Award Lecture . . .

REFLECTIONS ON TEACHING CREATIVITY

JAMES J. CHRISTENSEN *(deceased)**
Brigham Young University
Provo, UT 84602

I would like to express appreciation to the 3M Company and members of the selection committee, to my family, and to all of those others who were involved in my nomination. I was extremely surprised and pleased at being chosen for this honor and award. However, I was totally unprepared for this selection and it surprised me for two reasons: I had never considered myself a candidate for this prestigious award, and the nominators did their work very carefully and secretively.

The 3M Lectureship Award is given to recognize and encourage outstanding achievement in an important field of fundamental chemical engineering theory or practice. As I thought about this talk, I considered such titles as 'The Joy of Calorimetry' and 'What You Always Wanted to Know About Thermochemistry But Were Afraid to Ask.' Rather than speak on my research area, I chose instead to speak about teaching creativity. I chose this topic for several reasons:

- I am not an expert in the field, so I can speak on the subject without limit and without fear.
- This talk is given at the summer school for a broad chemical engineering audience which is mainly concerned with educating chemical engineers.
- Current times find our profession in a state of change. This includes the application of chemical engineering principles into new areas of processing as well as the molding of curricula as we decide what relevant classes are to be taught. I think that creativity bears on both of these areas.

I have had experience over the past 20 years in teaching a class on creativity. This is a class taught at the Master's degree level, but it includes undergraduate as well as graduate students. I have also taught several short courses (day-and-a-half) on creativity in industry. I would emphasize that neither the class nor the short course is on creative problem solving, but more of an exposé on creativity as outlined by Robert C. Reid of MIT (*CEP*, June 1981). That article deals with the definition of creativity, the value of being creative, an examination of the creative process, and the problems of being creative. On the other hand, a recent article by Richard M. Felder of North Carolina State (*Eng. Ed.*, Jan. 1987) discusses the education of creative engineers by focusing on exercises in problem solving, quizzes, and tests. In this lecture, I have reflected on my experiences and tried to distill out the main ideas and concepts concerning teaching creativity. In other words, I will focus on the essence of my experiences in this area.

. . . the single greatest hurdle to teaching creativity is the widely held idea that [it] cannot be taught. . . . There are many who argue that the ability to create is largely gene-dominated, and that you cannot therefore *teach* creativity. . . . Still others argue that the creative process is primarily a function of external experiences.

CAN CREATIVITY BE TAUGHT?

I have found that the single greatest hurdle to teaching creativity is the widely held idea that creativity cannot be taught. Can creativity be taught? There are many who argue that the ability to create is largely gene-dominated, and that you cannot therefore *teach* creativity. You may be able to teach some tricks and methodology, but you cannot affect the basic capability. Still others argue that the creative process is primarily a function of external experiences.

To better examine this question, we need to look at the ways in which the brain is thought to work.

*This paper was prepared, using Dr. Christensen's notes, by Dee H. Barker, Professor Emeritus, and Richard L. Rowley, Associate Professor, Chemical Engineering, Brigham Young University.

Many think that the brain is dominated by heredity or genes. They argue that we have fixed "outlets" in our minds and that we are creative only to the extent that we are "plugged in" or can make the right connections. That is, we are all "idiot savants" to one degree or another. We can be very bright in one area but totally disconnected in others. The best we can do is simulate or encourage inherent abilities. This philosophy is questioned by many people. Arguments on both sides include:

- **Everything else can be taught (*e.g.*, physics and art), but not creativity.**
- **All fields have their natural geniuses (*e.g.*, Einstein and Van Gogh), but we still believe that we can teach these areas to others.**
- **There are creative geniuses (*e.g.*, Edison, Tesla, and Steinmetz), but creativity is *mystical* and *cannot* be taught to others.**

My personal view is intermediate between the gene-dominated and the teachable positions. I believe that it can be taught to some extent, but perhaps it is better to say creativity can be *enhanced*. Some examples from my own experience may serve to illustrate this:

- ***A recent poll of chemical engineering graduates requested a ranking of what they found of value in their educational experience at Brigham Young University. Creativity ranked very high, with thirty-nine responses indicating that it was valuable. Evidently something was taught.***
- ***One of the exercises in class is to identify as many uses of a common object as possible. One student took this principle to heart in his research. He was trying to figure out a way to collect samples from a coal combustion unit, but the samples were very fine grains that needed to be weighed. He came to me and said, "Creativity really works! I thought of all the different common things that could be used and finally decided to use a condom as a collector." He put the condom on the sample port and finally weighed the collector and contents. Now that's being creative! He was not the only one to make the connection between a prophylactic device and separations. An article in the* Journal of Sedimentary Petrology *(Vol. 44, No. 1) entitled "Prophylactic Separation of Heavy Minerals," had the following abstract: "A method is proposed for separation of heavy minerals that eliminates the need for dry ice or liquefied gas in mineral recovery. The technique consists of using a rubber contraceptive device inserted in a cyndrical tube. The technique is rapid and inexpensive." The authors were glad that in Oklahoma, their home state, prophylactic devices were available through the health department. They were not sure how their purchasing department would have reacted to the purchase of eight gross of condoms.***
- ***Utilizing the principles that I have been teaching in creativity has been a great help in designing the calorimeters in our laboratory. As I run into a problem, I employ the principles taught in that course and am amazed at the varied solutions that can be obtained.***
- ***I have demonstrated many times that the best way to enhance creativity is to have more ideas. If ten ideas***

The ASEE Chemical Engineering Division Lecturer for 1987 is James J. Christensen of Brigham Young University. Professor Christensen died shortly after presenting his Award Lecture (see page 72 of the spring 1988 issue of CEE). We are grateful to Professors Dee H. Barker and Richard L. Rowley of Brigham Young University for recreating this Award Lecture from Dr. Christensen's notes and submitting it to CEE for publication. The 3M Company provides financial support for this annual lectureship award.

James Christensen earned his BS and his MS from the University of Utah, both in chemical engineering, and his PhD from Carnegie-Mellon University (1958), doing work in the fields of heat transfer and fluid flow. He joined the faculty at Brigham Young University in 1957 and served as chairman of the chemical engineering department from 1959-1961.

His primary research interests were in the fields of coordination chemistry, thermodynamics, and calorimetry. These interests led him into such varied areas as calorimeter design, thermodynamics of proton ionization and metal-ligand interactions, metal-macrocycle interactions, facilitated transport of metals through membranes, prediction of vapor-liquid equilibria from heats of mixing, and measuring heats of mixing and heats of absorption.

Dr. Christensen won numerous university and national awards for his teaching and research, and has held a number of national and regional committee posts in technical societies. He was a member of a number of honorary professional societies and was listed in many national and international biographical references.

Creativity is difficult to define. It is much like trying to define pornography—it's hard to define, but you know it when you see it. However, it is also like pornography in that everyone has a different idea of what it is. Creativity can be recognized when it is seen.

give one creative idea, then twenty ideas will give two creative ideas. What we need are more ideas, whether bad or good, in order to find the good ones.

WHAT IS CREATIVITY?

Creativity is difficult to define. It is much like trying to define pornography—it's hard to define, but you know it when you see it. However, it is also like pornography in that everyone has a different idea of what it is. Creativity can be recognized when it is seen. For example, Utah is the second driest state in the United States, but in recent years heavy spring rains and high snow-melt created a flooding problem in Salt Lake, with water flowing down one of the main streets. The University of Utah capitalized on this in an advertisement for graduate students showing sandbagged river-streets. The title of the advertisement said, "Fluid Mechanics in Utah?" and added, "We can't promise the spectacular attractions you may have seen on TV. But we can assure you that other interesting experiments are going on. Some are conducted by graduate students in Chemical Engineering in the University of Utah and some make a big splash of their own."

The problem with definitions is that they never really match the particular cases. Consider this 1922 definition of chemical engineering, taken from the British Institute of Chemical Engineering inaugural meeting in 1922: "A chemical engineer is a professional man, experienced in design, construction, and operation of plants in which materials undergo chemical or physical change." Only two years later, A. Duckham, in his Presidential Address to the same society, admitted, "We have come to the conclusion that a chemical engineer, as such, does not really exist."

In general, creativity is seen to be a joining together of two or more concepts, *etc.*, to produce a new idea or useful product. A synthesis to get something new and useful.

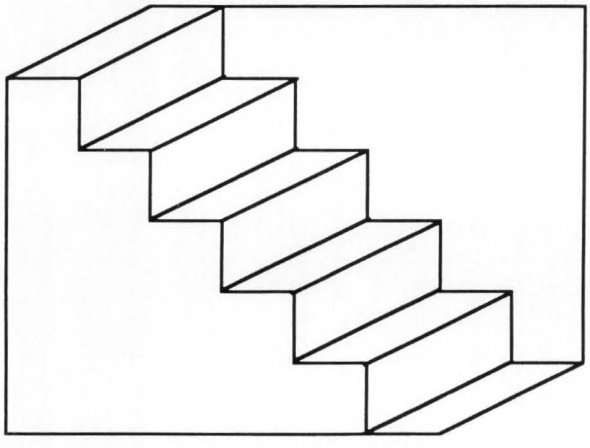

FIGURE 1. Schröder's reversible staircase

MAJOR CONCEPTS IN TEACHING CREATIVITY

If it is agreed that creativity can be taught, and we know what creativity is, let us examine some of the major ideas or concepts involved in teaching creativity.

1. The first concept has already been mentioned—that is, *have more ideas*. Too often we are concerned about what others may think of our ideas, and so we do not allow them to blossom nor do we express them until we are sure that they are good ideas. Being creative means having more ideas. Some may be bad, but the total number of good ones will also go up. You will be surprised at how many successful ideas result from ideas which may at first appear dumb.

2. Develop an ability to see or *observe things in different ways*. The Roman goddess Janus is the patron saint of this concept. Janus had two faces, enabling her to see things from two different perspectives. An example of this is Figure 1, Schröder's reversible staircase. It can be seen to either go up or go down, depending on your point of view. Another example is shown in Figure 2. An engineer and an art student were asked to complete the figures shown in (a). As you can see from (b) and (c), the art student had much more imagination and creativity than the engineer. Part of the reason for this will be discussed later in this paper, but the artist was not limited to a quick closure of the figures; he saw them as part of a bigger picture.

3. *Defer judgement of ideas* until they can be tried, tested, analyzed, and viewed in relationship to other ideas and concepts. We might call this the "deferment-of-judgement" principle. Frederick Sheeler had this

to say when a friend complained about not being creative enough:

> **The reason for your complaint lies, it seems to me, in the constraint which your intellect imposes upon your imagination. Here I will make an observation and illustrate it by an allegory. Apparently it is not good—and indeed it hinders the creative work of the mind—if the intellect examines too closely the ideas already pouring in, as it were, at the gates. Regarded in isolation, an idea may be quite insignificant and venturesome in the extreme; but it may acquire importance from an idea which follows it. In the case of a creative mind, it seems to me, the intellect has withdrawn its watchers from the gates, and the ideas rush in pell-mell, and only then does it review and inspect the multitude. You reject too soon and discriminate too severely.**

This principal is the basis of the "brainstorming" method developed by Alex Osborne, of "Synectics," developed by Gordon N. Prince, and of "lateral thinking" by DeBono. In these concepts we lay out all our ideas, no matter how irrational they may seem. We try to think of as many possible ways of accomplishing the goal as possible, and only then do we begin to pass judgement on them and begin to analyze the pros and cons of each.

4. Students in engineering are often *too quick to pounce on a solution.* They are so glad to finally obtain a solution, any solution, that they never look back for alternatives.

5. There are also *creative inhibiters* that must be guarded against and eliminated. These roadblocks to creativity often fall into two categories: habits and mental blocks. Let us look at examples of some mental blocks that limit our creative thinking:

- **An example is shown in Figure 3, which is the solution to the traditional nine dot problem. The task is very simple—connect all nine dots with four straight lines without lifting your pencil from the surface. The block arises from the fact that people think that they have to stay within the bounds of the nine dots. Once you have seen an example of a solution that breaks the artificial boundaries we im-**

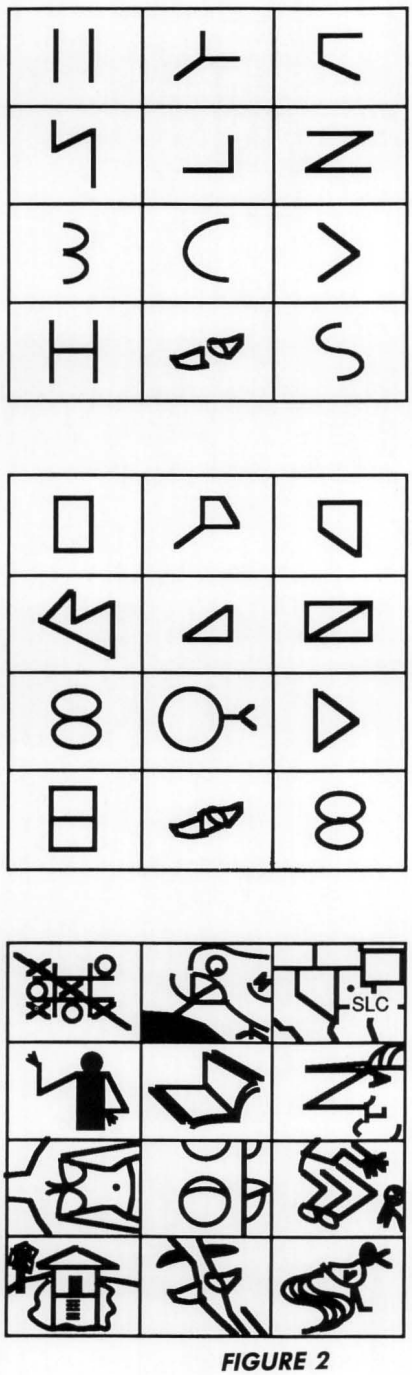

FIGURE 2

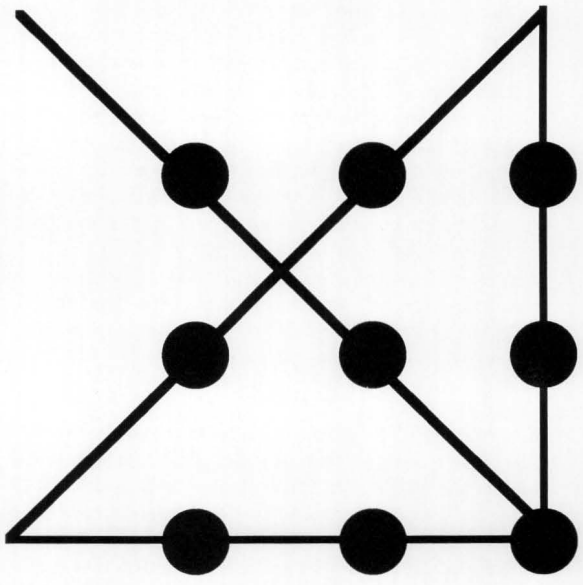

FIGURE 3

Too often we are concerned about what others may think of our ideas, and so we do not allow them to blossom nor do we express them until we are sure that they are good ideas. Being creative means having more ideas. Some may be bad, but the total number of good ones will also go up. You will be surprised at how many successful ideas result from ideas which may at first appear dumb.

pose on ourselves, many more ideas and solutions flow. In fact, we can think of many solutions that use even fewer than four lines: three lines that are angled slightly, one line on the surface rolled on a cylinder, *etc.*

- Another example of a cultural block is the story of Abdul in the boat with his child, his wife, and his mother, and he is asked if the boat were sinking which would he save? This posed no problem for Abdul, since in his culture the mother was the most revered. Abdul responded, "One can always get another wife and another child, but never another mother."

- Another example of perceptual blocks is shown in Figure 4. The problem is to add one line to the Roman numeral XI so that it is changed to the number X. Figure 4 lists several ways in which this can be done. This block is a constraint of expected or implied results assumed from the way the problem is worded or phrased.

6. There are also helps that can be used to *enhance creativity:*

- You can develop a check-list of sets of questions. A sample list of questions is shown in Table 1. One recent example of minifying is Burger King's mini-cheeseburgers sold in sets of four. The technique of reversing and rearranging is illustrated in the following newspaper clipping:

  PHOSPHATE PROCESS TREATS ACID MINE DRAINAGE. *Use of phosphate rock before lime neutralization step in treating contaminated waters reduces sludge handling problem, aids iron removal. A quartet of scientists from Wright State University, Dayton, Ohio, has turned a sewage treatment technique upside down and developed a new process for treating stream waters contaminated by acid mine drainage. Ordinary phosphate rock is a major ingredient in the method. According to the Dayton team, treatment with phosphate before lime neutralization greatly reduces the sludge handling problem and also is more effective in removing iron.*

  Superconductors also came into being through a combination, substitution, and reversal process. Drs. Müller and Bednort reversed conventional wisdom by testing substances so electron-poor that they normally do not conduct at all.

- You can use triggers to help get outside of the mental block and try to analyze from a more objective viewpoint. One such trigger is to ask, "How does nature do it?" In 1876, in Nevada, the ground-structure and over-burden was such that mine cave-ins were a serious problem. Someone conceived the idea of putting the shoring in cells like a bee's honeycomb, and this resulted in a successful ability to mine the structure. Other triggers are shown in Table 2.

7. *Looking at examples* of successfully creative individuals and their characteristics helps our own creativity. Consider, for example, the following success stories:

- Al Kuwait and Carl Courrier needed to raise a sunken treasure ship intact. They discovered that Donald Duck

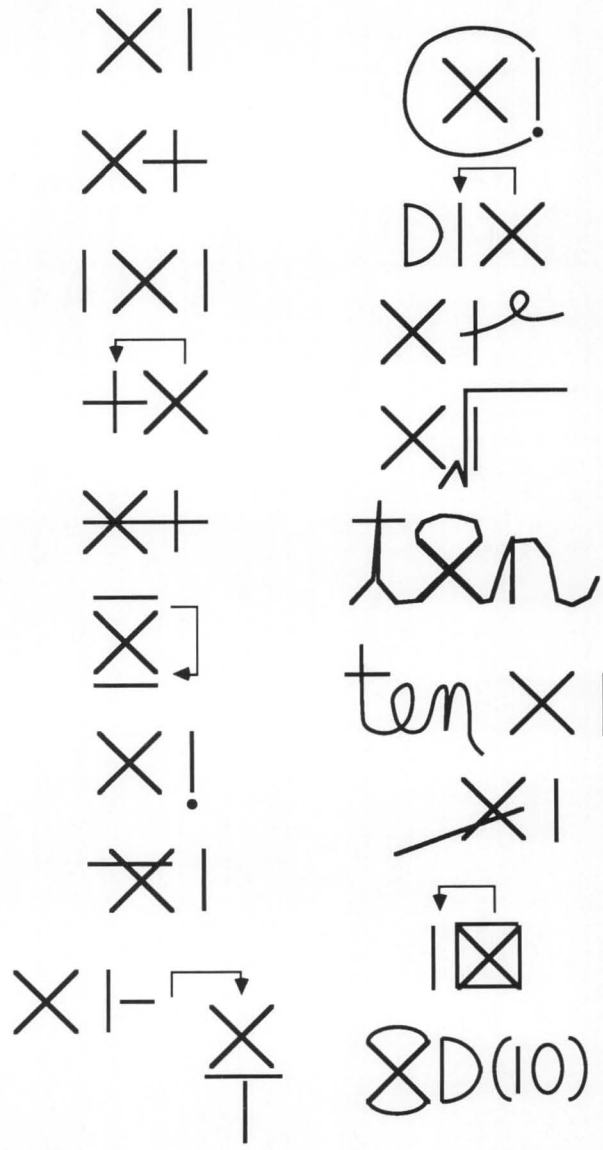

FIGURE 4

TABLE 1
Questions as Spurs to Ideation

PUT TO OTHER USES?
New ways to use as is? Other uses if modified?

ADAPT?
What else is like this? What other idea does this suggest? Does past offer a parallel? What could I copy? Whom could I emulate?

MODIFY?
New twist? Change meaning, color, motion, sound, odor, form, shape? Other changes?

MAGNIFY?
What to add? More time? Greater frequency? Stronger? Higher? Longer? Thicker? Extra value? Plus ingredient? Duplicate? Multiply? Exaggerate?

MINIFY?
What to subtract? Smaller? Condensed? Miniature? Lower? Shorter? Lighter? Omit? Streamline? Split-up? Understate?

SUBSTITUTE?
Who else instead? What else instead? Other ingredient? Other material? Other process? Other power? Other place? Other approach? Other tone of voice?

REARRANGE?
Interchange components? Other pattern? Other layout? Other sequence? Transpose cause and effect? Change pace? Change schedule?

REVERSE?
Transpose positive and negative? How about opposites? Turn it backward? Turn it upside down? Reverse roles? Change shoes? Turn tables? Turn other cheek?

COMBINE?
How about a blend, an alloy, an assortment, an ensemble? Combine units? Combine purposes? Combine appeals? Combine ideas?

had accomplished a similar feat in a comic book with table-tennis balls. They raised the ship by filling it with 27,000,000,000 polystyrene balls.

- Buckminster Fuller is another example. In 1927, as a short, wiry 32-year-old, he stood silently on the shore of Lake Michigan. He had been a poor student and was then living with his wife Ann in a Chicago slum. He had twice been expelled from Harvard University. Their first daughter had just died, and he was bankrupt. There he stood, contemplating suicide. It was a "jump or think" decision, he recalls. Fortunately for the world he chose the latter. "A major change came about in my life. Up to then I had been conditioned to live in accordance with inspiration, biases, values, concepts, results, laws, loyalties, and credos evolved by others. I resolved to do my own thinking, and to see what the individual, starting without any money or credit (in fact with considerable discredit, but with a whole lot of experience) could produce on behalf of his fellow men." Since then he has been the Charles Elliot Norton professor of poetry and has taught at Southern Illinois University and the University of Pennsylvania. He holds 39 honorary degrees, 118 patents in 55 countries, and has published 18 books. He is the designer of geodesic domes, of which 100,000 have been built. "Every child," Bucky claims, "is born a genius, but is enslaved by the misconceptions and self-doubt of the adult world and spends much of his life having to unlearn that perspective. After all," he says, "I'm really nothing special. I'm just a healthy, low-average human being who happened to be nudged out of the nest. It is something anyone could do." He pauses and smiles, "Perhaps that is the good news."

TABLE 2
Other Triggers

TRIGGER 1: *How does nature do it?*
TRIGGER 2: *Juxtaposition or random input of 3 words, or use of "chance" or "force fit"*
TRIGGER 3: *Personal analogy*
TRIGGER 4: *Wildest fantasy*
TRIGGER 5: *What if? In the extreme*
TRIGGER 6: *Functional analogy*
TRIGGER 7: *Appearance analogy*
TRIGGER 8: *Symbolic analogy/Simple replacement*
TRIGGER 9: *Subproblem*
TRIGGER 10: *Book title*
TRIGGER 11: *Morphology*
TRIGGER 12: *Reversal*
TRIGGER 13: *Use a checklist*

- Now consider Charles Kettering (who even has a creativity principle named after him), Research Director of General Motors at Dayton. Charles Kettering continually made use of Trigger #4 (Wildest fantasy), Trigger #5 (What if in the extreme), and Trigger #12 (Reversal). For example, a man came to see his new diesel engine. "I would like to talk to your thermodynamics expert about it," said the visitor. "I am sorry," Kettering replied, "we don't have anyone here who even understands the word 'thermodynamics,' much less is an expert on it. But if you want to know how we developed this engine, I'll be glad to show you." On another occasion, Kettering put three men to work in a little room and told them they ought to be able to develop a gasoline that would give the motorist five times as many miles per gallon. They never found what they were after, but they did hit on the idea of lead, and that resulted in ethyl gasoline. As a result, instead of increasing the mileage of gasoline, they decreased its knocking.
- Many creative things seem to occur because of good luck. Table 3 presents some of the things which might occur because of luck. Nevertheless, good luck is not very often blind luck but comes to those with certain personality

TABLE 3
Good Luck and Personality Traits

Good Luck is the Result of	Classification of Luck	Elements Involved	Personality Traits You Need
An Accident	"Blind Luck"	Chance happens, and nothing about it is directly attributable to you, the recipient.	None
General Exploratory	The Kettering Principle	Chance favors those in motion. Events are brought together to form "happy accidents" when you diffusely apply your energies in motions that are typically non-specific.	Curiosity about many things. Persistence, willingness to experiment and to explore.
Sagacity	The Pasteur Principle	Chance favors the prepared mind. Some special receptivity born from past experience permits you to discern a new fact or to perceive ideas in a new relationship.	A background of knowledge, based on your abilities to observe, remember, and quickly form significant new associations.
Personality	The Disraeli Principle	Chance favors the individualized action. Fortuitous events occur when you behave in ways that are highly distinctive of you as a person.	Distinctive hobbies, personalized life styles, and activities peculiar to you as an individual, especially when they operate in domains seemingly far removed from the area of discovery.

traits which foster and encourage that luck. Increased "luck" can result from fostering those character traits.

8. *Problems and games* can also embellish our creative ability. Here is a statement on an aluminum alloy that decomposes in water:

> ***An aluminum alloy that has all of the classic characteristics of conventional metals—strength, durability, machinability, and electrical conductivity—but can be decomposed rapidly by cold water has been developed and is being marketed by T.A.F.A., a firm in Bow, New Hampshire. Away from the water the alloy is stable under a wide range of atmospheric conditions and has shown no sign of erosion or deterioration over long test periods, according to the firm.***

You could have the students figure out the many uses that this alloy could be put to. It is not necessary, in creativity, to use chemical engineering in all examples. In fact, I tend to stay away from a lot of chemical engineering problems and try to present creativity in a broader sense. This also helps in breaking the habit patterns which have been instilled in chemical engineering students. I use many other examples in my teaching, such as ways to use a box of paper clips, what to do with bricks, and visualizing objects as having other functions. All of these help in developing creativity in students.

SUMMARY

Great works (of creativity) need not only the flash, the inspiration, and the experience; they also need hard work, long training, relevant criticism, and perfectionist standards.

Creativity may require two differing sets of personality characteristics. The creative person may more closely resemble two thinkers in tandem than one fully integrated being. The two facets of creativity suggest that a completely creative person may have need of both a mode of thinking conducive to generation of original ideas and a separate mode useful for discerning feasible ideas from the rest.

Creativity has everything going for it. Everyone wants to be more creative in their daily lives. The teaching of creativity adds a new dimension to the abilities of chemical engineering students, both at the bachelors level and at the graduate level. It can also be offered to students outside of the chemical engineering department as a service course. I have done this primarily in teaching industrial groups in an industrial environment.

And finally, it is fun to teach. It helps to keep my ideas flowing and helps me in my daily work in adding creativity to the things which I do, both in my professional and in my social life. □