What *are* Creativity? And how can we understand *them*?

PRAVEEN K PARITOSH
Department of Computer Science, Northwestern University.
Creativity and Problem Solving, Winter 2001

"The intuitive mind is a sacred gift and the rational mind is a faithful servant. We have created a society that honors the servant and has forgotten the gift." – Albert Einstein

INTRODUCTION

Creativity is, undoubtedly, an interesting and important subject to study. A lot of our life hinges on the creativity of people around us, teachers, lawmakers, engineers, organizations (such as government). The impact of creative scientific research, art, politics, just to pick some, have been overwhelming on the society. As any unexplained and interesting problem, it is subject to scientific inquiry; and people from different domains have long been interested in it. I, for lots of reasons find it a very interesting subject with a lot of potential usefulness. In the course of my literature survey, in which I found a large number of works by people in different disciplines, one of my non-trivial discoveries was that creativity means different things to different people. The subject of creativity is vast, and the act of trying to hastily come up with a definition or explanation, might be limiting the scope of inquiry itself. Following are a few questions that the reader should keep in mind while going through this paper –

1. What would it mean to understand creativity?

2. What are the advantages of this understanding?
3. What should the creativity research be doing now, and what should we expect?

We start with a summary of works on creativity, which I have organized along the different distinct dimensions that they are concerned about. Then I talk about what I think is the core issue in creativity research – the mental processes underlying individual creativity. There are definitely, a lot of other interesting research issues; this I believe is at the heart of most of others, and my personal interest as well. The last section summarizes and concludes the paper.

UNDERSTANDING CREATIVITY

Without any commitment to a working definition, or demarcating the territory of creativity, one might easily get lost in the maze of scholarly work. If everybody had his/her own interpretations of creativity, it might even lose its significance. To borrow Wittegenstein's phraseology, are there *family resemblances* and *overlapping meanings* in this myriad of interpretations? Here, I will diverge, and present all possible avenues of study, and try to enumerate what all we can talk about. There are a bunch of things which are close, if not related to the notion of creativity. Intelligence, problem-solving, lateral thinking, critiquing, subject-matter expertise are some examples of such mental processes. But wait, did I say creativity is a mental process? Following are the different levels one could localize creativity –

1. The *process* of creativity – This level is concerned with the mental processes that lead to creativity. So, questions like what went on in the minds of Picasso while making *Les Demoiselles d'Avignon*, or Einstein as

he mulled over theories of relativity; to take examples of some geniuses, can be asked here.

2. The *product* of creativity – This level is concerned in the intrinsic property of the product – a scientific theory, a piece of art, a composition, that makes it creative. People have vehemently questioned if there are any such properties [Amabile, 1982]; or it all lies in the eyes of the beholder.

3. The creative *person* – Are there attributes independent of the painting, or the theory of relativity, but of personality, interests and background that made Einstein or Picasso creative? For example, interest in knowledge from different domains, ability to communicate, etc, might be some candidates. The intuitive reason for having this level distinct from above two is that we usually tend to think of someone as creative, even independent of his/her work. So, although one could not be goaded to producing a creative piece of art, these person-level attributes could be a positive catalyst in the process. There are lots of attempts to make catalogues of attributes that make one creative, but Barron (1969) was one of the first attempts to explain how these lead one to engage in creative processes.

4. The creative *environment* – This level asks if there are some general properties of environments that encourage or enhance creativity. The boom of art in Florence at one time, German engineering, Russian mathematics, not to imply a lot from these generalizations, are such examples at macro-levels. Having an understanding of the effect of environment, one could fine-tune schools, research labs, etc to develop and foster increased creativity.

Clearly, understanding of creativity at each of these different levels is useful. The question that now comes to mind is if there is just one type of creativity. I will make two types of distinctions. One is based on the magnitude – so the creativity of a 3-year old playing with legos and coming up with a new configuration, an architect coming up with a new design for a commissioned building, and that of Picasso in making the *Les Demoiselles d'Avignon*, are clearly of different magnitudes. Although it is apparent that there are differences in magnitudes of creativity, the difficult question here is where to draw the lines, and which distinctions to make – will it suffice to say ordinary, moderate, and exceptional; even if we had one such distinctions made, we do not have a uniform scale of creativity to decide which goes in which bin. There is some work in this direction [Arieti, 1976; Milgram *et al*, 1978], but most of these make arbitrary distinctions.

The second distinction is based on the nature/domain of creativity. It seems plausible to expect that the creative processes underlying sciences, arts and politics, for example, might have differences, in spite of commonalities that might exist. Rather than tying a new type of creativity with every domain (Physics, Chemistry, Chemical Engineering, etc) that we come across, the important thing here is to make the core and necessary distinctions that cut across domains. What follows is the distinctions that I felt were important, which is influenced by Taylor (1959) –

1. *Fluid*: Total free play, as in spontaneous drawings of children.
2. *Recombinant*: Combining pre-existing elements, methods and techniques in novel ways to produce end-results that are new, and useful.
3. *Improvemental*: Starting with a base, modifying it in new and interesting ways. Lots of restrictions and structure imposed by the domain.
4. *Emergenative*: Coming up with an entirely new principle or assumption around which new schools, movements, and the like can flourish.

Creative work in any domain could be described as a combination of all these four different dimensions, albeit with different weights. Art, for example, might emphasize 1 and 4 more than others.

The following figure tries to illustrate the point of orthogonal and independent dimensions in the study of creativity. Although along each dimensions, each of the distinctions might not always follow a strict order, this figure tries to capture all types of creativity that we see in the research.

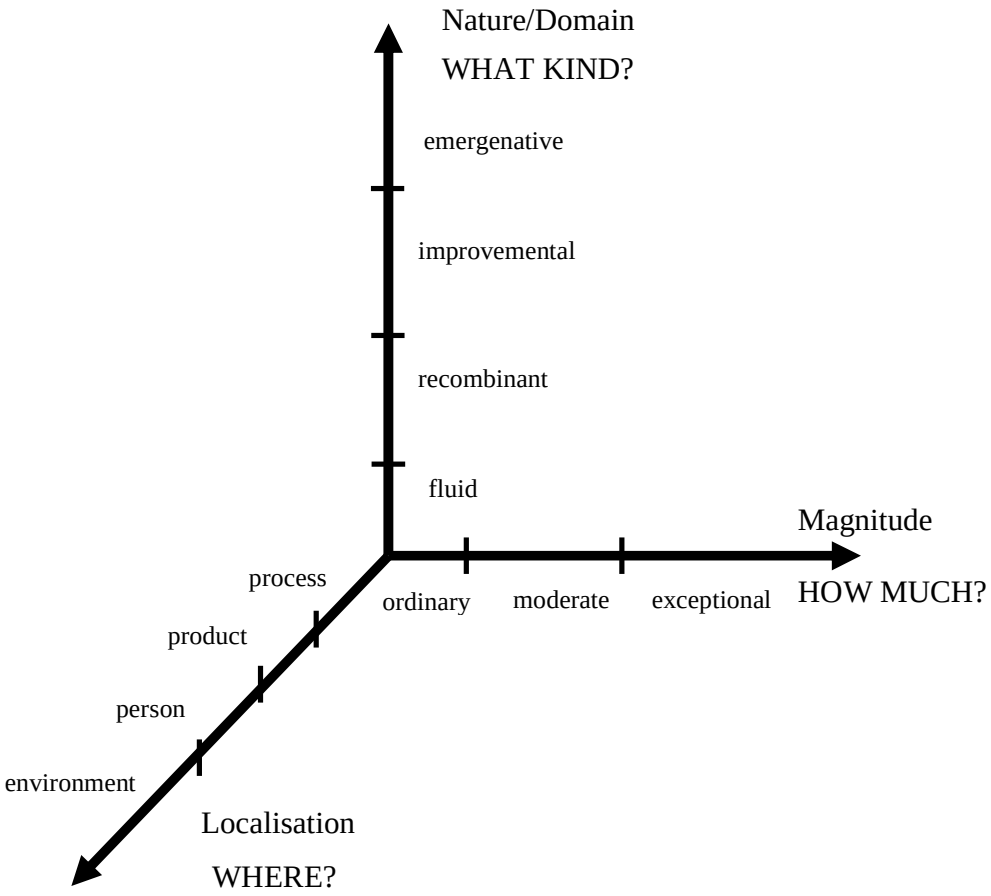

Figure 1. The dimensions of creativity

This organization leaves us with two different types of questions –

1. In the space of creativity shown in the above picture, how do we characterize each of the different regions?
2. Are there overarching similarities in this entire space of creativity?

As any science, the study of creativity requires generating explanatory hypotheses in response to observations; testing, refining, and generalizing them, drawing conclusions and forming theories. Of course, there are difficulties – elements of observation, "creative people," are not often available for controlled experiments. Even personal memoirs of creative people can be inaccurate – even in domains like mathematics, where the final result of creativity are neat and elegant theorems, the path to them is usually vague, filled with "intuition", and unstructured, almost magical [Allendoerfer, 1962]. Thus, we have a host of approaches to studying creativity, and the following table summarizes the different distinctions.

Everyday	Genius
Science	Arts
Personal (Psychology)	Environmental (Sociology)
Static components	Interactions/Systems/Emergent
Domain specific	General
Novelty	Quality
Problem-finding	Problem-solving
Private (One-man)	Ecosystem
Structured/Algorithmic	Non-algorithmic/Evolutionary/Random

Table 1 Distinctions people make in creativity. Interpret elements of each row as being landmarks on a continuum of possible distinction.

CREATIVITY AS A MENTAL PROCESS

One of the important things to note in the above section is that an understanding of the mental processes underlying creativity is central to all other aspects of studies on creativity. And since we are far from having a formal understanding of this process, in my opinion, this is the most interesting and important facet of creativity research. There is some agreement that the creative process involves the application of past experiences or ideas in novel ways. Psychology and computer science have the set of tools to unravel this. Computer science provides us a framework for implementing our hypotheses and well-understood algorithms about processes and test them in conditions which would be difficult for psychology. Also computer science forces more finer detail, and formal understanding, as one cannot implement a system without a good understanding of the process.

Creativity stands as an integral part of intelligence, and thus is an important challenge for Artificial Intelligence (AI). Creativity, all would agree, is creating something new – it can be novel to the creator, or to the entire humanity. AI considers the former as the basic definition of creativity, of which later is a subset. The three types of creativity that AI programs try to model, and some of them exhibit are –

1. *Recombinant*: Novel/Improbable combination of already familiar ideas. Examples of this include poetic imagery, and analogical reasoning.
2. *Exploratory*: Every domain has structured conceptual spaces, and this type of creativity is about searching this space for a novel and potentially

interesting ideas. A lot of science, music, art is a result of exploratory creativity in already defined conceptual search spaces.

3. *Transformational*: This involves the transformation of (one or more) dimensions of the conceptual space, so that new structures can be generated which could not have arisen before. Depending upon how powerful the transformation, the more potentially creative, and different the newly-possible structures would be.

There are a large number of AI programs that attempt to capture the above types of creativity, and it will be difficult to provide a complete summary because of space constraints. I'll mention a few important systems. Copycat [Hofstadter, 1995] and SME (Structure Mapping Engine) [Gentner, 1983] are examples of two systems that use completely different architectures and underlying theories to explain how analogies are made. EMI (Experiments in Musical Intelligence) [Cope, 1991] is a program that composes in the styles of Mozart, Stravinsky, Joplin and others. It uses powerful musical grammars expressed as Augmented Transition Networks; and "signatures," which are melodic, harmonic, metric and ornamental motifs characteristics of each individual composers. Using general rules to vary and intertwine these, it produces novel compositions preserving the style of the composer. Koning and Eisenberg (1981) implemented a shape grammar using which their program was able to generate all the prairie houses designed by Frank Lloyd Wright, and others which were different, but looked like the architect's creation. AM and EURISKO [Lenat, 1983] use the notions of heuristics and meta-heuristics to search domain-knowledge to come up with theories. These two are examples of transformational systems. Genetic Algorithms capture the element of (structured but) random search that might be part of creative activity.

It turns out that the generation of new ideas is far simpler than the evaluation of a new idea. It is the genius of creative minds to be able to distill the important and potentially interesting ideas, and discard others. The evaluation becomes even more difficult in the case of the third and the highest type of creativity, transformational, where out of a multitude of possible transformations of the conceptual space, only very few are meaningful, and far less are creative. The other bottleneck is in capturing domain expertise, which is required for mapping the conceptual space that is to be explored/transformed. A lot of the algorithms underlying the above attempts to make creative AI systems borrow heavily from psychological research on the representations and the processes they try to capture.

CONCLUSIONS

In this paper, I looked at the different dimensions and distinctions that the creativity research makes. Considering this vast scope of creativity research, I then converged on creativity as a mental process being at the heart of a large amount of the space of research. I then argued for a mixture of psychology and computer science providing us with the right sets of tools to answer these questions. I presented a brief review of programs that are trying to implement specific sub-processes of creative activity in specific domains. These AI programs have answered few, and raised many interesting questions about the processes themselves other approaches have missed. Although we are far from the ultimate proof of artificial creativity – a program that generated an idea hitherto unknown, and which initially perplexed us, but the program was able to persuade us into recognizing the value of the idea; it is an exciting path to there.

REFERENCES

Barron, F. (1969). Creative person and creative process. Holt, Rinehart and Winston, New York, USA.

Cope, D. (1991). Computers and Musical Style, Oxford University Press, Oxford.

Finke, R.A, Ward, T.B. and Smith S.M. (1992). Creative Cognition: Theory, Research, and Applications, MIT Press, Cambridge, USA.

Gentner, D. (1983). Structure-mapping: A theoretical framework for analogy. *Cognitive Science, 7*, 155-170.

Hofstadter, D.R. (1995). Fluid Concepts and Creative Analogies, Basic Books, New York, 1995.

Koning, H. and Eizenber, J. (1981). The language of the prairie: Frank Lloyd Wright's prairie houses, *Environment and Planning*, B8, 295-323.

Ladd, G.W. (1987). Imagination in Research: An Economist's view, Iowa State University Press, Iowa, USA.

Lenat, D.B., (1983). The role of heuristics in learning by discovery: three case studies, in Machine Learning: An AI Approach, Tioga, CA, 243-306.

Milgram, R.M., Milgram, N.A., Rosenbloom, G. and Rabkin, L. (1978). Quantity and Quality of creative thinking in children and adolescents. Child Development, 49,385-388.

Runco, M.A. and Albert, R.S. (1990). Theories of Creativity, Sage Publications, California, USA.

Shea, W.R and Antonio, S. (1990). Creativity in the Arts and Science, Science History Publications, USA.

Shrager, J. and Langley, P. (1990). Computational Models of Scientific Discovery and Theory Formation, Morgan Kaufmann, San Mateo, USA.

Sternberg, R.J., (1988). The nature of Creativity, Cambridge University Press, Cambridge, USA.

Taylor, I.A. (1959). The nature of creative process. In P. Smith (Ed.), Creativity, 51-82pp, Hastings House, New York, USA.