

DEVELOPING HIGHLY EFFECTIVE ENGINEERS: THE SIGNIFICANCE OF TRIZ

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ABSTRACT

Engineers are generally effective at problem solving but often do not look for the most highly effective and creative solutions. This paper explores ways in which the constraining mindsets can be unlocked for breakthrough solutions, both at the personal, professional and organisational level, to enable 'development' of highly effective engineers.

This paper begins by looking at the habits of highly effective people and then asks 'what is a highly effective engineer'? The paper concentrates on the areas associated with systematic problem solving and creativity i.e., producing breakthrough solutions. Fundamental to this area is the concept that most problems are not problems as such but only limitations brought on by the practitioner's mindset. If one can 'break' the mindset then there is often 'no problem' as the answer or path to the answer is 'obvious'. This paper establishes links to show that TRIZ has the capability of an extremely effective set of tools/approach to help break mindsets, and thus to solving problems effectively. The approach taken is by relating the TRIZ tools to the attributes that other authors have suggested as being associated with highly effective engineers. It is thus found that the TRIZ tools have a significant place in the skills base of the highly effective engineer.

1. INTRODUCTION

In a previous paper (Filmore 2007), the author looked at the practical implications of 'teaching' TRIZ through developing an awareness of mindsets and their power to limit effectiveness. This paper was really aimed at university-level teaching, but had far wider application in the professional development of all engineers. In part summary it said that that the TRIZ teacher has to first to develop awareness in the student that **they themselves are the reason why a solution is not being found!** This awareness has to encapsulate the habits of: not understanding the problem, not fully defining the problem, overlaying assumptions, not being aware of resources available, using only specific thinking preferences (which includes not being able to brainstorm effectively due to misunderstanding), not being aware of psychological barriers etc. These issues are collectively here called 'mindset'. Rather than looking at all the issues leading to a 'mindset', this paper takes a different approach by searching for characteristics of people who 'do not' exhibit an inhibiting mindset nature. A literature search is undertaken for authors who have written about 'highly effective engineers' or similar. As will be seen, little has been published on the engineer in general and so the search has had to be widened to 'highly effective people' in general. The characteristics mentioned are extracted and summarised. These characteristics are then related to general problem solving and the TRIZ toolset in particular.

A Google search or bibliographic database search for 'highly effective engineers' or 'high performance engineers' finds very few hits. The few hits are associated with other

professions e.g., 'highly effective programmers'! Looking at an example (Meier, 2007), finds an issue that has to be taken into account with all papers i.e., that many of the characteristics are not associated with the problem solving and creativity domain or mention explicitly implications in unlocking mindsets in these areas. For example Meier suggests seven habits of highly effective program managers:

- 'Habit 1, Frame problems and solutions.
- Habit 2, Sell visions.
- Habit 3, Deliver incremental value.
- Habit 4, Manage communication.
- Habit 5, Connect with customers.
- Habit 6, Execute.
- Habit 7, Leverage the system.'

Many of the habits are associated with skills of communication, personal management (e.g., time management) etc. and so are outside the domain being considered here. Other areas though need to be analysed carefully. Meier says of 'Habit 1': 'Frames are the things mental models, metaphors, and conceptual frameworks are made of. Simply put, they're frames of reference. Effective PMs (Program managers at Microsoft) create useful ways of looking at the problems and solutions. They create shared frames of reference that help narrow and focus, while keeping perspective.' While issues such as awareness of mental model/metaphors etc are very relevant to mindsets, it is uncertain here what the author is suggesting. Is the author advocating the sharing of mental models (inter-personal communication issue)? If so, how is this done? One could take the issue of 'narrow and focus, while keeping perspective', as part of the process of problem solving. The issue related to this paper is that there is not enough information here to elicit the characteristic related to being 'highly effective'. Another example from Meier also reinforces this observation. For 'Habit 7', Meier says 'Effective PMs know the system they are operating in. For example, they know their product cycle, software development life cycle, key milestones, and key events. They also know who or what influences who. Basically, they know how the system works. While they could paddle down the river without a map, this map helps them anticipate the obstacles and opportunities.' From this one could elicit that he may be suggesting that systems thinking is an effective skill. He, however, goes on and says 'The secret here is that experience alone doesn't create this map. ', but does not fill in with what else is needed!

Relaxing the search criteria to 'highly effective people' etc. finds thousands of hits associated with Stephen R. Covey (e.g., 2004) books on habits of highly effective people and so this is an area that will be considered. Another area that was followed up was to look briefly at the literature on leaders of innovation, particularly in the R&D domain. The rationale here was that leaders are likely to have been/ are highly effective engineers and so would demonstrate the characteristics being looked for. The specific leadership skills, though, are considered to be outside this area of investigation.

2. HIGHLY EFFECTIVE ENGINEERS (PEOPLE)

This section looks at what has been written in the literature about highly effective engineers. The scope is also broadened, as discussed above, to more general issues of highly effective people. Key issues that may be associated with 'breaking mindsets' are identified in this section, by highlighting relevant phrases from different authors in italics and bold. These phrases are then summarised in Table 1.

As has previously been noted, there is little written information on 'highly effective engineers'. It is useful, however, to start with two exceptions. The first is a paper by Kelley (1999) on 'How to be a Star Engineer'. His research team asked top executives, middle managers, engineers, and other researchers for their opinions on how star performers and solid middle performers differ. They gathered 45 factors that managers and star performers believed led to outstanding performance. The four main areas identified were: 'cognitive factors, such as higher IQ, logic, reasoning and creativity; personality factors, such as self confidence, ambition, courage, and a feeling of personal control over one's destiny; social factors, such as interpersonal skills and leadership; and work and organizational factors, such as the worker's relationship with the boss, job satisfaction, and attitudes toward pay and other rewards'.

He observed and commented:

- 'Perplexingly, after two years, our data showed no appreciable cognitive, personal or psychological, social, or work or organizational differences between stars and non-stars'.
- 'Yet, by recognizing this, had we not discovered something critically important? That the four factors we presumed were vital to star performance-cognitive, psychological, social, and organizational characteristics-were not the real drivers at all?'
- 'Most engineers come to the workplace with more than enough potential to succeed splendidly, but most end tip as run-of-the-mill. The stars were not standouts because of what they had in their heads but **because of how they used what they had.**'
- 'The productivity mystery lay in learning how to transform their talents into high productivity--much like turning potential energy into kinetic energy.

Stars, we saw, are made, not born.'

In summary, Kelley (1999) identified 9 strategies to be a 'star engineer':

- 'Initiative (blazing trails)
- Networking (knowing the right people and doing it faster)
- Proactive Self-Management
- **Perspective (getting the big picture)**
- Followership (actively engage)
- Leadership (small I-leadership)
- Teamwork (as joint ownership of a project)
- Organizational Savvy (promote cooperation, prevent conflict, get things done etc.)
- Show-And-Tell (selecting the right message for the right audience)'

The second exception, is the paper by Mullett, (2002) on 'The effective engineer: a challenge - define your own excellence!' Charles Mullett's paper reports on the work of Kelley and Covey (see below). It also discusses the influential book 'Emotional Intelligence' by Daniel Goldberg (1995). Key areas reported, of working with 'extremely effective people' include:-

- Aspiration: **aspiring above the natural 'conformity to peer performance'. NB Effective people 'defined their own excellence'**
- Effective self-organisation
- Effective communication (phone calls, email, writing)
- Effective project management: clear project definition & vision
- Effective time management
- Effective people management (consider how all the different choices will affect each of the different people involved i.e., seeing the whole picture which include people)

In the well known book by Stephen R. Covey (2004), 'The Seven Habits of Highly Effective People', he identifies seven habits, which are examined here. The habits, adapted from the Wikipedia's (2007) entry on the book, are:-

- **First Habit - Be Pro-active.** Being "proactive" means taking responsibility for everything in life. Covey talks about 'Stimulus and Response' and between which we have the power to choose the response.
- **Begin with the End In Mind.** This chapter is about setting long-term goals. Covey recommends formulating a "personal mission statement" to document one's perception of one's own purpose in life. He sees visualization as an important tool to develop this. He also deals with organizational mission statements.
- **Put First Things First.** Here, Covey describes a framework for prioritizing work that is aimed at long-term goals, at the expense of tasks that appear to be urgent, but are in fact less important.
- **Think Win/Win** describes *an attitude whereby mutually beneficial solutions are sought*, that satisfy the needs of oneself as well as others, or, in the case of a conflict, both parties involved.
- **Seek First to Understand, Then to be Understood.** Covey warns that giving out advice before having empathetically understood a person and their situation will likely result in that advice being rejected i.e., thoroughly listen to another person's concerns etc.
- **Synergize** describes a way of working in teams. *Apply effective problem solving.* Apply collaborative decision making. *Value differences.* Build on divergent strengths. Leverage creative collaboration. Embrace and leverage innovation. It is put forward that, when this is pursued as a habit, the result of the teamwork will exceed the sum of what each of the members could have achieved on their own. *"The whole is greater than the sum of its parts."*
- **Sharpen the saw** focuses on balanced self-renewal. Regaining what Covey calls "production capability" by engaging in carefully selected recreational activities.

Elkins & Keller (2003) reviewed the literature on leadership in research and development (R&D) organisations. They cite over 70 papers. They conclude that 'transformational project leaders who communicate an inspirational vision and provide intellectual stimulation and leaders who develop a high-quality leader-member exchange (LMX) relationship with project members are associated with project success. *Boundary-spanning activity* and championing by the leader are also found to be important factors for project success.' They also report work by Bass(1985) that 'transformational leaders encourage followers to *view problems from new perspectives* (intellectual stimulation), provide support and encouragement (individualized consideration), communicate **a vision** (inspirational motivation), and engender emotion and identification (charisma) '.

It is useful to also look at what other people have said about personal effectiveness. Some quotes and statements have been collated in Box 1 below. One other area that could be considered further in the future is to directly focus on the problem solving and creativity literature. A downside of this is losing the link with professional people expressing personal experience on 'effectiveness'. An example is the paper by Dung (1997) arguing for 'wider' problem solving skills c.f. those shown by specialists and suggesting approaches for this, including TRIZ.

In summary, this brief review of the literature has tried to collect together key attributes of highly effective engineers associated with the problem solving and creativity domain. The attributes identified have been tabulated in Table 1 below referenced with their source.

'Knowledge is a process of piling up facts; wisdom lies in their simplification'
 Martin Fischer (1879-1962)

'To understand is hard. Once one understands, action is easy'
 Sun Yat-sen (1866-1925)

On Effective Behaviour:-

- *without initial hesitation*
- *quick in execution*
- *simple but efficient*
- *highly creative, improvisational, yet capable of resolving both the immediate situation and of addressing the big picture as well*
- *expressed from a foundation of poise*
- *liberated from word-thoughts and personal concerns*

James Austin

On Systems Thinking:-

A 'shift of mind' is necessary:

- *from seeing parts to seeing wholes*
- *understanding two kinds of complexity -*
 - *'detail' complexity, where there are many variables;*
 - *'dynamic' complexity, where the relationships are subtle and involve time-lags and feedback processes of which there are two kinds:-*
 - *'reinforcing' feedback processes which are a feature of growth;*
 - *'balancing' feedback processes - as with a regulator or thermostat.*

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Box 1: Quotes and ideas on personal effectiveness

Key characteristics/ approaches	Author
Seeing the whole rather than the parts/ Visioning	Kelley 1999 (perspective), Meier 2007 (Habit 2 & 7)?, Elkins & Keller 2003 (boundary scanning; transformational leadership: creating a vision), Convey 2004 (Synergise), Box 1: Senge & Austin, Dung (1997)
Valuing difference	Convey 2004 (Synergise: particularly related to people)
Aspire above conformity	Mullett 2002
Being aware of our assumption	Meier 2007 (Habit 1)?
Developing win-win solutions	Convey 2004 (Think Win/Win)
'Thinking outside the box'	Elkins & Keller 2003 (view problems from new perspectives; idea generating)
Looking for 'breakthrough' c.f. incremental innovation	See section 3
Risk taking	Elkins & Keller 2003 (leader support of risk taking; project champions)

Table 1: Key characteristics/ approaches demonstrated by highly effective people that may be related to 'breaking mindsets'.

3. CREATIVITY IN THE ENGINEERING ENVIRONMENT

There are many definitions of creativity. A useful collection is given by Dewulf & Baillie (1999), e.g., ‘conceptual combination – merging of two or more concepts resulting in a novel entity’ (Ward et al 1997). Dewulf & Baillie also develop a definition: ‘Creativity is shared imagination’. They also say, ‘creativity becomes innovative when a commercial application becomes apparent’ and ‘if the creativity is not domain specific, it becomes an invention’. A different approach to the definition of creativity is a visual approach from technological forecasting (Meredith & Mantel 1995) or TRIZ trends of evolution (Mann 2002), showing breakthrough innovation as the jumps between ‘s-curves’ (see Figure 1). This identifies another key attribute for engineers, namely looking for ‘breakthrough’ c.f. incremental innovation.

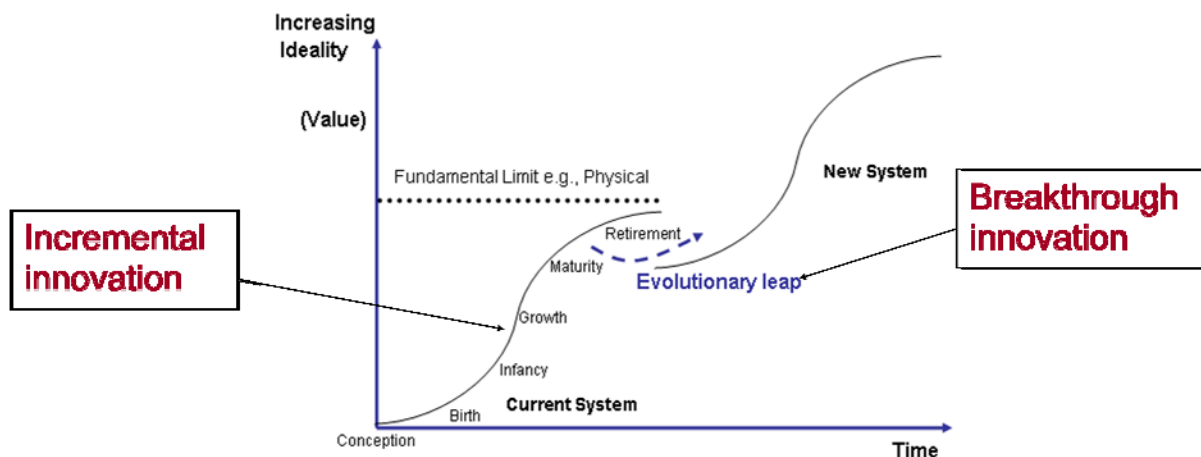


Figure 1: Showing the jump (‘creativity leap’) between s-curves.

4. MINDSETS

Mindsets were defined in section 1 as covering:- not understanding the problem, not fully defining the problem, overlaying assumptions, not being aware of resources available, using only specific thinking preferences (which includes not being able to brainstorm effectively due to misunderstanding), not being aware of psychological barriers etc. Figure 2 shows a very simple model using the TRIZ tool associated with contradictions.

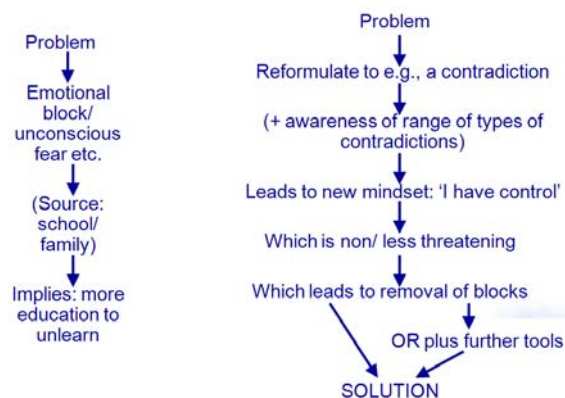


Figure 2: A simple model showing ‘removal’ of a mindset

The approach suggested is that being able to 'see' a structure/ strategy associated with options, rather than just a 'blank wall' (the problem), opens the mind to possibilities and away from stultifying fear etc., i.e. blocks. In Table 2, tries to identify the points helping in unblocking mindsets for a number of the TRIZ tools. It should also be acknowledged that each of the tools is underpinned by a background of published practice/ experience which the learner can explore e.g. The TRIZ Journal. Future research needs to identify good examples associated with each tool and related them to this table.

TRIZ tool/ approach	Points helping in breaking mindsets
Resources and Constraints	* Helps understand and define the problem, and that everything available may be a resource
Functional analysis	* See the problem visually/ holistically/ overview as a system of interactions. * Understand relationships and the different types of interactions e.g., excessive, harmful, insufficient etc. * Identifies intangibles e.g., missing links that need to be explored.
Ideal Final Result (IFR)	* Balancing trade-offs is a limited way of thinking. Start with the ideal and work backwards to a practical position. * It helps identify the benefits. * Some things are free! NB these may be unused resources etc. Believe it!
Contradictions	* Do not use the word 'problem'. Defining a contradiction in terms of an improving and worsening pair(s) makes the issue seem more manageable. * Formulate the contradiction in terms of space or time etc. further helps to open possibilities of understanding and so by reduce mental blocks.
The Matrix	* A great resource of solution triggers * Brainstorm, or use other creative approaches e.g. using Syntetics, starting with these given triggers
Trends	* There is a (physical) limit where putting in large effort will get very little reward i.e., little increase in efficiency/ ideality etc. * Other industries have jumped s-curves already, so why reinvent the wheel? * The difference between incremental thinking and breakthrough thinking (i.e., jumping s-curves). * Which trends have you not considered as being relevant? * Shows us where and when to invent.
9-Windows	* Gets one away from the 'present' and 'systems' level thinking, by forcing one to consider the past and future and sub and super system level. * Helps to zoom in and out of problems e.g., identifying invisible problems and design points.
Problem Hierarchy tool	* Elucidates why you want to solve the problem and what is stopping you etc. * Helps define broader and narrower problem levels
Trim	* Helps to re-simplify a system, as the solving process often adds more complexity e.g. parts. Trim solution to same functionality.

Table 2: Ideas as to how TRIZ helps to break mindsets so that problem solving becomes easy.

The final essential stage is relating the TRIZ tools with what other authors have suggested as attributes needed for highly effective engineers. This is attempted in Table 3, which shows the identified characteristics against tools. NB Details of the tools can be found in Mann (2002).

Key characteristics/ approaches	TRIZ tool/ approach
Seeing the whole rather than the parts	IFR (Ideal Final Result) tool, Functional Analysis
Valuing difference	Being a creative TRIZ practitioner can make one have this awareness as one is always looking for difference.
Aspire above conformity	IFR tool. NB Being a TRIZ practitioner by definition, in the present climate, means aspiring to seek/ learn better tools
Being aware of our assumption	9 Windows, Trends, Resources tool
Using all resources available	Resources & Constraints tool
'Thinking outside the box'	Trends, 9 Windows, Functional Analysis, Smart Little People, Space-time-interface-cost
Looking for 'breakthrough' c.f. incremental innovation	IFR tool, Trends
Developing win-win solutions	Contradictions, Matrix, IFR, Trends
Risk taking	IFR, trends. NB TRIZ practitioners are looking for highly 'unusual' solutions, if using all the tools. Risk in the solution space is thus a common occurrence in practice.

Table 3: TRIZ tools etc. related to key characteristics/ approaches demonstrated by highly effective people.

5. CONCLUSION

This paper has identified a number of attributes of highly effective engineers (Table 1) associated with their potential for creativity and problem solving. It has suggested that creativity and problem solving potential are reduced due to the mindset of the practitioner, using a simple model. It identifies the potential of using different TRIZ tools to break mindsets (Table 2). Finally it relates the identified attributes of highly effective engineers to the TRIZ tools/ approach (Table 3). What should be evident from Table 3 is the strong overlap shown here by the TRIZ tools/ approach, i.e. the tools provide help in all the identified attributes. This implies that TRIZ has very serious advantages that need to be taken seriously by the professional engineering community and should form part of professional development for engineers in general. If future work is undertaken to compare other creativity and problem solving tools to the identified attributes, then perhaps technical managers etc would better come to appreciate the significance, i.e. potential of TRIZ over the useful but very specialised (focussed) tools of e.g., 6Sigma, QFD, Functional Analysis, FTA, FMEA, Taguchi, VA/VE, TQM, Lean etc. which have prominence today. TRIZ thus has yet to see its time of fruition i.e., general acceptance in the portfolio of skills required for highly effective engineers.

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