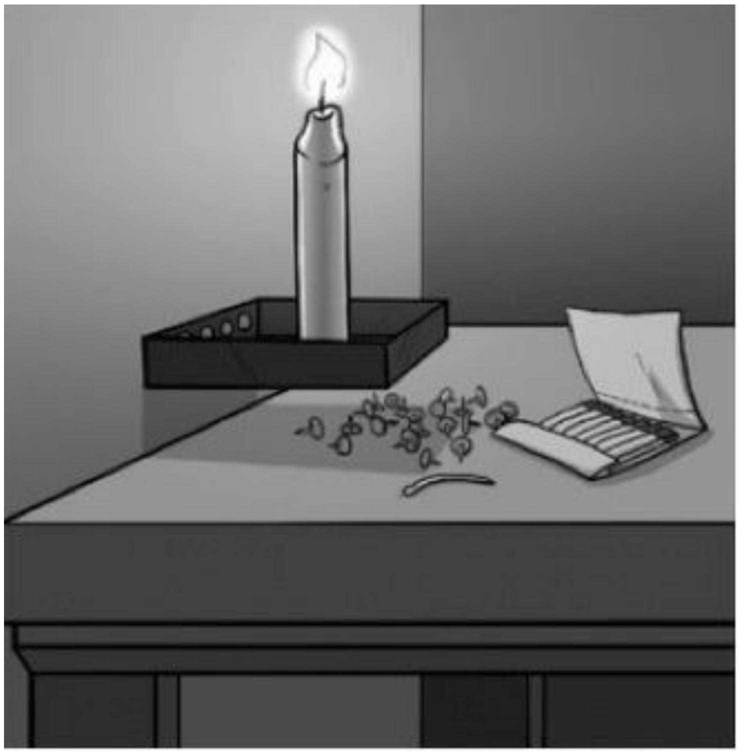
The Candle Problem

The participants are given

- a candle
- a box of tacks
- a book of matches

and are asked to attach and light the candle on a wall so that the candle wax won't drip onto the table below

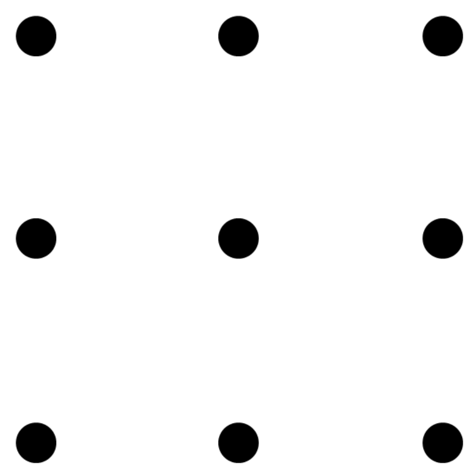
The Solution



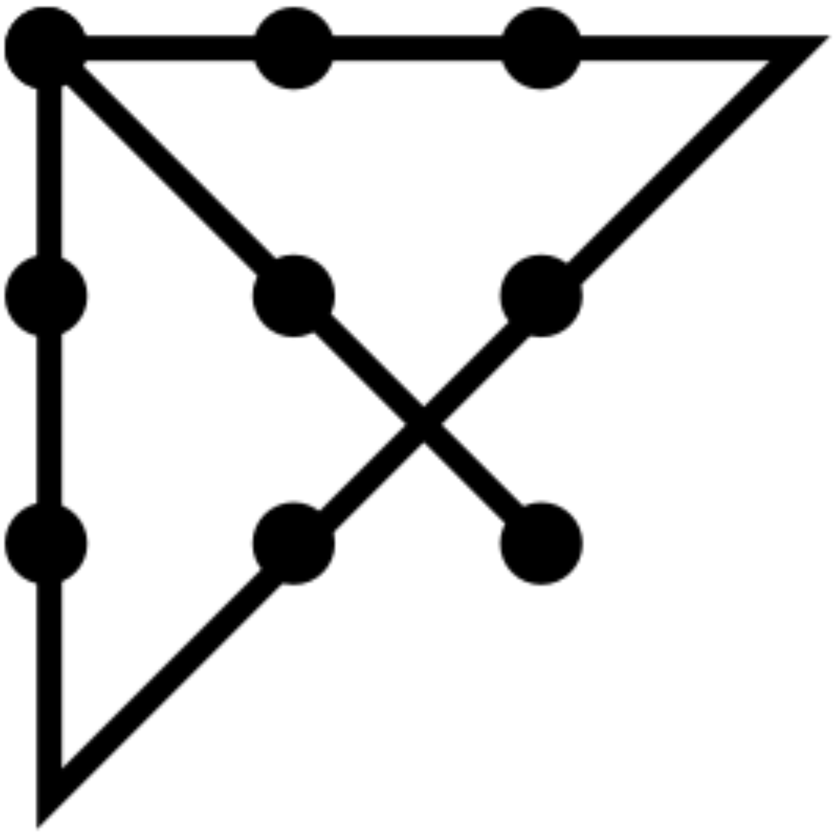
The concept of functional fixedness predicts that participants only see the box as a device to hold the tacks and not immediately perceive it as a separate and functional component available to be used in solving the task

The Nine Dots Puzzle

- The nine dots puzzle or Christopher Columbus egg puzzle appears in *Sam Loyd's Cyclopedia of 5000 Puzzles, Tricks and Conundrums with Answers* (1914) by Sam Loyd 1841—1911
- The challenge is to draw four straight lines that pass through the center of each of the nine dots without lifting the pencil from the paper



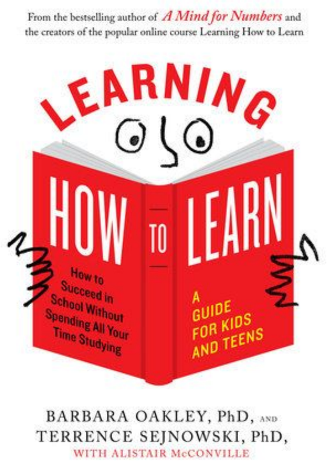
The Solution

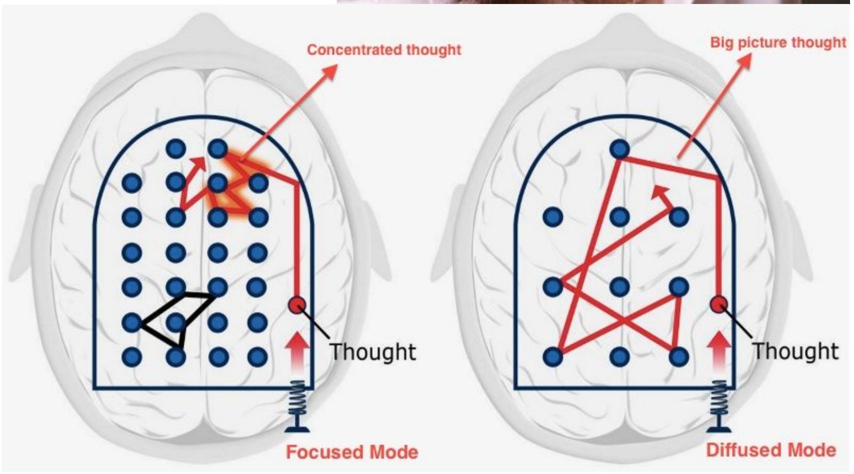


- Thinking outside the box is to look further and to try not thinking of the obvious things, but to try thinking of the things beyond them
- Not to be confused with an out-of-the-box (OOTB) feature or functionality also called commercial off-the-shelf (COTS), particularly in software, is a feature or functionality of a product that works immediately without any special installation, configuration, or modification—available for all users by default, and are not required to pay additionally to use those features

Learning How to Learn

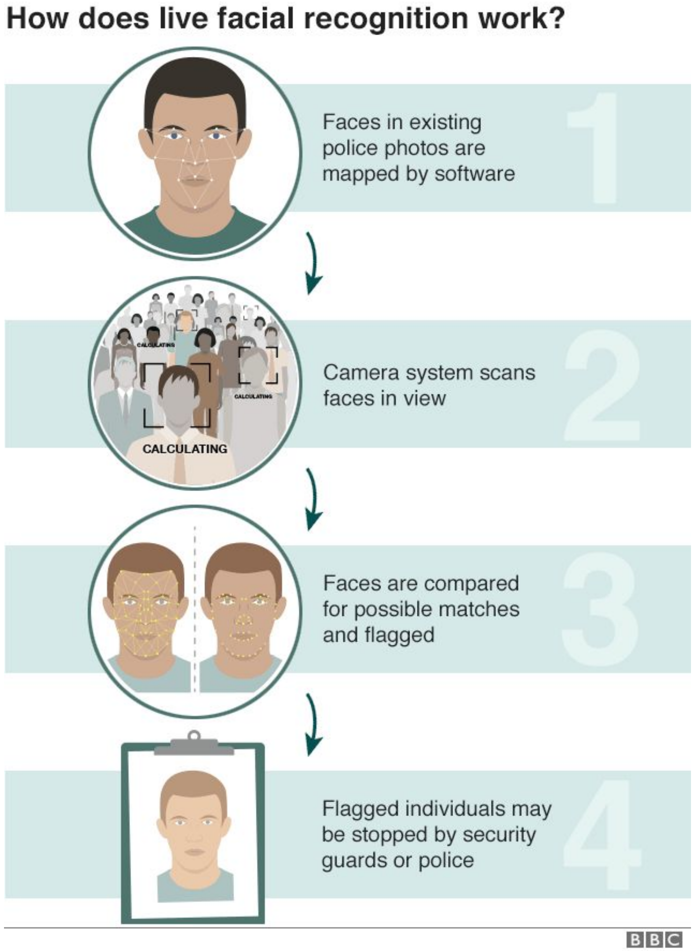
https://barbaraoakley.com





- Prof. Barbara Oakley, Oakland University, Rochester, Michigan
- Use both focused and diffused modes of thinking while learning
- Use the Pomodoro Technique—25 minutes of focused concentration followed by mental relaxation
- Practice the Feynman Technique: concept-explain-gap-analogy-simplify
- Tackle procrastination by focusing on the process instead of the product
- Avoid the Einstellung effect of predisposition to solve a given problem in a specific manner even though better or more appropriate methods exist

Facial Recognition Systems



- A facial recognition system is a technology capable of identifying or verifying a person from a digital image or a video frame from a video source by comparing selected facial features from given image with faces within a database
- Although the accuracy of facial recognition system as a biometric technology is lower than fingerprint or eye iris recognition systems, it is widely adopted due to its contactless process
- On the other hand, one study found that overall accuracy rates for identifying men (91.9%) were higher than for women (79.4%), and none of the systems accommodated an understanding of non-binary gender

Founders of Kepner-Tregoe

http://www.kepner-tregoe.com

Charles Kepner 1922—2016 Benjamin Tregoe 1927—2005