A Comparison of the Problem Solving and Creativity Potential of Engineers between using TRIZ and Lean/ Six Sigma

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Abstract

The paper introduces the concepts of mindsets and how they may block breakthrough thinking, where breakthrough thinking is considered a characteristic of a person who is highly creative and uses systematic problem solving methods. It introduces previously identified 'highly effective engineer key attributes' and their relation to TRIZ. The paper then reports the development of a questionnaire, where the identified attributes are explored with Six Sigma/ Lean practitioners. Follow-up phone interviews helped to clarify the results. The results were compared between TRIZ and Six Sigma/ Lean practitioners. The results show that Lean Six Sigma has the closest tool set/ approach with that relevant for 'highly effective engineers', with Lean and then Six Sigma of lesser match. It is shown that even with Lean Six Sigma, there is a place for a TRIZ gateway dependant on problem type, and a recommended implementation is suggested here. It is also noted that with all methods, some of the TRIZ tools are relevant to help with the general problem solving stage of any process. Overall in this initial exploratory investigation, TRIZ appears to offer great problem solving and creativity potential for engineers than Lean/ Six Sigma.

1. Introduction

The aim of this paper is to compare the problem solving and creativity potential of engineers between those using TRIZ and those using Lean/ Six Sigma. To do this I shall take previous work on developing 'highly effective engineers' (Filmore 2007a, 2008) and work on 'breaking mindsets' (Filmore 2007b) as the basis. In the work on 'highly effective engineers', key attributes of engineers were identified (and will be discussed here) and then linked to the creativity/ problem solving potential of TRIZ practitioners. Using the 'highly effective engineer key attributes' previously identified, this paper attempts to see how these are manifested by the Lean/ Six Sigma practitioners. It is then possible to 'compare' the TRIZ practitioners with the Lean/ Six Sigma practitioners and to make appropriate observations.

2. Mindsets and Learning

Mindsets were previously suggested (Filmore 2008) as being shown by people who either in full or part:-

- did not understanding the problem,
- did not define the problem,
- overlaid assumptions,
- were not aware of resources available,
- used only specific thinking preferences (which includes not being able to brainstorm effectively due to misunderstanding),
- were not aware of psychological barriers etc.

Mindsets are linked in the literature to learning, i.e., the flexibility to change. For example, having gone through a learning experience, will the person, in the future, if exposed to a similar stimuli, act differently, i.e., have they learnt from the first experience. To learn, one needs to go around the complete Learning Cycle (Figure 1). Whether one learns or not, depends on whether one updates one's individual mental models (mindsets). Note that part of one's mindset is related to shared mental models, i.e., from one's organisation, society etc (see Figure 2). Examples of individual (box titled 'Internal or Individual Personality') and shared (related to 'External or Organisational Environment') mental models are also shown in the creativity model presented in Filmore 2007b.

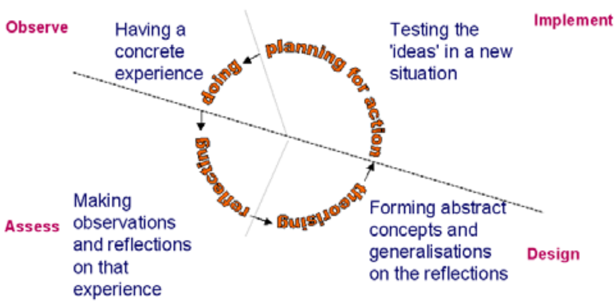

Figure 1: The Learning Cycle and its place at the centre of 'Individual Learning'.
Key: The Kolb Learning Cycle (centre), Lewin's Model (middle), Koffman/Kim (Organisational Learning: outer)

In Single Loop Learning (Figure 2), an individual has tried something out (*implement - action*) and observed a response. They have learnt something, e.g., acquired some knowledge, but with the same circumstances in the future, they **will act in the same way,** i.e., a definition of a 'Mindset'. (NB., the individual and shared mental models may be drawn on, i.e., to affect the individual's actions, but they are not updated.)

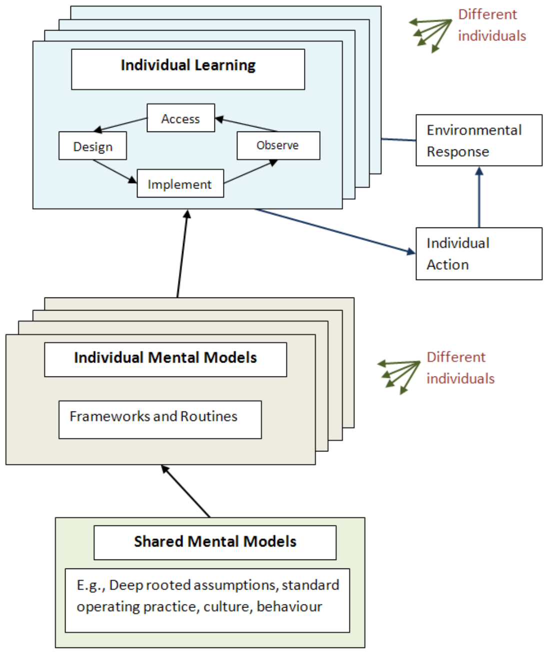

Figure 2: Single Loop Learning; adapted from Kim (1993).

In Individual Double Loop Learning (Figure 3), learning has taken place as a result of assessment (theorising), which has altered the individual's mental models i.e., frameworks or routines (or both). In this case, when for example the same environmental response occurs, then a **different** assess*ment* (reflection) would lead to a **different** implement*ation* (action plan) i.e., it affects future action. (NB., again shared mental models may be drawn on).

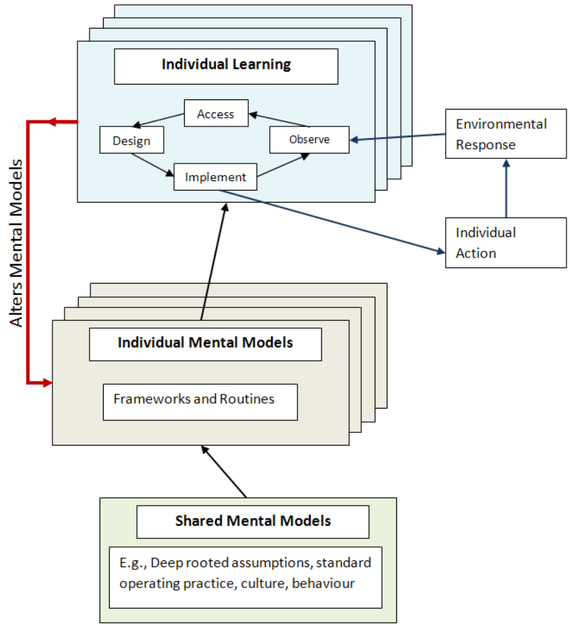

Figure 3: Individual Double Loop Learning; adapted from Kim (1993).

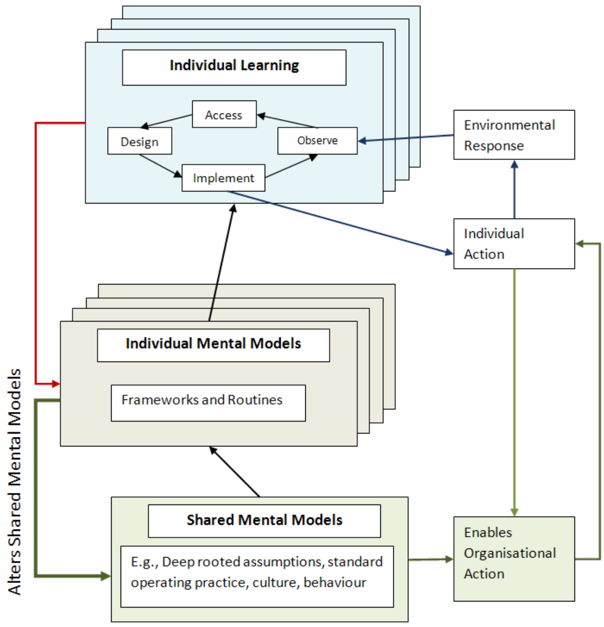

Figure 4: Organisational Double Loop Learning; adapted from Kim (1993).

Organisational double loop learning (Figure 4) occurs when individual mental models become incorporated into the organisation through shared mental models, which can then affect organisational action. E.g., double-loop learning occurs when an error is detected and corrected in ways that involve the modification of an organisation's underlying norms, policies and objectives.

Using the above thinking, the author suggests that there is Team double loop learning (Figure 5) which occurs when individual mental models become incorporated into the team through shared mental models, which can then affect team action. E.g., double-loop learning occurs when an error is detected and corrected in ways that involve the modification of a team's underlying norms, policies and objectives. NB., different teams can act differently as they can have different shared mental models, i.e., different effectiveness level. All the teams though also draw on the organisation's shared mental models.

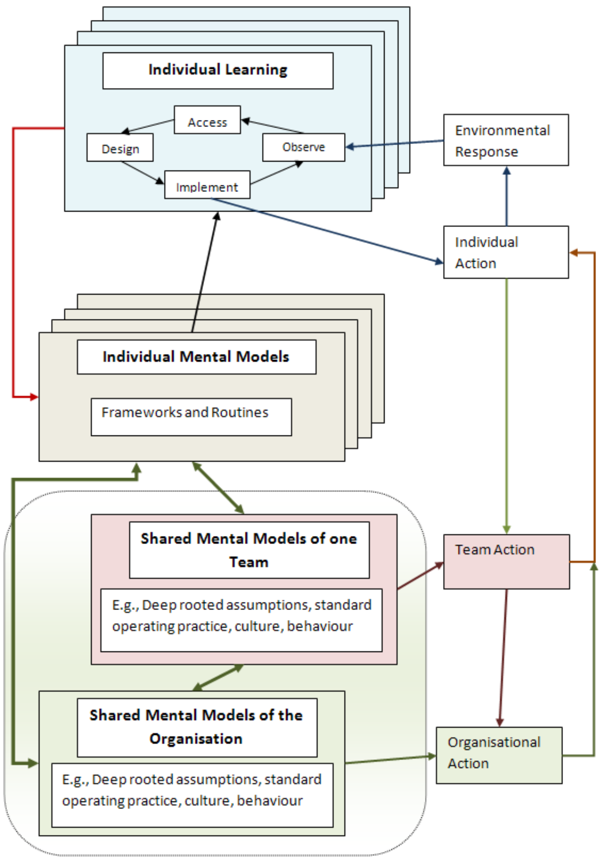

Figure 5: Team Double Loop Learning; based on Kim (1993).

3. TRIZ and Effectiveness

This section reviews briefly the work on identifying the attributes of highly effective engineers and the associations with TRIZ from previous papers (Filmore 2008, 2007a). There is little written about highly effective engineers. What is written is mostly based on how people adapt the soft skills to become extremely effective. As an example Meier (2007) suggests seven habits of highly effective program managers (at Microsoft). Meier says of 'Habit 1' ('Frame problems and solutions'): '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.' This is an example of Individual Double Loop Learning (Figure 3).

The attributes identified (Filmore 2008, 2007a) are tabulated in Table 1 referenced with their source. Table 2 shows how TRIZ helps to break mindsets so that problem solving becomes easy. Table 3 shows TRIZ tools etc. related to key characteristics/ approaches demonstrated by highly effective people.

4. Six Sigma/ Lean and Effectiveness

As discussed earlier, the reason to look at Lean and Six Sigma is that these methods have strong currency and so are promoted by many engineering managers.

A simple questionnaire was developed and circulated to engineering companies in the UK and USA with whom the author had contacts. The contacts asked their Lean or Six Sigma colleagues to fill in the questionnaire. The contacts thus had no link with the author and the majority did not know about TRIZ. The purpose of the questionnaire was to compare if Lean/ Six Sigma could be considered as 'effective' as TRIZ in breaking mindsets i.e., in developing break through solutions. Results were received from the Pella Corporation (USA), Honeywell (USA), Xyratex (UK), Atlantic Inertia (UK) and others.

The questionnaire simply asked the Lean or Six Sigma practitioner to identify:

- Tools that had mindset breaking potential i.e., to fill in both columns of a blank Table 2 (see below).
- Relate the tools to the previously identified 'highly effective engineer key attributes' i.e., to fill in a blank column 2 of Table 3 (see below).
- Give a brief background to their company implementation of Lean/ Six Sigma.

The practitioner was also supplied with the TRIZCON2008 paper (Filmore 2008) which gave the background to the work

5. Results

Six Sigma (Table 4) has fewer tools that people mentioned which could equate to the key characteristics/ approaches of highly effective engineers. Lean (Table 5) appears in a better position with more tools that could be considered to stimulate the above characteristics. Lean Six Sigma (Table 6) certainly shows up the best as it has an identified greater spread of tools. After a number of telephone interviews for clarification, the author was surprised that there was still an apparent underlying assumption that, having gathered all the data, the solution will pop out! As an example, see over, a quote from a Lean Design Manager:-

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), Covey 2004 (Synergise), Box 1: Senge & Austin, Dung (1997)
Valuing difference	Covey 2004 (Synergise: particularly related to people)
Aspire above conformity	Mullett 2002
Being aware of our assumption	Meier 2007 (Habit 1)?
Developing win-win solutions	Covey 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’ (Filmore 2008).

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 Synetics, 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: Initial ideas as to how TRIZ helps to break mindsets so that problem solving becomes easy (Filmore 2008).

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 (Filmore 2008).

Key characteristics/ approaches	6Sigma tool/ approach	6Sigma tool/ approach (e.g., table 3 in the attached paper)	6Sigma tool/ approach
Seeing the whole rather than the parts	SIPOC: A tool for defining Problem, inputs, outputs, suppliers, process, and customers.	Process Flow, Fishbone, DOE	DMAIC, if one doesn't get bogged down in minutiae.
Valuing difference		Run Chart, Histogram, Distribution (plot the data, plot the data, plot the data) different chart formats will tell you different things.	Control charts and COV studies.
Aspire above conformity		The whole 6 sigma tool set – reduce variation, don't just aim for spec limit – aim for nominal.	COV looks for biggest contributor to variation; DMAIC asks that the result be linked to business need.
Being aware of our assumption	Comparative analysis: Tool looks at where and where not, when and when not, what and what not, and how many/how big.	FMEA. DOE will give you fact, assumptions & models can be wrong.	Process Map – Controllable, SOP, Noise, & boundaries
Using all resources available		Maximum info for minimum effort – stats tools will help.	
'Thinking outside the box'		DOE – push process to extremes – even if you don't need to go there – you will learn, and see the process signal more clearly from the noise.	Process Map – finding noise factors often finds a way to a solution.
Looking for 'breakthrough' c.f. incremental innovation		-	COV looks for biggest contributor to variation; DMAIC asks that the result be linked to business need. DOE/Regression looks for the 'big' effects relative to the inherent variation (noise variation…not to be confused with noise factors in process map!)
Developing win-win solutions		-	
Risk taking		Stats tools will help to reduce risk, confirm the data is reality	Predictions based on models of data (DOE/Regression)

Table 4: Six Sigma result examples

Key characteristics/ approaches	Lean tool/ approach
Seeing the whole rather than the parts	Value Stream mapping
Valuing difference	Lean Team experience has proven to me that more successful problem solving teams include different genders, Different generations, different backgrounds, different occupations, and different problem solving styles.
Aspire above conformity	At Toyota a projects success is based not only on traditional launch metrics (cost, timeliness, quality) but also on how much additional knowledge the project has added to the business.
Being aware of our assumption	Toyota production system is an ideal state to strive for in any process. In striving to meet the ideal state of one piece flow reasons arise that we can not meet it. In finding the reasons we are able to further examine the situation and find assumptions that keep us from being able to meet the ideal. Many cases a policy or rule of thumb is an impediment to making improvement rather then a physical constraint.
Using all resources available	
'Thinking outside the box'	Brainstorming both individually and jointly leads to some breakthrough thoughts Trystorming – quickly creating models to simulate, explain, and better understand the concept leads to new discoveries. Partial solutions – team is encouraged to share solutions that may solve some, but not all issues at hand. The diverse team can many times help to fill in the gaps, or may use the understanding gained from the one partial solution to improve the overall final solution.
Looking for 'breakthrough' c.f. incremental innovation	Moonshining – keeping brainstorm solutions alive that may not have an applicability immediately but may down the road. Observance of Nature – how does nature do it and what can we learn from it.
Developing win-win solutions	Improvement of the overall system is a win for all 3 key stakeholders – the customers, the owners, and the employees.
Risk taking	Individuals that understand and believe in the tools and the philosophy know the business very well on many different levels. They have a very deep level of understanding and can make traditionally risky decisions easier because of this understanding. Lean is also very much a culture of constant change for the better

Table 5: A Lean result example

Key characteristics/ approaches	6Sigma tool/ approach
Seeing the whole rather than the parts	Lots of Tools can be used but I would start with "Big Picture Mapping" then use "Value Stream Mapping" in most cases
Valuing difference	Impact Matrix, Pugh Diagrams, Value Stream Mapping etc…
Aspire above conformity	Kano
Being aware of our assumption	DMAIC project management cycle
Using all resources available	Good project management
'Thinking outside the box'	6 Thinking Hats
Looking for 'breakthrough' c.f. incremental innovation	DMEDI/DFSS Tools
Developing win-win solutions	DMAIC project management cycle
Risk taking	Kai-Zen low hanging fruit

Table 6: A Lean Six Sigma result example.

'*My opinion is that we don't need to look for creativity in solving 95% of our problems. We generally know or can quickly identify the issues. It's then **a matter of doing something to correct it**. That's the hard part! The creativity would come into play with new product design. TRIZ certainly would have a place for us there.*'

Surely, '*It's then a matter of doing something*' is the need for creativity/ TRIZ at this point? Not just at the design stage. I think the problem may be that Lean/ Six Sigma thinking is so heavily analytically focused, e.g., on asking questions such as: '*Identify all potential sources of variation: What steps do we do in this process and what are the inputs into each step that could cause variation in the output?*' See Figures 6 and 7. In the authors opinion there is the need to add a gate/ stage in Lean/ Six Sigma (see Figure 8) to give the option of bringing in TRIZ. TRIZ has to be introduced here, if creative or breakthrough solutions are required (NB., this is not needed if only optimisation or trade off solutions are necessary). In many cases, a careful selection of TRIZ tools, not full ARIZ, should be used to promote general problem solving.

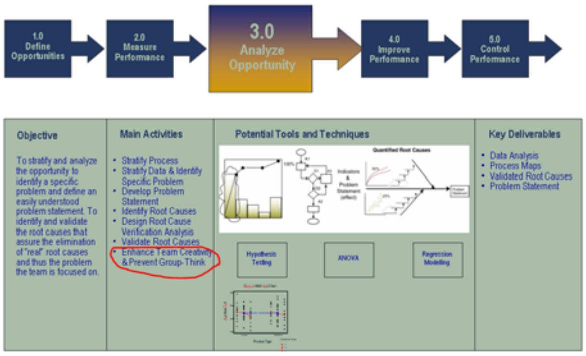

Figure 6: Lean Six Sigma Process stage, where the problem is identified and 'creativity' is encouraged. Acknowledgement Xratex.

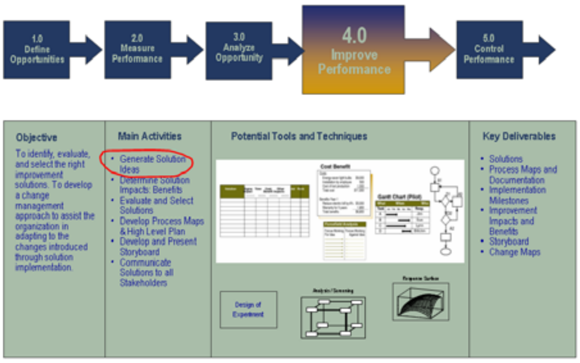

Figure 7: Lean Six Sigma process stage, where the 'generate solutions' takes place. Acknowledgement Xratex.

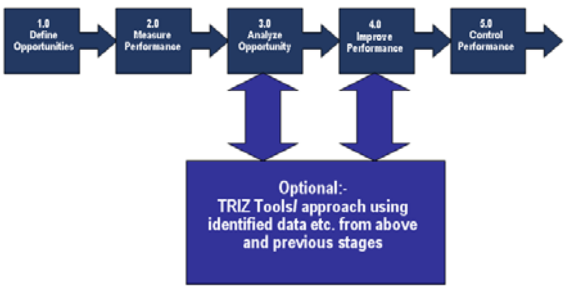

Figure 8: The Future: Lean Six Sigma AND TRIZ

As a TRIZ practitioner, the author finds that TRIZ seems to have a much broader suite of tools to help support the 'highly effective engineer key attributes' (comparison of Tables 3 with 4, 5 and 6), i.e., that TRIZ is better endowed to support engineers in being highly effective. Also the author considers that the TRIZ tools identified (Table 3) are more associated with double loop learning (Section 2), i.e., using the tools is more likely to make the practitioner change their mental model or the teams shared mental model with use. This is less likely to happen with an analytical, e.g., statistical tool, where the result is, e.g., a number, and cannot therefore be easily related to an overview, trend, etc. TRIZ with the 'higher level learning' is thus more likely to lead again to breakthroughs.

So why is TRIZ not yet widely recognised (except at Samsung, Intel(early stages) and a few other companies)? Some of the reasons must be due to:-

- Huge 'vested interests' of the trained Six Sigma/ Lean managers/ black belts etc.
- The reality that Six Sigma/ Lean works well for many industrial problems.
- The lack of understanding that Six Sigma/ Lean does not work for problems requiring breakthrough thinking.
- That Six Sigma/ Lean practitioners perhaps are so steeped in statistical and process thinking that moving outside this arena is very difficult and may even feel threatening.

In retrospect the results from the Lean/ Six Sigma practitioners probably reflected busy professionals who had not (fully) grasped the background to the research or were too interested to show their system (as they were leaders promoting Lean/ Six Sigma) in good light. The majority of the practitioners actually sounded interested in this work and were happy to discuss further. This work really needs face to face interviews to tease out the key factors to some depth before any definitive comparison between TRIZ and Six Sigma/ Lean can be made. The reality, made apparent here, is that TRIZ is doing something different i.e., it is useful for the 5% of problem solving problems that need breakthrough thinking. For the other 95% of industrial problems, a judicious choice of particular TRIZ tools should help the incremental thinking problem solving process, but is not always necessary.

6. Conclusion

This paper employed the previously identified attributes of highly effective engineers associated with their potential for creativity and problem solving to form the basis of a questionnaire. Using the questionnaire it attempted to identify the potential of using different Six Sigma/ Lean tools to break mindsets and secondly to relate the identified attributes of highly effective engineers to the Six Sigma/ Lean tools/ approach (Tables 4 - 6). It shows that TRIZ apparently has a more focused toolsets for creative and breakthrough thinking type problems; i.e., those that have been associated with highly effective engineers previously. The results show that Lean Six Sigma has the closest tool set/ approach with that relevant for 'highly effective engineers', with Lean and then Six Sigma of less potential. Even with Lean Six Sigma, there is a place for a TRIZ gateway dependant on problem type. Also with all methods, some of the TRIZ tools are relevant to help with the general problem solving stage of their particular process. Finally, the TRIZ tools have been associated more closely with the higher order (double loop) learning, in the Learning literature, and so have the potential for greater breakthroughs.

These reasons suggest that TRIZ has very serious advantages that need to be taken seriously by the professional engineering community and should form part of professional development (CPD) for engineers in general. There is need for future work to back up these preliminary results. This will need in-depth interviews. TRIZ thus has still yet to see its time of fruition i.e., general acceptance in the portfolio of skills required for highly effective engineers.

7. References

Filmore, P. (2007a) Developing Highly Effective Engineers, The Third TRIZ Symposium in Japan 2007**,** Yokohama, 30/8/07-1/9/07.

Filmore, P. (2007b) *Teaching TRIZ as a Systematic Problem Solving Method: Breaking Mindsets*, TRIZCON2007, Louisville, Kentucky USA, 23-25th April 2007, Condensed version at:- http://www.triz-journal.com/archives/2008/02/05/#authors.

Filmore, P. (2008) Developing Highly Effective Engineers: The Significance of TRIZ, TRIZCON2008, Kent State University, Ohio, USA, 13-15th April 2008.

Kim, D.H. (1993), The Link Between Organisational and Individual Learning, Sloan Management Review, Fall 1993, pp 37 - 50.

Kolb, D. A. (1984) Experiential Learning. Experience as the Source of Learning and Development. Englewood Cliffs, NJ: Prentice-Hall.

Meier, J.D. (2007) *7 Habits of Highly Effective Program Managers: Software Engineering, Project Management, and Effectiveness*, Blog published 09 http://blogs.msdn.com/jmeier/archive/2007/04/09/7- April 07, habits-of-effective-program-managers.aspx, date accessed 2/3/08.

Mullett, C.E (2002) *The Effective Engineer: a Challenge - Define your own Excellence!* Applied Power Electronics Conference and Exposition, APEC 2002, Seventeenth Annual IEEE, Volume 1, 10-14 March 2002 pp 8 – 13.

8. Presenter's Profile: Paul Filmore

Dr. Paul Filmore has been teaching creativity, personal, professional, entrepreneurial and research skills for more than a decade at the University of Plymouth, UK. At present he introduces TRIZ to over 100 first year engineering degree students and 100 technology Masters (postgraduate) students each year.

Paul runs an innovation consultancy 'The Insight Centre': www.insightcentre.com where TRIZ and other systematic problem solving skills predominate and have recently been augmented by research and practical understanding of how disruptive innovation thinking can help to further break mindsets. He most recently introduced breakthrough thinking methods to a large engineering company in the USA to great effect, with hardly mentioning the word TRIZ! Paul can be reached by email at pfilmore@plymouth.ac.uk and would be happy to hear from others who would like to take this research further or are interested in stimulating breakthrough thinking in their organisation.