TRIZ – trans-disciplinary innovative methodology

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SESSION S2: Educating the Edisons of the 21st Century

CONTEXT

Tremendous rise of knowledge in all spheres of human activity has led the need to find answers on eternal question about education content (subject, “what to teach“) and form of education (manner, form, “how to teach“). The curricula content is being by broad variety of specialisations. The form of education is aimed at securing an extensive knowledge base for students to acquire subject knowledge (to know ´what´). Much less accent is put on the development of student´s habits and soft skills to learn methods (to know ´how´). The effort to develop a systematic approach to the technical problem solving and creativity potentials (to learn ”how better” or “how else”) receives little attention. The last two issues, a systematic approach and creativity are not cultivated enough throughout the educational process and in companies. On the other hand, analytic and synthetic methodology is available derived from the patent state of the art called Teoriya Resheniya Izobretatelskikh Zadach - TRIZ. It is the Russian title and acronym for the “Theory of Inventive Problem Solving”. The methodology can go with users, step-by-step, through systematic object analysis up to creative conceptual solutions.

PURPOSE

The purpose is to illustrate the innovative potential of the TRIZ methodology for engineering education and for innovative projects solved in companies. The aim is to summarise the experience of implementation of TRIZ in Czech Republic and Slovakia obtained during the last 20 years.

APPROACH

The TRIZ methodology is explained shortly, then benchmark and two successful practical applications in practice are presented. And in the third part of the paper the experience of TRIZ implementation is summarised. The benefits of TRIZ methodology are illustrated on the basis of evaluated answers given by the students and mainly specialists from R&D departments. The question why TRIZ as an analytic and synthetic methodology is not implemented to a greater extent remains unanswered.

RESULTS

The potential of TRIZ to improve attractiveness of engineering studies and to increase self-confidence sot those coming up with real innovations is unique. Nevertheless, mastering of the relatively complex and sophisticated TRIZ is not easy. That is why experienced lectures able to motivate students are needed as well as coaches for implementation in companies.

CONCLUSIONS

The TRIZ methodology can be studied and mastered. TRIZ can bring qualitative change in teaching and learning and increasing the ability of users to solve technical problems systematically and creatively. A systematic approach together with creativity is combination of skills required in today´s engineering education and in tomorrow´s innovative practice.

KEYWORDS

TRIZ, education, engineering, innovation.

What is TRIZ

The life cycle of a technical object is always accompanied by problem solving through all phases. First of all, the problems have to be analysed to identify the crucial ones correctly. Then derived inventive tasks can be formulated and tackled effectively.

TRIZ is the methodology developed since 1946 by G. A. Altshuller (1956, 1989). It is still being developed and applied in many countries by his followers. TRIZ respects a systematic approach to the object to be innovated and, consequently, enhance of its users.

Of course, TRIZ does not replace the designer’s thinking, but methodically and significantly improves concentration and focus of solvers on step-by-step analysis of the object to formulate problems relevant to the target of the innovation project. Then it offers the generic (heuristic) recommendations for dealing with typical inventive tasks transformed from innovative problems. Whether the user interconnects abstract recommendations with specific conditions of the problem solved in his mind and intensifies his knowledge in this way - depends on his/her mental ability.

The methodology of TRIZ consists of two complementary methods.
The first method is advanced VEA – Value Engineering Analysis of the object (design or process). It is a systematic support of users which helps to find the answers to the questions “what and why” in the object has to be improved. The result of the object analysis is a list of formulated problems to be solved.
The second method is the heuristic Algorithm of Invention Problem Solving. It is translation of the Algorithm Reshenia Izobretatelskikh Zadach – ARIZ of Russian origin. It is a working procedure of the algorithmic type, a chain of the thinking ´tools´ for seeking idea of solutions, the tactics of users, the algorithm which assists in seeking the answers to the questions of ´how´ an innovation problem, resulting from previous VEA, could and should be solved.
Those interested in more information and TRIZ study will find many available publications and offers on the web portals.

How TRIZ helps a solver

The user of TRIZ in team cooperation initially analyses the object and its inherent problems. Then, within the frame of mentioned algorithm, innovative problems have to be transformed into inventive tasks in several typical forms which are: Technical Contradiction - TC; or Physical Contradiction - PC; or Model of Conflict of two interacting substances – MC; or Problematic Technical Function - TF; eventually unsatisfactory ´state´ of some component. After that the specified TC can be overcome by the recommended Inventive Principles - IP. The detected PC can be resolved by means of relevant Separation Principles - SP. The model of substance-field conflict - MC can be solved by several transformation Models of Solutions - MS. Problematic TF can be improved or principally changed by the recommended Effects from natural sciences - EF. Future ´state´ of the object can be predicted by ´consultation´ with more Trends of Engineering System Evolution - TESE. All the mentioned abstract recommendations offered within the frame of ARIZ can be understood as being heuristic, inspiring various inventive ideas to tackle inventive tasks identified inside the innovative problems (Devoyno, 1996; Salamatov, 1996; Souchkov, 2010).

Some of these inventive tasks and recommended heuristics will be shortly demonstrated in the following educational example and then in two examples of a real innovations.

A problem, derived tasks and heuristics recommended for its solutions

A clarifying benchmark will be used now to explain the four typical formulations of inventive tasks (TC, PC, MC, ´state´ of the object) and relevant heuristics mentioned above.

As a case the following problem will be considered: “How to improve the stability of the yacht intended for sailing under the conditions of strong side wind”? It is known already that the problem should be reformulated into the form of several typical inventive tasks.

Technical contradiction (TC) and Inventive Principles (IP) to overcome it

TC is specified in the problem when the usual manner to improve one characteristic or parameter leads to the worsening of another characteristic or parameter (Figure 1). For example: when the width of the hull is increased to improve stability (positive effect, **+**), the speed of the yacht decreases (negative effect, it is **-**). The one generalised inventive principle (IP, heuristic) relevant to dealing with this specific TC is: ´Segmentation´.

Physical contradiction (PC) and Separation Principles (SP) for its solution

A deeper analysis of TC (according to several steps in ARIZ or built-up Root Cause Analysis – RCA diagram) leads to the physical contradiction PC as the cause of TC.
An extremely important feature of PC formulation is that it indicates only one component and dictates contradicting values for one specific parameter of the component. In case of the yacht there is one possible formulation of PC: The hull´s (component) width (parameter) has to be increased (value of parameter) to achieve stability (**+**) and the hull has to be narrower (opposite value) to retain (do not lose) speed (**+**). For engineers unfamiliar with TRIZ and ARIZ the formulation of innovation task in the form of PC is hardly acceptable. But it is important and good to know that PC is a dialectical formulation and the best possible formulation of the cause of TC as well as the problem to be solved. That is why the paradoxical formulation of PC shifts solver´s thinking to the "aha effect", to the moment of finding an idea solution. One of the relevant separation principles offered (SP, heuristic) to solve the PC is: ´Separate in space´. (Devoyno, 1996; Souchkov, 2010)

Model of Conflict of substances (MC) and Model Standards (MS) for its solution

Perceived as a model conflict of two substances – MC can be the conflict (in this case insufficient interaction) between the hull and water because the hull in water can be easily inclined under action of strong side wind. The so called ´Su-Field´ analysis - another part of ARIZ - offers several model solutions - MS for such MC. Particularly for MC – insufficient hull interaction with water - ´Segmentation in space´ is recommended again (Belski, 2007).

Recognised ´state´ of the object and offered inspiration from trends

An analysis of the object gives good information concerning the state of each component, including the working ´tool´. One of the several trends of engineering systems evolution - TESE states: "Working tools of technical systems develop in a trend of rising segmentation". The working tool of the yacht is the hull delivering shipload principle to the yacht. A standard hull is a monolith. According to the ´trend´ mentioned, the hull should be divided.

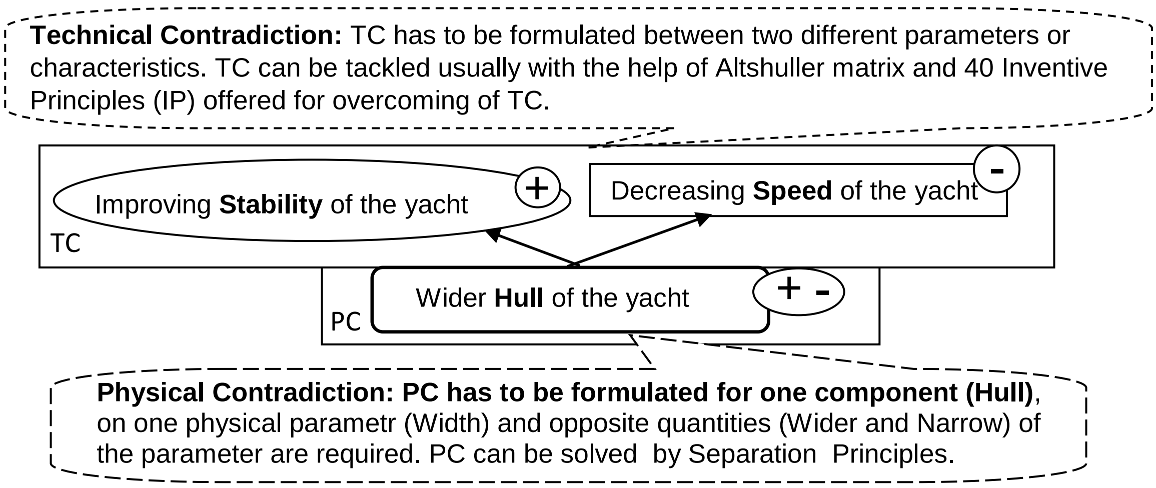


Figure 1: Positive (stability) and negative (speed) effects in TC and PC (wider hull) as a cause

Now, after this extremely short demonstration of only four solving instruments (IP, SP, MS and TESE) a provocative question is relevant. How far or near is the problem solver from the ´aha effect´, from the moment of finding an idea solution? Well, the solver obtained four heuristics, abstract but more or less relevant recommendations how to arrive at ´win – win´

solution. The solver should think about ´segmentation´ evoked several times. How to transform these heuristics into an idea and conceptual solution? How to improve parameter stability AND retain the speed of the yacht in this case? Psychologically inert men remain ´far away´ and intact, while an ingenious engineer should be inspired enough. It depends on the solver´s abstract thinking ability. It is known that an engineer should be able to combine abstract and specific thinking. “If you think you are an engineer – think” (TRIZ folklore).

Product and process Innovations with TRIZ – case studies

Two case studies will be presented as cases of successful application of TRIZ. But it is not easy and effective to describe application of the analytical and synthetic part of the TRIZ methodology and innovations achieved, because the paper format is limited. Only short description of problems, solving ´instruments´ used, figures (Figure 2, 3 and 4) and summarisation of results in tables (Tables 1 and 2) comparing the states before and after innovations follows in this section.

The first case presents an innovation of an active hinge of car bonnet, which was innovated to improve security of pedestrians in collision with cars namely at pedestrian crossing in towns where the most severe accidents are occurred (Figure 2). Fast and controlled lifting of the bonnet by motion of an active hinge, can extend deformation zone, absorb impact energy and mitigate the consequences of collision between pedestrian´s head and rear end of front car bonnet.

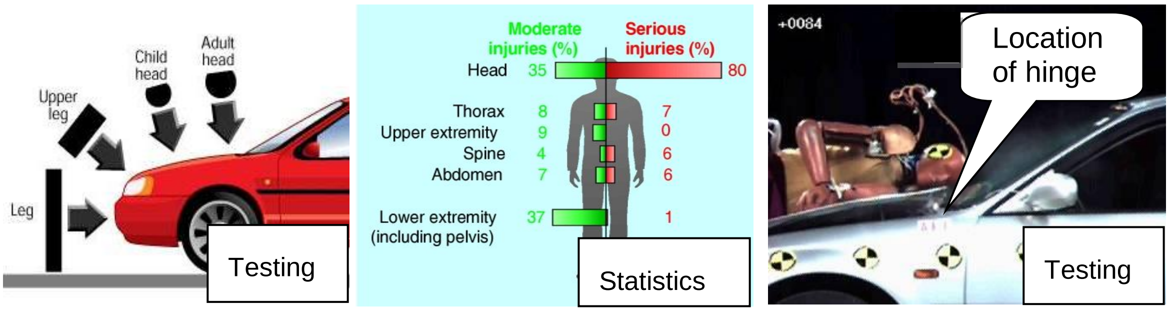


Figure 2: Statistics indicate the percentage and severity of head injuries (Euro-NCAP, 2012)

Which parts of TRIZ methodology have been used? At first it was analysis of the existing complicated and slow active hinge of the bonnet. Then some parts of ARIZ were applied. It means formulation of TC and partial inspiration from IPs, formulation of PC and inspiration from SPs, trimming components and merging of two alternative systems (Figure 3), key technical function and inspiration from “ball lock” effect for design of a new actuator were considered.

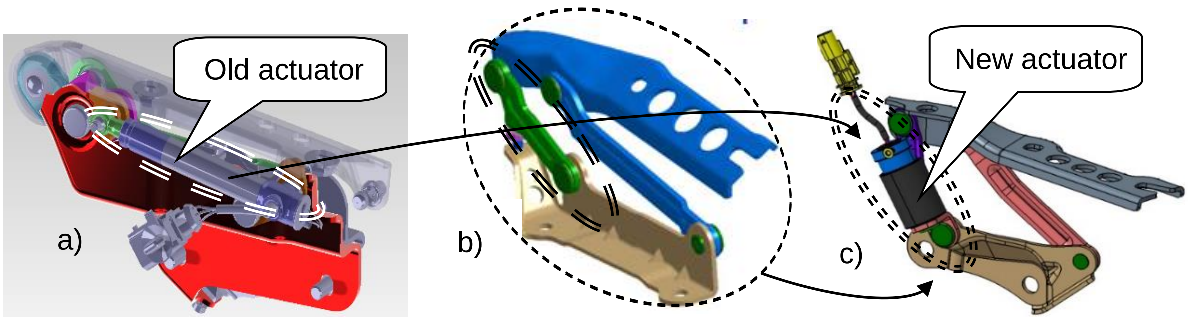


Figure 3: Old complicated and slow active hinge of front car bonnet (a), old passive hinge (b) and new simple and quick active hinge with new actuator (c)

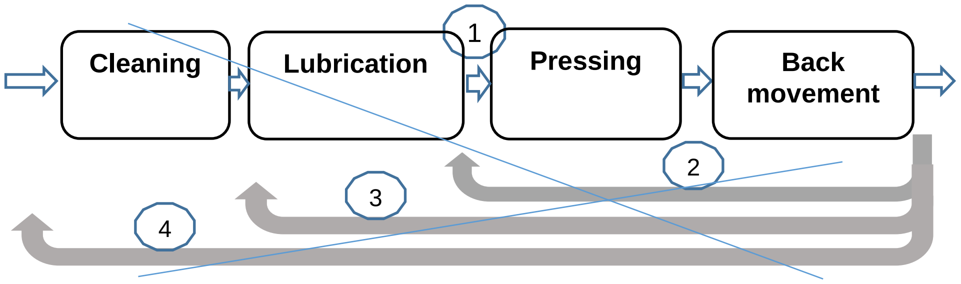
The new active hinge of the bonnet design with a new actuator meets technical and legal requirements and has several important benefits (Table 1).

Table 1: Comparison of the old and the new active hinges of car bonnet

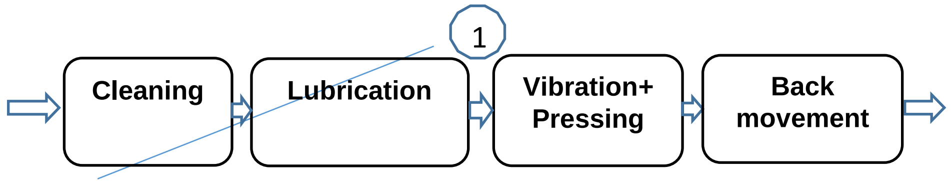
Comparison criteria	Old active hinge	New active hinge
Number of parts of the old and new active hinges	100%	48%
Uniformity of parts (passive hinge / active hinges)	20%	75%
Production cost	100%	60%
Time necessary for relaxation	4-6 ms	Lower than 1 ms
Pyrotechnic element: cost of replacement	100%	55%

The second case presents an innovation process, in particular improving effectiveness of ceramic cores production in pressing process.

Casting systems often include ceramic cores produced by pressing. The specific pressure on the pressed mass during pressing process is relatively high, and therefore negative effect occurs - "sticking" of the pressed mass to the surface of the mandrel. To reduce this negative effect, the ceramic core cannot be pressed on one stroke of the mandrel but has to be shaped in 4 cycles including 13 sequential operations (Figure 4). Value of the original pressing process is low.



Pressing process before innovation: Four cycles,13 operations in total.



Innovated pressing process: One cycle, only 2 operations

Figure 4: Comparison of original and innovated pressing of ceramic cores for casting

To increase the productivity of the pressing process of quality ceramic cores, some parts of TRIZ methodology have been used. At first, Root Cause Analysis – RCA diagram has been performed (Souchkov, 2010) to identify and visualise contradictions resulting in the negative effect of „sticking“. Then a good new solution of contradictions has been found with the help of inventive principles and separations.

Table 2: Comparison of original and innovated pressing of ceramic cores for casting

Pressing process	Number of mandrel movements	Number of operations	Production time [s]	Productivity [cores/7hours]
Original, 4 cycles pressing	8	13	25	810
Innovated, 1 cycle pressing	2	**2**	12	1550

Experience from implementation

TRIZ methodology has been popularised in the Czech Republic in technical journals sporadically since 1980. Since 1993 several original publications from Russian or English have been translated into Czech (Altshuller, Devoyno, Belski, Salamatov, Ivanov, Souchkov, Guin, etc.). Since 1996 TRIZ has been taught on a regular basis at Brno and some parts of TRIZ have been implemented in Prague, Liberec, Pilsen, Ostrava, Zilina and Kosice universities.

TRIZ has been an optional course for Master students of two departments of the Faculty of Electrical Engineering and Communication (FEEC) at Brno University of Technology (BUT) since 1996. As a rule, there have been 15 to 30 students or up to 55 in some years. Last year the course of TRIZ was launched as an optional course also for eleven PhD students from FEEC. Starting from this academic year the course is optional for Master students of all departments of FEEC. Moreover, within the frame of project Modern and Opened Study of Technics - MOST the course TRIZ is offered as a ´trans-disciplinary´ optional and faculty independent course for all students of all faculties of BUT Brno from this academic year.

Over the long period of TRIZ implementation in education and practice in the Czech Republic the methodology has received favourable responses which is the result of the popularization activity of several teachers and consultants organized in ´TRIZing´ Czech Association, member of MATRIZ International Association.

Content of TRIZ optional course at BUT Brno

A short content of TRIZ course for Master and PhD students at FEEC and BUT Brno:
1. PM: Basic terms of Project Management (Aim and purpose of innovative project, SWOT, outputs, activity, resources, people, technology, time, space, money, Log Frame description).

2. TRIZ as an innovative methodology:
- VEA: Analysis of the object (system modelling, components, structure, functions, parameters, costs, evaluation of components), RCA diagram, trimming, additional functions, list of problems to be solved. Analyses of many case studies are presented.
- ARIZ: Transformation of problems into inventive tasks and search of idea solutions (technical contradiction and inventive principles, physical contradiction and separation principles, model of substances in conflict and models of standard solutions, problematic technical function and effects known from natural sciences, state of the object and possible inspiration from evolution of engineering systems). Synthesis of many cases are presented.

3. Application of TRIZ within the frame of a ´micro-project´. Students elaborate approximately 20 pages describing the analysis and synthesis of the selected object to demonstrate ability to apply the VEA analytical steps and synthetic solving instruments from ARIZ to find realistic idea how the object could be improved. To be efficient, TRIZ education requires individual work.

Students on the course (26 hours of lectures, 26 hours of training, case studies, work with software support) are evaluated through 3 tests (PM, VEA, ARIZ), a micro-project (20 points) and written and oral examination at the end of semester (60 points).

TRIZ for companies

The second part of the course is offered as a three-day educational course to the companies. TRIZ is attractive namely for companies with an active R&D department. The most effective way of introducing TRIZ to the companies is the direct communication with the head of the department. This person, usually of technical qualification, has to innovate products and that is why he/she is able to recognize possible TRIZ impact on innovation processes. It is mostly ineffective to offer TRIZ through HR department.

Authors come to companies to give three-hour motivation lectures. As a rule, a short-term 2+1 day educational course follows. It is our good practice proven over the past ten years.

Anyway, the educational course can be followed with repeated practical TRIZ applications only in the companies where an adjusted combination of several internal factors is present. Especially staff and management qualifications and motivation are key factors for acceptance and implementation. Then TRIZ as a non-trivial methodology can ´resonate´ with other advanced factors creating the ´innovative culture´ inside a company.

Important for education at universities and the future of the TRIZ methodology is the fact that the vast majority of TRIZ touched engineers recommend studying and mastering the methodology during university studies (Figure 5, question and answers 5).

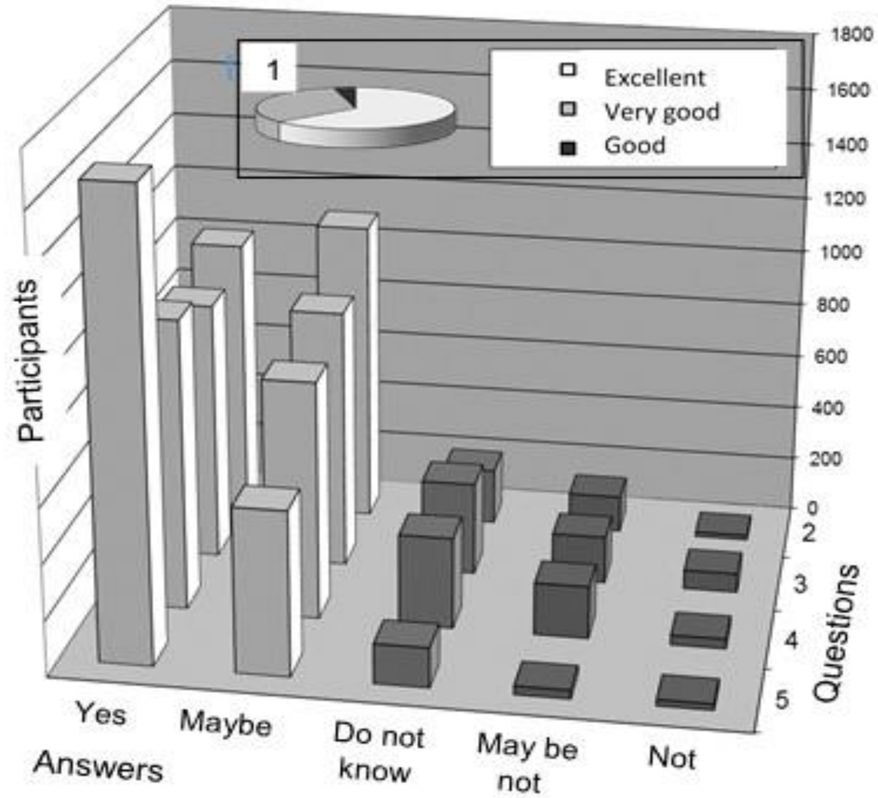


Figure 5: Answers of 2500 participants after motivation lectures or 2+1 day courses of 2 - 20 hours. Results from companies / universities (90/10) as of September 10, 2017

Questions asked:

1. How do you understand the content and form of the TRIZ methodology?
2. How do you evaluate applicability of TRIZ and software support in your company / school?
3. Would you be interested in occasional consultation of your innovative tasks?
4. Would you be interested in studying and mastering TRIZ methodology?
5. Would you recommend TRIZ to your son / daughter, or school and university students for studying and mastering?

Experience from answers: The more time spent with TRIZ, the more positive the references were. But no matter how many positive references there are from more than 2500 listeners, mostly from companies, the methodology has not become a common issue either at universities or in corporate development departments yet (Bušov; 2002 - 2016).

Mastering the non-trivial TRIZ methodology (if compared with some others ´methods´) requires serious study, educational examples and time for real applications. That is nothing new; reality always puts obstacles in the way to obtaining all values. Only valueless thing can be obtained easily and immediately. The same applies to good education and good schools. Knowing that there is no cheap and so called ´caesarean´ way into TRIZ, authors will stimulate further effort, with others educators and engineers, how to implement TRIZ into education and innovative practice more effectively.

Conclusion

There's no doubt that engineering graduates provided with the methodology of systematic and creative thinking would adapt more easily and rapidly to the variable demands of the dynamic reality in practice. The paper presented TRIZ as a challenge, as relatively universal because trans-disciplinary methodology, as well as elaborated and instrumental, analytic - synthetic methodology, which guides the solvers through a comprehensive analysis of the problem object to the formulation of various innovative problems and then to the formulation of typical inventive tasks to be solved. Then TRIZ offers appropriate recommendations (heuristics) on seeking ideas and solving concepts for implementation.

TRIZ is the empirically derived, systematic, relatively complex methodology understandable for students as well as for teachers who wish to make the educational process more attractive for all participants. The same applies to engineers - solvers of technical innovative problems in practice - who wish to deal with innovative projects more effectively.

The methodology can be studied and mastered. It supports both the system approach and creativity needed for inventive solving process. It is a challenge for teaching and learning, for developing the ability of users to solve not only but namely technical problems systematically and creatively. These ´ingredients´ are needed for most human activities, particularly for engineering education and innovative practice in companies. A systematic approach together with creativity is necessary in today´s engineering education as well as in today´s and tomorrow´s innovative practice. TRIZ is a challenge for ambitious teachers.

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