Lessons that I Have Learned

Table of Contents

Introduction

After reading some of my earlier essays,[1] several students have written to me asking that I post at my website more advice for students. While I am not an old man,[2] what I have learned from experience may be of interest to students.

---

1 Particularly, *Creativity in Science and Engineering,* http://www.rbs0.com/create.htm (Sep 1998) and *Why Attend College?,* http://www.rbs0.com/edu.htm (March 2001).

2 I wrote the first draft of this essay in June 2005, when I was 55 y old.

Learning Diagnostic Skills

debugging computer programs

I taught myself to program digital computers during the summer of 1968. Back in the 1960s and 1970s, computer programs were written on punched cards and submitted to an operator through a window. With luck, one might get two opportunities in one day to compile and run a program on a mainframe computer at a university. I bought my first desktop computer in 1981, and thereafter I could run my programs anytime I wanted.

A common expectation amongst novice programmers is that their program will correctly compile and run on the first try. In reality, a novice programmer is lucky to get a program to compile correctly after a half-dozen attempts. And then the hard work begins of finding defects in the program that cause erroneous operation, but which defects are *un*detected by the compiler. Even a little fifty-line program can take more than a dozen attempts to make it correct.

The process of diagnosing a defective computer program is difficult, frustrating, and learned only by experience. Diagnosing a defective program is more art than science. While a thoughtful and experienced programmer could write a useful book about debugging defective programs (and —more importantly — good programming style that will avoid bugs), I expect that readers would always need to learn the process of debugging through their personal experience.

In 1975, I bought a copy of a now-famous book[3] and realized that there are design rules that one can use in computer programming to both avoid common errors and to make a program easier to diagnose. In other words, a program could be *designed* to be easy to develop, understand, and maintain. During the 1980s, as I accumulated more than a thousand hours of experience writing, debugging, and revising my computer programs, I developed more style rules. By the early 1990s, after more than twenty years of part-time experience in writing programs, I began to occasionally write a program that would not only compile correctly on the first run, but also would give correct results on the first run. I emphasize that it would be ridiculously *un*reasonable for a novice programmer to expect his/her programs to function correctly on the first run, without any debugging and without any revisions. But such a pleasant surprise can sometimes happen to an experienced programmer who makes a conscientious effort to design programs with a good style.

---

[3] Brian W. Kernighan and P.J. Plauger, *The Elements of Programming Style,* 147 pp. (1974).

debugging electronic circuits

During 1973-1989, I designed both analog and digital electronic circuits that were used in my scientific and engineering research projects. During 1979-89, I taught electronic circuit design to electrical engineering majors at three different universities. Again, when one designs and builds an electronic circuit it is routine to find that the circuit does not perform as intended, and one must engage in a sometimes frustrating process of diagnosing the defects.

During the 1980s, I slowly accumulated a collection of personal rules for good style in designing electronic circuits, to make the circuit easier to diagnose and to increase the reliability of the circuit.

diagnosis in medicine

During the 1980s, I read my wife's *New England Journal of Medicine,* every issue of which contains a clinical diagnostic case, intended to be an intellectual exercise for physicians. I realized that the art of making a diagnosis in medicine is quite similar to debugging a defective computer program or diagnosing a defective electronic circuit. In medicine, a patient appears before a physician with some vague complaint like "my stomach hurts" or "I have a headache."
A physician must quickly work through a long list of possible causes, do some tests or observations to exclude some causes, and arrive at a diagnosis. When the treatment prescribed by the physician does not solve the problem, the diagnosis or treatment must be re-evaluated. With experience, a physician can quickly focus on likely causes of the patient's complaint, but such a quick reaction can overlook rarer causes, which may be more serious. So it is always a good idea to be careful and deliberate in making a diagnosis. I think the lesson from medicine is to be *thoughtful* about the process of making a diagnosis, instead of either merely guessing or blindly making changes in a computer program or electronic circuit.

universality

My observation of similarities in the process of diagnoses in computer programming, electronic circuit design, and medicine suggests to me that after understanding *one* area of science or engineering, it is easier to learn other areas of science or engineering,because problem-solving skills are universal. In my case, I was a full-time physics student for ten years during 1967-77, during which time I taught myself computer programming,[4] and later taught myself electronic circuit design.

In addition to common techniques in the art of making diagnoses, I think there are also common elements in finding creative solutions to problems. Someone who is *un*creative and a mere rule-follower is condemned to be *un*creative in everything that they do.

Instead of just quickly writing a computer program, or quickly tossing together some components on an electronic circuit board, I urge that people do a thoughtful *design* of the program or circuit. A program or circuit should be *designed* to be easy to diagnose, functional, reliable, and easy to maintain. The design should consider not only today's immediate goals, but what future tasks could be accomplished with the same or similar program or circuit. And the designer must be alert for ways that the program or circuit could be misused, which might cause it to fail.

Finally, it seems to be human nature that we want to *believe* that our creation (e.g., a computer program or electronic circuit) correctly functions as intended. The reality is that there are many ways creations can misbehave, and some of the misbehaviors have only subtle symptoms. Therefore, a conscientious scientist or engineer must not only test his/her creations, but also be alert for such symptoms. When a symptom of malfunction is detected, one must make an adequate investigation of the symptom, despite the pressures of deadlines and despite distractions from other work.

Writing

When I was a student in universities during 1967-77, I agonized over my writing, struggling through drafts of essays, term papers, my master's thesis in 1975, and my doctoral dissertation in 1977. It did not help that back in the 1960s and 1970s, I had to retype every page of every draft, which greatly added to the chore of revisions. For that reason, many of my drafts of term papers were handwritten. I was envious of some of my professors who could quickly write good prose, and who had secretaries to do their typing.

[4] My only formal class in computer science was a graduate-level class in numerical methods that I took in 1971, without having any of the prerequisite classes.

But, as I became a more skillful writer, I also became more picky about what was acceptable quality in my writing, so I continued to write at least three drafts — and often more than six drafts — of every professional document that I produced. So, in one sense, I never did learn to write quickly. Although my first drafts now are far superior to my clumsy first drafts as a student, my first drafts are still full of places where there needs to be either more explanation or better organization of my thoughts.

The concept of style is well-known in writing.[5] There are many published guides for style in writing, in contrast to only a few books about style of computer programming and even fewer books about style in design of electronic circuits.

Because of the importance of writing in my career in scientific and engineering research, I bought my first wordprocessor in 1983 and that machine made it much easier to prepare documents:

- no need to retype text in successive drafts
- easy to copy blocks of text from an earlier document into a current document
- spell checker
- automatically format footnotes
- automatically insert page numbers in a Table of Contents or in cross-references in text

By the late 1980s, I was purchasing paper in quantities of 10,000 pages at one time, because of my large number of drafts of chapters in my book, papers, and proposals.

Every book on writing style emphasizes the importance of *multiple* drafts and polishing one's writing. I certainly don't see any other way to be a good writer.

---

[5] My own style guide, *Technical Writing,* http://www.rbs0.com/tw.htm , which I began in 1978, and which I first posted at my website in September 1999, has become the most frequently accessed document at my two websites.

Encouragement

If you are a student who is taking the appropriate courses[6] with competent faculty who have high standards, you undoubtedly will feel stressed, pushed to your limit, wondering how you will possibly understand all that you need to know, and full of doubts about your ability to succeed. This is *normal* for students in science, engineering, and medicine at quality colleges. Not only is the subject matter difficult to learn, but you will find little help with the practical side of learning to diagnose and learning how to be creative.

I think there are three ways that many students get the illusion that success comes quickly. First, movies and television programs show in the space of approximately an hour, a scientist, engineer, or physician confronting a new problem and successfully solving it. These programs are *fiction:* these programs omit the inevitable delays, setbacks, wrong turns, etc. The truth is that confronting and solving a new problem usually takes at least months of time (and that quick success is generally possible only in a well equipped laboratory with adequate funding), and in many cases takes years of time. Second, science and engineering textbooks present neatly packaged information, with no hint of the personal effort and struggle that accompanied the discovery of this information.[7] Third, most textbook problems can be solved in less than a few hours, and it is often a shock to a young graduate student who first encounters a research project that will need more than a thousand hours of his/her time to complete. Scientists and engineers need to be persistent, tenacious, and even a bit stubborn in pursuing their goals.

During the summers of 1973-76, I worked in atmospheric physics research at a balloon hangar on a mountain ridge. Helium diffuses through the plastic skin of balloons, so when we arrived each morning at the hangar, some of the balloons that had been properly inflated on the previous day, were now dragging on the ground. The technicians would add more helium to each balloon and the balloon would again proudly float on its tether. I have come to see "puffing up" balloons as a metaphor for encouraging students and young professionals. <*smile*>

Many men are accustomed to solving problems, so when someone complains to them about a situation, the listener commonly assumes that the complainer wants a solution to his/her problem. But I have learned that the complainer often only wants either sympathy or assurance. Giving a complainer a suggested solution to his/her problem, instead of giving sympathy or assurance, is

---

6 People who have chosen easy classes, in order to sculpt a high grade-point-average and "earn" a college degree without needing to work diligently, have wasted their parents' money (or wasted the student's debt) on a so-called "education", and those people have squandered an opportunity to learn that may not come again during their life.

7 I suggest that science and engineering students also read biographies of scientists and engineers, as well as books on history of science and engineering, to get some insight into *how* important discoveries are made.

like a physician who prescribes the wrong therapy. And it is very *dis*satisfying to the complainer: they received what they did *not* want and they failed to receive what they needed.

One of my student evaluations at The Pennsylvania State University during the 1980s said that "taking a class from Prof. Standler is like taking a drink from a fire hose." There is a lot of material that learned professionals need to know to do their job successfully, and not much time to learn it, which makes a student's life frantic and very stressful. On the other hand, students who can not succeed under this kind of frantic, stressful educational experience probably would not be successful in a professional career in either scientific research or engineering design, which is also frantic and stressful.

It is no exaggeration to say that I studied more than 80 hours/week in undergraduate and graduate colleges, took few vacations (except the mandatory Christmas and summer vacations when I was an undergraduate student), had almost no recreational activities, and almost no social life.[8] My life as a professor during the 1984-1990 was equally focused: I spent most of my time either doing research, trying to get financial support for my proposed research projects, or writing publications. I don't think there is any other route to success in the learned professions, other than long hours of difficult work. One time in the late 1980s, I was working past midnight in my laboratory at the Pennsylvania State University and a senior professor, who was an immigrant from China, came into my laboratory and said "Ronald, you are one of us."[9] We were there, *not* because some manager told us to work more than 60 hours/week, but because that is what we *wanted* to do. I feel sorry for people with boring, routine jobs that they hate, who put in the mandatory 40 hours/week at their job and then go home and do something they enjoy. To be a successful scientist, one needs to have creative zeal, intense dedication, and a genuine passion for grappling with the unknown — what some might call an *obsession.*[10]

Because of the annihilation of financial support in 1990 for research in all of my areas of physics and electrical engineering, I went to law school during 1995-98, when I was 45 to 48 years old. It was a strange experience to again be a student who was overwhelmed by large amounts of new material, so that when I took the time to understand part of last week's material, I was already seriously behind. After being a professor or independent consultant for 18 years, I had forgotten

---

[8] My limited social life was largely spent in conversations during lunch and dinner in the student cafeteria. In looking back, I'm not sure that it was healthy for me to spend so much time alone, reading books, doing homework, spending time alone in a physics laboratory, etc.

[9] One of the things that I have noticed in universities is that the students from China, Korea, and Japan are eager to work 80 hours/week, not only late at night, but on weekends and holidays too.

[10] I admit that I know a *few* successful colleagues who don't work much more than 40 hours/week, who have a family life, and who enjoy recreation. However, they are the exceptions to the general rule about successful scientists and engineers who work intensely for more than 60 hours/week.

how it felt to be a student. The experience of being overwhelmed and uncertain is well known to scientists and engineers who are doing research on the frontiers of new knowledge. I think what bothered me most about law school was the lack of *control* that I had over my life: there was little time remaining after I finished the reading assignments in my classes. Many times in law school, I simply rebelled for a day or two, skipped the reading assignments, and spent some time in the law library intensely reading about some detail in law that interested me. In my fourth and sixth semesters of law school, I took the maximum amount of independent study classes, to get some control over my time. Looking back on the experience, I think it is important that people finish their formal education before they reach about 25-26 y of age, and before they get accustomed to managing and controlling their own life.

By the way, I often work with successful litigators in prominent law firms, and I notice that is common for them to be working late at night and on weekends. I suspect long hours of intense concentration are essential to success in *all* of the learned professions. Regardless of whether a physician interrupts his evening, night, or weekend activities to assist a patient, or whether a research scientist is struggling to overcome ignorance and frustrations, professional success takes intense dedication and long hours of difficult work. The gruesomely long hours experienced by science and engineering students is just the beginning of a lifetime of hard work. But, as remarked in the previous paragraph, the good thing about being an established professional is that one has some *control* over one's time. It's a lot more enjoyable to do something because one *wants* to do it, than to do something because an instructor or manager assigns the work with a short deadline.

Looking Forward to an Illusion

When I was an undergraduate student during 1967-71, I purchased hundreds of books to build my personal library. The university that I attended then gave a discount to faculty and staff (including graduate students with either a teaching assistantship or research assistantship). Every time I purchased a book during my undergraduate years, I looked forward to being a graduate student and saving some money on my purchases of books. I was a graduate student at two other universities during 1971-77 and — later — a faculty member at three different universities during 1977-1990, but *none* of those five universities offered a discount at their bookstore. Even in the year 2005, I still feel cheated that I never received my faculty/staff discount at the bookstore. <*grin*>

Similarly, when I was an undergraduate student, and then a graduate student, and struggling to solve homework problems or research problems, I looked forward to a day when I would understand the material and have fewer frustrations. But as I got more experience and more credentials, the problems that I faced got more difficult, so I *never* escaped from the frustrations and challenges of solving problems. Furthermore, when I became a professor, I was expected not only to find and solve important problems and publish my results, but also I was expected to attract more than $100,000/year in funding to support my research projects. I conclude that if a person does not, in some sense, actually *enjoy* the frustrations and challenges of fighting ignorance, then they should find some routine job and avoid research.

As a third example of chasing an illusion, when I was a graduate student during 1971-77 I looked forward to being a professor who had a secretary to do typing of drafts of proposals and publications. But at the universities where I was a professor during 1978-90, the secretaries were overworked (an average of more than nine professors giving work to one secretary) and generally too poorly educated to handle mathematical equations that appeared in my text. Most of the secretaries only had a high school education and were unfamiliar with the format and style of scholarly writing, such as footnotes, bibliographies, and abbreviations of Latin phrases.
As mentioned above, I purchased my own wordprocessor in 1983 and thereafter I prepared *all* of the drafts of my book, *all* of my proposals and reports to sponsors of my research, and *all* of my published papers. It was important to me to be able to get a new printed draft whenever I wanted it, including when I was working on weekends or holidays, instead of wait several weeks for a secretary to do a poor job of typing from my handwritten notes.

It seems to be a general rule in life that when one intensely looks forward to some future experience and imagines that life will be better then, the reality is that there are *always* disappointments, frustrations, and apparently insurmountable challenges. And if the future would have been better, the rules will change to make it worse than it should be.

No Reward

My parents taught me the value of suffering today, in order to have a better distant future. Looking back, I'm not certain that this was precisely the right expression of this virtue. I wonder if a better expression is that diligent intellectual work — the struggle to overcome ignorance — is a fundamental Good, regardless of any hope of a reward in the future.

On thinking about this issue, it seems that the concept of a reward is ubiquitous. Students in the USA are told to work hard, in order to earn a good grade.[11] Employees are told to work hard, to get salary increases and promotions. The major religions teach people to do Good things now, in order to be rewarded sometime after death.

---

[11] Pupils are told to earn good grades in high school, so that they can be admitted to a prestigious college. Students in undergraduate college in the USA are told to earn good grades, so they can be admitted to a prestigious graduate school, law school, or medical school, or so they can be hired by a major corporation at a high starting salary. Students in law school in the USA are acutely aware that prestigious law firms typically hire only students whose grades are in the top 5% of their law school class. In all of this emphasis on good grades, I conclude that the purpose of education in the USA has been subverted from *learning,* to acquiring credentials that are useful to earn money. I criticized this obsession with grades in my essay *Why Attend College?,* http://www.rbs0.com/edu.htm (March 2001).

Working for a reward sets a person up to be disappointed. People in positions of power often *neither* respect *nor* reward either meritorious accomplishments, creativity, or intellectual ability.[12]

In my experience, scientists or engineers who become managers were usually motivated by either (1) a higher salary, (2) more power, authority, and prestige of a management position, or (3) escape from research, because of their personal lack of creativity, curiosity, or diligence that is necessary for success in research. Because managers have different values from scholarly researchers, meritorious researchers are not consistently rewarded. For example, managers value tangible results, so a professor who publishes an average of three papers per year in peer-reviewed journals is three times "better" than a professor who publishes an average of one paper per year. Never mind that the three papers may be tiny fragments of an ongoing project, while the one paper may be a reasonably complete, thorough, and significant contribution to the literature. Managers see publications like scoring goals in a *game,* instead of seeing a published paper or book as a final, permanent record of some significant research. I find it distressing to see managers treat scholarly research as a game to be played, with the managers keeping score.

As another example of the failure to reward meritorious work, a professor who is working in an obscure field may publish a paper that has a significance and importance that is recognized only ten<u>s</u> of years after its publication, perhaps too late to reward the author, and certainly too late to assign more resources to the professor to enable him/her to increase his productivity.

What actually gets rewarded in most organizations is loyalty to the boss (and loyalty to the group, as explained later in this essay). People with integrity are seen as problems or threats by their boss.[13] Creative people, who can accomplish more than their boss can control, are also seen as problems or threats by their boss.[14]

At the highest levels of management, the managers will likely have an education in business, law, or liberal arts, and will have no understanding of either science or the process of scientific research. In that way, science and engineering are isolated from the highest levels of political power and business management in the USA, which explains why funding for scientific research

---

[12] Not only do scientists and engineers get an uncertain reward, but also nominations to the U.S. Supreme Court by the president are based on political considerations, *not* intellectual ability. Historians of law lament that Judge Learned Hand of the U.S. Court of Appeals for the Second Circuit was never nominated to the U.S. Supreme Court in the 1930s and 1940s. In our own time, Judge Richard Posner of the U.S. Court of Appeals for the Seventh Circuit, perhaps the most intellectual judge in the USA and a prolific author of books on law, has not been nominated to the U.S. Supreme Court.

[13] See my essay, *Professional Ethics & Wrongful Discharge,* http://www.rbs2.com/ethics.htm (July 2000).

[14] See my essay *Creativity in Science and Engineering,* http://www.rbs0.com/create.htm (Sep 1998).

in the USA (1) has a generally low priority, (2) is *in*consistent on a scale of three to five years, and (3) tends to be considered a luxury that is reduced when there is a budget crisis.[15]

However, scientists who made important discoveries have their names recorded in the history of science, while the names of their bosses have been forgotten. For example, no one cares who was dean of the Arts & Sciences college at Yale University during the years 1871-1903, when Prof. Gibbs was there, doing his landmark research in theoretical physics and physical chemistry. So, from the viewpoint of history, creative scientists are finally judged more important than managers.

On the other hand, engineers who design novel products tend to be forgotten, unless they wrote a significant archival paper, good textbook, or treatise, or unless a historian wrote a book about them.

Groups of People

It seems to me that people have an innate tendency to “think”[16] and act as members of a group, like a pack of wolves.

People define themselves in terms of their membership in a religion, their membership in a political party, as well as their membership in other groups (e.g., professional societies, labor unions, ethnic groups, etc.). There is a fiction that *all* members of one group have the same beliefs and opinions, and there is intense peer-pressure for members to conform to the official dogma of each group.

A person who is an individualist (i.e., a person who makes his/her own opinions, instead of adopting dogma of a group) tends to be a lonely outcast after he/she disagrees with group dogma. The fear of being either criticized as disloyal, rejected, ostracized, or excommunicated enforces orthodoxy. The dilemma of believing that one’s personal opinion is right, but not wanting to openly defy a group’s dogma, motivates people to be hypocrites, who publicly affirm the group’s dogma, but privately defy that dogma.

I have repeatedly seen groups of people tolerate, or even openly welcome, members who are either technically incompetent, dishonest, cheaters, or perpetrators of a fraud. On the other hand, I have seen groups of people ostracize an individual member who has the courage to criticize the group’s dogma and make a constructive proposal for change. Therefore, it is clear to me that

---

[15] R. Standler, *Funding of Basic Research in Physical Science in the USA,* http://www.rbs0.com/funding.pdf (Sep 2004).

[16] I put *thinking* inside quotation marks, because it is *not* genuine thinking to react automatically according to dogma of a group of people.

groups accept the wrong people, reject the wrong people, and are dangerous to society because of their *un*questioning reaction according to the group's dogma. It is a recipe for scandal when loyalty to the group is more important than loyalty to philosophical principles, such as morality, integrity, honesty, etc.[17] Moreover, groups encourage orthodoxy and oppose innovation that might threaten the group, thus causing stagnation.

The worst examples of human behavior have occurred as a result of treating individual people as members of a group. Wars are fought, and innocent people on each side die, because of group mentality. Six million Jews were murdered by Christian Germans. Horrid prejudice and bigotry has existed throughout the history of man, in which people were discriminated against solely because of their race or religion.

A group of people (e.g., a manufacturing company) tends to ignore or denigrate ideas from outsiders. This tendency is so widespread, it has a name: Not Invented Here (NIH). The basic premise of NIH is that outsiders can not possibly produce good ideas. Of course, the NIH view is arrogant (i.e., in-house personnel are smarter than everyone else) and rigidly xenophobic (i.e., an outsider's ideas are either automatically targeted for denigration or defined as *un*worthy of consideration). It may also be that an in-house group has pride in their ability and wants to be creative, even if a proven solution already exists elsewhere.

This group mentality is pervasive. Although I am an individualist, I see examples of group mentality in myself. I prefer to be with other physicists, because they understand my use of scientific or mathematical nomenclature, they share my use of metric units[18] of measurement, and they share the high value that I place on scientific research. I don't like hearing nonprofessors criticize professors, even if the criticism is basically valid, because I identify with the group of professors, and therefore feel an obligation to defend *my* group from attack by outsiders. Perhaps the innate human tendency to behave as a member of a group can not be completely defeated by learning and understanding the importance of responding as an individual.

Despite my grousing about groups of people, it is obvious that a group of people working towards the same goal allows large tasks to be accomplished, while one person working alone would be *un*able to accomplish such a large task. And there is no doubt that some groups of people do good things. In my opinion, participation in, and loyalty to, a group is appropriate if the group is both (1) engaged in desirable activities, and (2) the group's activities are moral, ethical, and lawful (i.e., *not* illegal).

---

[17] See my essay that discusses six major scandals, *Morality and Education,* http://www.rbs0.com/morality.pdf (Sep 2004).

[18] Use of metric units outside of physics, chemistry, and electrical engineering is weird and highly *un*conventional in the USA, even in the year 2005. In contrast, I have used metric units exclusively in my personal and professional life since 1970.

A particular problem is that many creative intellectuals in science and engineering are more comfortable working alone than in large groups of people.[19] It may be that scientists and engineers dislike inevitable compromises that are made by committees and groups. It may be that some scientists and some engineers lack social skills that are necessary for effective functioning in a group of people. The decision of some scientists and some engineers not to participate in committees and other groups may limit their ability to get their ideas accepted by mainstream society. Because of the nature of people to be influenced by a prestigious group, or to jump on a bandwagon, change in people's attitudes is more likely when that change is endorsed by a respected committee or other group.

Secret of Success

Above, at page 7, I mentioned my long hours of study and scholarly research as essential to my education and productivity. During high school, undergraduate college, and graduate school, I had on my desk the following quotation from Benjamin Disraeli, a British politician during the mid-1800s: "The secret of success is constancy to purpose."

This quotation neatly summarizes the need to consistently pursue a long-term goal, and to reject distractions. However, there is a danger that a consistent focus on a goal can blind one to changing conditions that make the original goal undesirable. A consistent focus can also blind one to hints that one's method is hopeless, and needs to be abandoned in favor of a better method.

Moreover, concentrating on goals and deadlines can make one overlook an *un*expected discovery that might be more important than the original goal, or might be a symptom of some defect or mistake. I believe it is important for creative intellectuals to have time to explore unexpected or unanticipated observations, and to revise and improve their work before publicly releasing it.

Despite my admiration for the above-mentioned quotation from Disraeli, the path to success is too complicated to be summarized in any terse quotation or simple nugget of information. A recipe for success includes talent (e.g., intelligence, curiosity, creativity), education, diligent work, intense concentration, and the good luck to be in the right place at the right time.

When I searched the Internet in August 2005 to verify the quotation from Disraeli, I also found another quotation from him: "One secret of success in life is for a man to be ready for his opportunity when it comes." I think "be ready" includes already having a broad education, a willingness to undertake difficult tasks, the courage to be unconventional, asking questions that everyone else ignores, and many other virtues.

---

[19] See my essay, *Creativity in Science and Engineering,* http://www.rbs0.com/create.htm (Sep 1998).

This document is at **www.rbs0.com/lessons.pdf**
begun 16 June 2005, last revised 2 Apr 2006

return to my homepage at http://www.rbs0.com/