An Overview of Synoptics and Six Challenges of Creativity

Martin Hyatt, PhD

Synoptics

This paper introduces Synoptics, an approach to creativity, in the context of six challenges to creativity. By looking at the approaches to deal with these challenges we see the themes of metaphor and tree structures that lie at the foundations of creative thought.

Synoptics was developed from a desire to understand the nature of existing creativity methods, asking: why do we have the current methods? how are they related? what other potential methods exist?

Overview

Even though we can recognize creativity in action, we find it difficult to be creative. One reason creativity may be so difficult is that the underlying challenges involved are not easily understood. This paper explores six central challenges of creativity. We find two common themes, metaphoric models and tree structures, that help to resolve these challenges.

We are concerned here with creativity as a problem solving process. Other aspects of creativity such as enhancing a person's general creative tendencies and enhancing an environment to foster creativity are important, but by themselves are insufficient towards a concerted effort against a specific problem.

The challenges below, clarify the issues of creativity. These challenges motivated a research effort (Hyatt, 2000, 2001) that led to the creation of a unifying framework called Synoptics.

We first look at these six challenges. Next, we look at how metaphoric models and tree knowledge structures fit into the creativity process. We will then look at the process as a whole and consider a possible end product for large-scale problems that can involve many participants from different domains.

The six challenges

The six challenges of creativity are:

Challenge 1. How do we generate ideas that meet the opposing constraints of novelty and utility?

We can define creativity as the generation of new and useful ideas. Both aspects of the definition ('new' and 'useful') are constraints that must be satisfied. Each is fairly easy to satisfy by itself. New ideas are easy to generate by force fitting a characteristic from a randomly chosen concept to a problem or issue (dictionaries readily serve the purpose of finding the random concept). On the other hand, useful ideas are generated all of the time by making incremental improvements to the existing idea (quality circles thrive on this kind of activity).

More generally, ideas that will be useful tend to be similar to existing ideas and ideas that are new tend to be very different to existing ideas. Thus these two conditions are at odds with each other. The constraints can be represented by regions of an idea space, as depicted in figure 1. At

the center of the figure are the existing ideas represented by squares. The two constraints are represented by distances from the existing ideas. Ideas that are unique tend to be distant from the existing ideas, as represented outside of the inner circle. Useful ideas are closer to existing ideas, represented as ideas within the outer circle. What we have is a target bounded between the two circles representing the conflicting requirements of novelty and utility. The width of the band between the two circles depends on the conventionality of the existing ideas and the ease of creating practical alternatives. Often these two leave little overlap and so we have a narrow ring as a target. Satisfying these two conflicting requirements to meet this narrow target is the first and fundamental challenge of creativity.

Figure 1. The narrow band of creative ideas.

The narrow target of creativity will be missed if one is overly practical or overly imaginative. A good creativity method will have a strong tendency to reach this narrow target. This is difficult to achieve since creativity is an abstract concept. Metaphoric mappings can translate abstract problems to common ordinary processes. We will see that metaphors enable crafting tools to generate ideas within the tight constraints of novelty and utility.

Challenge 2. How do we know when the full space of potential ideas has been generated?

Often one creative idea is not enough. Most of us have had the experience of finding a creative solution only to find that someone else finds an even better idea. We wonder why we did not come up with this improved idea. One reason is that once someone finds one idea it is difficult to have the same motivation to find other solutions. Perhaps part of the reason for this is that we have little sense of the space of possibilities.

This space of possibilities is used in other disciplines. For instance, in decision-making practice there is something called the 'wince factor' to suggest direction. The wince factor is that part of the situation that gives the maximum disturbance or discomfort. Similarly, in planning there is the critical path that is the most important part of the plan to manage. In both cases the focus is given by considering the entire space of possibilities. It is difficult to know what to do or what

to work on without knowing the full space of possibilities. Indeed, how can one determine what the true problem is without this space? The second challenge is motivated by finding the space of potential ideas.

Each creative method uses different techniques, so naturally we want to use the method that will have the greatest impact. Unfortunately, the methods have very little overlap and only span a small subset of the creativity principles. Some creativity principles are not used in any of the mainstream methods. To be assured of dealing with the most critical part we must have a methodology that would span all possible creativity techniques. But to find a complete set we must know what we do not know.

Amazingly there is a solution, a way to infer the space of techniques. The answer comes from recognizing that the approaches one can take are based on what we can imagine or conceive. What we conceive is based on the way we represent reality. Think about it this way. If we wanted to know all the possible words one could make, it would be difficult to articulate them. But if instead we recognize that all words are spelt by the same alphabet we can construct the list of all possible words by generating all combinations of letters. In our case, the principles are the words and the letters are the basic elements of the representation.

If we knew what we use to represent abstract reality we could construct the set of all principles. Recent work in cognitive science points to metaphor as that basic element of representing reality. As Lakoff puts it, "To study metaphor is to be confronted with hidden aspects of one's own mind and one's own culture. ... To do so is to discover that one has a world view, that one's imagination is constrained, and that metaphor plays an enormous role in shaping one's everyday understanding of everyday events". (Lakoff, 1992) The research points to a small set of metaphors that we use to describe reality. They are in essence wisdom's alphabet from which we can construct a basic set of principles of thought.

The second challenge of creativity is to completely cover the idea space. This requires knowing what you do not know. To choose the right principle we must have all the possible creativity principles to choose from. There are a number of sets of creativity principles among the different methodologies, but none of them are complete. But without completeness there is no way to assure finding and applying the critical principle. The key insight is that all of the principles are rooted in metaphor. Since our conceptions are based on a small number of these metaphors, by examining the principles derived from these metaphors we obtain a complete coverage of the possible conceptions. This approach to creativity is called synoptic because it takes a comprehensive view. Only with a complete approach are we assured that we will meet the real problem and not merely a superfluous aspect of the problem.

Challenge 3. How can we develop or refine creativity techniques and practice?
Even with a complete set of principles there are two things we would like to be able to do. First, the principles span the space of ideas and provide a map of what can be done, this map has the high level detail. We want to be able to zoom in on the map, expanding or refining the repertoire of tools that can be assembled against a problem. Second, we want to extend the practice of the

different ways we use the tools. We have been assuming that the creativity process is being applied against an existing problem. Other forms of practicing creativity can be imagined. For example, we might want to proactively anticipate problems and deal with them beforehand or we might want to improve the existing circumstances without reference to a problem. We might also want to identify what creativity approach is most likely to resolve a stated problem rather than exhaustively go through every approach.

The third challenge is how can we meet these two needs of expanding the techniques and extending the practice to other forms of application. Again we will turn to the use of the metaphoric models to point the way to these extensions.

Challenge 4 How do we ask the right questions?
Often the most difficult part of solving a problem is to properly define it. Sometimes the act of defining the problem determines the answer. Even when this is not the case, a clear definition helps to understand where to focus the thinking. A problem can often have one or more logical equivalents. If any one of the problem statements yields a solution, the problem is solved. Also a logical specification of the problem can involve a decomposition, which can help to isolate the critical feature of the problem.

The fourth challenge is to represent the problem in a way that helps to identify what the real problem is so that the right questions can be asked. The logic tree was developed to meet these needs. It is a representation of the problem requirements, options, and difficulties, to specify a clear and complete definition of the problem.

Challenge 5. How can one manage the explosion of knowledge and channel it into potential solutions?
Much of creativity is matching up the problem with an already existing solution. Rarely, does an answer come in a form that is radically new. It is usually some novel modification or combination that is distinctly new. This highlights the need to draw from existing sources of knowledge.

The fifth challenge is how to navigate through this large store of knowledge that is growing at an accelerating rate. The solution is the same as any large indexing task, the principles are organized in a hierarchy or classification tree. This old idea has new uses when used in conjunction with the logic tree.

Challenge 6. How can one deal with the large number of possible alternatives that can be generated?
By solving the other challenges, we can potentially generate a vast number of alternative solutions. In order to have a complete approach, we may apply a number of problem solving principles. In the process of meeting the challenge of asking the right question, we may have a number of problem specifications again multiplying the number of alternatives generated. Finally, in incorporating the large number of potential solutions using a hierarchical index we again expand the number of possible alternatives. Added to these basic multiplying factors to

generate alternative solutions, there are simple ways of generating solutions by taking combinations of ideas.

The sixth challenge is to manage the multiplicity of alternatives that can be generated. Again we turn to the use of trees to manage the large numbers.

In summary, for each of the six challenges, two tools have been proposed as the solutions. We propose metaphoric models of thought to:

1. meet the trade-off between novelty and utility.
2. achieve completeness of creative approaches.
3. extend the creativity tools and practice.

We propose tree structures to:

4. ask the right questions.
5. search the large number of potential ideas.
6. manage the number of alternatives.

We now take a closer look at two tools that answer these six challenges, metaphoric models and tree structures.

Metaphoric models

The first three challenges all deal with the nature of creativity. The key to these riddles is how we represent creativity. Like other disciplines we employ models as a representation. Unlike formal disciplines like physics and economics that use mathematical models, the models to reason about creativity are more subtle. Thinking is conceived in terms of metaphoric models. Creativity is one application of these metaphoric models of thought.

We actually make extensive use of metaphoric models. In fact, we use metaphors to structure many of the most critical aspects of our concepts of reality including causality, time, identity, ethics, life, as well as thought. A metaphorical model is a mapping from one domain to another. For example, we can conceive of thinking as moving.

- problem solving is moving from our current state of knowledge to a desired state of knowledge
- the current state of knowledge is our location
- the desired state of knowledge is the destination
- the set of ideas or options is the space in which one can move
- difficulties are obstacles in moving
- constraints are boundaries
- the approach we take is the direction
- attempts to improvements are paths
- the solution is a complete path from the start to the destination

Unlike analogies which make strict comparisons, metaphors are fluid. We can use all types of modifications to express characteristics particular to thinking. For example, if we are taking advantage of someone else's thought process, we are following them. Someone with a good thinking ability is quick.

Metaphors consolidate wisdom. This is because metaphors are prototypical examples that apply over the widest set of circumstances. When one metaphor does not work we adopt another. But typically a few will span most circumstances. Since systems of principles and techniques are derived from the metaphors, a familiarity with the metaphors gives direct access to the wisdom instead of a second hand use through the techniques.

Now let us look at the first challenge. How do we generate ideas that are both new and useful. To a limited extent this problem has been solved from methods that already exist. Somehow they have a tendency to produce ideas that fall within the narrow target of being both new and useful. But how do they do it, and what can be done to generalize this capability?

The answer is that the methods draw from new and useful acts within the metaphoric models of thought. For example, one of the leading creativity methods is de Bono's Lateral Thinking. The idea of Lateral Thinking is that problems are the result of obstacles. To get to the destination we must change from a direct approach to taking an unexpected direction that moves us around the obstacle. This act is using the Thinking is Moving metaphoric model in a way that is both new and useful.

The resolution to the first challenge is to use techniques that satisfy a new and useful action within a metaphor i.e. within a model of thought. This points us to the narrow target of methods that produce new and useful ideas.

To resolve the second challenge of creativity, spanning the space of creative alternatives, we must know what the set of metaphoric models of thinking are.

The results of an extensive survey (Hyatt, 2000), showed that the creativity methods correspond to one of three metaphoric models: 'Thinking is Perceiving', 'Thinking is Moving', and 'Thinking is Manipulating Objects'. The creativity acts for each creativity method correspond to a new and useful act described within the metaphor.

In addition to surveying the methods of creativity, the conceptions of creativity were also surveyed. The sources were:

- Statements from creative individuals
- Writings pertaining to creative methods
- Statements from computational approaches to creativity
- Linguistic studies of metaphor used in ordinary discourse
- Polysemys, words that have multiple but *related* meanings (polysemys are good indicators of metaphor)
- Etymological polysemy, different words that have a common root word that was a polysemy
- Statements describing creativity across different cultures

In each case the evidence pointed to using one or more of the three basic metaphoric models of thought.

It is this universal applicability within this small set of three metaphors that solves the second challenge of creativity, generating the full set of potential ideas. By knowing the full space of

possible approaches, namely the new and creative acts within the three metaphors we can now actually bound the space of idea-producing techniques.

The three primary metaphors complement each other. The perceiving metaphor deals with representing and synthesizing information. It also deals with illusion and identifying additional perspectives. Its strength is in problem definition and defining the solution space. The thinking is moving metaphor deals with transforming a problem to another. Essentially, the metaphor is a model of a search process. The model effectively deals with sequencing, obstacles, alternatives, and problem linkages. The thinking is object manipulation metaphor deals with restructuring issues, how ideas interact and how they combine, whether they are compatible, interfering, or connected.

Most creativity methods draw only from one aspect of one of the metaphoric models. Even the best of the methods has at most three principles in its repertoire. The strength of these methods is that they are very good at exploiting one or two principles. We saw that de Bono's Lateral Thinking (de Bono, 1971) draws from the 'Thinking is Moving' metaphor. Similarly, in TRIZ, Altshuller's separation principle (Altshuller, 1984) is the foundation for many original key TRIZ practices, draws from the 'Thinking is Object Manipulation' metaphor. Adams' perceptual rules (Adams, 1963) are an example of a creativity method drawing from the 'Thinking is Perceiving metaphor'. By drawing on all of the three metaphors, Synoptics has all existing principles combined with newly discovered ones directly from the metaphors to have 10 to 20 times as many principles as many of the best methods. In addition, the metaphors can be drawn from directly to find principles that are customized to the problem. This is how some of the most powerful principles have been discovered.

This creation of additional principles is part of the resolution of the third challenge, to create new creativity techniques. The other part of the resolution is to use the metaphoric models in other ways to expand the practice of creativity.

New techniques are derived from drawing from the metaphoric models for new and useful acts. Variations of the metaphors are especially fruitful areas for new principles. If we consider metaphoric models as a map, the three primary metaphors of thinking are like continents in a map of the world. Refinements of the metaphor are like regions. The finer the refinement the smaller the area. For example, a refinement of the perceiving metaphoric model is the manner of perceiving. Variation in the refinement puts us in a different place in the metaphor map. Cultures can use different metaphors[1]. For example, Western methods draw from metaphors of seeing. In the Eastern world methods draw from metaphors of hearing. The difference gives rise to entirely different approaches not commonly found in Western approaches to creativity.

New practices are derived from using the metaphoric models in new ways. We have seen that the techniques come from looking for new and useful acts within the metaphor. In the thinking is moving metaphor a new and useful act is taking a shortcut.[2] Another way to use the metaphor

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[1] In fact culture may be determined in some degree by the variations of the metaphors employed.

[2] An engineering application of shortcuts is called trimming. Here eliminating unnecessary components is metaphorically like taking a

is to look for ways to avoid entrenched ways of thinking sometime called psychological inertia. Psychological inertia corresponds to standard actions in the metaphor such as always going in the straight direction. Another question we can ask is what indicators might exist to help us identify the technique to use. In this case we ask what in the metaphor indicates a new and useful act. In our case, a misaligned situation metaphorically corresponds to a winding path indicates the potential existence of a short cut. A third way to extend the practice is to project what the ultimate solution might be of a long line of creative improvements. If we could anticipate the ultimate solution we could move right to it. In the moving metaphor, the ideal path is a straight path which extends from the current situation to the objective. The metaphoric models are a fountainhead to continually expand and refine creativity techniques and create significant extensions to the practice of creativity.

Knowledge Tree Structures

The last three challenges all deal with managing large amounts of knowledge. Challenge four is about the multiple ways of representing the problem and the potential types of solution. Challenge five is about the vast reservoirs of knowledge that could be used. Challenge six is about navigating through the different alternatives to be creative and to solve the problem. In each case, by using a tree structure we can manage these large quantities of representations, alternative approaches, and domain knowledge that can lead to solutions.

Trees help to isolate solutions through a systematic search through the branches; they also facilitate including large knowledge bases by adding branches. To better appreciate the significance of tree structures consider two other approaches, lists and flowcharts. Lists do not capture the interrelations between the ideas. Usually when lists are generated, creativity is manifested in the transition from one idea to the next. Often this transition branches to multiple ideas, but only one is captured in the list. A great deal of effort can be saved by thinking in terms of a tree structure and focusing on the fruitful branches and eliminating the unfruitful.

Flowcharts are another approach that is similar to trees, in which a series of questions guide one through a series of branch points. This approach seems to overcome the shortfall of lists of having no branch points. For routine problems, not demanding creativity, flowcharts work fine. However, these same static questions in flowcharts inhibit the generation of new ideas for creative thinking. The simple tree structure is the best of both worlds maintaining large numbers of ideas through branching yet having the flexibility to add new ideas.

Trees are used extensively in creativity practice, notably in FAST (Bytheway; Akiyama, 1989), mind mapping (Buzan, 1990), and the theory of constraints (Goldratt, 1990). Our discussion makes two contributions. First, trees use different logics, each drawing from one of the three different metaphors (a complete discussion goes beyond the scope of this paper). The logic tree integrates these types of logic together. Second, the three trees discussed can be integrated together into a knowledge map.

We now look at the ways that tree structures can be used to solve the remaining three challenges. The logic tree resolves the fourth challenge by managing the problem representation.

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direct path.

Ontologies, hierarchical knowledge bases, resolve challenge five to search through potential solutions. A hierarchy of creativity principles resolves challenge six. These three structures are integrated into a knowledge map.

Logic Trees

In the process of developing Synoptics, the patterns of logic in problem solving also emerge. Logic plays an important role in both isolating critical questions and managing the multiplicity of ideas. Logic provides a framework for the creative process to work in.

Problem solving is like working through a maze. One can try to visually find the path, but marking the maze to trace the path makes finding the solution much easier. This is because

1) untried options are easily identified,
2) entire branches can be eliminated, and
3) multiple paths can be explored in parallel working on the most promising, but alternating as appropriate

In problem solving it is similarly important to try to trace the development of ideas. The traces in the paths of the logic trees has parallel benefits:

1) unexplored options can be tracked,
2) related ideas can be eliminated by their common branch, and
3) multiple ideas can be developed in parallel often lending to forming a solution drawing form several lines of thinking.

The logic tree represents logical equivalencies of different problem statements. The tree starts with a problem statement. Moving up the tree, each level is an equivalent statement that provides the motivation or cause of the problem. Moving down the tree are equivalent statements that provide the implementation of the problem. These equivalencies are specified in logical terms by necessary and sufficient conditions.

The logic tree has met several challenges in creative problem solving. The primary purpose of the logic tree is to resolve challenge four to isolate the right problem and ask the right questions. The tree structure also deals with two other central challenges. For the many alternatives generated, the logic tree can help branch and bound solutions or design space. The tree structure also facilitates drawing from hierarchical knowledge bases, greatly enlarging the number of alternatives that are considered.

Ontologies

A knowledge hierarchy arranged from general categories to specific is called an ontology. Ontologies have had a long history in philosophical thought to study the nature of things. Ontological knowledge hierarchies have received a renewed interest with the desire to maintaining organizational knowledge and creating standards of communication. Ontologies are also compatible with the tree structure of the logic tree. In the solution process, a stored ontology can be retrieved to add hundreds of alternatives, which can be immediately added to a problem's logic tree.

Searching for ideas and generating a complete set of alternative ideas is difficult. Ontologies can be especially helpful in meeting this fifth challenge. By developing ontologies of solutions over

time, we will have a representation that incorporates experience developed from solving other problems, and added to in previous creativity efforts. The ontology of solutions becomes a master reference source. A complete approach to creativity is much easier with such a comprehensive ontology.

Currently, six ontologies have been developed:
1. Technologies - we pay particular attention to technology because of its rapid growth and since it is the basic source of solutions for many problems.
2. Emerging technologies - these are called out in that they are a rich source of untried solutions. Identifying them separately accelerates the adoption of good ideas.
3. Physical effects - this is useful in cases where a needed device does not exist, one can turn to first principles. (Software packages such as Ideation's Innovation WorkBench and Invention Machine's TechOptimizer do something similar).
4. Alternative problem frames - unlike the other ontologies this one is used early in the process and provides a way of rapidly identifying the most helpful frame for the problem out of the many possible.
5. Standard solutions - the TRIZ methodology of looking at abstract ways of structuring problems can be put into a hierarchy (Royzen, 1998).
6. Vulnerability and threats - this is the inverse of the problem solving, namely determining what problems might arise or how to create a problem for someone else.

Managing the alternatives and the hierarchy of creative principles

We are now at a state in which we can generate many alternatives from looking at different problem representations, stored solutions, and the drive towards a complete set of creativity principles. The sixth challenge is to manage this multiplicity of alternatives. Using a tree structure will get us there.

With the logic tree and the ontologies we almost have everything structured in a tree, but not quite. The logic tree gives the different ways of representing the problem that starts the process and the ontologies give the ways to implement the solution to finish the process. In between are the principles of creativity. They are used to build the logic tree to get to the point of searching for specific implementations. We now need to put these principles into a tree and we will be done.

Again we turn to the metaphoric models of thought. These metaphoric models provide the most generic, abstract prototype problems. This is why the solution principles of these simple situations apply to so many other problems and describe the space of creative principles.

The metaphoric models provide a basis for organizing the creative principles. The key is to organize them in a tree structure so that we can treat the principles in batches according to the branches, as well as finding applicable principles by indexing down through the branches. Such a tree can be built because some metaphors are more abstract and general than others. For example, a variety of characteristics like hard, rigid, brittle can be described by a rock. As soon as we want to bring in aspects of growth or a system we have to use a living thing for the metaphor. If we want to describe behavior metaphorically we want to use something from the animal kingdom. Such considerations lead to creating a hierarchy of metaphors arranged

according to generality. By mapping the creativity principles to the most general metaphor possible we have the hierarchy of creative principles that we want.

Benefits

Before looking at the process of integrating the logic tree, creativity techniques and ontologies we review the advantages of these three tools.

Managing the multiplicity of ideas. For all three tools by working with entire branches large numbers of alternatives can be easily added or eliminated.

Uses of the logic tree

- The logic tree isolates the critical question:

- what is the real problem?
- what is its linchpin? - most problems have them.
- what knowledge to search for to find the solution?

Rather than relying on the obvious options, the logic tree isolates the critical components of the problem so that the right questions can be asked and the needed information sought after. The logic tree compensates for any lack of expertise by identifying the critical areas of the problem, which supplemental research can be conducted to get the needed knowledge.

- Find problem equivalencies. The logic tree transforms the problem into a logically equivalent one that may be more tractable.
- Increase number of alternatives Experience shows that an unorganized approach generates only a fraction of alternatives are found when the logic tree is used. The logic tree locates points to look for other alternatives: branch points, breaking into subfunctions, or intermediate levels. Finding intermediate levels is an especially good way to find overlooked alternatives. Levels are like hidden questions that are a problem transformation or another level of abstraction.

Framework of the logic tree

- Compatible with hierarchical knowledge bases The tree structure naturally absorbs other tree structures. Predefined trees of potential solutions can immediately be attached to the logic tree to add many alternatives effortlessly.
- Compatible with creativity principles hierarchy Since the logic tree was developed from the same models as Synoptics the logic tree serves as the platform for the Synoptic creativity process.
- Communication and collaboration The logic tree serves as a communication tool in which all participants can share the same representation of the problem.
- Organizational memory Knowledge can be maintained over periods of time preventing loss from either neglect or from being buried in a mountain of information. The logic tree is a clear record of what has been tried and what were the difficulties. Furthermore, knowledge can be structured for reuse on other problems.

Logic trees are extremely powerful as a systematic procedure in developing solutions. No other method that was surveyed is as comprehensive, integrated, and systematic.

The process and the end product

The end product is a fully developed logic tree that serves as a *knowledge map* of the space of potential solutions. This knowledge map is a synthesis of the three tree structures: 1) the logic tree, 2) the creativity techniques, and 3) ontologies.

The process of building the knowledge map begins with the initial construction of the logic tree. This is a logical specification of the problem, downward extending branches give the necessary and sufficient conditions. The tree is constructed upward by referencing the context of the problem, i.e. 'why is this a problem?'. This can lead to alternative problems statements meeting the same objectives. These alternatives lead to parallel branches of alternatives. Earlier developed alternatives with their difficulties are also added. Alternatives are generated from the creativity tools and from the hierarchical knowledge bases. Gaps of knowledge are filled in through archival search and interviewing experts. Participants observe the development of the tree, making suggestions and discussing differing points of view until reaching a consensus.

Figure 2. The process to build the knowledge map

The high levels of a knowledge map define the problem and identify the major alternatives and issues to its solution. The next levels of the knowledge map are more detailed and use more expert knowledge. The branches include all there is to know about the subject in terms of options. Working down the knowledge map, these branches explicate the way to achieve the problem's objective from broad categories of alternatives down to specific details. Because these objectives may be useful to solving other problems, these branches in the knowledge map can be stored for later use.

With the knowledge map, large networks of individuals can collaborate on problems. Knowledge can be maintained over periods of time preventing loss from either neglect or from being buried in a mountain of information. The knowledge map records past efforts, isolates difficulties, and identifies areas needing further research. Cross references (hyperlinks) can

denote sources. The full space of potential opportunities are laid out for further development, communication, and organizational memory. Furthermore, knowledge can be structured for reuse on other problems.

The knowledge map is a natural tool for collaboration. It is not limited to a local group. Using its ability to identify critical questions and problems it can be used to focus research and track progress on parallel fronts. The knowledge map can facilitate the synthesis of ideas that large problems require. The pressing problems of our day, such as curing the major diseases, resolving environmental problems, national security, dealing with limited energy, water and other resources, and ending poverty and ignorance could be represented in knowledge maps to focus an entire research community. These problems need a focus on what the roots of the problems are, the diffuse and diverse expertise needs a common forum, and these problems need creative approaches from the distilled wisdom of all of the problem solving approaches available.

- How many times has a path been halted because of a seemingly insurmountable obstacle only to prove to be on a solution path long after the obstacle quietly becomes an accepted but fallacious constraint? The knowledge map, represents and maintains the alternate paths providing constant reminders of other possible solutions.
- How many times is the focus shifted from the critical problems to what is politically desirable? Again the knowledge map maintains a focus.
- How many times are differing views forgotten in the details over time? The knowledge map maintains these views so there is no misunderstanding on the alternative perspectives of the problem.

In summary, knowledge maps promise to take creativity to a larger scale. They can facilitate the collaboration of large communities. They can maintain focus and record the essential aspect of a problem. Knowledge maps also facilitate the use of ontologies, structured archives of expert knowledge. The knowledge map becomes a representation of the problem that facilitates and enhances creativity, communication, memory, and decision making.

Conclusion

We have two types of tools to advance creativity. Much has been made of the differences of thinking between the two hemispheres of the brain. Creativity is largely bringing these two types of thinking together.

The metaphoric models reveal the nature of creativity. They provide the insights of what types of mental acts will generate creative ideas and what the full space of these acts are. Metaphors provide the artistic medium to form approaches to be creative.

The tree structures enable a more analytic, logical form of thinking that is the backbone of the creative process. The trees are the scientific side of creativity. As in the brain, creativity is a marriage of these two different thinking processes.

The tools resolve six of the central challenges of creativity, but the combining these two leaves enough mystery the process of creativity will probably always be an intriguing process.

While the mechanisms of creativity remain mysterious, we have seen that we can make great progress in understanding and harnessing the process. We need to get away from being overawed with creativity. Too often our efforts are misused and misdirected. Too often we choose between bad alternatives rather than putting our efforts into creating good alternatives. Too often resources go towards speed when the direction is still not clear. Creativity has been too often neglected as a mysterious gift that does not merit serious attention in our designs.

Synoptics is offered as an additional block in the foundation of serious creativity that will help in its acceptance and use. Systematic creative thinking is an extraordinary lever that can move difficult obstacles. I think Isocrates, the ancient rhetorician said it best. He said that if every man in Greece could lift twice as much, run twice as fast, jump twice as far, and so on, the world would be little better off - animals and machinery do the fast and heavy work anyway. But if just one man could think twice as clearly as anyone does now, the whole world could be blessed forever after. (Norlin, 1968)

Background

Dr. Martin Hyatt's doctoral work was in creativity at Stanford University where he also earned with highest honors two Master's degrees in Decision Engineering and Management Science. He also earned a Masters degree from the University of Southern California in Electrical Engineering. He has 18 years experience designing advanced algorithms primarily for data analysis, and developing concepts for advanced sensors. He has received several awards for his innovations. He has written *Creativity and the Models of Thought*. He has also done seminars and consulting in creativity and decision making.

(408) 245-4403
mtphr@juno.com