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Application of the TRIZ creativity enhancement approach to design of inherently safer chemical processes

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Abstract

The paper gives a brief overview of the creativity supporting methods of potential interest to process engineering community. Information about computer implementations of the presented methods is introduced as well. Creative problem solving can be broadly classified into intuitive and analytical methods—the paper suggests the analytical approaches to creative problem solving as the most promising group for process engineers. Special attention is given to TRIZ, a popular method for systematic creativity. Classical TRIZ needs to be modified in order to be used in a specialised domain such as process engineering. We discuss the changes needed and illustrate the application of the modified TRIZ to the design of inherently safer chemical processes. A discussion of the advantages and drawback of creativity enhancing methods in the context of process engineering is also presented along with directions for future development.

Keywords: TRIZ; Creativity; Innovation

1. Introduction

During the last few years, several trends can be observed in the processing industries: lowering of profit margins on commodities, growing importance of sustainability considerations and the environmental aspects of production, high costs of R&D, significance of low-tonnage, high value-added products as well as customer-oriented products, compression of the time from development-to-market, and shortening of product life-cycles. These factors motivate process engineers towards increasing product and process *innovation*. Usually innovativeness is understood as the result of creativity of individuals and the management process inside of an organisation. Traditionally neither aspect of innovation has been of specific interest to process engineers. For example, in Elsevier's ScienceDirect journal articles database, as of 2004, there are around 8000 articles dealing with creativity, however, only around 150 papers, cite this word in the chemical and process engineering literature in the last 10 years. This reflects the weak interest of the chemical and process engineering community in research on creativity. In this article, we review the literature on creativity that is relevant to the community and using a case study of inherently safer process design, show how some of these ideas can be fruitfully applied.

One of the difficulties in the practical study of creativity arises from its imprecise notion and the widespread belief that it is the domain of psychology, philosophy or sociology. There are hundreds of definitions of creativity [1]. For the sake of simplicity, in this paper, we use the following working definition that is convenient for engineering applications: "creativity is a cognitive process leading to the generation of the solutions (products, processes, services, behaviours, etc.) which are new, unexpected, and useful." Research on creativity usually concentrates on five main aspects:

1. The essence of the notion: How is it defined and to what are the different types?
2. Its assessment: How to measure creativity?
3. The process: How to get a creative idea?
4. The person: What are the features of creative people? and
5. The product: What are the attributes of a creative product)?
6. An excellent review of the different aspects of creativity from the "soft" sciences point-of-view is given by Sternberg [1].

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Creative problem solving is a process comprising of six steps [2]:

1. problem identification;
2. fact finding;
3. problem definition;
4. idea generation;
5. ideas refining;
6. evaluation.

Our observations of the different aspects of engineering activities and discussions with practitioners have lead to three main conclusions:

1. The main interest of process engineers in creativity is in the methods and tools for the generation of new ideas.
2. The field of application is mainly processes (troubleshooting, de-bottlenecking, synthesis, and design) and products (identification of new products and their formulation).
3. Of the nearly 150 methods for generation of new ideas [1], only a small fraction are of potential use for engineers.

In this paper, we therefore focus on the idea generation step of the creative problem solving process. In Section 2, we present a brief overview of the different methods for enhancing creativity support. In Section 3, we illustrate the application of one such method, TRIZ to idea generation for a specific problem in process engineering—design of inherently safer process.

2. Methods for enhancing creativity

The generation of ideas consists of manipulation of objects or their features. Several types of manipulation are possible—associations, selections, integrations, adaptations, etc. [3]. These different manipulations can be grouped into three basic models of creativity (an extension of the original classification by [4])—(1) *combinational creativity*, where ideas are created from a combination and synthesis of existing ideas, and (2) *exploratory creativity*, which involve creation of *new* ideas within the framework of existing rules and (3) *transformational creativity*, which introduces new ways of thinking by altering the framework through new rules and dimensions.

The three types of creativity result from different cognitive processes and provide the basis for the following differentiation between discovery, invention, and design. An insight into new interdependencies leads to the processes of *discovery*; an origination of new artefacts guides the process of *invention*; a creation of solutions to a new problem directs the processes of *design*.

Creativity enhancement is understood as actions that improve the ability to define the problem and to generate new, useful and unexpected ideas. While it does not guarantee generation of creative solutions, creativity enhancement only makes them *more probable* by focusing the designer's thinking and directing his/her attention to the most essential problems. The enhancement of creativity can be realised by education (through removal of the barriers), training (focusing on the person's cognitive abilities, motivation, and social skills), or application of specific methods (focusing on the problem). These lead to the many methods for enhancing creativity (see [5] for a description of over 150 methods). These methods are not a replacement for fundamental subject knowledge, rather they require a "prepared mind" with solid knowledge of physics, chemistry, biology and mathematics as well as specific domain knowledge (e.g. engineering), to result in the highest quality of solutions. In the specific case of idea generation which is of particular interest for engineers, the various creativity enhancement methods can be classified as either intuitive or analytical. *Intuitive methods* are based on use of emotion, fantasy, or other sources of inspiration that are difficult to be formalised. These are usually founded on experience and do not have a formalised logical structure or internal coherency. In contrast, *analytical methods* are well-structured and are characterised by the systematic search of the solution space.

The following intuitive methods are commonly applied to the engineering problems:

Brainstorming: It is the most popular creativity enhancement method. Originally introduced by Osborn [6], it is based on the following four rules: evaluation of ideas must be done later; the quantity of the generated ideas is the most important; encouragement of strange and "wild" proposals; and improvement and combination of the generated ideas is welcomed. Many variants such as stop-and-go, Gordon–Little variation, and trigger method are common. The interested reader is referred to Proctor [7] for a detailed description. An example of brainstorming in the chemical engineering domain is hazard and operability (HAZOP) analysis, a popular method for process safety analysis [8].

Synectics: This method developed by Gordon [9] exploits two mechanisms to look at the problem from a different perspective—to make familiar strange and vice versa, i.e., to make the strange seem familiar. To achieve this, a set of four analogies are used—personal (where emotions and feelings are used to identify an individual with the subject of the problem), direct (where the problem is compared with homogeneous facts, information, or technology), symbolic (use of personal images), and fantasy (based on how the problem can be solved in the 'wildest fantasy'). Detailed description of the synectics method is presented by Proctor [7].

Lateral thinking: This is a group of methods originally introduced by De Bono [10] and is based on a unconventional perception of the problem. The main factors enabling lateral thinking are identification of the dominant ideas, search for new ways of looking at the problem, relaxation of the rigid thinking process, and use of chance to encourage the emergence of the other ideas.

Among the analytical methods the most common ones applied to engineering problems are:

Morphological analysis: The method was introduced by Zwicky [11] and is based on the combination of the attributes of the product or process (like properties, functions, etc.) with