TRIZ as a tool to develop a TRIZ educational method by learning it

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Abstract

Since last year, in France, an official education program includes more than 50 hours of innovation methodology and training mainly based on TRIZ methods! But the problem is that teachers of the classes (sciences and technology for engineers and sustainable development) do not have any training on TRIZ, or will only receive it in the next years... So the contradiction is that teachers have to be taught about TRIZ methods to be able to teach it, but teachers could not be taught on TRIZ methods as there are no time resources to do it.
With the aid of an external TRIZ expert, it has been proposed to use as a main resource a team of 6 teachers and the time of course preparation to both teach teachers and develop a new, innovative teaching method. This experiment started this year for 2 classes to inventively teach TRIZ to teachers "in real-time" while students learn it by practicing the innovation methodology and creativity tools through a project.
The paper describes the 3-level approach to “develop a new educational method”, to "teach the teachers" and to enable students to learn through a "creativity challenge for innovation". The identified key problems related to this new educational method and the results of this new approach will be presented. As results, one can notice a new way of evaluating where everybody wins (education system, teachers, students), based on contradictory parameters in a "2D radar" highlighting students’ inventive abilities. From initial state to Ideal Final result, the paper explores the key success factors, the next steps and the set of problems linked to the implied actors: teachers and students, and also the educational system. The originality of the approach is that typical solutions used in learning with industries have been applied in the educational system, whereas it is traditionally the opposite…

Keywords: TRIZ; education system; teaching method development; innovative evaluation.

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1. Introduction

Since last year, in France, an official education program includes more than 50 hours of innovation methodology and training mainly based on TRIZ methods! But the problem is that teachers of the classes (sciences and technology for engineers and sustainable development) do not have any training on TRIZ, or will only receive it in the next years... Thus school teachers faced a contradiction: they had to teach methods for which they did not have any knowledge. This initial problem has in fact been recognized as a set of problems teachers were facing: teaching without knowing, defining a program without having the required knowledge, and so on. Fortunately, the staff of teachers met a TRIZ expert, Pascal Sire, glad to help with the transmission of TRIZ knowledge to young students. Based on the pedagogical competences of the teachers, and based on TRIZ expertise, it was then necessary to define the educational method to transmit TRIZ know-how on problem resolution to students. This educational method has to take into account students' specificities, knowing that they are young students, without the normal technical background that can be expected from an engineering student.

1.1. How to enable teachers to be taught at the same time that they had to teach students?

Teachers do not have time to learn, and moreover they do not have any resources to obtain knowledge from, nor TRIZ-based methods prior to teaching them to their students. So their only useful resource was the expertise of the TRIZ expert. This totally new situation led to the definition of an educational method at two levels: a new way to teach teachers and a new way to transfer know-how to students.

The teachers' training had to enable teachers to always keep a step ahead in terms of acquiring methods in comparison with the students. This was partially solved by the fact that teachers already had a technical background, already knew about systemic thinking, and about function description. So students had to familiarize themselves with these new approaches and moreover to acquire know-how on problem-solving methods in the context of design. But teachers also had to take into account that all these differences (methods, models of description, and way of thinking) could lead to too big a cognitive gap between them and the students. So three levels of expertise were identified:

1. Students, with no particular knowledge in design, no technical knowledge, and not involved in problem solving methods training sessions;
2. Teachers as technical experts also involved in the process of the problem-solving educational methods;
3. TRIZ expert, only focused on transmission of problem-solving methods.

In this particular situation, one favorable condition was the fact that teachers had to practice and learn new knowledge in the same context, so at least they did not face one of teaching difficulty. They generally acquire knowledge in a particular passive context and had to transmit the knowledge in a front-facing active context.

1.2. What to propose to students?

For the first time, students were also facing a new situation; they would not have to learn knowledge, as they were used to, but to develop skills, know-how, moreover in a context they are not familiar with: design situation. Designing requires technical knowledge and the development of intelligent thinking. Intelligent thinking is recognized by Perkins (1986) as a sum of tactics, power and content. "*The Power component relates to those elements of intelligence that depend on neurological efficiency. The Content component of intelligence expresses the need for a strong knowledge base in the discussed domain, such* *as mathematics, physics, or technology. The Tactics component consists of strategies, tactics, and techniques used in solving a problem.*" [1] in [2]

The main objective of the sessions defined with students was not to increase the content aspect, as it was neither an objective to feed students with technical knowledge, nor to change their neurological efficiency, so it was limited to give them efficient strategies, tactics to face and to solve problems. To enable them to solve problems, without spending time on technical knowledge, it was decided to process in project conditions, letting students choose their problems, choose the object they aimed to design, and thus letting them look by themselves for the knowledge they required. Apart from time management, this project approach also had a second benefit: to motivate the students, as they totally appropriated their projects and this let them be proactive in the education process.

1.3. How to evaluate when no predefined solution exists?

A last challenge in this project was to find a way to motivate students, and enable them not to be blocked or afraid by the evaluation. So the evaluation process had to enable the promotion of each student's personality.

Another aspect of the evaluation process is linked to the staff of teachers. For them it is also difficult to accept that the problem they proposed to their students does not have one a priori known solution, and to accept that the evaluation mode has to be redefined.

So a double constraint had to be taken into account concerning the evaluation process: giving enough confidence to the students to face a new situation when for the first time they did not have to reproduce something they were taught to do; and also building confidence for the teachers to be able to evaluate a situation for which there were no predefined and no better solution.

Boden, in [3], proposes to differentiate H-creative (historical) and P-creative (psychological) ideas. "*The H-creative idea brings a creative product as a result related to market or society represented by patent; whereas the P-creative idea brings a creative product as a result to process related to whom solve the problem*". As the students were not experts in the domain they were analyzing problems, it was obvious to choose to evaluate creativity as P-creative ideas. But then a trick had to be found not to enable students to propose trivial solutions and also not to be blocked by the lack of expert knowledge.

2. Known partial solutions

2.1. Training without being trained

So teachers were facing a real contradiction, they had to be trained, taught TRIZ-based methods to be able to teach them to their students, but it was not possible for them to be trained and taught as they had no time resources available. With the help of the TRIZ expert, it was decided that the development of a new, innovative pedagogy would be the first application of a TRIZ-based method; and thus that the definition of this pedagogy would be considered as a problem to solve and would be the case of training teachers. So the teachers were trained by the TRIZ expert using the direct application of the TRIZ-based method to their own problem. To be put in the context of learning application is a common and well-known pedagogy: Problem-Based Learning (PBL), which has been applied successfully in different conditions [4], [5]. This approach is in accordance with the way Dreyfuss described the expert knowledge. In [6] was described that one has to abandon the traditional idea that a beginner starts with specific cases and then, as he progresses, will bring out by abstraction and internalize increasingly sophisticated rules. On the contrary, the acquisition of know-how would be to move from abstract rules to particular cases.

Another aspect of the pedagogy that had to be developed was to build a trusting relationship between the teachers and the students. For that the students had to feel that teachers had enough knowledge to help them in the project, but at the same time the teachers had to be able to explain their expectations a way that could be understood by the students.

Then a second contradiction was faced: the cognitive distance between students and teachers had to be high to build a trusting relationship, but the cognitive distance between students and teachers had to be low to create a good communication and a good transmission of knowledge.

A third aspect, which is also very important for teachers, is that generally they are trained in a learning context, totally different from the context in which they will have to teach. And so they have to acquire both knowledge and understanding of the studied subject, but also specific know-how and good behavior to convey to the students.

2.2. Problem-based learning

PBL is based on the principles of adult learning. Knowles [7], the father of adult learning theory, proposed that a learning environment which is characterized by physical comfort, mutual respect and freedom of expression is conducive for adult learning. Differences are accepted, the learners perceive learning goals as their own and accept partial responsibility for planning and conducting the learning sessions and their active participation in the learning process is encouraged. PBL has been applied in many domains, principally in the sphere of medicine [4], [8], [9], but also in engineering domains [10]. As noted in [4], *"The combination of PBL and simulation offers students a variety of ways of learning and transforms knowledge in different yet controlled and safe environments. The ultimate goal is to challenge students to think for themselves. This merger cultivates an awareness of creative thinking, critical analysis, and decision-making abilities from extrapolating and relating the theoretical and practical knowledge presented in each cycle."*

The main goal of problem-based learning is to provide students with opportunities to apply knowledge, not just acquire it. PBL focuses on problem formulation as well as problem solving. It seeks to simulate real-world engineering research and development. Barrows [11] describes the main features of PBL in this way:

- *"Learning is student centered, i.e., students make choices about how and what they want to learn.*
- *Learning occurs in small student groups and promotes collaborative learning.*
- *Teachers are facilitators or guides or coaches.*
- *Problems form the organizing focus and stimulus for learning.*
- *Problems are a vehicle for the development of authentic problem-solving skills.*
- *New information is acquired through self-directed learning."*

The PBL could thus solve problems to develop the pedagogy both for teachers training and for students transfer: with the TRIZ expert playing the role of coach for the teachers and teachers being coaches for the students.

2.3. Project-based learning

Another well spread approach to learn to develop professional competencies is the project-based learning (also quoted PBL). Project-based learning forces learners to explore "*important and meaningful questions through a process of investigation and collaboration*" [12]. Among the many benefits of project-based learning, the following ones are cited in [13] and can be recognized as meaningful for our situation:

- Project-based learning projects are the curriculum, "*students learn the central concepts of the discipline via the project*"
- The projects can be based on an ill-defined problem, for which no a priori solution exists.
- The projects imply a "*goal-directed process that involves inquiry, knowledge building, and resolution".*
- The projects are not scripted, teacher-led, the students build their own approach to the curriculum.

Project-based learning and problem-based learning are quite similar in their outcomes and in their multidisciplinary orientation. But some differences are noted in [14], among them:

- *Project tasks are closer to professional reality and therefore take a longer period of time than problem-based learning problems*
- *Project work is more directed to the application of knowledge, whereas problem-based learning is more directed to the acquisition of knowledge*
- *Self-direction is stronger in project work, compared with problem-based learning, since the learning process is less directed by the problem*

As in the situation, the objective is more to enable students to acquire basic knowledge and develop competencies, as the allocated time is quite short and as young students are not able to confront professional situation, the problem-based learning approach seems more adequate.

2.4. Developing creativity

As cited in [15] "*Creativity is often defined as the ability to produce work that is both novel (original, unexpected, imaginative) and appropriate (useful, adaptive regarding task constraints)*". Then the authors explained that to enhance creativity it is necessary to have a set of suitable heuristics that narrow the scope of a problem. In their experiments, they propose to make students work in groups of two to three on designing and constructing an original technological system. The conclusion was that the use of a systematic way to analyze the problem was helpful for students to direct their attention and discovery.

In [16] the authors also demonstrated that training students on inventive techniques such as Synectics, Fermi Approach, TRIZ and so on, helped in increasing their creativity and especially if this training takes place as early as possible.

In [17] the author also tried to evaluate the benefits of TRIZ learning for students. In an experiment the students were trained on four thinking tools of TRIZ: Situation Analysis, Method of the Ideal Result, Contemporary Substance-Field Analysis, 40 Innovative Principles with the Contradiction Table. The result of analyzing of the impact of such training for students was the increase in confidence for students to solve any problem they will face and especially in tackling unfamiliar problems. In [18], "*the authors were able to conclude that the introduction of TRIZ does lead to an increase in creative output*".

Then, Toru Nakagawa presented in [5] a way to introduce TRIZ-based learning in education of undergraduate students by the definition of a 3-step program. But this program is dedicated to people with a minimal technical and design knowledge.

3. Proposed solution

To learn TRIZ, it was decided to start at the beginning in the situation of a concrete project, with the willingness to venture beyond the seemingly intractable problem "teach TRIZ without knowing," and to learn how to solve the problem "teach TRIZ" by solving the initial training "know TRIZ."

In the working group, several teachers intuitively formulated the contradiction in terms of an ideal, which facilitates the change of perspective necessary for their learning. Moreover, these teachers themselves willingly accepted being in situations of the TRIZ project with the expert, just as students would be in the next level with them, under the TRIZ principle known as "Matrioska". As stated by Sokol and al. in [19], *“The TA (Thinking Approach) is based on the idea of a non-linear nature of learning and thus non-linear organisation of the learning/teaching process. Instead of a linear or cyclic curriculum model the TA offers a modular course based on a number of learning technologies.”*

The expert in innovation methodology was identified in the close circle of teachers, by using networks of colleagues of teachers with representatives of engineers’ associations working regionally with high schools (linkage of the worlds of business and education). He was immediately attracted by this opportunity to "plant a few seeds" and test his concept of the "knowledge spiral" from the business world.

He first met the team of 6 teachers 4 times from October 2011 to January 2012 to teach them basic TRIZ notions and methods. After that introduction, the teachers started to work with the students on the projects 4 hours a week for 5 weeks. During this period, the expert just came one time to help the students and the teachers in the use of TRIZ.

The 60 students worked by groups of 4 to solve problems related to housing and they had to defend their results in front of all the groups and a board of examiners (teachers and experts in innovation).

These students are experimenting a new educational program including creativity for the first time. They are 16-17 years old and will be graduated in 2 years.

3.1. "Everybody wins", ideal philosophy of TRIZ!

In the first meetings with the TRIZ expert, once a month during the first semester, teachers are confronted with the major concepts illustrated by specific examples drawn from everyday life to help them to appropriate more easily, which corresponds more to the original request for "evidence of a concrete practice of TRIZ by an industry expert known in the region". As noted by Clarissa S. Thompson [20], *“In learning in and from practice novices use small pieces of the broader terrain of teaching and learning (examples of practice) to understand more deeply what happens in teaching and learning.”*

The transfer to the student level was then done in the second half by an introductory lecture (same general principles as those previously learned by the teachers, traditional path to education [Fig.1]) as a prelude to a "challenge of creativity for innovation" to stimulate learning and motivate students themselves (groups of four students from two classes and with different specialties), rather than a contest that would have discouraged them by an individual competition too common in schools.

As outlined by King and Kovacs in [21], the quality of learning varies from extrinsic to intrinsic motivation. *“If we wish to improve the quality of learning, then we need to develop a relationship among teachers and students that is towards the right end of this continuum. In other words, a key feature of improving the quality of learning is to increase the extent to which students are responsible for their own learning and intrinsically motivated to learn. The teacher is a skilled facilitator of learning drawing upon their pedagogical knowledge, knowledge of ways to teach ‘content’ and their profound knowledge of theory for improvement. To enable students to take on increased responsibility for learning, we must equip them with the skills and capacities necessary for them to do so.”*

The educational establishment was careful from the beginning of this experiment, through the presence of the regional pedagogical inspector (as early as during the second meeting with teachers), then during the development of a new evaluation method, where he actively encouraged it (please note that the risk was low because the rating of the project creativity will be needed in the formal curriculum of the students only the following year).

3.2. "Knowledge spiral", universal attractor?

To channel the whirlwind of innovative ideas, their efficient transmission to students and the broad dissemination of creative methods in the high school, the problem of setting in motion these linked actions was resolved by the close relationship established immediately between the TRIZ expert and the group of teachers and between teachers and their students.

The coupling effect is maximal if the distance between successive spirals and the time of implementation are adapted in real time [Fig.2] according to three criteria for self linkage: first "skate and rub", then "join and adhere", finally "follow and empower". The TRIZ evolution laws underlying these criteria are harmonization, conductivity of the energy, and transmission to the super-system.

If the purpose of education is to make students freer to make their choices and independent in their learning, then teachers are placed more involved in the strategies to adopt, obtaining resources, and the necessary impetus for the conservation movement of the whole class of students. An additional benefit: teachers as evaluators are also themselves TRIZ learners!

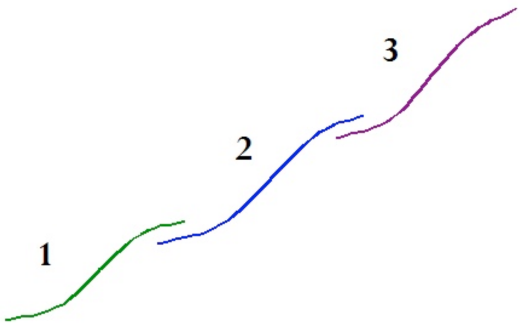

Fig. 1: Traditional education curves (1=students, 2=teachers, 3=expert)

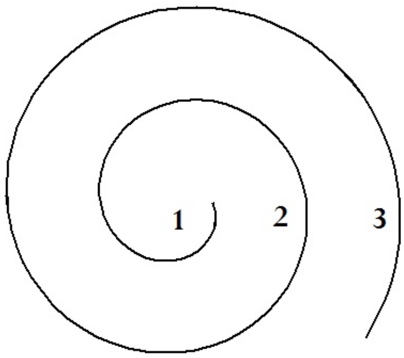

Fig. 2: Knowledge spiral "attractor" ("high and low" cognitive distance)

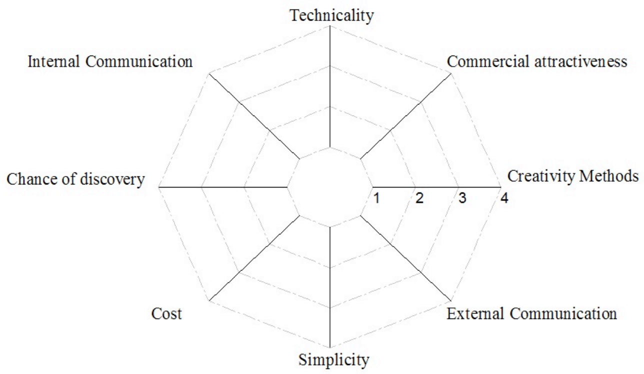

Fig. 3: Experimental evaluation "2D" radar
(opposed pairs of innovative criteria)

3.3. Dimension change for a positive evaluation

Traditionally, students scoring is done by a single score in the range 0 to 20, leaving little flexibility for teachers to include non-measurable parameters in assessing their students. The TRIZ expert proposed to move from this one-dimensional "linear" dimension to a "surface" measurement, by analogy with the "radar charts" used in the industry to incorporate different characteristics in the evaluation of complex situations.

To assess measurable outcomes of students but also their personal and group qualities, this evaluation "in square meters" can not only take into account several factors, but may also enhance the contradictory qualities that an ideal innovator should possess. The "2D Radar" [Fig.3] therefore includes opposed pairs of criteria, encouraging each students group to express these qualities present in one of them or their group. As noted by Ferreira and Andrade in [22], "*This type of chart, because of its versatility in knowledge representation, is often used in the analysis of organizational development and measurement of quality. In an academic environment still in transition, where there is an increasing penetration of technology associated with pedagogical changes, radar charts are suitable and adaptable.*"

As innovation is "an idea with market success", the criteria used after discussion with teachers therefore highlight technical and commercial considerations, internal or external communication, methodology or chance, cost and simplicity. By adding a surprise indicator (the famous "WOW factor") and a "like" (want to buy or follow, now well understood attitude in social networks), this new evaluation system quantifies all aspects of the proposed and evaluated innovation.

4. Best result of the students

The board of examiners had difficulty choosing the winner due to the quality and variety of the teams' delivery (half of the 14 teams could have been in the first 3 places on the podium), so it was decided to recognize the biggest well-shaped "2D radar" with the highest rate of "WOW" and "like" if a difference was needed! The winner is... "the door in the door" as the team itself summarized their project (in a successful marketing way) in front of their 60+ classmates, after a clear and simple presentation of their study, the problem to solve, the TRIZ process they followed, and the concept of solution they arrived at.

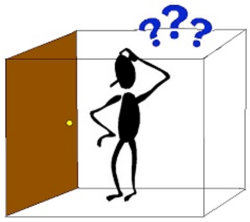

Fig. 4: how to open a door by always pushing it?

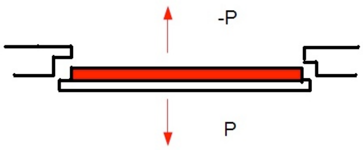

Fig. 5: the "door in the door"!

Problem to solve: how to change the principle of a door to always open the door by pushing it (whatever the direction of arrival at the door) without modification of the environment (ie. keeping existing frame of the door to avoid replacement cost)?

Model of problem: the physical contradiction [Fig.4] is to open the door in both directions, without changing the frame.

Model of solution: apply the usual principle to solve physical contradictions and allocate a property P to the system and a contradictory property -P to a subpart of the system, ie. primary property P is "the door opens to the right" and secondary property -P is "the door opens to the left".

Solution concept: Evolution law No. 7 suggests that the work is performed in a system, first on the object itself, then on a specific part of this object, when the system evolves [Fig.5].

Last but not least, the winning team not only received an official certificate and a few articles in the regional newspapers, with the recognition of their peers and visibility at the ETRIA conference, but also the protection of their idea (in France, a "Soleau" envelope ensures the date of an idea) offered by the High School, so that the team could claim royalties in the future if an industry partner develop their idea.

5. Discussion

To evaluate the success of our approach, we noted several key points at all levels, as well as the usual concluding remarks by authors like Moshe Barak, in [15], *"The most important aspect of teaching pupils an inventive problem-solving course of the type discussed in this study is creating a climate of thinking and problem-solving in the class. Beyond the direct teaching of terms, thinking schemes and heuristics related to inventive thinking and problem-solving, it is important to give the pupils the time and opportunity to develop their own thinking methods and explain or justify their ideas."*

The teachers managed to both train themselves and train students during a school year despite starting with strong contradictions at the beginning. A traditional approach (train teachers and students thereafter), would not have been able to train students (at least not during the current year). In addition to the basics of TRIZ tools, teachers also had practical experience of using these tools in different projects, and a beneficial teaching experience of these tools which remains the heart of their business. As an example of other positive output induced by the challenge of creativity for innovation, the mini company "ErgoTechJr" of the High School was awarded the prize for "excellence and innovation" in the regional championship of mini-companies.

The results of the projects submitted by students were rated at a good level. For example, to assign the 2nd and 3rd places in the challenge, the board of examiners faced six teams (from a total of 14) who all deserved to be on the podium. This particular situation was observed by Ogot and Okudan in [18], "*From a learning styles perspective it appears that methods such as TRIZ that match the learning styles preferences of a broader proportion of the student population during their use, as compared to the sole use of traditional methods such as brainstorming, should result in an increase in the creative potential* *and output of the students."*

The teachers noted also a stimulation of all stakeholders (experts, teachers, students): given the close links between each of them, the progress of some of these stakeholders was immediately beneficial to others, whereas in a sequential mode of training, the teachers do not take advantage of the progress of their students.

This positive dynamism also spread outside the walls of the school and made teachers reach an upper level by pushing them to formalize the process that they undertook, and to present it to ETRIA 2012.

Given the speed of technological change and increasingly rapid obsolescence of knowledge, this approach of continuous teacher training, with its advantages in terms of resource savings in time, is promises to be deployed widely.

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