This is an author-deposited version published in: https://sam.ensam.eu
Handle ID: .http://hdl.handle.net/10985/10538

To cite this version :

Malte SCHÖFER, Nicolas MARANZANA, Améziane AOUSSAT, Claude GAZO, Giacomo BERSANO - The value of TRIZ and its derivatives for interdisciplinary group problem solving - Procedia Engineering - Vol. 131, p.672-681 - 2015

Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 131 (2015) 672 – 681

Procedia Engineering

www.elsevier.com/locate/procedia

World Conference: TRIZ FUTURE, TF 2011-2014

The value of TRIZ and its derivatives for interdisciplinary group problem solving

Malte Schöfer[a,b], Nicolas Maranzana[a], Améziane Aoussat[a], Claude Gazo[a], Giacomo Bersano[b]

[a]LCPI, Arts et Métiers ParisTech, 151, Boulevard de l'Hôpital, 75014 Paris, France
[b]Active Innovation Management, 7, Rue de la Croix Martre, 91873 Palaiseau, France

---

Abstract

The value of TRIZ for technological problem solving is widely recognized. Initially designed for an inventor working (alone) on a technical problem, it is today often used as a tool for group creativity. In this article, we report on a an experiment which was designed in order to investigate the value of concepts and tools of TRIZ and its derivatives like USIT for joint problem identification, modeling and creative problem solving in a non-technological domain by multidisciplinary teams. Further, we briefly discuss the categorization of the outcome of the creative process by a combination of TRIZ and USIT analysis tools.

Peer-review under responsibility of the Scientific Committee of TFC 2011, TFC 2012, TFC 2013 and TFC 2014 – GIC

Keywords: TRIZ, USIT, group creativity, multidisciplinary problem solving;

---

1. Introduction

Innovative product design becomes more and more an issue of interdisciplinary teams, especially in areas with high growth potential, like bio- and nanotechnology industry. Nevertheless, there still exist many problems concerning the sharing and communication of knowledge originating in distant scientific domains. In this article, the authors give an overview on the theory of creativity and problem solving in general and on the topic of group creativity. Further, we report on an experiment which was designed to test the value of TRIZ and its derivatives like USIT for problem solving in a non-technological domain by multidisciplinary teams.

Peer-review under responsibility of the Scientific Committee of TFC 2011, TFC 2012, TFC 2013 and TFC 2014 – GIC
doi:10.1016/j.proeng.2015.12.353

2. Creativity, group creativity, and application of TRIZ on non-technological domains

In order to discuss the value of TRIZ and its derivatives for interdisciplinary problem solving, it is necessary to understand basic concepts of knowledge and knowledge transfer. Then, we briefly discuss theories of creativity and scientific reasoning. Finally, we give an overview on the application of concepts and tools of TRIZ and its derivatives in the domain of natural science.

2.1. Knowledge and knowledge transfer

According to Polanyi [1], there exist two types of knowledge, tacit knowledge, whose personal quality makes it hard to transfer, and explicit knowledge, which can be codified in signs and thus can be communicated more easily. Nonaka [2] refers to this classification and identifies four types of knowledge creation by conversion of either tacit or explicit knowledge into again either tacit or explicit knowledge. He calls these types of conversion socialization (tacit → tacit), externalization (tacit → explicit), internalization (explicit → tacit), and combination (explicit → explicit). Szulanski [3] introduces the concept of sticky knowledge. He qualifies knowledge to be sticky when its transfer within an organization is difficult. Finally, Blacker [4] distinguishes five types of knowledge: embrained knowledge, which is dependent on conceptual and cognitive skills; embodied knowledge, being only partly explicit and action oriented; encultured knowledge, representing processes which lead to shared understandings; embedded knowledge, which is inherent to systemic routines; and encoded knowledge, which can be communicated by symbols and signs and which is thus similar to Polanyi's definition of explicit knowledge. All these classifications have in common that they differ between knowledge which is easy to communicate and thus to transfer, and knowledge which is not.

2.2. Theories of creativity

Three interesting theories of creativity in the context of multidisciplinary problem solving are those of Finke et al. [5], Simonton [6], and Newell et al. [7].

In their Geneplore model, Finke et al. [5] describe the process of creativity as consisting of two parts, a generative and an exploratory one. During the generative phase, the problem solver constructs mental representations, so called preinventive structures capable of fostering creative discovery. Preinventive structures can be e.g. visual patterns, mental models, and verbal combinations. During the exploratory phase, the special properties of the previously generated structures are interpreted in meaningful ways in order to produce the creative outcome. Examples for these exploratory interpretations are exploring potential uses of functions, and shifting the context of the structures.

Simonton [6], based on the work of Campbell [8], proposes a model of blind-variation and selective-retention to describe creativity. He as well describes the process of creativity as being divided into two parts. The first is characterized by a subconscious generation of a huge number of ideas or elementary concepts and their random combination. The second consists in the conscious or subconscious retention of those combinations of ideas which bear a certain value. According to Simonton, the percentage of ideas that are worth retention is very small, which makes a huge number of initial combinations necessary. Simonton supports this model of creativity by several statistic analyses of creativity.

Newell et al. [7] state that 'creative activity appears to be simply a special class of problem-solving activity which is characterized by novelty, unconventionality, persistence, and difficulty in problem formulation.' (p.5). They further define a problem as being a maze, i.e. a set of paths of whom only some are correct paths because they bear a reward at their end. Consequently, they divide problem solving processes into solution generators, i.e. processes that 'determine the order in which the paths shall be explored' (p. 21) and solution verifiers, i.e. processes that 'determine whether a proposed solution is in fact a solution' (p. 21). Finally, the term heuristic is used by Newell et al. in order to describe 'any principle or device that contributes to reduction in the average search to solution.' (p. 22).

2.3. Creativity and scientific reasoning: Analogies, and heuristics

According to Newell et al. [7], there is no significant difference between cognitive processes in science and problem solving strategies which are used in other domains. In scientific problem solving as well analogies, algorithms and heuristics play an important role. Miller [9] for example holds that exceptional scientific discoveries have been more likely the product of creative combinations of metaphors and mental images than the result of complex deductions. Osowski [10] identifies metaphors as concrete structures on which further abstractions and theories can be built and tested. Pelz' [11] empirical findings of the positive relation between a researcher's contacts to colleagues of dissimilar domains and his performance also support the theory of the importance of interdisciplinary analogies for science.

Klahr [12], based on the assumption that scientific reasoning is some sort of problem solving, identifies five so called 'weak methods' in scientific reasoning. Those methods can be called heuristics as they constrain the search of the correct problem solving path (cf. paragraph 2.2). The heuristics identified by Klahr are: Generate and Test; Hill climbing, Means-End Analysis; Planning; and Analogy. The heuristics are briefly described in Table 2. Finally, Simonton [13] describes janusian thinking as an important process leading to creative results; it refers, to the conception of two or more opposites or antitheses at the same time [14 in13].

2.4. Group creativity, diversity, and communication of knowledge

Brainstorming [15] is probably the most widely used method to enhance group creativity. Nevertheless, researchers [16] have shown that brainstorming can actually lead to a loss of group creativity. Reasons for this loss are e.g. blocking, i.e. the reduction of generated ideas due to periods where group members cannot express their ideas because others are expressing theirs [16]. Research also supports the finding that the introduction of new perspectives on problems is more important for group creativity than are comfort and the feeling of belonging to a group [17]. Pointing to a literature review, Simonton [13] states that exposition of group members to ideological or behavioral dissent tends to lead to the discovery of solutions to problems that are at the same time novel and 'more likely correct rather than incorrect' (p. 155). Diversity and dissent can also have positive impact on group decision processes. Brodbeck et al. [18] show that minority dissent, i.e. a point of view expressed by a minority of the group, justified or not, improves the informational basis on which group decisions are made. When decision-making groups cannot be composed into diversity groups, the same authors [18] suggest the mimicry of preference diversity by techniques that create these diverging views.

Regarding the communication of knowledge, Roberts [19] stresses negative consequences of the increased use of information and communications technology for knowledge management because that technology can lead to a reduction of initially rich and complex knowledge into small components that only seem to be most important at the given time. This statement seems to be of special interest if one considers the need to transform and translate knowledge in order to make it more easily accessible to different cognitive contexts [20], [21].

2.5. TRIZ and its derivatives in scientific reasoning

Since the beginning of TRIZ, the theory has not only been used in order to identify physical and chemical effects to solve technological problems but also in order to model scientific reasoning or to model - and find solutions to - scientific problems. Examples are Altshuller's [22, 23] reports on the solution of problems in natural science with concepts of TRIZ like the discovery of the reason for Russel's Effect by using Physical Contradictions (PC) and Separation Principles (SP) by V.V. Mitrofanov. Another one is the modeling of the development of methods in numerical mathematics by Inventive Principles [24]. Schöfer et al. [25] give an overview on the application of TRIZ concepts on the modeling of reasoning and problem solving in natural science and mathematics. In the same paper [25], an example for the analysis of physiological processes in the human body by the Multi-Screen/System Operator Tool and the first Evolution Law (System Integrality) is given.

Analyzing the 'weak methods' in scientific reasoning identified in [12] (cf. paragraph 2.3), we come to the conclusion that most of these methods, except for 'generate and test' - which can be translated to 'trial and error' and thus should be avoided by using TRIZ - can be mapped to specific concepts and tools of TRIZ and USIT (Unified Structured Inventive Thinking) [26, 27] (Table 2).

Table 1: Mapping of 'weak methods' in scientific reasoning [12] and concepts and tools of TRIZ and USIT

'Weak' methods in scientific practice [12]	'TRIZ complex' concepts and tools
Generate and test: Trial and error	*To avoid in TRIZ and derived methods*
Hill climbing: Searching in the local area for the steepest performance gradient and following the direction of this gradient	*TRIZ:* STC-Operator *USIT:* Parameter change
Means-End Analysis: Detection of differences between current and goal state; then searching for operators to reduce this difference	*Detection of differences:* *TRIZ:* Ideal Final Result; Contradictions; SuField-Modelling *USIT:* Particles method *Operators:* *TRIZ:* Innovative Principles; Separation Principles; Inventive Standards *USIT:* Solution Operators; Particles Method
Planning: 1. Abstraction by omitting details; 2. Modelling of problem in abstract problem space; 3. Application of weak methods to develop plan; 4. Transfer plan into original problem and execute	*The process corresponds exactly to the underlying process of TRIZ and the derived methods.*
Analogy: - Surface mappings - Relational mappings - Complex structural mappings	*Surface mappings:* *TRIZ:* Laws of Technical System Evolution *Relational mappings:* *TRIZ:* Contradictions; Law of System Completeness *Complex structural mappings:* *TRIZ:* Smart Little Creatures

2.6. Conclusion

From this literature review we conclude the following:

- There exist different types of knowledge of which some types are more difficult to communicate than others [1, 2, 3]. The communication of knowledge can be particularly difficult for multidisciplinary teams. Automated approaches using information and communications technology are often not suitable for the communication - and thus the transfer – of knowledge in a way that satisfies the needs of the transfer target [19, 20, 21].
- The process of creativity is characterized by the search of paths that lead the creative problem solver from the problem statement to the solution. There exists a certain number of heuristics which can facilitate the reduction of possible solution steps, which leads to more effective creative problem solving [7]. Further, heuristics in scientific reasoning seem to be very similar to heuristics in inventive problem solving [12] (Table 2).
- Furthermore, the process of creativity is divided into two phases. The first is characterized by the generation of a huge number of elements and their often subconscious combination. The second step consists in the retention of those combinations of elements which bear a certain value [6].
- TRIZ and its derivatives offer concepts and tools that bear value for the analysis and modeling of complex systems and problems in non-technological domains [22, 23, 24, 25].

We believe that problem solving in multidisciplinary groups should, in the ideal case, lead to the optimal exploitation of resources at hand. This means that every group member, independent from his/her knowledge domain or expertise in the problem domain, should be able of contributing to the generation of solution elements which can later be combined in order to conceive complete solutions. In this respect, especially the contribution of elements implementing distant domain knowledge is important [9]. In order to make these contributions possible, the different participants of a group creativity session must be able to communicate on the problem at hand and on the solution elements they can provide. Finally, in order to assure an ideal combination of solution elements into complete solutions, a mapping process is required. This process should allow the identification of missing elements, the generation of whom is required in order to increase the quality of the complete solution.

We believe that TRIZ and its derivatives offer a certain number of concepts and tools that help to facilitate the above mentioned creativity process of multidisciplinary groups. In order to test this assumption, we designed the following experimentation.

3. Experiment

The experiment was designed for three purposes: To test the value of TRIZ and its derivatives:

- for the solution of problems in non-technological domains
- for the solution of problems by multidisciplinary teams
- for the ideal exploitation of solution concepts (solution elements) into complete solutions for a complex problem setting.

The experimental protocol as well as more of the quantitative findings regarding the influence of group composition and methodology on the outcome of the problem solving process are described in detail in [28]. Here, we will focus on key features of the experimental setting, the qualitative comparison of the most creative concepts and on the value of TRIZ and its derivatives for the exploitation of these concepts into complete solutions.

3.1. Population and team building

The participants of the experimentation were 45 students with life science background and 15 students with mechanical engineering background. These participants were randomly assigned to 20 three-person teams. These teams differed along two dimensions: the disciplinary background and the methodological training of the team members. Table 3 explains these differences in group composition.

Table 2: Assignment of participants into problem solving teams/groups (LS: life science; ME: mechanical engineering)

		Methodological training	
		Classical creativity	*TRIZ and USIT*
Disciplinary diversity	*Monodisciplinary*	**5 gr. (3 LS); 1 gr. (3 ME)**	**4 gr. (3 LS); 1 gr. (3 ME)**
	Multidisciplinary	**4 gr. (2 LS/1 ME)**	**5 gr. (2 LS/1 ME)**

3.2. Training and tool mapping

In order to compare TRIZ and its derivatives (TD) to classical methods for group creativity (CC), two trainings have been designed. Half of the participants attended to the TD training and half of them attended to the CC training. The goal was to provide the participants which attended to the TD training in a very short time (4.5 h) with the most important concepts and tools of TRIZ and USIT. The choice was made after a literature review followed by a mapping of TRIZ tools against USIT tools according to Nakagawa et al. [27, 29]. The chosen concepts and tools were:

- Problem analysis: *USIT:* Reformulation and Sketch; *TRIZ:* SOT + Resources , Ideality, Law of System Completeness
- Problem Modeling: *USIT:* Magic Particles Algorithm, Closed World Algorithm; *TRIZ/USIT:* Space/Time Analysis; *TRIZ:* Physical Contradictions
- Solution generation: *TRIZ:* Resources usage, Separation Principles; *USIT:* Solution Operators .

The trainings were followed by a case study at which the participants had the possibility to apply the content of the training.

3.3. Problem setting and documentation of the creative process and its outcome

The problem which the participants had to treat under experimental conditions was taken from virology. The participants had to find creative solutions to the problem of adenoviral infection of children which are immunosuppressed due to a recent bone marrow transplantation. The participants had been previously provided with scientific articles of the subject and were free to use the internet as source of information and inspiration. Further the participants were asked to document their reasoning as well as the generated solution concepts and solutions on prepared sheets.

3.4. Evaluation

The 20 groups generated 163 solution concepts and 46 solutions. These were evaluated by two domain experts on 7-point Likert-type items according to the following criteria [30]: feasibility, applicability, effectiveness, profundity (a mixture of implicational explicitness and completeness), and originality.

4. Results

Except for four solution concepts and one solution, all outcome could be evaluated with an acceptable inter-rater reliability (Cronbach-$\alpha = 0.728$). The quantitative and qualitative analysis process is still ongoing. Nevertheless we will present here some first findings.

4.1. Quantitative analysis of the outcome of the group creativity process

The quantitative analysis of the solution concepts and solutions provided some interesting insights. It could be shown that the originality of the outcome of the creative process is higher for multidisciplinary groups when these groups attend to TD training. Monodisciplinary groups however produce more original outcome when they attend to CC training. This significant relationship was found both for the solution concepts ($F(1/159) = 11.77$; $p = 0.001$) and the solutions ($F(1/45) = 7.83$; $p = 0.008$). These and other quantitative findings are reported in [28]. Another interesting point, even though independent from the methodological training of the participants, is the impact of group composition on the profundity of the generated solutions. Multidisciplinary groups generate solutions which are significantly more profund than those of monodisciplinary groups with LS or ME background participants ($F(1/45) = 4.42$; $p = 0{,}042$).

4.2. Impact of training and group composition on the diversity of the best generated solution concepts

In order to compare the best generated solution concepts (i.e. concepts which scored the highest on applicability, effectiveness and originality) with respect to their diversity, it is important to analyze the problem setting in a systemic and temporal/processual way. The authors did so by jointly using the System Operator Tool (TRIZ) and the Operational Time Analysis (USIT). The result is a seven by two matrix presenting the infection process on its abscissa and the systemic level on its ordinate (Figure 1). In order to define the systemic level of the solution concept, the authors identified the main object of interaction featured in the solution concept. In order to identify the processual stage of the concept, the authors identified when the main action which is featured in the concept is carried out.

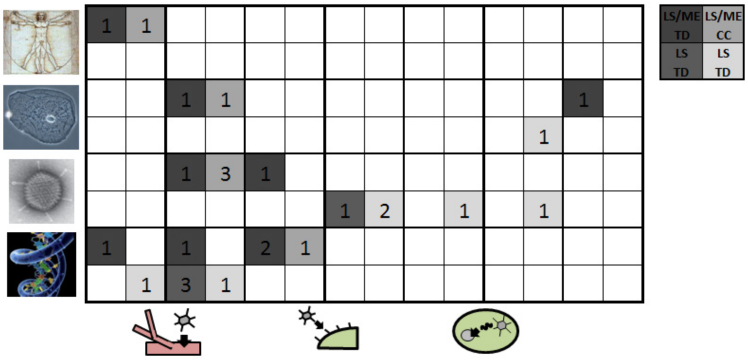
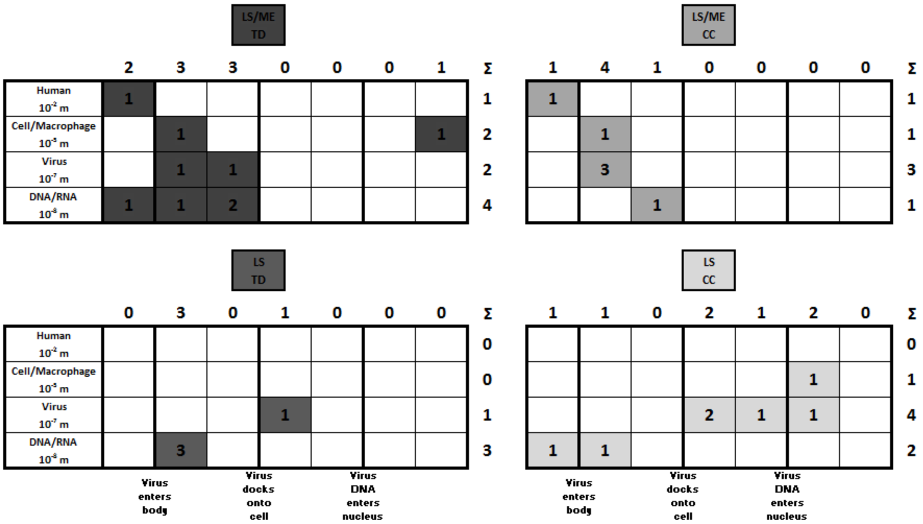


Figure 1: Categorization of solution concepts in a matrix combining systemic and processual categorization



LS/ME TD

	2	3	3	0	0	0	1	Σ
Human 10^{-2} m	1							1
Cell/Macrophage 10^{-5} m		1					1	2
Virus 10^{-7} m		1	1					2
DNA/RNA 10^{-8} m	1	1	2					4

LS/ME CC

	1	4	1	0	0	0	0	Σ
Human 10^{-2} m	1							1
Cell/Macrophage 10^{-5} m		1						1
Virus 10^{-7} m		3						3
DNA/RNA 10^{-8} m			1					1

LS TD

	0	3	0	1	0	0	0	Σ
Human 10^{-2} m								0
Cell/Macrophage 10^{-5} m								0
Virus 10^{-7} m				1				1
DNA/RNA 10^{-8} m		3						3

LS CC

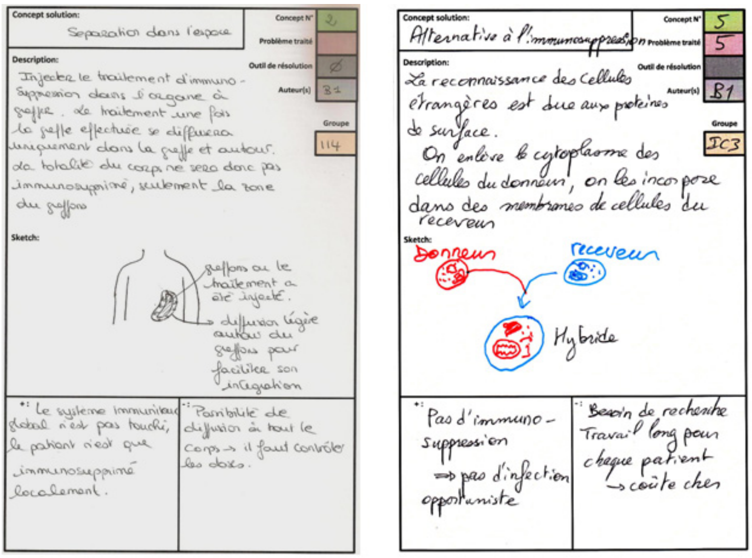
	1	1	0	2	1	2	0	Σ
Human 10^{-2} m								0
Cell/Macrophage 10^{-5} m						1		1
Virus 10^{-7} m				2	1	1		4
DNA/RNA 10^{-8} m	1	1						2

Figure 2: Comparison of solution concepts as a function of group composition and methodological training

Comparing the concepts proposed by the different teams (Figure 2), two remarkable observations can be made. Multidisciplinary teams generated five concepts which target the problem on the upper two systemic levels of human (10^{-2} m) and cell/macrophages (10^{-4} m). For the monodisciplinary teams, this was only the case for one concept. Comparing the generated concepts with respect to their position in the process of infection, it was found that the vast majority (17 out of 19 or 89.5 %) of the concepts proposed by the LS/ME TD, LS/ME CC and LS TD groups target the problem at its early steps (i.e. before the virus docks onto the cell). For the LS CC teams, however, this was only the case for a minority of the concepts (2 out of 7 or 28.6 %).

4.3. Presentation of interesting solution concepts

Figure 3 (in French) shows two solution concepts which were proposed by a LS/ME TD group (left) and a LS/ME CC group (right). These concepts target the problem at a very high systemic level and at a very early stage. They target the root cause [31] of the problem by proposing ways either to reduce the necessity of the immunosuppresion to a certain area of the body (left) or even to make it obsolete (right). The proposition of reducing the area of the immunosuppression is the result of the identification of a physical contradiction and the solution of this contradiction by separation of the contradicting parameter states in space.



Concept solution: Separation dans l'espace
Concept N° 2
Problème traité
Outil de résolution Ø
Auteur(s) B1
Groupe 114

Description:
Injecter le traitement d'immuno-suppression dans l'organe à greffer. Le traitement une fois la greffe effectuée se diffusera uniquement dans la greffe et autour. La totalité du corps ne sera donc pas immunosupprimé, seulement la zone du greffons

Sketch:

+: Le système immunitaire global n'est pas touché, le patient n'est que immunosupprimé localement.

-: Possibilité de diffusion à tout le corps → il faut contrôler les doses.

Concept solution: Alternative à l'immunosuppression
Concept N° 5
Problème traité 5
Outil de résolution
Auteur(s) B1
Groupe IC3

Description:
La reconnaissance des cellules étrangères est due aux protéines de surface.
On enlève le cytoplasme des cellules du donneur, on les incorpore dans des membranes de cellules du receveur

Sketch:

+: Pas d'immuno-suppression
⇒ pas d'infection opportuniste

-: Besoin de recherche
Travail long pour chaque patient
→ coûte cher

Figure 3: Proposed solution concepts targeting the root cause of the stated problem

5. Discussion and further research

The findings presented here have important implications for group creativity, research of inventive design methodology and its application on non-technical domains: It could be shown that multidisciplinary teams composed by participants with a life science background and participants with a mechanical engineering background are capable of providing quality solution concepts that differ from those produced by monodisciplinary groups in terms of systemic level. If we combine this finding with the capability of TRIZ and its derivatives to lead to more originality in multidisciplinary groups [28] we can argue for a real value of concepts and tools of the "TRIZ complex" for the definition, modeling and solution of non-technological problems by multidisciplinary teams.

Further TRIZ and USIT tools for systemic analysis prove to be useful for the analysis and categorization of the outcome of creativity processes. The authors believe that this categorization, together with a functional decomposition, e.g. by Gero's [32] Function-Behavior-Structure framework, (which is currently carried out) can eventually lead to new ways of combining ideas of distant knowledge domains into creative solutions.

Finally, by the quality outcome of the creativity process of teams trained in TRIZ and USIT methodology, it could be shown that even a very short training, in combination with a short case study [28], can lead to basic comprehension and reasonable application of this methodology by students.

6. Conclusions and next steps

In the present article, the authors give an overview on the theory of group creativity and on the literature on the application of TRIZ methodology and its derivatives on non-technical problem solving. Further the authors report on a large-scale experimentation designed to investigate the influence of the said methodology on problem solving in a non-technological domain by multidisciplinary teams. Finally, the usage of TRIZ and USIT tools in order to analyze the outcome of the problem solving process is proposed. As next steps, a detailed work with experts on proposed solutions is planned, in order to arrive to solid medical hypotheses to treat this children disease. To do this, complementary use of TRIZ and derived heuristics is foreseen in a smaller multidisciplinary group of scientists.

Acknowledgements

The authors are grateful to the participants of the experiment coming from Ecole de Biologie Industrielle (EBI) and Arts et Métiers ParisTech, to Dr. Pensé-Lhéritier of EBI for her support at the organization of the experiment, to Prof. Richardson and Dr. Klonjkowski from Ecole Nationale Vétérinaire d'Alfort for the elaboration of the problem setting and the evaluation of the products of the creative process, to Pierre-Emmanuel Fayemi for his advice concerning life science issues and his help during the design of the training, and to Stéphanie Buisine for advice concerning statistics.

References

[1] Polanyi M. *The Tacit Dimension*, London: Routledge & Keagan Paul, 1966.

[2] Nonaka I. *A Dynamic Theory of Organizational Knowledge Creation*, Organization Science, volume 5, 1994, pp. 14-37.

[3] Szulanski G. *The Process of Knowledge Transfer: A Diachronic Analysis of Stickiness*, Organizational Behavior and Human Decision processes, volume 82, 2000, pp. 9-27.

[4] Blackler F. *Knowledge, Knowledge Work and Organizations: An Overview and Interpretation*, Organization Studies, volume 16, 1995, pp. 1021-1046.

[5] Finke R., Ward T., Smith S. *Creative Cognition: Theory, Research, and Applications*, Cambridge: MIT Press, 1992.

[6] Simonton D. *Creative thought as blind-variation and selective-retention: Combinatorial models of exceptional creativity*, Physics of Life Reviews, volume 7, 2010, pp. 156-179.

[7] Newell A., Shaw J., Simon H. *The Processes of Creative Thinking*, Article Presented before a symposium at the University of Colorado, 14 May, 1958.

[8] Campbell D. *Blind variation and selective retention in creative thought as in other knoweldge processes*, Psychological Review, volume 67, 1960, pp. 380-400.

[9] Miller A. *Insights of Genius*, Cambridge: MIT Press, 1996.

[10] Osowski J. *Ensembles of Metaphor in the Psychology of William James*, in D. Wallas and H. Gruber (eds.) *Creative People at Work – Twelve Cognitive Case Studies*, pp. 127-145, New York: Oxford University Press, 1989.

[11] Pelz D. *Some Social Factors Related to Performance in a Research Organization*, Administrative Science Quarterly, volume 1, 1956, pp. 310-325.

[12] Klahr D. *Exploring Science*, Cambridge: MIT Press, 2000.

[13] Simonton D. *Creativity in Science: Chance, logic, genius, and zeitgeist*, Cambridge: Cambridge University Press, 2004.

[14] Rothenberg M. *Psychopathology and Creative Cognition: A Comparison of Hospitalized Patients, Nobel Laureates, and Controls*, Archives of General Psychiatry, volume 40, 1983, pp. 937-942.

[15] Osborn A. *Applied Imagination*, New York: Charles Scriber's Sons, 1957.

[16] Diehl M., Stroebe W. *Productivity Loss In Brainstorming Groups: Toward the Solution of a Riddle*, Journal of Personality and Social Psychology, volume 53, 1987, pp. 497-509.

[17] Nemeth C., Ormiston M. *Creative idea generation: Harmony versus stimulation*, European Journal of Social Psychology, volume 37, 2007, pp. 524-535.

[18] Brodbeck F., Kerschreiter R., Mojzisch A., Frey D., Schulz-Hardt S. *The dissemination of critical, unshared information in decision-making groups: the effects of pre-discussion dissent*, European Journal of Social Psychology, volume 32, 2002, pp. 35-56.

[19] Roberts J. *From Knowledge Management to Ignorance Management*, International Conference on Organizational Learing, Knowledge and Capabilities, 26-28 April, Amsterdam, 2009.

[20] Autio E. *New, technology-based firms in innovation networks symplectic and generative impacts*, Research Policy, volume 26, 1997, pp. 263-281.

[21] Fontes M. *The process of transformation of scientific and technological knowledge into economic value conducted by biotechnology spin-offs*, Technovation, volume 25, 2005, pp. 339-347.

[22] Altshuller G. *Flügel für Ikarus – Über die Moderne Technik des Erfindens*, Moscow: MIR, 1983.

[23] Altshuller G. *Creativity as an Exact Science*, New York: Gordon and Breach, 1988.

[24] Berdonosov V., Redkolis E. *TRIZ-Fractality of mathematics*, TRIZ Future Conference 2007, Frankfurt, 6-8 November, 2007.

[25] Schöfer M., Maranzana N. Aoussat A., Bersano G. *From Design Research to Research Design – Transfer of Design Theory to Natural Science*, DESIGN 2012, Dubrovnik, 21-24 May, 2012.

[26] Sickafus E. *Unified Structured Inventive Thinking: How to invent*, Grosse Ile: Ntelleck, 1997.

[27] Nakagawa T., Kosha H., Mihara Y. *Reorganizing TRIZ Solution Generation Methods into Simple Five in USIT*, TRIZ Future Conference 2002, Strasbourg, 6-8 November, 2002.

[28] Schöfer M., Maranzana N., Aoussat A., Bersano G. *Testing the Value of TRIZ and Its Derivatives for Knowledge Transfer in Problem Solving Attempts by Multidisciplinary Teams*, Article submitted to ICED 2013, Seoul, 19-22 August, 2013.

[29] Nakagawa T., Kosha H., Mihara Y. *Usage of USIT Solution Generation Methods: A Simple and Unified System of TRIZ*, TRIZCON 2003, Philadelphia, 16-18 March, 2003, http://www.osaka-gu.ac.jp/php/nakagawa/TRIZ/eTRIZ/epapers/e2003NakaPapers/eTRIZCON2003/eTRIZCON03Usage 030303.html

[30] Dean D., Hender J., Rodgers T., Santanen E. *Identifying Quality, Novel, and Creative Ideas: Constructs and Scales for Idea Evaluation*, Journal of the Association for Information Systems, volume 7, 2006, pp. 646-699.

[31] Khomenko N., Ashtiani M. *Classical TRIZ and OTSM as a scientific theoretical background for non-typical problem solving instruments*, TRIZ Future Conference 2007, Frankfurt, 6-8 November, 2007.

[32] Gero J. *Design Prototypes: A Knowledge Representation Schema for Design*, AI Magazine, volume 11, 1990, pp. 26-36.