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A thorough examination of synectics theory and the literature on creativity convinced the author that visualization plays an important role in the creative process. This article describes an experiment he conducted to confirm that hypothesis. The implications of his findings are discussed as they relate to engineering education.

The Role of Visualization in Creative Behavior

It will be necessary to define what is meant by creativity and visualization in this article. *Creativity* concerns itself with man's ability and predilection to create. Since man is not yet able to create something from nothing, a creative act in its most elemental form must involve the rearrangement or reordering of at least two components. In professional circles the word creativity also implies originality. That is, while a man may be considered creative when he makes a discovery new to himself, he is considered more creative if the discovery is also new to all of society.

A second requirement sometimes placed on creativity, especially in engineering, is that it be useful and capable of implementation. Because new ideas by their very nature generate new rules and new contexts, this requirement is exceedingly difficult to impose. Persons asked to judge an idea on this basis are all too often the ones committed to the old order which the new idea would displace. I retain the idea of originality in defining creativity, but substitute a criterion of intellectual honesty for implementability. In other words, if a solution was a conscientious effort to solve the test problem, it was deemed intellectually honest, and thus a valid solution.

Perhaps a more difficult word to define is *visualization*. A traditional psychologist would use the word to describe a situation where something was "seen" when there was nothing in the immediate physical environment to justify it. Today the viewpoint that sensory perception is divorced from the cognitive process is being called into question. Increasing numbers of psychologists are beginning to see perception itself as a part of the higher order events of cognition; that is, perception is an active constructive event in which prior experience plays an important role.[1,2] This would explain why a doctor can look at an x-ray and see a tumor where the layman can barely make out ribs, or why an archeologist can pick up an arrowhead that a dozen other persons had walked over.[3] According to this view, no two people really see the same thing because each brings a totally unique set of prior experiences to each sensory experience. Visualization then may be thought of in a more general sense; it may take place with or without a physical object in the immediate physical surrounding. In light of this view of visualization, when I examined the manner in which over two dozen famous scientists and inventors made their discoveries, I was forced to hypothesize the following: *there is a relationship between a person's visualization skills and his creative abilities.*

Visualization Test

To test this hypothesis, 28 subjects were solicited from the College of Engineering at Tufts University. Represented were a cross section of engineering disciplines (civil, mechanical and electrical) and classes (freshman through graduate). Each subject was given one hour in which to find a solution to a general engineering problem. A comfortable office with a large desk and drawing supplies was provided. The problem statement read as follows:

> Imagine that you are a world renowned designer known for creative ideas. You have been asked to re-evaluate the feasibility of a two-mile high tower. The sponsor of the project was disappointed at the traditional approach of the original consultants. He feels they could have been more active in suggesting more dynamic ways for surmounting the technological problems.
>
> Your job is to develop new concepts for this tower. Read the next two pages containing a description of the first tower design, then use the attached paper to come up with your own design. Show all your work (and play), including the process by which you got your ideas. Daydreaming is permitted!

Attached to the problem statement were photocopies of the Fuller-Sado solution which appeared in *Progressive Architecture*.[4] The problem of designing a two-mile high tower was chosen because it was a real engineering problem, involving as it did icing, wind, pressurization, weight, and cost, yet was one which no one was likely either to have thought about before or to have seen anything quite like. That is, it had an air of realism, especially since someone with $300,000,000 to spend wanted one, while it was wild enough not to restrict imagination to traditional solutions (or clichés such as the laser). It is unfortunate that this problem should be so impractical,

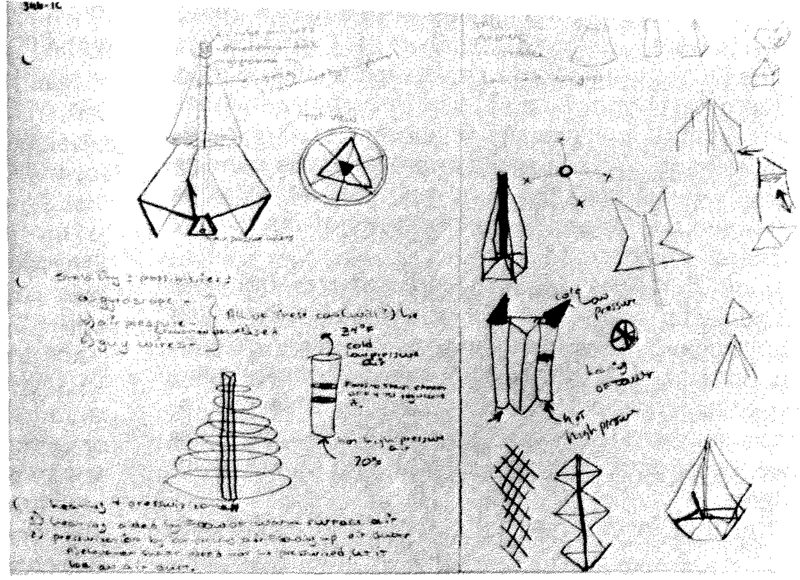

Figure 1. Two out of three pages of a test subject's work. Note the tentative idea sketches on the right page as compared to the finished design on the left.

but it is an observation from Synectics training that the closer one comes to a real problem in a person's experience, the more he will tend to freeze up.[5] In summary the problem was real and free.

Analyzing the final test consisted of: 1) scoring each subject's work for visual elements; 2) ranking the creativity of each subject's final design; and 3) correlating these two results.

Scoring for evidence of visual elements in the actual solution-finding process was accomplished as follows. A score sheet was drawn up which had a column for each of the explicit ways in which visual elements might be expressed. The test numbers were entered on the right side, and checks were placed in the appropriate visual element columns. Each test's score consisted of the sum of the checks marked.

The first visual element column was for ex post facto drawings, i.e., drawings made after the invention process was complete. The six remaining columns represented visual elements which were an actual part of the problem-solving process. The first two were for drawings of a different sort than the final design. If a paper had a tentative, formulative type of sketch or doodle, it was given one check; if there were more such drawings than one, it got another. These process drawings are easily distinguishable because they are incomplete "trial balloons" lacking the elaboration and labeling of a finished idea.

Visualization may be evidenced in other ways besides drawings, e.g., prose or poetry. Therefore, credit was given for two styles of verbalized visualizations: visual words, and more rare, visual descriptions. If a paper had one or two words denoting a visual feeling ("MacDonald's Arch", "steel roots", "beehive-like windows") it was given one check; three or more, two checks. The same was done for visual descriptions (for example, "punching up into the air").

Obviously this visual score is a measure of visualization only as indicated by explicit material. If a subject were an active visualizer but did not put anything on paper, he did not receive any credit. Since this probably did occur, the visual scores may be seen as a conservative estimation of the visualization which took place.

Judging the creativity of each design was not done from the student's own work. Instead, each subject's final design was redrawn, incorporating the ideas which he had developed. For many tests this only required copying the subject's finished tower exactly. For a few this meant bringing ideas together from several different pages, or substantial redrawing of the final design in order to make it look presentable. The result was that each drawing had a similar format and neat appearance. In this way bias due to differing artistic abilities and presentation techniques was hopefully eliminated. Three subjects suggested two

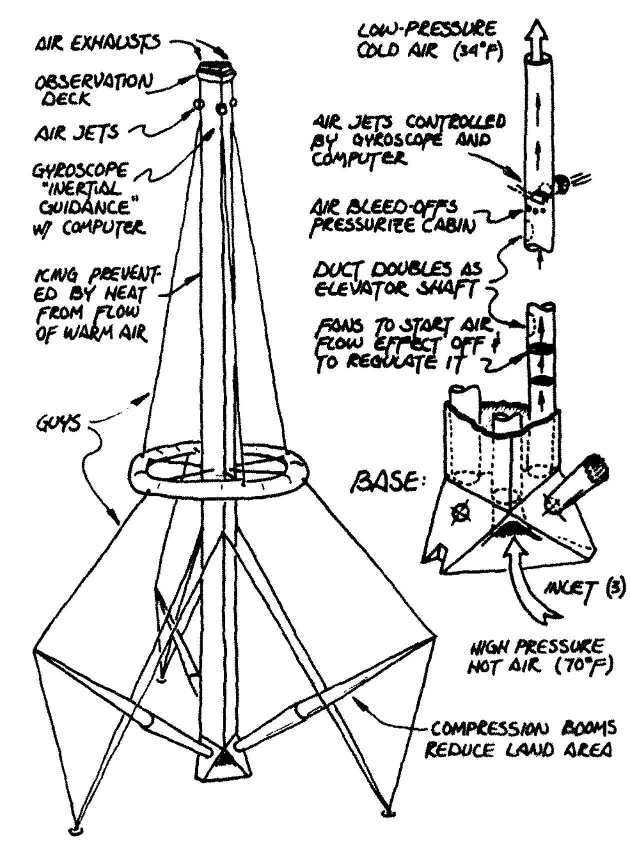

Figure 2. Redrawn tower solution for same subject as above.

final designs. When the judging was complete, these subjects were given credit for their best solution.

The judges were asked to rank each test in relation to the others, from 1 to 31, and to assign a number grade from 0, intellectually dishonest, to 10, exceedingly elegant. While it would appear that the number score is redundant, this was requested in order to determine the judges' overall opinions of the quality of ideas presented to them.

In all, thirty-one solutions were gathered from the 28 subjects. Visual scoring was done at Synectics Educational Systems by 3 judges; creativity ranking was done at Tufts University by one psychology and two engineering professors. At a later time the redrawn solutions were also ranked at S.E.S., so results have been computed for both 3 and 6 creativity judges.

The test results may be summarized as follows:

1. Spearman Rank Correlation, r_s, for visual ranking averaged over 3 judges versus creativity ranking with 3 judges: .411 (significant beyond the .05 level).

2. Spearman Rank Correlation, r_s, this time with 6 creativity judges: .685 (significant beyond the .01 level).

3. Kendall Coefficient of Concordance, W, between various judges:

(3) creativity judges $W = .649$, $r_s = .473$ (.01 level)
(6) creativity judges $W = .473$, $r_s = .378$ (.001 level)
(3) visual judges $W = .926$, $r_s = .889$ (.001 level)

4. Correlation, rho, between visual scores and creativity scores for 3 judges: .519 (significant beyond the .001 level).

In summary, all correlation and concordance coefficients were significant. I therefore feel secure in concluding that there is indeed a positive relationship between a person's creative abilities and his skills of visualization.

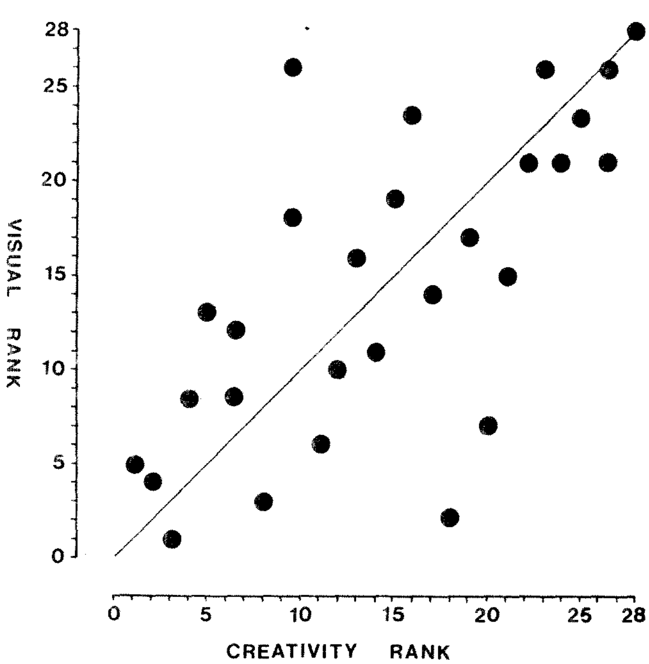

Figure 3. Scatter Plot of Visual Rank vs Creativity Rank

Implications for Synectics and Creative Problem Solving

Such a positive correlation between visualization and creativity indicates that it should be possible to develop operational visual approaches to problem solving. In fact, it was the lack of such devices in the Synectics problem-solving techniques that led to my involvement in this study. It seemed that Synectics had gained a largely poetic nature rather than visual, due perhaps to the oral-verbal way in which Synectics sessions are run. Knowing my own mode to be visual, I inquired why this was so.

Synectics had, in fact, begun to be used in visual material, especially in connection with educational programs. In workbooks, pictures provide an ideal way to present metaphorical material and elicit drawings in response. However, the existing operational mechanisms (Direct Analogy, Personal Analogy, and Compressed Conflict) have not been analyzed from this viewpoint.

At first glance it would seem that Direct Analogies would benefit the greatest amount from visual techniques, but it presently appears that Personal Analogies may gain the most. Personal Analogies (empathetic identification with one's analogue) are the most difficult for beginners to have success with. Identifying with an object may be eased into by imagining what this object sees prior to imagining what the object feels. What a person sees is a function of the code he decides to impose on a scene. Often in fact, this code will be chosen by what he feels (hungry, for example). Thus, deciding upon a code which an animal or object would impose on a scene, and imagining what it would see with such a code applied, is a big step toward understanding how something feels.

The Compressed Conflict is not so well suited to visualization. Actually, it may be thought of as a null state between two images. The Compressed Conflict wrings a two-word description of the conflict contained in the image which is being developed. These two words then act as a verbal pivot. Momentarily they hang by themselves, words without meaning. Quickly new images and analogies are evoked. Thus, the Compressed Conflict acts as a bridge between two images.

It is not unreasonable to think about creating a "visual pivot." Perhaps the first thought or idea could be symbolized, much in the same way as corporate identities are. Such a symbolized conflict would then act as a Rorschach ink-blot—bringing new images to different people. In this way, a new concept would emerge. Unfortunately such a visual distillation would probably be time consuming, and one of the advantages of the Compressed Conflict is the speed and ease with which a group of people can arrive at one.

A more profitable approach to solving problems by visual means is probably to discard the formal Synectics structure but retain the goal that structure attempts to achieve—Making the Familiar Strange. To that end I am working on a book which will hopefully provide new ways at looking at problems. So far I have thought of over two dozen ways in which the familiar can be made strange using visual techniques. While many of them are humorous in nature, one or two may strike home for any given individual. More important than the separate exercises will be the attitude encouraged by the whole: a willingness to play with new ways of perceiving the problem.

Implications for Education

Synectics has grown to encompass both the creative process and the learning process. The learning process is a creative act in itself. The student must make an original jump from what is known and what is unknown. Making the Strange Familiar (learning) may be thought of as the reverse of Making the Familiar Strange (invention). In *The Metaphorical Way of Knowing and Learning,* William J. J. Gordon shows that the Synectics mechanisms work in both directions.

A connection has been demonstrated between visualization and creativity. Therefore, we have every reason to suspect an equally strong relationship between visualization and learning.

> Creative perception depends on making metaphors that are necessary and sufficient connective conditions between known and unknown, and between known and known. Learning in art and science is simply an extension of creative perception.[6]

How can teachers encourage such creative perception? A few ideas come to mind quickly:

1) Teachers should provide visual footholds, i.e., illustrations and examples. It is especially important to encourage students to find their own "footholds." Metaphorical techniques provide one effective way in which this may be done.

2) Learning may be thought of as gaining new codes for looking at things. Because learning such a code looks easy after it has been accomplished, teachers should attempt to remember the specific difficulties they had while they were learning the material, and recall the ways in which those problems were surmounted.

3) Teachers should be on the lookout for the odd ball, especially those students whom they do not like. Probably one of the more difficult things a teacher must do is encourage the creative student with whom he does not agree.

Of these, the first two are reasonably obvious and self-explanatory; the third requires more explanation. An examination of the judges' creativity rankings for the tower problem revealed many interesting observations. The first was that, out of seven people who ranked the final designs, there was no agreement as to which design should be ranked first. And while four of these choices were backed up by second place votes, the tests which placed second, third and fourth in the over-all re-ranking were not among these original seven tests! The explanation for this is not all that difficult to find, and gives a real insight into the nature of creativity. As it turns out, 4 of these original top 7 also received votes for 30 and 31 (last place), and in all but one case the majority of judges disagreed with the first place vote completely. Agreement was not impossible, as was shown by three of the tests; in one case it was even remarkable—scores for test 20 were 13, 13, 14, 14, 14, 11 and 10. Over all then, there was much agreement in the center and wild disagreement at the extremes.

How is all this to be explained? Certain tests are standouts. You cannot help but notice them because they are different. It is easy to decide which of several similar tests is best. But what to do about the loner, the one that is not similar to anything? To make a long story short, we either like this odd ball or we do not. Like a flamboyant personality, we either love it and put it first, or hate it and put it last. Anywhere in between simply will not do. And this is not surprising. Traditionally creative work is always greeted by a small number of admirers and a large crowd of skeptics.

Two more points may therefore be added to the list:

4. Eliminate grades in *any* course which claims to encourage creativity, new points of view, or open-ended discussion. Grades in such courses mock the freedom they advertise.

5. Teachers should attempt to expand their own viewpoints and become as open minded as possible.

A final suggestion which would pertain more to an engineering program in general:

6. Conduct 'how to see', not 'what to see', training.

What immediately comes to mind is education in the arts. Such training may have two approaches: art history, in which one learns to appreciate perceptions of the past and other cultures in order to tolerate new ones of our own; and studio courses, where one learns to manipulate forms and create new images.

Darwin once said, "In order to be a good observer one must be an active theorizer."[7] Drawing may be one of the best techniques for learning to make hypotheses, because it requires making guesses in an iterative fashion. In engineering education the vehicle for teaching such drawing exists in graphics courses. However, these courses at the present time emphasize graphics as a communication skill rather than an aid to thinking.

In *Visual Thinking,* Arnheim says, "The most effective training of perceptual thinking can be offered in the art studio."[8] In general I agree, but there are pitfalls. Generally art classes make the same mistake all classes make by assuming that everyone enrolled is going to become an artist. The resulting class is often slow and laborious, especially concerning technique, for a person really desirous of becoming a physicist. Of the art courses I have had, one was a delightful exception taught by Richey Kehl at the

(Continued on page 146)

Rolf A. Faste, P.E., was born in Seattle in 1943. After graduating from Stevens Institute of Technology (B.S.M.E. '65) he studied art and architecture part time at the University of Washington while working four years as a project engineer for Marine Construction and Design Co. Returning to Tufts University, he did his graduate work with Prof. Percy H. Hill. Since receiving his M.S. in engineering design in 1971, he has been an assistant professor of industrial design at Syracuse University.

design of the company's production facilities. This will simultaneously make the engineer more a member of the top management team, and put on him more heavily the burden of communication and collaboration, the capacity to translate strategic abstraction into bricks, mortar, and machines.

Nowhere will the engineer's capacity to translate strategy into product and plant be more severely tested than in the effort of business to meet the challenge of the consumer movement. This will require human engineering and human systems thinking of perhaps the highest order of all.

The means of dealing with high and rising consumer expectations will be widely varied—from a million dollar bonus program to encourage the employees of TWA to smile, to a free 24-hour national telephone number so you can get help if your automatic ice cube maker goes berserk. The engineer will not have sole responsibility in any of these areas. He will be a member of a large and varied team. But his contribution will be critical at every phase and stage if he knows how to make it.

Thus, as I see it, the engineer, who today is too often the scapegoat of public criticism for the problems technology has created in our society and our environment, will necessarily come to play a leading role in finding solutions to those problems. But to do this the engineer will need not only better technical preparation and a broader general background, but the capacity to move beyond his discipline into positions of influence and leadership.

If he can do it, it will be richly rewarding, both for him personally, and for his society.

C. W. Cook, chairman of General Foods Corporation, has been the company's chief executive since April 1, 1965. He was elected president in November 1962 and chairman in October 1966. Mr. Cook joined General Foods in 1942 as chief engineer. After a succession of increasingly important manufacturing and production posts in the Maxwell House Division, he transferred to the marketing side of the business in 1951. He is a director of Whirlpool Corporation and Chase Manhattan Bank. He also is chairman and trustee of The Conference Board (formerly known as the National Industrial Conference Board); a member of the Executive Committee of the Business Council; a trustee of The Rockefeller University and Tuskegee Institute; a member of the University of Texas System Development Board, and the Visiting Committee of Massachusetts Institute of Technology's Department of Nutrition and Food Science. He is a graduate of The University of Texas. President Nixon named Mr. Cook chairman of the panel on food processing and manufacturing for the White House Conference on Food, Nutrition and Health which was held in December 1969.

Faste, *cont. from page 127.*

University of Washington (see *100 Ways to Have Fun with an Alligator,* by Normal Laliberte and Richey Kehl). This course sought to teach what artists refer to as innocent vision—a way of looking at things which discourages labeling, in order to see what is really there. Such a viewpoint encourages what Guilford calls "transfer recall" as opposed to "replicative recall," the usual school fare.[9] Kehl's course did not attempt to produce artists; rather, it stressed creative ideas over techniques, and as a result was excellent for non-majors, especially engineers.

A course specifically aimed at developing visualization skills is being taught by Robert H. McKim at Stanford University. Many of the ideas I have been talking about are discussed in his newly released book *Experiences in Visual Thinking.* This volume stresses the interaction between seeing, imagining, and idea sketching. I recommend it to all educators interested in design.

A final comment is necessary in respect to the extreme word orientation of our educational system. There should be no conflict between language and visualization. The two work together to help us solve our problems in our everyday world. Words are used by our conscious minds to express and manipulate rational thoughts. It is not until we become "blocked" that this becomes a problem. In Poincaré's words we must then "think aside" [10] and take advantage of our unconscious and our visualization. You might say the language for a new way of looking at something has to be invented. The attitude fostered in school is that words (and mathematics) are the only tools required to be creative. This article has sought to demonstrate that this is not so.

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Recommended Books (all available in paperback editions)

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