

Accelerated Adoption - Strategies for Generating Maximum TRIZ Benefit in Minimum Time

Authors

Prakash R. Apte and S. A. Soman, IIT Bombay

Darrell L. Mann, CREAX

Abstract

The paper reports the output of a large ongoing programme of research to determine high effectiveness strategies for deploying TRIZ. The most successful single study in the research involved 2nd to 4th year engineering students at IIT. Starting from zero prior knowledge, a batch of 12 students was exposed to 10 hours of specially formulated TRIZ lectures spread through a one month 'turbo-innovation' programme. The students were given 'current' problems in the field of MEMS and as a result of TRIZ application the students received a 'best paper' award at an International conference and filed a couple of patent applications.

The paper further reports how cultural contrasts affect the desire to use software aids and how age/experience come into play when certain TRIZ tool are accepted while others are rejected. We believe that successful wider adoption of TRIZ would depend upon matching of age to tool-type. The paper ends with a series of recommendations for organizations and academic institutions wishing to create successful, self-sustaining TRIZ innovation cultures.

1. Need for TRIZ Training

The need for bringing TRIZ to an industry is primarily for "Problem Solving" for example harm elimination and for "Opportunity Creation" as in 'conflict removal' and generating Intellectual Property (IP). The main purpose for introducing TRIZ in an academic institution could be "training students" in 'Systematic Innovation' methods so that results of systematic innovation could be presented at conferences or published in refereed journals. In either case, it is a two step process

- (1) Identifying problems and then escalating them to a 'world-level' problem
- (2) Finding several 'creative' solutions concepts

2. Strategy for teaching TRIZ to IIT students

2.1 Purposes:

There are three 'Main Purposes' of teaching TRIZ to IIT students,
first to get the students trained in formulating the problem in TRIZ way

second to get them to find a new ‘innovative’ solution by working around a ‘well known’ solution (to a specific) problem

third to create ‘opportunities’ by suggesting several alternate solutions to a stated problem.

2.2 Course contents: (5 lectures of 1 ½ hrs on TRIZ)

A 1-month long TRIZ camp was held at Indian Institute of Technology at Bombay, India during May 19–June 18, 2003. Twelve B. Tech. and M.Tech. students of electrical and mechanical engineering departments attended the camp and have applied TRIZ to obtain Innovative solutions to problems related to Micro-Electro-mechanical Systems (MEMS) and these have since been accepted in international conferences!

2.3 Zoom-out : Overview of TRIZ

The course began with an 1 ½ hour overview of TRIZ methodology – giving historical background and introduction to various TRIZ tools.

2.4 Zoom-in : Physical Contradiction

The first 1 ½ hour lecture, after the overview, was on “Physical Contradiction”. The lecture included several examples showing the students how to formulate a ‘physical contradiction’ from the word statement of a problematic situation and how to overcome the contradiction by using the “6-separation principles”.

This lecture was followed by another lecture in a tutorial format wherein a simple problem from day-to-day life having ‘physical contradiction’ was given. One prevalent solution to this problem was explained and the specific separation principle, that was used, was identified. Students were then asked to think of using each of the remaining 5-separation principles to come up with several possible solutions.

Six groups, with two students each, were formed and each group was given a world-problem related to Micro-Electro-mechanical Systems (MEMS). Every week, the progress made by each group in (i) identifying the physical contradiction, (ii) intensifying the contradiction, (iii) selecting the ‘low’ or ‘high’ level and (iv) obtaining the ‘plusses’ of the unselected level by using one of the 6-separation principles was reviewed. All students participated in the discussions.

By the last week of the month, 5 of the 6 groups had come up with several ‘novel’ solutions to the specified ‘world-problem’. The drawbacks of existing

solutions ('prior art') were not only overcome but also a few additional advantages were obtained. Abstracts were sent to international conferences that had sessions in MEMS. The earliest abstract was sent on 30th June 2003. The last abstract was sent on 6th Oct 2003. All abstracts have since been accepted for presentation at the conferences. **One of the papers presented at the ICMAT-2003 conference in Singapore during 7-12 Dec 2003 has received 'best-paper' award!!**

2.5 Zoom-out: Various TRIZ tools

The 2nd, 3rd and 4th week had 1 ½ hour lectures on various TRIZ tools.

2nd week lecture was on elimination of "Technical Contradiction" using the classical Contradiction-Matrix. Each lecture had a 'tutorial' at the end of 45 min in which they were given word statements of some problems and they were required to formulate several 'technical contradictions' and then use the inventive principles to get a few solution concepts.

3rd week lecture and tutorial was on "S-Field model" for eliminating 'harmful effect'. 4th week lecture and tutorial was on "Trends of Evolution" and "Ideal Final Result".

The main idea of zoom-out was that when students come up with novel solutions to the physical contradiction, they should check whether these solutions had in fact something in common with the solutions offered by other TRIZ tools. They were asked to check the following, (i) any of the 40 inventive principles, (ii) absorbing or isolating harmful effects, (iii) a move towards Ideal Final Result and (iv) a move along a trend of evolution.

3. Results:

The students were given 'current' problems in the field of MEMS (which is my area of interest and there is a project with large funding that requires collaborative activity between Electrical, Mechanical and Bio-Medical engineering departments).

- First-stage outcome was related to the formulation of the 'Physical Contradictions'. I acted as the TRIZ facilitator.
- Second-stage results were obtained by using the '6-separation principles' to eliminate the physical contradiction and converting these ideas into MEMS solutions. In most cases, the innovative solutions were simulated and results were compared with known (starting) values. Both pluses and minuses of existing and novel solutions were noted.

- Third-stage results were related to correlating the novel solutions, obtained from separation principles, with some of the 40 inventive principles and with the elimination of harmful effects. The solutions are checked for any moves towards IFR or along specific trends of evolution.

3.1 Papers accepted in International MEMS conferences and journals:

The students were able to submit abstracts as early as July 15th and the last one being on Oct 6th.

All abstracts submitted by the students have been accepted for International conferences of repute in the field of MEMS.

List of papers accepted:

1. Symposium G – on MEMS (a part of annual Material Research Society, MRS meeting – ICMAT-2003 to be held at Singapore during Dec 7-12, 2003.

Following papers have been **accepted** and full length papers have been submitted.

“A novel heatuator”

Authors : Rakesh P. Dhote, Sudhir S. Chiluveru, Saurabh A. Chandorkar and Prakash R. Apte, IIT Bombay

This paper is based on ‘Physical Contradiction’ – 3 more solutions have been suggested using the remaining separation principles

The paper has received the ‘best-paper’ award

2. Photonics West 2004 Featuring SPIE International Symposia: “Micromachining and Microfabrication”, located in San Jose, CA, 24-29, January 2004

Following paper has been **accepted** for presentation and journal publication.

“Improvement in reliability of MEMS resonator using multilayered structures”

Authors : Prakash R. Apte, Nilesh Birari and Priyadarshan Patankar

based on ‘Physical Contradiction’ – Separation in space and by moving to micro level. More solutions using the remaining separation principles. This paper will be presented by Mr. Patankar.

- 3) Photonics Europe 2004, SPIE Conference on MEMS, MOEMS, and Micromachining (EPE106), 26–30 April 2004, Strasbourg, France

The following paper has been **accepted** for presentation and publication in proceedings.

“Temporary Supports to MOEMS Devices for Rigidity during Transportation and Handling”

Authors : Prakash Apte, Sudhir Chiluveru and Omkar Karhade, IIT Bombay.

The paper is based on ‘Physical Contradiction’ – Separation in space and time. More solutions using the remaining separation principles

3.3 Examples of Novel solutions obtained by students

- a) “A Novel Heatuator”
the paper presented at Symposium G on MEMS (a part of annual Material Research Society, MRS meeting) at ICMAT-2003 to be held at Singapore during Dec 7-12, 2003.

The paper was adjudged as the ‘best-paper’.

The heat actuator physical contradiction, faced by the world, is,

The Lower arm should be thick so that

++ Resistance R is lower, heating / temperature “T” is higher (good),

-- but bending is difficult, moment of Inertia “ I ” is higher (bad)

The Lower arm should be *thin* so that

++ Bending is easy, moment of Inertia “ I ” is lower (good),

-- but the resistance R is higher, heating /temperature “T” is higher (bad)

Note that one of the criteria is related to “Electrical Domain”

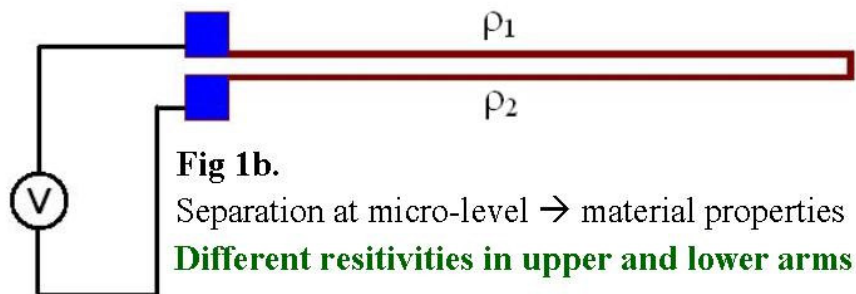
“Electrical Resistance/ heating / Temperature”

Note that the other criterion is related to “Mechanical Domain”

“Mechanical Bending / moment of Inertia”

The **existing solution** is shown in fig 1a. The electrical resistivity of both arms is kept constant (technology constraint has been imposed) and the physical contradiction has been solved in the “mechanical domain” – by choosing the width of the lower arm as narrow near the fixed end and

keeping it wider elsewhere. This allows ease in bending and has been an accepted solution world wide! This obviously uses “separation in space” to resolve the physical contradiction..



The **novel solution** is obtained from considering other separation principles! The principle of moving towards micro-level all the way to material properties has been suggested by students. This would need a change in the material property of the lower arm – specifically its resistivity. When one uses this solution, there is no more a need to make the two arms of unequal width (Fig 1b). The solution not only overcomes the main contradiction but also gives several additional advantages like faster time response, less heating energy to operate etc.

- B. “Temporary Supports . . . during Transportation and Handling”,
a paper to be presented at the Photonics Europe 2004, SPIE Conference on
MEMS, MOEMS, and Micromachining (EPE106), 26–30 April 2004,
Strasbourg, France

Micro-mirrors made in MEMS are usually broad structures and hence are held by cantilever shaped springs as shown in fig 2. The physical contradiction for such a micro-mirror has been,

PHYSICAL CONTRADICTION

The cantilever support for the mirror should be *compliant (flexible)*

++ for ease in deflecting the mirror (good),

-- but it tends to break during transportation and handling (bad)

The cantilever support for the mirror should be stiff (strong)

++ for it to withstand shocks during transportation and handling (good), --

-- but it is no more compliant (bad)

Note that one of the criteria (ease of deflection) is related to the
“life stage of operation/use”

Note that the other criterion (breaking due to shock) is related to the
“life stage of packaging and transportation”

There is no existing solution! The separation principles suggest separation,
(i) in space, (ii) in time (iii) moving towards micro-level → change in
properties and (iv) on condition

When all these separation principles were applied, the students came up
with a solution that uses all 4 principles. The solution provides temporary
supports during manufacture and transportation (see Fig 2a and Fig 2b).
These supports are to be ‘broken’ once the device is installed in its final
location. The suggestion is that the narrow supports be ‘fused’ by passing
electrical current through them.



Fig 2a. Unsupported polysilicon cantilever mirror



Fig 2b. Polysilicon cantilever mirror with supports

3.4 Novel solutions leading to patents

Two of the problems given to the students have lead to ‘novel’ solutions that were judged by IIT Bombay’s IPR committee as worthy of filing for patents! Accordingly, further idea development and prototype building has been initiated.

4. Discussions:

4.1 Background on MEMS :

The lead authors are working in a field called Micro-Electro-Mechanical Systems (MEMS) and the field consists of making sensors (defined as any energy form to electrical energy) and actuators (electrical energy leading to mechanical stresses/ strains/ displacement/ motion).

In MEMS, the three domains of interest are Electrical, Thermal and Mechanical. All the domains are modeled by differential equations and each domain experts have software packages to solve complicated structures and non-linearities.

4.2 Improvements using knowledge from your own domain

If all have same model, then their problems and solutions should be similar! Since I am an electrical engineer, I know how to simulate electrical circuits – why should I not simulate all other domains by simulating ‘circuit analogues’ for the other domains like ‘Thermal’ and ‘mechanical’ that are important to understand their interaction with ‘electrical’ domain!

All three papers, including the one that got the best paper award belonged to this category – tough mechanical problems were solved by using electrical domain knowledge.

4.3 Inventions using knowledge from other domains

TRIZ recommends “use knowledge from other fields” to make your solution strong, but *paradoxically* we reverse the suggestion (a la ‘inventive principle – do the other way around’) and use knowledge from ‘my field’ into ‘other fields’

This has also worked very well with students who have ‘little’ background or interest in ‘other fields’. They prefer to learn more in their own fields.

I look at a contemporary system (that is delivering a function) or even look at a patent that describes a better, improved system (with modified/ superior/ additional performance) and

If - I can identify a 'Physical Contradiction' and know 'one' solution → then I can attempt the (5) remaining separation principles!

This has been found to be an instant success with students. Both patent applications involve eliminating problems in electrical domain by using mechanical domain knowledge!!!

4.4 General Overview Of Educational Learnings

The paper reports the output of a large ongoing programme of research to determine high effectiveness strategies for deploying TRIZ. The programme, both at IIT and beyond, has now included a broad range of disciplines, skill-types, age groups and cultural backgrounds. Collecting together the experiments described here plus those taking place in other parts of India, in Malaysia and in parts of Western Europe, to date, over 1500 students and industry participants have been involved. The main theme of the research and of the resulting paper is the identification of strategies that generate high quantity and quality of output in relation to the time devoted to teaching the philosophy, methods and tools of TRIZ.

Some of the resulting quality and quantity of output has been measured in terms of number of patentable solutions and, in the case of academic situations, in the number of papers produced. In the IIT case and in others, delegates undergoing the education usually start from zero prior knowledge of systematic innovation. Typical 'turbo-innovation' programmes contain 10 hours of specially formulated TRIZ lectures. In the IIT case, these lectures were spread over a one month period. In industrial settings, the period usually reduces to an intensive two-day programme. A clear finding when comparing these two extremes is that the benefits of the elongated timespan are significant.

There is a strong connection to the well-known Peter Senge discussion with a Ford engineer reflecting on her experience in learning a systems engineering approach; in that story, a comparison with calculus was drawn. No-one expects to master the intricacies of calculus in three days, and yet we expect that it is possible to teach things with a comparably rich content in a three day workshop. The additional thought that can be drawn from the experiments done at IIT and at a comparable course taught at the University of Bath in the UK is that given the 'right' structure it is possible to deliver a deep understanding of TRIZ ideas in a relatively short period of time. An important element of the definition of 'right' in this case is the concept of zooming-in and zooming-out described in this paper. Being able to convey the essence of a big-picture in parallel with the teaching of

the necessary details of the various individual tools in the TRIZ toolkit appears to be an important success factor.

This big-picture perspective becomes more difficult as education shifts to the industrial setting we have found. This is because delegates frequently have a worldview that is significantly broader than that found in a population of undergraduates or fresh graduates. In this situation, we believe it is vital to set TRIZ in the context of the tools and techniques that delegates are already familiar with. Strategies that attempt to ignore the existence of other techniques (QFD, Axiomatic Design, DeBono, Buzan, Simplex, etc) are almost pre-destined to fail. This undoubtedly causes difficulties from a teaching perspective – for a start it means that the education materials will need to be modified potentially for every different audience. Difficult as this might sound, it is our belief that it is a fundamental issue. The zoom-in/zoom-out approach becomes important in attempting to satisfy this adaptive material requirement since it is primarily the ‘zoom-out’ parts that set the context and allow delegates to connect their world to that of TRIZ.

Another finding that emerges from a comparison of the long time-span versus two-day intensive teaching strategies is the important role that incubation plays in the outcome. The human brain continues to process information even though we may not be consciously aware of it – one of the ways we can see this process in action comes when we think of how many times the ‘good’ ideas come to us at apparently quite random moments, often when we are relaxed and far away from the work setting. As yet, we do not have sufficient data to know whether the one-month camp method is any kind of optimum. What we do know, on the other hand, is that if we imagine a spectrum of possibilities ranging from the two-day intensive to the one-month camp that there is a highly non-linear relationship between total duration and benefits. A shift to a one-day-plus-gap-plus-one-day, or (even better) to a two-day-plus-gap-plus-one-day has produced significantly stronger results in terms of both likelihood of continued use of the tools and solutions obtained than the two-day intensive workshop. Structures that have extended this idea to a two-day-plus-gap-plus-one-day-plus-gap-plus-one-day format have not thus far produced results that are significantly better.

4.5 Software

TRIZ is primarily a thinking process rather than a software tool. In this area the studies identified sharp cultural contrasts in both the desire to use software aids and the quality of the solutions obtained to given types of problem. The IIT camp was taught exclusively without software. Generally speaking, when the authors teach other formats with delegates previously unfamiliar with TRIZ, the teaching is also done without software. Or, if software is used, it is merely there to act as either a repository of knowledge (for example exercise to familiarize delegates with the trends of evolution seem to work much better in the presence of animated

graphics) or as a convenience (for example, drawing a function and attribute analysis model – where it is often helpful to be able to manipulate images as they evolve; something that is difficult to do when using pen and flip-chart). The prerequisite if software is used in either of these settings is that the learning curve should be zero. A brain that is in the mode of learning to use a piece of software appears to be using parts that are quite dissimilar to one that is seeking to develop inventive solutions to a problem. The separation of mechanistic and creative aspects in a workshop, therefore, also appears to be an important success factor.

In some contexts, we have that the presence of software causes other problems. In India, for example, we often see a strong inclination towards using software (do an exercise on the Inventive Principles, for example, using software as an aid is almost guaranteed to produce a room full of people fighting to get their hands on the mouse and looking at every other tool apart from the Inventive Principles within about five minutes). In other parts of the world, and when delegates are older, there is usually a struggle to be the one furthest from the mouse or keyboard.

4.6 Psychological Inertia

Psychological inertia is one of the main problems in the design of the human brain that TRIZ tries to resolve. In this part of the research we explored strategies for overcoming the common psychological inertia effect of delegates arriving at a workshop with neutral or often negative perceptions of ‘creativity’ education. Frequently in the industrial setting, the idea of people being sent on a workshop to help them become more ‘creativity’ can very easily result in a group of delegates with a very negative mindset at the outset.

There appear to be many issues at stake here. Reference X has discussed the subject of resistance to the use of TRIZ (or in fact any other method) at length, identifying a whole roster of different reasons why people may be resistant to learning about TRIZ. One factor, however, appears to emerge as dominant. This is an effect we usually refer to as ‘me-versus-TRIZ’. Any student or workshop delegate that enters a mindset where they are trying to prove to themselves (and, even worse, to others) that they can do a better job than TRIZ will achieve only one thing; sure-proof in their minds that they have. Strategies to avoid the ‘me-versus-TRIZ’ effect are an important element of a successful outcome.

Achievement of an ‘early success’ is another important psychological effect. Here a very strong correlation between the solving of an apparently intractable problem and the likelihood that people will want to go on and learn more aspects of the toolkit. There also appears to be a significant ‘observer’ effect in action too – in that students seeing their colleagues having successes makes them more likely to want to learn the tools and to achieve successes of their own.

4.7 Age effects.

We still have insufficient data to report definitively on the correlations we observed between the age of people receiving the TRIZ knowledge and the types of tools within the toolkit that they were most likely to accept or reject. On the other hand, there are a small number of phenomena that appear to be consistently applicable:-

- i) the older the recipient the less likely the physical contradiction separation principles or 40 Inventive Principles are to be seen as 'valuable'. (Exception: non-technical managers appear consistently adept at using the Principles with no prior awareness – provided they are presented in a suitably no-technical manner)
- ii) there appears to be little significant correlation between acceptance of the trends part of TRIZ and age. On the other hand, the older the audience, the greater the tendency to want to challenge validity and to try and find exceptions.
- iii) The S-Fields part of TRIZ appears to polarize recipients like no other tool. The tool requires a very different mode of thinking than is natural to the way in which most people have been taught. Here we have noticed two common reactions; in younger recipients there is an initial open-ness to the concept, but this is very often followed by rejection on the grounds that the tool is too abstract. At the other end of the spectrum, the reverse phenomenon consistently occurs with older delegates, where important insight follows initial rejection.

We believe this matching of age to tool-type has important implications on the successful wider adoption of TRIZ.

Conclusions

The IIT TRIZ 'turbo-innovation' camp has been shown to be a highly successful model for use in an educational context. The academic output is a strong testament to both the pulsed-lecturing and zoom-in/zoom-out teaching strategy. We believe that the model has much to contribute to improving the manner in which industry-based workshops are taught.

Context appears to be the next most important factor in the success or otherwise of TRIZ teaching programmes. Specifically, programmes that seek to teach TRIZ without due consideration of the world-view of its audience is also doomed to failure in the large majority of instances.

Research to identify other teaching factors that will contribute to the successful deployment and application of TRIZ is still ongoing. At the present time, the focus is on age, culture and psychological inertia issues as the next three most significant factors influencing teaching outcome.

References

'If TRIZ Is So Good, Why Isn't Everyone Using It?', CREAX newsletter, April and May 2003.