Creativity for Operational Researchers

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Abstract
This paper presents some modern and interdisciplinary concepts about creativity and creative processes specially related to problem solving. Central publications of Creativity-OR are briefly reviewed. Creative tools and approaches suitable to support OR work are also presented. Finally, the paper outlines the author's experiences using creative tools and approaches to: Facilitation of problem solving processes, strategy development in organisations, and design of optimisation systems for large scale and complex logistic systems.

Keywords
Creativity, Problem Solving, CPS, Facilitation, Strategy Development, Optimisation.

1. Introduction

The need of using creative thinking in problem solving has been actualised during the last decades due to the radical changes experienced in industrialised countries. New information, communication and biological technologies are reshaping the material, human and social basis of Society. Therefore, decision-makers have been emphasising the crucial need for creativity and innovation to be able to utilise the new opportunities and to solve the many serious problems that Society is facing today.

The above-described situation implies that OR workers are facing new demands: problem solving in collaboration with a group of stakeholders. The main qualification in this respect is the ability **to facilitate change** processes, involving participants actively and being able to regard the problematic situation in relation to a dynamic context of different environments. The essence is the ability to alternate between modes of rationality, reflection and creativity in cooperation with the stakeholders, rather than being locked into one of these modes.

Creative thinking is an area that has largely been disregarded in the OR curricula and almost totally ignored in the quantitative modelling disciplines. Nevertheless, the successful application of OR in the real world usually depends on a high degree of

creativity and ability to innovate. This situation is even more paradoxically if we take into consideration that the great masters of our discipline: Russ Ackoff, George Dantzig, Arne Jensen, Stanford Beer to mention some few, have shown both creative and rational thinking in their work.

The main purpose of this paper is to present some concepts, tools, and approaches from the broad interdisciplinary field known as Creativity and Problem Solving that will enrich the toolbox of the OR workers and that will complement the traditional rational approaches.

In Section 2 several conceptualisations of the term "creativity" are discussed, a definition is presented and a set of common barriers to individual creativity is outlined. The main OR publications related to the theme of this paper will be briefly reviewed in Section 3, there are so few publications that an extensive review is easily done. In this section it is concluded that there is a need to enhance creative thinking in OR.

Interdisciplinary research work related to several aspects of creativity and creative processes has exploded during the last decades. An overview of this research work is presented in Section 4. From this overview, we have decided to focus on creativity tools and approaches specially related to problem solving because of their immediate relevance to OR. In Section 5 some of the most popular tools are shortly presented. The Creative Problem Solving approach, a 6-steps process to deal with large scale and complex problems in a creative way, is presented in Section 6.

It is usually while facilitating groups in problem solving tasks that OR workers need to use creative tools and methods. In the next three sections the author's experiences using creative thinking will be discussed. Hence, Section 7 presents the concepts behind the so-called Vision Conferences: a participative workshop designed to facilitate creative problem solving. Strategic development in organisations is the theme of Section 8, while Section 9 is dealing with the design of computerised optimisation systems for large scale and complex problems. Finally, Section 10 presents the last remarks.

2. What is Creativity?

E. Paul Torrance (Millar, 1997) has been a pioneer in creativity research and education for more than 50 years. Torrance sees creativity as a process and has developed a battery of tests of creative thinking abilities. He believes that all individuals are creative and that creativity can be enhanced or blocked in many ways. He considers creativity developmentally, opposite to those who believe that a persons creativity was established at an early age (two or three years old), however his research has shown that creativity does not develop linearly and that it is possible to use activities, teaching methods, motivation and procedures to produce growth, even in ageing. Torrance asserts that creativity is an infinite phenomenon; you can be creative in an endless manner.

You find creativity in many apparently different areas: humour (haha), science (aha) and art (ah). Koestler (1976) presents the theory that all creative activities - the conscious and unconscious processes underlying artistic originality, scientific discovery, and comic

inspiration have a basic pattern in common. He calls it "**bisociative thinking**" - a concept he coined to distinguish the various routines of associative thinking from the creative jump which connects previously unconnected frames of references and makes us experience reality on several planes at once. Koestler introduced the concept of a "matrix" to refer to any skill or ability, to any pattern of activity governed by a set of rules - its "code". All ordered behaviour, from embryonic development to verbal thinking is controlled by the rules of the game, which lend it coherence and stability, but leave it sufficient degrees of freedom for flexible "strategies" adapted to environmental conditions. The term code is deliberately ambiguous, and reflects a characteristic property of the nervous system: to control all bodily activities by means of coded signals. The concept of matrices with fixed codes and adaptable strategies, is proposed as a unifying formula, and it appears to be equally applicable to perceptual, cognitive, and motor skills and to the psychological structures variously denominated frames of reference, associative contexts, universal discourse, mental sets, schemata, etc. These silent codes can be considered as condensation of learning into habit or associative thought. Bisociative thought is the challenge of habit by creativity.

The creative person

We can characterise at least three types of creative persons. First, the problem solver where the person (subject) is trying to solve a problem (object) in a creative way, this is the case of OR workers, engineers, scientists, advisers, etc. Secondly, the artistic person (subject) who creates a new piece of art (object) usually it will be a close interaction between the subject and object, the “soul of the artist” will be in the object, this object can be a product (painting, music, film) or a process (dance, theatre, performance). And thirdly, the persons that adopt creativity as a life-style being creative at work, at home and everywhere, both in an extrovert and introvert way (inventors, artists, mode designers, etc).

Amabile (1983) has documented that creativity in each individual has three components: expertise, creative-thinking skills and motivation. Expertise is in a few words knowledge in its many forms: technical, procedural and intellectual. Knowledge can be acquired both theoretically and practically. Learning to learn is an important tool for becoming an expert in modern Society. Creative-thinking skills determine how flexibly and imaginatively people approach problems and tasks. It demands courage to be creative because you will be changing the status quo. Individuals can learn to be more creative and can learn to use creative tools in problem solving. Motivation is the last component. An inner passion and desire to solve the problem at hand will lead to solutions far more creative than external rewards, such as money. This component, usually called intrinsic motivation, is the one that can most immediately be influenced by the work environment. Amabile's research has identified six general categories that support creativity: Challenge, freedom, resources, work-group features, supervisory encouragement, and organisational support.

Teresa Amabile (1998) after many years of research focusing on creativity within organisations has also concluded that individual creativity gets killed much more often that it gets supported. Mostly, it is not because management has a vendetta against

creativity, it is undermined unintentionally because of the optimisation of short business imperatives: co-ordination, productivity, efficiency and control. Her research has shown that it is possible to develop organisations where both profit and creativity flourish, but you need a conscious strategy. Torrance´s research has also shown that children's creativity gets killed in the primary schools and it is possible to design schools and education systems where both rational and creative work flourish (Goff, 1998). Amabile (1998) has also drawn attention to the crucial importance of intrinsic motivation in creative endeavour. Business has traditionally rewarded people extrinsically with pay and promotion but creative actions often arise out of a long-standing commitment to and interest in a particular area. She appreciates this is only one part of the equation, and that expertise in the domain concerned, and sufficient mental flexibility to question assumptions and play ideas, are also important. In addition, she points out the critical importance of challenge, for instance, matching people to tasks they are interested in and have expertise in, permitting people freedom as to how they achieve innovation, setting a sufficiently diverse team the task of innovation, along with sufficient resources, encouragement and support.

It is difficult to give a simple and general definition of creativity. It is easier if we focus to study creativity in relation to problem solving tasks. Herrmann (1996) gives a short definition that encapsulates many other definitions presented in the literature:
"What is creativity? Among other things, it is the ability to challenge assumptions, recognize patterns, see in new ways, make connections, take risks, and seize upon chance."

Let us elaborate a little more on this definition: Challenge assumptions means questioning the basis of the problem formulation; recognise patterns because usually chaos and complexity are caused by simple patterns which, when recognised, lead us to the solution to the problem; see in new ways means looking for patterns from different perspectives: a rational or logical, an organisational or procedural, an interpersonal or emotional, and an experimental or holistic; make connections, or "bisociate", because many creative ideas are the result of synergy occurring between two thoughts or perceptions; take risks because there always exists the probability that your ideas will lead to failure due to many factors out of your control; and seize upon a chance means to take a calculated risk in order to take advantage of an opening that allows to move forward toward a creative solution.

In addition, a response is creative if it is **heuristic** rather than algorithmic. A heuristic is an incomplete guideline or rule of thumb that can lead to learning or discovery. An algorithm is a complete mechanical rule for solving a problem or dealing with a situation. Thus, if a task is algorithmic it imposes its own tried-and-true solution. If a task is heuristic it offers no such clear path, you must create one.

Barriers to Creativity
To be creative you have to be open to all alternatives. This open mindedness is not always possible to meet because all humans build up blocks or mental locks in the maturation and socialisation process. Some of those locks can have external causes, such

as family environment, the educational system, and organisational bureaucracy. Other blocks are internally generated by our reactions to external factors or by physical factors. A key to improve your creativity is to become aware of your locks and do something about them. While everyone has blocks to creativity, blocks vary in quantity and intensity from person to person. Most of us are not aware of our conceptual blocks. Awareness not only permits us to know our strengths and weakness better but also gives the needed motivation and knowledge to break down these blocks. Adams (1986) identifies the mental locks as perceptual, emotional, cultural, environmental, and intellectual.

Perceptual locks are obstacles that restraint us from clearly perceiving either the problem itself or the information needed to register the problem. It is well known that our eyes can deceive us in observing some figures. Our perceptions are not always accurate.

Emotional locks restrict our freedom to investigate and manipulate ideas. They prevent the communication of our ideas to others. These locks are also called psychological barriers and are the most significant and prevalent blocks that impede innovation. Fear of something new is a common characteristic of many individuals in the developed world.

Cultural locks are adapted by exposure to a given set of cultural patterns. The culture of the industrialised countries trains mental playfulness, fantasy and reflectiveness out of people by placing stress on the value of efficiency, effectivity and moneymaking. Taboos and myths are predominant blocks to creative behaviour. Therefore, it needs courage to be creative in a culture that does not support creative changes.

Our near social and physical environment imposes environmental locks. Creative persons have usually had a childhood where they were free to develop their own potentialities. We have seen that Amabile (1998) has documented that organisational climate can be a barrier or a stimulus to creative activities.

Intellectual locks are caused by conservatism and lack of willingness to use new approaches. The same approaches, the same tools and the same persons are tackling the same problems for years. Persons with intellectual locks are usually very negative to changes and are fast to criticise new proposals.

The Systems View of Creativity

Creativity is usually seen as a mental process but creativity is also a cultural and social activity. Csikszentmihalyi (2001) asserts that any definition of creativity will have to recognise the fact that the audience is as important to its constitution as the individual who is producing novelty. This environment has two main aspects:

- The domain, a cultural or symbolic aspect, and
- The field, a social aspect.

For creativity to occur, a set of rules and practices must be transmitted from the domain to the individual. The individual (or a group) must then produce a novelty in the content of the domain. The field for inclusion in the domain then must select the novelty.

Creativity occurs when a person (or a group) makes a change in a domain, a change that will be transmitted through time. But most novel ideas will be forgotten if some group does not accept them entitled to make decisions as to what should or should not be included in the domain. These gatekeepers are the field. The field is the social organisation of the domain, those who decide what belongs to a domain and what does not. Therefore the occurrence of creativity is not just a function of how many gifted individuals there are, but also of how accessible the various symbolic systems are and how responsive the social system is to novel ideas. Csikszentmihalyi has outlined a systems theory of creativity, relating creative effort by individuals to the state of the domain they are working in and the characteristics of those who assess the worth of the creative endeavour in the field concerned. This offers a penetrating analysis of how creative endeavour emerges within a social field. Drawing on years of research in the field, he hypothesises about the interplay between knowledge about the domain, gatekeepers in the field and creative individuals. In addition, many of the points made by him in relation to other domains apply equally well to creativity and innovation in organisational settings. Csikszentmihalyi has drawn attention to the social context out of which creativity and innovation emerge. For example he has demonstrated the beneficial role of working at a place and time in which other individuals are engaged in related creative activities.

3. Creativity in the OR literature

It is commonly accepted that real life problem solving supported by OR is both a **science** and an **art** (Ackoff, 1978). There are many publications and research work about the science (the rationality) of problem solving: decision analysis, modelling, optimisation, simulation, algorithms, heuristics, statistical analysis, validation, and so on. On the other hand, relatively little has been written about the art (the creativity) of problem solving, this topic has been largely ignored in spite of the fact that creativity is a powerful element of the OR problem solving process. There are so few references that an extensive review is easily done.

One of the first papers about creative thinking in modelling is by Morris (1967). He argues that model building is very much an art, and as such, requires a significant amount of creativity. He has provided one of the few discussions of this aspect of modelling and emphasises the modelling process as being intuitive, and as such it can be supported by creative techniques. Morris suggests specific steps to help individuals acquire modelling skills.

The following book appeared in 1978: The Art of Problem Solving (Ackoff, 1978). This is probable the first book about creative problem solving in OR. Ackoff has shown decision-makers the way to more creative, artful problem solving. This book is a practical guide that shows you step-by-step how to develop an understanding of the art of creative thinking and the design of creative solutions to planning problems. Later, Ackoff and Vergara (1981) published a remarkable paper, an invited review of the research on creativity of relevance to problem solving and planning. This paper presents several approaches for enhancing creativity. In this context, creativity is restricted to “the ability of a subject in a choice situation to modify self-imposed constraints so as to enable him

to select courses of action or produce outcomes that he would not otherwise select or produce, and are more efficient for or valuable to him than any he would otherwise have chosen." Ackoff (1993) recommends the use of idealised design or redesign of a system and its environment in creating corporate visions for an organisation. Such a design is one that the stakeholders in the system would have now if they could have any system they wanted.

Evans (1989, 1991a) has done important work in connecting Creativity and OR. The first publication is a double paper given the foundations for the second one, the only book on Creativity and OR. The purposes of these publications were: To review the diversity of literature about creativity, to examine the use of creative problem solving techniques to enhance OR methodology, and to offer insights and suggestions for integrating creativity into the practice and education of OR. In the period of 1991-1993 a series of papers related to Evans' research were published in Interfaces, see for instance Evans (1991b, 1992, 1993a, 1993b). The work of Evans has been restricted to mathematical modelling and has not had major impact in the field.

Saaty (1998) advocates the need for a systemic integration of the diverse approaches used in quantitative OR within a single framework for all areas, including dependencies and feedback among influences to maintain the full integrity of the problems we solve using creativity and intelligence to move the process of creating a theory beyond the traditional process of problem solving.

Now-a-days it is not sufficient to talk about OR in general, we have to specify whether we are dealing with hard, soft or critical OR, see Mingers (1992) for a meta-theoretical discussion of these different modes of practicing OR. Usually, hard or technical OR is focusing on mathematical modelling and model solving, soft or practical OR is concerned with participation and negotiation using soft methods and critical OR is preoccupied by the problems of alienation and empowerment while using hard and/or soft OR. Obviously, the creativity tools to be discussed in the next sections are of central relevance to the different modes of OR, it is in this sense that we can talk about technical creativity, social creativity and critical creativity.

Keys (2000) argues that the place of creativity, design and style in OR has never been doubted but there has not been a unified approach to understanding the varied and significant roles they play. In this paper a means of examining creativity, design and style is presented that seeks to show the key role that they play in explaining how practice in OR goes beyond the application of technique and involves analyses in a rich mix of processes and activities. Thus, hard OR leads to an emphasis upon the creativity involved in understanding situations and designing tools, usually quantitatively or IT based, to support decision makers, such a focus is called "technical creativity". On the other hand, soft OR leads to an emphasis upon the creativity involved in managing the relationships between consultants and clients and the design of such processes (the facilitation of problem solving processes), such a focus is called "social creativity". A further discussion of this hard/soft paradigm related to creativity and OR problem solving can be found in Tsoukas and Papulias (1996).

It can be concluded that in the different OR schools, there is a tremendous need to:

- Introduce modern interdisciplinary concepts about creativity,
- To adopt creative tools and approaches that can be included in the OR toolbox to complement the traditional hard and soft rational approaches, and
- To show how creativity methods can be used in the practice of OR workers.

4. Creativity Research

The description of the incubation or discovering process by the French mathematician Henri Poincaré (1854-1912) was the beginning of creativity research. Based on these experiences the psychologist Wallas (1926) formulated a four step creative problem solving process: preparation, incubation, illumination, and verification. Incubation and illumination characterise the individual's creative process. Incubation involves the flashes of insight while in the process of puzzling over a problem or dilemma, mulling it over, fitting the pieces together, trying to figure it out, this the part of the creative process that calls for little or no conscious effort. The flashes of insight come while you are going to sleep, travelling, dreaming, taking a shower, reading a newspaper, relaxing or playing (Eureka experience). Research on creativity was intensified after the Second World War. In the 1950s American psychologists started to investigate the mental origins of creativity and develop creativity tests, the works of Torrance and Guilford started at this time. In Europe, Koestler's research work was carried out during the 1950s and his monumental book, "The Art of Creation", was first published in 1966. Stenberg (1999) has edited a book presenting an overview of 50 years of research in the creativity field. Now-a-days creativity research work can be classified in the following five domains: the product, the environment, the personality, the process, and learning and cognition.

The product

Focusing on the tangible that is new, useful, original, surprising, etc., this includes works of art, scientific discoveries, inventions, consumer goods, problem solving, adaptations, modifications, etc. Product innovation is usually the main theme in the broad field denominated as Design. Buchanan (Buchanan and Margolin, 1995) writes: "Design is a humanistic discipline – the art of conceiving, planning and realizing all of the products that are made by human beings to serve human beings in accomplishing their individual and collective purposes." Bionics is the name given to borrowing ideas for novel products or processes from nature. The list of improvements inspired by an observation of nature is very long. The inventor of the ballpoint pen was allegedly walking through a park on a frosty morning and watched some youngsters rolling a ball down a slope covered with dew. The brilliant idea was to make the connection between what he saw and the apparently un-connected problem he had on trying to improve the liquid-ink-based fountain pen.

The environment

Focusing on the organisational culture or climate that encourages or kills creativity. There will be things that happen either formally or informally and either of these may in turn help or hinder; there may also be things that the organisation does not do that affect the quality of problem solving. Environmental factors conducive to creative thinking

include: The freedom to do things differently, an environment that encourages risk taking and self-initiated projects, and provides help and time for developing ideas and individual efforts; an optimal amount of work pressure, a no punitive environment, a low level of supervision, resources and realistic work goals; shared responsibilities, timely feedback, confidence in and respect for co-workers, and shared decision-making (participation); interaction with others outside the work group; and open expression of ideas, particularly of-the-wall ideas. All these factors will increase individual motivation and the happiness of enjoying your work, essential elements for creative and innovative work. Many organisations do not foster these conditions. Cultural change, education, and training are necessary within a global strategy to develop an action plan to make an organisation more creative. Managers at all levels, especially engineers and scientists, educators, and graduate students have much to gain from understanding how to foster a creative climate. Barriers to creativity include habits and routines, judgmental thinking, oppression and hierarchy, and various perceptual, emotional and cultural blocks seen in the last section, see further Amabile (1983, 1998)

The personality

Focusing on the characteristics of the individual who creates. Factors such as temperament, personal attitudes, and habits influence creativity. Creative thinking is largely a function of divergent thinking - the discovery and identification of many alternatives. Psychologists have performed considerable research on the characteristics of creative individuals that promote divergent thinking. These included: knowledge, imagination, evaluative skills, awareness and problem sensitivity, capability to redefine problems, memory, ideational fluency, flexibility, originality, penetration, self-discipline and persistence, adaptability, intellectual playfulness, humour, nonconformity, tolerance for ambiguity, risk taking, self-confidence, and scepticism. Recent research has shown that creativity is more than just divergent thinking. The two complementary patterns of convergent and divergent thinking must run alongside one another. Gardner (1983) has identified seven kinds of intelligences or pathways to learning: linguistic (writers and speakers), logical-mathematical (scientists), musical (composers), spatial (visual artists), bodily kinaesthetic (dancers, athlete), interpersonal (educators), and intrapersonal (therapists). It could be possible to think of creativity in the same way. However, creativity scholars and practitioners have not made any move in this direction, but they have recognised that there are many ways of being creative. The intelligence testing (IQ) movement originated in attempts to predict academic competence. Using familiar situations with prior knowledge and reasoning (intelligence) may be sufficient to solve some problems or dilemmas. However, there are instances in everyday life in which new and different problems and dilemmas emerge, which require some cognitive bridging or creativity. Results have been published showing that there is not a meaningful correlation between intelligence (essentially IQ) and creative problem solving (Goff, 1998)

Maslow (1987) distinguishes between "special talent creativeness" and "self-actualising creativeness" and he found that creativity is a universal characteristic of self-actualising people. Self-actualisation may be described as the full use and exploitation of talents, capacities, potentialities and the like. Such people seem to be fulfilling themselves and doing the best that they are capable of doing. He identified the following characteristics

of self-actualising creativeness: perception or fresh appreciation and wonder of the basic good of life; expression or ability to express ideas and impulses spontaneously and without fear of ridicule from others; childlike or innocence of perception and expressiveness, natural, spontaneous, simple, true, pure and uncritical; affinity for the unknown; resolution of dichotomies or the ability to synthesise, unify, integrate; and peak experiences or fearless, wonderful, ecstatic experiences which change the person and his/her perception of life. Their codes of ethics tend to be relatively autonomous and individual rather than conventional. They regard upon the world with wide, uncritical, undemanding, innocent eyes, simply noting and observing what is the case, without either arguing the matter or demanding that it be otherwise. Self-actualising creativeness is "emitted", like radioactivity, and it hits all of life, regardless of the problems. Maslow (1987) mischievously wrote: "Science could be defined as a technique whereby noncreative people can create".

The process

Focusing in the way that creative solutions and products were developed. Wallas' four-stage model has given inspiration to the development of approaches to be used by individuals or groups in the creative solving process. In the next two sections we will see some of these methods. Some definitions of creativity are closely related to the process of sensing problems, forming ideas or hypotheses, testing and modifying these assumptions and communicating the results. In this respect creativity is the ability to see a situation in many ways (divergent thinking) and continue to question until satisfaction is reached (convergent thinking). The creative process can involve tiny creative leaps or giant breakthroughs. Both require that an individual or a group go beyond where they have gone before, embracing the unknown, the mysterious, the change, and the puzzling without fear. The creative process may be considered as a new way of seeing, a different point of view, an original idea or a new relationship between ideas. It is the way or manner in which a problem is solved. It is the process of bringing something new into being. It is the process of combining previously unrelated ideas or perceiving a new relationship from previously unrelated ideas. Whether solving problems alone or in a group, you really must have a guided process i.e. a plan or a map of the steps to be followed. This is especially so in a group due to the need to align the capabilities of the members in a positive way. This map is usually called the creative problem solving process and under this denotation there exists a huge number of methods, tools and techniques to support the creative process. It is also a good idea to facilitate the group creative process. The facilitator will support the process, will elaborate a plan of the steps to be followed and will manage the whole process to secure that an action plan will be elaborated and implemented.

Learning and Cognition

This research area is focusing in the abilities of creative learning, thinking and cognition in relation to problem solving. All these activities are related to the physiology of thinking and therefore to the function of the human brain. Creative learning is a natural, healthy human process that occurs when people become curious or excited about understanding or knowing more. Anytime we are faced with a problem or dilemma with no learned solution, some creativity is required. Creativity, by its very nature, requires

both sensitivity and independence. In our culture, sensitivity is a feminine virtue while independence is a masculine virtue. Landrum (1994) outlines some specific differences between male and female approaches to learning. The female approach can be characterised as based on: negotiations, feelings, understanding, personal relationships, intuition, and win-win outcomes. The male approach is based on: aggressiveness, competition, ego gratifying, impersonal relationships, and win-lose outcomes. All people learn trough their senses: touching, smelling, tasting, feeling, hearing and seeing. According to Matte and Henderson (1995) more than half of the population in the USA are visual learners (they want to read it). The rest of the population are with fifty percent probability either auditory (they want to hear it) or kinaesthetic (they want to experience it). The understanding of different forms of cognition and creativity is related to the structure and function of the brain, a research area known as neuro-psychology that has undergone a huge expansion and that has contributed to the understanding of individual creativity.

5. Which tools?

We have seen a variety of abilities that characterises creative individuals or groups. Four of the key abilities will be discussed in this section as well as tools to enhance them in concrete problem solving situations. They are: Fluency, flexibility, originality and elaboration. In this section we will only present some few tools, those being the most popular and especially suitable for group work. Higgins (1994) presents many other tools and at the end of the list of references addresses of the best-known creativity home pages are presented.

Fluency

Fluency is the production of multiple problems, ideas, alternatives or solutions. It has been shown that the more ideas we produce, the more likely we are to find a useful idea or solution. Fluency is a very important ability especially in the creative problem solving process. To have too few alternatives is not a good thing in problem solving, especially if you have to be innovative. There are many tools for producing ideas, alternatives and solutions. Several researchers have shown that training and practice with these tools cause a better fluency.

One creative tool, which has been widely used with big success for generating many ideas, is Brainstorming. Osborn (1953) invented it for the sole purpose of producing checklists of ideas that can be used in developing a solution to a problem. The tool is directed to generating unconventional ideas by suppressing the common tendency to criticise or reject them summarily. He tried to separate idea-evaluation from idea generation because he believed that if evaluation comes early, it reduces the quantity and quality of the ideas produced. Therefore in a Brainstorming session no criticism is permitted, and freewheeling generation of a large number of ideas and their combination and development are encouraged. Brainstorming is founded on the associative premise that the greater the number of associations, the less stereotyped and more creative the ideas of how to solve a problem will be.

However, nothing in Brainstorming is directed at changing the assumptions or paradigms that restrict the generation of new ideas. This is an excellent technique for strengthening fluency, fantasy, and communication skills. It is a good idea to have a facilitator to prepare and warm-up the Brainstorming session, to lead and support the session, and to evaluate the whole process. This tool gives the possibility for the group to use more than one brain achieving a synergetic effect. Generate a multitude of ideas and some of them will be truly useful, innovative and workable. Asking individuals for inputs gives them an increased sense of importance and produces an atmosphere for truly creative and imaginative ideas to surface and be acknowledged. Brainstorming combined with other methods has been used for a wide diversity of problems, including not only marketing and product issues but also strategy development, planning, policy, organisation, leadership, staffing, motivation, control, and communication. However, this tool is not appropriated for broad and complex problems demanding high-qualified expertise and know-how. Some of the ideas produced may be of low quality or obvious generalities. Brainstorming is not a good idea for situations that require trail and error as opposed to judgement.

Flexibility

Flexibility is the ability to process ideas or objects in many different ways given the same stimulus. It is the ability to delete old ways of thinking and begin in different directions. It is adaptive when aimed at a solution to a specific problem, challenge or dilemma. Flexibility is especially important when logical methods fail to give satisfactory results. Looking at modern paintings requires flexibility, they demand looking from different perspectives in order to see different objects, images and symbols. Seeing persons or objects in the clouds requires the flexibility of seeing concrete shapes in cloud formations. Flexible thinking provides for changes in ideas, detours in thinking to include contradictions, differing viewpoints, alternative plans, differing approaches and various perspectives of a situation.

A family of creative tools, known as verbal checklists, has been created to enhance flexibility in the creative process. Usually this is a checklist of questions about an existing product, service, process, or other item to yield new points of view and thereby lead to innovation. Osborn (1953) has developed a very extensive verbal checklist while he was a partner of a major US advertising firm. The idea behind the verbal checklist is that an existing product or service can be improved if one applies a series of questions to it and pursues the answers to see where they may lead. The main questions take the form of verbs such as Modify? or Combine? These verbs indicate possible ways to improve an existing product or service by making changes to it. Then you add definitional words to the verb, for instance combine ideas, combine appeals, combine purposes, combine units, etc.

Elberle (1971) developed a short verbal checklist known as the SCAMPER technique to assist people in improving their flexible thinking. When using such checklist, you will usually follow the following steps:

- Identify the product or service to be modified
- Apply each of the verbs on the checklist to suggest changes in the product or service

- Make sure you use many definitional words for the listed verbs, and
- Review your changes to determine which one meets your solution criteria.

Another important tool for encouraging flexibility is the use of provocative questions. These questions will open up a situation to a broader and deeper direction of thinking which otherwise might not be produced or considered. They encourage people to think about ideas or concepts they have not thought about previously. Some provocative questions can be: What would happen if: water tasted like whisky? Cats could bark? Women could fly? How is: A PC like a ship? A flower like a cat? A sunset like a lake? A car like a fork? What might happen if: It never was Sunday? It was against the law to be perfectionist? People were not creative? Image what might happen if: By law it was forbidden to have children? Cars could fly? Men could have children?

Originality

Originality means getting away from the obvious and commonplace or breaking away from routine bound thinking. Original ideas are statistically infrequent. Originality is a creative strength, which is a mental jump from the obvious. Original ideas are usually described as unique, surprising, wild, unusual, unconventional, novel, weird, remarkable or revolutionary. You need courage to be creative, because as soon as you propose a new idea, you are a minority of one. Belonging to a minority is unpleasant. In addition the original thinker must be able to withstand the ridicule and scepticism, which will be directed toward his/her ideas and himself/herself. To enhance creativity we have to be respectful of unusual or crazy ideas or alternatives.

Picture Stimulation is a very popular technique used to provide ideas beyond those that might be obtained using brainstorming. The members of the group will look at a set of selected pictures and relate the information gained from the picture to the problem, otherwise the rules of brainstorming should be followed. Photo excursion uses the same principles of picture stimulation but instead of using prepared pictures for stimulation, participants are required to leave the building walk around the area with a (Polaroid or digital) camera, and take pictures of possible solutions or visual ideas for the problem; when the group reconvenes, ideas are shared. Another related technique is the Object Stimulation tool where instead of pictures a variety of different objects (e.g. a hammer, a pencil, a board game, etc.) will be used. Sometimes you can use words instead of pictures or objects, an associate them to your problem.

Originality can also be enhanced by analogies and metaphors. An analogy is a comparison of two things that are essentially dissimilar but are shown through the analogy to have some similarity. A metaphor is a figure of speech in which two different universes of thought are linked by some point of similarity. In the broadest sense of the term, all metaphors are simple analogies, but not all analogies are metaphors. Nature is a good source to provide analogies. Poetry is a good source of metaphors. Similes are specific types of metaphors that use the words "like" and "as" - for instance, the wind cut like a knife; his hand was as quick as a frog's tongue, he sees like a condor and digs as fast as a mole. Similes can be used to suggest comparisons that offer solutions.

Elaboration
Mind Mapping is a visual and verbal tool usually used to structure complex situations in a radial and expanding way during the creative problem solving process. A mind map is by definition a creative pattern of related ideas, thoughts, processes, objects, etc. It is difficult to identify the origin and the creator of this technique. It is probable that this tool has been inspired by research on the interplay between the left and the right hemisphere of the brain. It can also be dated back to experiments with the brain and accelerated learning. It has been, among others, Buzan (1983) who has made Mind Mapping a well-known technique with many applications.

The principles to construct mind maps are few and easy to understand. The best way to learn it is by practice. After short time you will do it automatically. If it is difficult for adults it is because they think linearly and take notes in a linear way (using the left hemisphere of the brain). To make mind maps you have to draw ideas from the centre of the paper and move in a radial and parallel way, to do that you have to use both your creative and your logical brain. With some experience you develop your own style, your own pallet of colours, your own symbols, your own icons, etc.

A Mind Map contains usually the following elements:

- The subject or the problem that has to be studied or analysed will be placed in the centre of the paper
- Keywords (names or verbs) are used to represent ideas, as far as possible only one word is used in a line
- The keywords are connected to the centrum through a main branch and sub-branches
- Colours and symbols are used to emphasise ideas or to stimulate the brain to identify new relations
- Ideas and thoughts are permitted to arise free; too much evaluation is avoided during the period of elaboration of the map.

When constructing a mind map, it is a good idea to start from left to right building main branches in a circular way. Then, to continue drawing sub-branches moving in a circular way until the whole sheet of paper is fill up with ideas. That is, you have been moving following an expanding spiral pattern. Then, move in the reverse way following a contracting spiral pattern supplementing the map with new ideas and connections. These spiral movements provoke the interplay between the creative and the logical parts of the brain, combining holistic thinking with particular details of the subject or the problem in question.

6. The Creative Problem Solving Process
Experience has shown that it is a good idea in a creative problem solving process to start with divergent thinking to produce as many ideas or solutions as possible and thereafter to switch to convergent thinking to select the few most promising ideas. This is usually illustrated in the form of a diamond.

Some of the rules for **divergent thinking** are:

- Image, reframe and see issues from different perspectives
- Defer judgement (criticism or negativity kills the divergent process), be open to new experiences
- Quantity breeds quality, to have good ideas you need lots of ideas
- Hitchhiking is permitted, in this way a synergetic effect can be achieved
- Combine and modify ideas, in this way you can create many ideas
- Think in pictures, to create future scenarios you can even simulate potential solutions
- Stretch the ideas, imagine ideas beyond normal limits, and
- Do not be afraid to break paradigms, avoid destructive criticism, and to add value to the challenged concept.

Some of the rules of **convergent thinking** are:

- Be systematic, find structure and patterns in the set of produced ideas
- Develop ways to evaluate ideas, assess qualitative and quantitative measures of ideas
- Do not be afraid of using intuition, this is the way most important decisions are taken
- Avoid quickly ruling out an area of consideration, take your time or better sleep on it
- Avoid idea-killer views, try the impossible
- Satisfy, do not expend too much time in looking for the optimal solution of an ill-structured multi-criteria problem
- Use heuristics, use common sense and experience based rules, and
- Do not avoid but assess risk, this does not mean being blind to risks, for serious consequences be sure to have a contingency plan.

As we will see below, creative problem solving processes always contain phases of divergent and convergent thinking. Divergent thinking produces as many solutions as possible within the available time. The participants will vary in the way they prefer to produce ideas; some will do it by association, others by unrelated stimulus. Convergent thinking on the other hand requires the participants to use skills in reality testing, judgement and evaluation to choose the one or two best options from a number of possibilities. It is not unusual that in a group some members will very easily diverge, that is build a list of alternatives, while others will converge very fast by trying to select the best solution from the list and the rest will be passive not knowing what is required of them. Hence the need of a facilitator, he or she designs a clear and visible process to align the group.

The CPS (Creative Problem Solving) Approach

Osborn (1953) described several basic steps to support groups and individuals to be more successful in creative problem solving. Later, based on these proposals, several researchers have formalised and extended these ideas into a systematic approach to creative problem solving known as the CPS approach or process. 4-steps, 5-steps and 6-steps models have been proposed. Here we present the most general version. It is called the 6-diamond model (Courger, 1995), where the upper part of each diamond represents the divergent sub-processes and the lower part corresponds to the convergent sub-processes. The 6 steps are:

- Mess finding: Identify areas of concern. Generate ideas about possible problematic situations from a holistic viewpoint. Identify the three most critical and general problems. Select one for further work.
- Fact finding: Observe carefully, like a video camera, while collecting information and data about the problem situation. Both objective facts and subjective experiences should be collected, explored and identified.
- Problem finding: Fly over the challenge or the problem by considering different ways of regarding it. Think about those possibilities.
- Idea Finding: Search for a variety of ideas, options, alternatives, paths, approaches, manners, methods and tools. Select potential solutions or ideas.
- Solution finding: Dig about the ideas in new and different ways, from other viewpoints and criteria. Assess the consequences, implications, and reactions to the selected ideas. Select ideas and solutions to develop an action plan.
- Acceptance finding: Develop ideas about how to implement the action plan. Search for ways of making the ideas or solutions more attractive, acceptable, stronger, more effective, and/or more beneficial. Develop a working plan for implementation.

Considerable research into the CPS process shows that a willingness to consider alternatives, to take some risks, to venture into insecure land, and to tolerate some uncertainty and ambiguity are important; see further Parnes (1997). Let us now focus on the different types of creative sub-processes that are needed at each step of the 6-diamond model:

- Mess finding. Here we will have the following creative sub-processes: Fluency, flexibility, originality, deferred judgement, and evaluation
- Fact finding. Here we will have the following sub-processes: Analysis and evaluation.
- Problem finding. Here the main sub-process is synthesis.
- Idea finding. Here we will have the following sub-processes: Fluency, flexibility, analysis, originality, and deferred judgement.
- Solution finding. Here the main sub-processes are: Synthesis, elaboration and evaluation.
- Acceptance finding. The following sub-processes are present: Synthesis, evaluation, originality, and flexibility.

As we can see at all these stages creativity tools can be used, but depending on the problem or the situation under study, both "hard" and "soft" methods can also be applied especially in the convergent phase of each step in the CPS process.

Depending on the size and complexity of the problem the whole CPS process might take a long time. During this process the work group at some stages will need a facilitator, an expert, or a supervisor to support the different types of decisions to be taken. These are some of the roles that the adviser or mentor of a group of students at the university working on theses or projects can take. On the other hand, a very important aspect in this respect is learning. Every person that has a “proactive” stance to life can easily learn the use of creativity tools and the CPS process. Because of their simplicity many of these

tools can be used in everyday life. Children at school and elderly people can creatively empower their life by being proactive instead of reactive. Moreover, being creative in a group is usually fun; creative teams at work usually laugh a lot, see further Goff (1998).

Depending on the actual problematic situation some more specialised approaches could be used combined with creative tools, for instance: Synectics (Gordon, 1961), Future Workshops (Jungk and Müller, 1987), TKJ (Kobayashi, 1971), SWOT (Sørensen and Vidal, 1999), The Search Conference (Emery and Purser, 1996), Idealized Design (Ackoff, 1978) and TRIZ (Kaplan, 1992)

7. The Vision Conference: Facilitating creative processes (Vidal, 2004)

The Vision Conference can be conducted for a wide range of purposes. They are usually used to help organisations and group of individuals to create visions, ideas, projects, etc., about the future. These visions will then be used as input to the process of strategy development. Similarly, they can be suitable for involving diverse groups affected by imminent developments in the larger systems, which include many actors such as industries, regions and communities. The Vision Conference ideally brings together 30-60 people representing all relevant stakeholders. The participants must adequately and accurately reflect the different range of interests, but participation must be voluntary.

This conference will be designed and managed by one or several facilitators. The duration might be from 3 hours to 3 days depending on the complexity of the task. We have used this concept to develop IT-strategies for primary schools (Sørensen and Vidal, 2001) and to support communities in the elaboration of ideas and projects to enhance a sustainable development of the region (Vidal, 2003).

Purpose

The purpose of the Vision Conference is not only to create ideas and visions about the future but ideas and visions that are suitable as a basis for the process of strategy development to be carried out by the organisation in question. The Vision Conference is both a learning and creative experience characterised by:

- The organisation learns about the different actors´ ideas, wishes and visions;
- The different actors communicate to each other their visions;
- The participants learn to work creatively, collectively, and purposely in a large group; and
- The participants learn how to design and manage (facilitate) Vision Conferences.

Design and Planning

Achieving such learning outcomes depends very much of how the Vision Conference is designed and managed. Two critical dimensions of Vision Conference design are: the definition of the conference **task** and the social **organisation and management** of the group. Initial definition of the task and the stages towards its completion is the responsibility of the facilitators (design-managers) of the Vision Conference. In consultation with the organisation responsible for the Vision Conference and through some prior research into the relevant issues, facilitators should first:

- Develop a tentative definition of purpose that will be meaningful to participants; and
- Suggest a program that provides both adequate direction and sufficient scope for the participants to assume control and responsibility as the conference progresses.

The primary purpose is to create the room and the opportunities for the participants to be creative, producing their visions for the future. This is possible only if both the information and ideas come from all the participants and if the group work is organised so that progress towards task completion is accepted as the participants´ as well as the facilitators- responsibility.

Pre-conference

It is a common belief that detailed planning at the pre-conference stage is essential to ensure that the facilitators help to create a group work at the conference that focuses on the task and that this needs tight organisation. Moreover, it is also argued that this first stage is as important as running the group work at the conference itself because without sufficient pre-planning the chances of success will be greatly reduced.

On the other hand, it is our experience that too much planning and organisation might kill spontaneity and creativity in the group work. Therefore, a suitable balance should be found, a suitable framework that gives space for the development of the rational and irrational processes, and for adaptive decision-making during the facilitation of the group work. At this stage, it is of central importance that the facilitators discuss with the organisers of the conference the purpose, the task, the organisation and the management of the group work. Good time should be allocated to discuss thoroughly these themes so that at the end of this stage the organisers of the conference and the facilitators have develop a consensus about the objectives and development of the conference. This goal compatibility is of extreme importance. In addition, it should also be discussed the processes, the creative tools and techniques that might be utilised during the conference. How will the participants react to them? is a central question to be discussed intensively at this stage.

The Conference

At the beginning of the conference day, it is important that the facilitators explain to the participants the purpose and the agenda of the conference, before going to work in sub-groups. Explain that the agenda can be changed if necessary, and that the time schedules have to be respected to avoid too long waiting times when the participants will be meeting for the plenary sessions.

In the Vision Conference some creativity tools will be used in the problem solving process. Usually the four types of tools presented in Sec. 5 are sufficient to support most problem solving processes. The facilitators should be convinced that the selected tools are the most suitable for the conference, but if during the sessions it is detected that the tools are not supporting adequately the facilitator should be capable of switching to other more appropriate creative tools. One thing is crucial: the participants should feel quite

easy with the facilitators, the process and the used techniques, in this way it is ensured true participation.

Post-conference
After the conference, the facilitators have to write an accurate report of the experience. This report should include the following themes:

- An outline of the background and purpose of the Vision Conference;
- The results obtained at each sub-group;
- The evaluation by the facilitator of the work in each sub-group;
- The evaluation of the whole conference by the facilitators, including the good and bad experiences; and
- What did we learn from the experience?

8. Strategy development in organisations

Organisations develop usually from day to day in a smooth evolutionary process, Sometimes, it can be foreseen that the organisation should not function as usual some changes are needed. This might occur due to radical changes in the environment (external factors) or/and major alterations within the organisation itself (internal factors). In such situations radical changes in the organisation are needed. It is our conviction that in such situations the organisation should develop a **strategy** for change to be able to cope with the changes that the future brings about. Strategy development involves explicit formulation or formation of reachable objectives (goals and visions) for the future of the organisation. Reachable objectives mean that although strategy development focuses primarily on objectives, account is taken of means and resources available.

In real-life, strategy development is conditioned by the way the organisation works while solving problems and taking decisions. Any organisation has a history and it will have a tendency to develop strategies in a similar way as problem solving is usually done in the organisation. Changing this routine demands creativity and innovation.

In highly hierarchical organisations, a strategy will be a set of guidelines to establish direction for the organisation formulated by top management that has been set forth consciously in advance prior to actions. This is usually denominated strategy as a position, a plan or a ploy. This conceptualisation of strategy implies the following: Firstly, top management knows what they wish to achieve, meaning that visions and goals have been identified and explicitly formulated. Secondly, the strategies are made in advance of the actions to which they apply. Thirdly, the strategies are made consciously and purposefully. Fourthly, once the strategy has been formulated what is left is the problem of implementation; this is a rather complex and uncertain top-down process demanding a lot of planning and control.

A simple and practical approach to strategy development that we have used in several organisations is composed of three steps:

- Diagnosis: What is the situation of the organisation now?

- Visions: What should the situation of the organisation be in the future?
- Action: What ought to be done?

Each step can be supported by different methods. A method usually used for diagnosis is SWOT-analysis. SWOT is an acronym formed from strengths, weaknesses, opportunities and threats. SWOT gives some guidelines for the systematic analyses of the internal and external environments of an organisation. It involves the assessment and appreciation of the external factors and from those identifies opportunities and threats posed to the organisation by the external environment. Similarly, the internal factors are used to list strengths and weaknesses inherent to the current status of the organisation. The representation of strengths, weaknesses, opportunities and threats in tabular form, gives origin to the SWOT matrix. This matrix suggests four different ways of generating strategies by combining the minimisation of threats and weaknesses, and maximisation of strengths and opportunities. This approach facilitates the identification and generation of different strategic areas; it does not suggest the best strategy for a given situation. Conclusions drawn by the author based on practical use of this approach in a number of different contexts seem to indicate that it does not often bring entirely new perspectives into consideration: The participants tend to find that the matrix only confirms views which they currently hold. However, if SWOT-analysis is combined with a creative workshop, it can become a very powerful approach to strategic management because new ideas and insights can be brought into the problem. Depending on the actual situation at hand appropriate creative tools could be used (Sørensen and Vidal, 1999).

At the second step different visions of the future of the organisation will be elaborated conditioned by an expected state of the environment of the organisation. At this step, the scenario method is usually the preferred approach to create visions about the future. A scenario is a story about how the future of the external environment might turn out. When developing strategic alternatives, it is useful to evaluate what that future environment may look like, so that an appropriate action plan may be produced (stage three). The following eight-step procedure is usually denominated the scenario development process (Borges et al, 2002):

- Set the scene,
- Generate predetermined and uncertain factors
- Reduce factors and specify factor ranges
- Choose themes and develop scenario details
- Check consistency of scenarios
- Present scenarios
- Assess impact of scenarios
- Develop ant test strategies

This scenario development process will be carried out as a facilitated conference for a work group having in principle the same structure as the vision conference presented in the last section. Conclusions drawn by the author based on practical use of this approach in a number of different contexts seem to indicate that it is good idea to carry out the

eight-step procedure following the principles of the CPS process, that is at each step we will start with a divergent phase and thereafter follows a convergent phase.

The last stage, Action, is usually a rational process where both hard and soft methods could be used see further Sørensen and Vidal, 2004.

9. Design of decision-support systems for complex optimisation problems

To design something is usually an activity related to innovation and creativity. You usually design something new and original: an object, a program or a process. In hard OR and Mathematical Programming, we are usually designing computerised systems and optimisation software to solve rather complex real-life optimisation problems, but very seldom is this design process conceptualised in terms of creative processes and tools. Much of the published literature is focusing in algorithm development, tests and implementation, which are convergent processes, completely disregarding the divergent part of the design process.

Many of my MSc and PhD students in Engineering are dealing in their work with the design of computerised system to solve real-life optimisation problems in production or logistics. Such a system has to be tailored to the actual situation although some sub-problems could be solved using some standard software but the global approach is heuristic (Silver et al, 1980). In such situations the students have to use the CPS approach to deal with the problem solving process in a participative and creative way in collaboration with the users or clients and other stakeholders as planners and programmers. Engineering students are extremely efficient in the convergent phases but they have difficulties in the divergent phases that demand creativity, imagination and dialogue with the participants. My task as an advisor is to support the students in a design of a thesis and to facilitate the students' creative problem solving processes.

A typical example is a computerised optimisation system for planning of high schools examinations in Denmark. This is a large-scale logistic and combinatorial optimisation problem that has been solved using both heuristics and standard algorithms. This system has been described in Hansen and Vidal (1995). The problem solving process followed the principles of the CPS approach. The OR worker's tasks were both:

- To design optimisation approaches to be implemented by professional programmers, and
- To facilitate the whole problem solving process using divergent and convergent processes involving users, planners, administrators and other experts.

This system has been running for nearly 10 years and it has evolved from year to year improving the way how some sub-problems has been solved. Many of the original stakeholders and experts have been changed. The only person that has secured continuity has been the OR facilitator.

10. Final Remarks

Creativity is a young multidisciplinary field that will play a central role at all levels of Society in this millennium. OR workers in their professional lives, both as facilitators and

as (hard and /or soft) model builders, need creativity concepts and tools to create satisfying ways of dealing with messes. There is a growing demand that educators all around Society enhance and adopt creativity in their teaching activities. Creativity is a way to cope with complexity. You need creativity to avoid the fate of specialisation. According to Heinlein (1973): “Specialization is for insects”

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Some useful web addresses:
http://members.ozemail.com.au/~caveman/creativity/index_htm/

http://www.thinksmart.com/
http://www.creax.com/creaxnet/creax_net.php/
http://www.creativity-portal.com/