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Exploring Non-Classical Solutions for Engineers

Instructor: John C. Huang, Ph.D, PE

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5272 Meadow Estates Drive
Fairfax, VA 22030-6658
Phone: 703-988-0088
www.PDHonline.com

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Exploring Non-Classical Solutions for Engineers

W.N. Weaver, PE and John C. Huang, PhD, PE

BACKGROUND

So your boss says "We need a new solution, something creative. You need to think outside the box on this one." So what does he mean?What box? Maybe the cubical I'm sitting in or maybe the whole building with all 100 cubical boxes filled with engineers? How do I get out of this box?

While "thinking out of the box" is not a technical subject the concept frequently provides a path to solutions to engineering problems. Although not applicable to all engineering problems the approach often satisfies the engineering requirements for elegant and inexpensive solutions to problems.

Even when the solution produced is "classical" the exercise of out of the box thinking broadens the engineer's perspectives. Although the process for each engineer is different based on experience and education once the thought process is considered some benefits will accrue. For most engineers the act of reading about the concept will cause some consideration of using the concept. Finally it is more fun than "classical" problem solving.

Many writers have criticized the concept since early discussions tried to show the concept as a new way to creativity. In reality all engineers employ this system to a greater or lesser extent and it is not really a path to creativity.

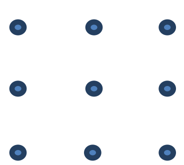
Among many others this is a problem solving aid encouraging the problem solver to look beyond the normal everyday solutions taught in colleges and universities. As opposed to thinking outside the box the "usual" process of thinking inside a box originates in allowing restraints present to prevent the engineer from considering some potential solutions. We'll explore the origins of these restraints to assist in getting out of the box.

DEFINITION

"out-of-the-box thinking,divergent thinking (The Free Dictionary on the web)
thinking that moves away in diverging directions so as to involve a variety of aspects and which sometimes lead to novel ideas and solutions; associated with creativity"

That's not really helpful to an engineer. So let's look at some classic examples of "out of the box" thinking involving engineers and then find a usable definition. To save space and maybe legal consequences I'll leave out names, places and dates and paraphrase as necessary.

EXAMPLE 1 The "nine dots" puzzle. The goal of the puzzle is to link all 9 dots using four straight lines or fewer, without lifting the pen and without tracing the same line more than once. This is supposedly the origin of the phrase "thinking outside the box" which is attributed to multiple individuals and companies.



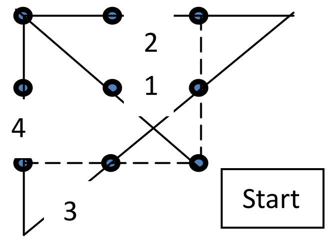
EXAMPLE 2 THE ELEVATORS (greatly paraphrased from the 1960's event)
XYZ Corporation was proud of its corporate office building and with all five hundred employees in one spot the efficiency benefits were significant. Costs for mailings, all staff meetings and other necessary face to face meetings were nearly zero. The five hundred employees occupied all twelve floors of the tower.
The twelve story building was serviced by three modern elevators. Complaints to management about the slow elevators were frequent and finally caused the management to bring in several consultants to solve the problem. Several consultants recommended converting some elevators to express units and others suggested staggering lunch and quitting times to reduce the loads. Two recommended adding extra elevators to the exterior of the tower. Minimum costs for these options were in the $1,000,000 (1960 dollars) range.

However, one mechanical engineer offered to solve the problem for $100,000 with a guarantee of no further complaints about the elevators. Upper management considered the bid and decided with his guarantee and the low cost it was worth the risk and accepted his proposal with no explanation of his plan included. Following a weekend's work the tower opened on Monday and at the end of the week there were no elevator complaints. However, as the story went, management could not detect what work was done or what changes the engineer had made.

EXAMPLE 3 TEMPERATURE CONTROL (shortened from author's experience)
ABC Company needed to store one drum of a self-polymerizing organic acid on the operating floor of one production unit. The area has an electrical classification of Class I Division I Groups C&D (Explosion Proof).
The reactive chemical MSDS (Material Safety Data Sheet) lists a max storage temperature of 95°F and a minimum storage temperature of 70°F; during the summer months in the open building the temperature on the production floor frequently exceeds 100°F and in the winter drops well below 60°F. Above 95°F the stabilizer begins to lose effectiveness and below 65°F separates out of the acid solution.
The self polymerization leads to heat build up and eventually to a drum rupture followed by acid fumes and potential fires.
The initial proposal offered a remote refrigeration unit with cooling for a small drum storage cabinet using an AHU (Air Handling Unit). The storage room had to be tall enough for fork truck access to the pallet holding the acid drum. The plan was to locate the refrigeration unit far enough away so that it could be electrically classified as General Purpose. However this drove costs up considerably for one 55 gallon drum.
A second concept was to build the refrigeration unit directly on the production floor but inside a fresh air pressurized room with interlocks to ensure the exclusion of flammable vapors from the space around the refrigeration unit, this could be done in compliance with the electrical codes (NEC). This unit would then cool the drum cabinet. However, this created cooling problems for the refrigeration compressors and again pushed costs above a reasonable level.
The process engineer offered to cool the interior of the drum cabinet for several hundred dollars and a small amount of ½" pipe with an almost zero maintenance cost and minimal operating expense. There would also be no concerns for the area electrical classification.

EXAMPLE 4 THE PACKED TOWER (1960's event from the Project Manager on the job)
In eastern Tennessee where the mountains are frequently covered in snow the tractor trailer carrying ceramic packing for the packed column slides off the curve and pulverizes the fragile packing inside.
The project is complete except for placing the tower packing. Replacement packing for what was lost in the truck accident is some months away. Searches (by phone in 1960) offered no hope of finding replacement packing.
The Project Manager, a chemical engineer, called in the construction company and produced suitable replacement packing in less than one week.
PROPOSED NEW DEFINITION
Engineering outside the box
"Design efforts pulling solutions for engineering problems from totally unrelated disciplines and fields."

SOLUTION 1 THE NINE DOT SQUARE
Here you'll find the solution for the puzzle as well as the infamous "box", formed by two added dashed lines, outside of which we need to think. By extending two of the lines beyond or outside the "box" we can form one of multiple simple solutions. The pen strokes are numbered in order of placement.



The nine dots form a natural "box" for most viewers attempting to solve the problem. They will not consider drawing lines outside this nine dot box even though **nothing in the instruction places that kind of restriction on the solution**.
I've highlighted this last statement because understanding whether you're in a limiting box or not impacts your range of solutions. For example if your boss says we need to paint the conference room and I'd prefer it to be *white* this time he has placed a restriction on the solution to painting the conference room. Regardless of what paints you may have on hand you can only use one if it is white. You're effectively in a box and there is no exit.
But suppose he had said "and I'd prefer it to be *pastel* this time" and leaves the color to you. It takes one gallon of paint to cover the conference room and you have a half gallon each of both a white and a yellow paint. By mixing these two colors you have a cream color matching the single restriction of "pastel" and requiring no outlay of money for paint. You effectively stepped outside the box of buying a gallon of pastel paint.
If you look at the offered definition and the examples you will see how far outside the traditional engineering education these engineers reached for their solutions to the original example situations. It is sometimes less important how far you reach and more important how diverse the point you pull the solution from turns out to be.
SOLUTION 2THE ELEVATORS

Here the mechanical engineer reaches into the field of human psychology for a solution. Over the weekend several crews of workmen placed floor to ceiling mirrors on either side of all the elevator doors. While waiting for the elevators people were involved with surreptitiously watching themselves and coworkers in the mirrors and not involved with keeping track of how much time it took the elevators to arrive. They had no complaints about the speed of the elevators because they were "entertained" by the show going on in the mirrors.

SOLUTION 3TEMPERATURE CONTROL

Here the chemical engineer takes an item of equipment used in electrical engineering and applies the principles to a refrigeration problem by finding a Joule-Thomson effect electrical cabinet cooler. These units expand air adiabatically producing a stream of cold air and a second stream of hot air. By connecting this small and inexpensive device to an existing plant air line and directing the cold air stream into the acid storage cabinet he effectively cooled the acid without resorting to expensive electrical or mechanical equipment. Balancing the air flow and providing a suitable thermostat to turn the air on and off completed the acid cooling system, winter conditions were solved with a suitably classified 100 watt incandescent lightin the cabinet.

SOLUTION 4THE PACKED TOWER

Here the chemical engineer takes information from a long ago geology class. The facility is built near a quartz outcropping. From his geology class the engineer remembered that quartz had the same level of inertness as glass and by having the construction people crush a quantity of quartz into the proper sized stones he could provide a suitable tower packing. The purpose of the packing being to provide surface area for liquid-gas contact was well served by the irregular shape of the crushed quartz. Obviously the stone packing weighs more than the ceramic rings (Rashing rings) so some reduction in packing volume was required but the tower was functional and survived startup and initial run-up operations until replacement material was available.

AM I IN A BOX?

How do you know if you're only engineering from within a box? Remember "if the only tool you have is a hammer then every problem looks like a nail."

If your first approach to solving any problem is a resort to the major reference book for your field (Perry's, Marks, etc.) then you might be in a box. If your first action is to sit back and consider the problem from different perspectives then you're on your way out of the box.

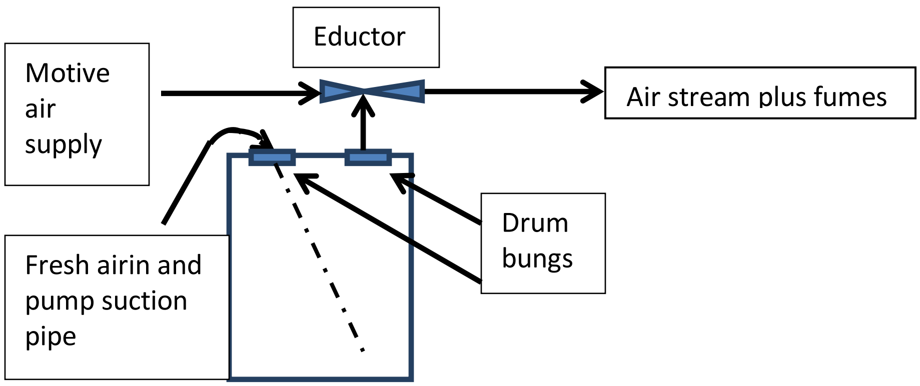
"Looking at a half full glass of water the optimist says the glass is half full, the pessimist says the glass is half empty and the out-of-the-box engineer says "The glass is the wrong size." Poor humor at best but it indicates the difference in perspective necessary to thinking outside the box. Everyone looks at the liquid level almost no one looks at the container. Obviously the liquid level is the problem but in reality the container may really be the problem. Developing the skills necessary to see all aspects (every characteristic) of the problem is critical to any problem solving technique.

EXAMPLE5 EDUCTOR FUME CONTROL

The plant uses an air diaphragm pump to transfer a noxious fuming acid solution from closed head drums to a closed vessel. Fumes from the two 2 inch openings (one for the 1" suction pipe and one to vent the drum) in the closed top drum are very irritating to the operator.

The existing plant liquid scrubber could destroy the vapor but did not create sufficient draft to control the vapors at the drum.

The process engineer had previously worked in a lab that used water eductors (aspirators) to operate small vacuum funnels from this he found an air driven eductor which could use compressed air to generate sufficient vacuum at the drum vent (rigidly piped to the drum bung) to control the acid fumes. Since the eductor could discharge against a positive pressure its discharge was rigidly piped into an inlet for the plant scrubber; its suction side connected directly to the drum vent. The pump and suction pipe were left out ofthe sketch below for clarity; the fresh air comes into the drum through the same bung and around the pump suction pipe.



EXAMPLE 6 AIR MOTOR

In a remote and little visited portion of the plant the screw conveyor handling a waste powder was frequently burning out its drive motor. The problem was an accumulation of the inert dust on the electric motor causing it to overheat. Because there were rarely operators in the area and the discarded powder was picked up by a company that used it as a filler for their product the company was not inclined to spend much money on dust control to protect the motor.

At the latest burnout the plant engineer selected a similar horsepower air motor with a geared output as the new drive to replace the 5 Hp electric motor. Because the air motor developed power by internally expanding compressed air it was self cooling and immune to the over heating caused by the accumulating dust.

EXAMPLE 7 SIDEWALKS

The building construction was complete and tenants were beginning to move into the new three story square building. One attractive feature was the open courtyard inside the box shaped building. All interior offices looked onto this courtyard except those on the ground floor where the internal hallway was against the courtyard walls and had two doors on each side of the square.
The building owner was happy with his new structure except there were no sidewalks in the courtyard although the tenants had walked across it enough to make it obvious which paths were most frequently used.
The owner asked the architect about the sidewalks and was told they needed to wait one more week in order to know where the sidewalks should go.He explained to the owner that the tenants

were establishing the most used routes for the sidewalksas they adjusted to the building by making paths through the courtyard.
Rather than establishing an engineered traffic flow the designer was letting the natural flow of traffic by the inhabitants do the design. This approach was more efficient and required fewer yards of concrete for sidewalks since they were poured only where actually needed.

LOCATING THE BOX
A variety of things can cause an engineer to work only inside a box:

- Management's frequent words "We've always done it this way."
- Rigid corporate engineering design guidelines
- Fear of failure
- A large number of "old hand" engineers on the design team
- National standards, NEC, OSHA, ASME, FDA, etc.
- Local government inspectors with specific expectations for solutions
- Strong union rules
- Validated equipment
- Plant standards, ex. Pipe Codes, Materials of Construction Codes

Today's meeting on a new product was about our inability to cool the chemical reaction fast enough. Everyone was concentrating on the overall heat transfer coefficient of the vessel wall from the jacket. We were not getting the expected cooling even though we were pumping the design rate of cooling water at the design temperature. The problem was resolved when it was pointed out that the vessel was only operating at 80 percent full and our calculation of the heat transfer area assumed the full area of the jacket whereas it was really considerably less than 100 percent of the vessel jacketed area. We could adjust the cooling water flow and the cooling water temperature but since the surface area was fixed it didn't appear in our problem solving options. We were inside a self imposed box and not seeing all of the options to solving the problem. This is not so much an out of the box example as an example of how we can put ourselves into a box which restricts our problem solving processes.
HOW FAR OUTSIDE THE BOX CAN I GO?
Within good engineering practices there is no limit as to how far or where you can go**.**The solution to an engineering problem should be elegant, inexpensive and functional. The solution needs to gain some support as the idea is digested by others; failure to gain support can easily cripple an excellent idea because of lack of effort to make it work by the non-supporters.
HOW DO I LEARN TO "THINK OUTSIDE THE BOX"?
The single most important aspect of thinking outside the box is to question the validity of whatever restrictions you think come with the problem. It is essential to understand that not all restrictions come with the problem, many and maybe most come with your experience,backgroundand education.

- EXPERIENCE RESTRICTIONS

Like many of today's engineers those whose experience consists of years in a design house have views of the available solutions limited to the engineering concentration of the design house. Engineers in large production facilities tend to have very narrow experience lines matching the problems from their facility. For example synthetic fiber facility engineers generally will have minimal exposure to combustion, dry powder handling or bottle filling engineering problemsolutions. On the other hand application of their differing industrial experience to combustion, dry powder handling and bottle filling probably represents thinking outside the box for those areas.

- BACKGROUND RESTRICTIONS

If you grew up in a town dominated by one industry you were most likely told "that's how we do it at the plant" coupled with stories of industrial problem solving success. Growing up in a town saturated with tobacco, textiles and electronics I heard my share of these solutions from family and friends. All of those solutions affected my future thinking about solutions to problems and they became part of my box.

- EDUCATIONAL RESTRICTIONS

If your engineering instruction came from individuals who have always worked in academics verses those in industry you are more likely to look at problems from a theoretical perspective as opposed to a practical approach.
As an example one of my professors was an expert in mass transfer operations (distillation, etc.) and even when he was teaching heat transfer the problems were generally related to heat transfer problems in mass transfer operations.

Your professor's background inadvertently becomes part of your box.

- EXTERNAL RESTRICTIONS

Some problems do not come with restrictions (nine dot puzzle), some come with unstated restrictions (electrical design must meet NEC code) and some come with specific restrictions (paint the conference room white). Occasionally the person presenting the problem includes restrictions without realizing he / she has done so.
One of the plant's managers came from the petrochemical industry and his experience in fluid flow problems was primarily in long transmission lines for oil or gas. Based on his experience he was always trying to solve plant fluid flow problems with the equations used for transmission lines. That experience carried over to his evaluations of his subordinate's solutions to problems.

PROBLEM SOLVING STEPS

There is an infinite list of the steps used to solve problems, most being applicable in some situation. However any attempt to provide a list of "out of the box thinking" steps creates a box of its own. The best that can be done is to provide a list of "Don'ts" of things that tend to impede the process. Learning how to think outside the box really means avoiding creating the box in the first place.

AVOIDING THE BOX

Rather than learning how to think outside the box the engineer must learn how to avoid the box instead. This means eliminating, as far as possible, the effects of various restrictions on the thinking process but not eliminating their constraints. For example painting the conference room pale yellow meets the boss's restrictions while eliminating the normal solution of purchasing pastel paint.

AVOIDANCE	EXAMPLE
EliminateEducational Restrictions	Forget your education as a **chemical engineer** and concentrate on your education as a **problem solving engineer**
EliminateBackground Restrictions	Table at the beginning the immediate classical solutions that appear, don't eliminate these solutions just don't let them dominate your thinking process
EliminateExperience Restrictions	Fall back on general engineering principles instead of those based on any of your long term employment
"Bosses" Restrictions	Try to look beyond his "we've always done it that way" speech
Look for ways around restrictions like the NEC (National Electrical Code)	Substitute a solution without violating the **concept** behind the code or by searching for a non-code solution
Look at each detail of the problem and analyze the activities required	Look at the individual activities required to accomplish the goal. For the conference room: choose paint color, obtain paint, apply paint. Analyze each item individually for solutions
Try to get to the lowest level of the problem	Consider the laws of physics that must be met to solve the problem rather than the equations of a specific engineering discipline
Work backwards	Look for the desired result of solving the problem then work backwards for methods of accomplishing the task
Don't reject fanciful solutions without analysis	Sometimes solutions appear fanciful because they are unusual
Keep thinking	Don't stop the searching process with the first viable solution
Consult with imaginative thinkers and avoid the stagnant ones	This isn't as age related as you might think, old timers with lots of experience are a reservoir of solutions and of solutions that didn't work.
Break the project down into individual activities along with their impact on normal operations: shut down, construction mess, required materials, required labor, etc. Then solve the individual problems related to these items.	Projects are normally broken down into these parts for costing, scheduling, etc. Use this normal activity for the problem solving activity.
Most engineers had to take courses in disciplines other than their own but generally considered those to be support, background or "rounding out the education" courses. These extra courses may have included physics and chemistry but they may also offer potential solutions to engineering problems.	Avoid educational restraints, back in the early 1900's a person educated as an engineer was trained in all engineering disciplines. Their education concentrated on solving diverse problems covering all engineering fields.

BENEFITS TO OUT OF THE BOX EFFORTS

Sometimes the major benefits of thinking outside the box are a new attitude on the part of the engineer as he / she faces future problems. It is important to recognize that not all problems require out of the box solutions, sometimes the simplest solution to a problem is sitting on the shelf at some supply house.

Attempting to force an out of the box solution onto some problems will sometimes create a box of its own and complicate the solution effort.

INCLUDED EXAMPLES	BENEFITS
THE ELEVATORS	Lowest cost option, shortest construction time, least disruption to normal operations, long lasting effects
TEMPERATURE CONTROL	Lowest cost option, lowest operational cost, lowest maintenance cost
THE PACKED TOWER	Lowest cost option, shortest delivery time option
EDUCTOR FUME CONTROL	Simplest solution, easiest installation
AIR MOTOR	A simple solution drawing from a different discipline than the classical solutions, eliminates the over heat problem through physics
SIDEWALKS	Eliminated an engineering decision and replaced it with a “users natural” design

CHARACTERISTICS OF OUT OF THE BOX SOLUTIONS

Obviously out of the box solutions are different from classical solutions by definition but the solutions do share some traits. Understanding those shared traits may make it easier for the engineer or manager to work with the concept.

CHARACTERISTIC	COMMENTS
Generally solves the problem without resorting to classical engineering solutions	For example solving the acid cooling problem by using a non-classical refrigeration process
Generally although not always less expensive than the classical solutions	This is frequently the driver for the approval of the out of the box solution
Most often comes from an imaginative individual or someone with varied hobbies and interests	Frequently pulled from areas not related to engineering
Frequently comes from individuals whose backgrounds include numerous positions in widely different industries	Crosses discipline lines
Frequently not initially seen as a solution by a major portion of the staff	Mirrors and elevators don’t appear to be connected
May resort to basic physical laws	For example the acid cooling solution resorts to thebasiclaws of physics
Frequently comes from a discipline different	Acid cooling for the process engineer from

from the engineer responsible for solving the problem	electrical engineering equipment
The solution may come in a form totally unrelated to the actual physical problem to be solved	For example bypassing an actual solution to the mechanical elevator problem by using mirrors.

REFERENCES
A search engine request on the internet using “thinking outside the box” produces dozens of potential articles and process descriptions for the process. Care must be taken as almost any attempt to produce detailed instruction for thinking outside the box tend to create a box of their own.

CONCLUSION
Most engineers utilize the concept of “out of the box” thinking without realizing it and without making anyone aware of it; they do this by applying parts of their education or experience not related to their educational major. Sometimes these solutions come from hobbies or other activities outside the work environment.

Application of the concept usually provides at least some entertainment and mental exercise for the engineer. At the least unusual solutions that work well generate a lot of surprised looks and comments.

Avoid trying to teach the process and avoid trying to put it on paper, instead concentrate on teaching people to broaden their view to see all sides of the problem and avoid the box.