

CREATIVITY AND MATHEMATICS TEACHING:

**Some Thoughts on Mathematics Teaching,
Computers, And Calculus**

By

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Some Thoughts On Mathematics Teaching, Computers, And Calculus

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Abstract. Why is it that the hardest thing in the world is to convince a student that he *can* think; that each one of them has his or her own special gift? And, that he can prove it to himself if he would just spend a little time in the trying. Why is it that, as educators, we spend so much time helping our students to memorize and so little time helping them to see the salient facts; the facts that will allow them so see the whole picture? In this dialogue, we will examine some of the problems that university faculty see in their students, and we will discuss how some of these problems might be addressed; with special attention to the teaching of undergraduate mathematics.

"The mind is not a vessel to be filled, it is a fire to be kindled." ... Plutarch

"It is not the teacher's task to teach interesting things. As the quacks proclaim. But to make interesting the things that must be taught." C.S. Slichter

1.0 Introduction. For as long as I can remember, I was fascinated with numbers, with equations, and with mathematics as a whole. I was lucky. I had teachers who encouraged me to examine crystal growth, the symmetry of biological organisms, and the building of my own Van de Graaf accelerator. I cannot ever remember wanting to be anything other than a mathematical physicist or *even* a mathematical biophysicist/biologist. Perhaps I knew, even then, without realizing it, what Adler(1985) meant when he said,

"The outstanding achievement and intellectual glory of modern times has been empirical science and the mathematics that it has put to such good use. The progress it has made in the last three

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centuries, together with the technological advances that have resulted therefrom, are breathtaking."

The demons of the microchip computer technology have been let out of Pandora's box and, as a consequence, the world that our children and our students face is one of increasing technological, social, and academic pressure. No longer will it be acceptable to be computer illiterate or mathematics ignorant. Rapid changes in the job market can be seen, as the influence of explosive technological changes touches the economic backbone of this country. New words and phrases creep into the everyday jargon you hear on the street; computer hack, computer jock, computer nerd, Silicon Valley, and pc are all common lay terms. Over-the-counter microcomputer magazines appear at rates rivaling the reproduction of the proverbial rabbit. And how-to books on the computer and its use are commonplace items on the bookshelves and magazine racks of the local grocery and drug stores. Pre-schoolers face the infamous LOGO turtle at successively earlier and earlier ages(Widnall, 1983; Chin, 1984; Shanker[40]; Frazier, 1980).

Businesses routinely make use of electronic spreadsheets for accounting, wordprocessing and desktop publishing for reports, sophisticated computer graphics workstations for their illustrations, electronic mail and bulletin boards for their employees, and sophisticated databses for their records management. Resesarch and development use highspeed computers(CRAY, CYBER, IBM, Alliant, MASSCOMP, the list is endless as it becomes a bandwagon product) for sophisticated numerical computation in engineering and scientific problems of all types: cell and tissue kinetics, fluid dynamics, wind tunnel studies, quantum mechanical computations, molecular design, aerospace simulation, mechanical engineering, and epidemic modeling to name just a few. Great advances are made daily in such areas as computer simulation, computer aided design(CAD), computer aided manufacturing(CAM), computer aided instruction(CAI), and computer aided engineering(CAE). In particular, computer controlled automation and robotics is touching an increasingly large variety of manufacturing areas. Even the arts have not been left untouched, electronic music(synthesizers, programmable organs and pianos, electronic drums), computerized studies of the dance, and computer graphics have all played roles in the new generation of artistic creation. We are all familiar, by now, with the movie TRON. This move illustrates the revolutionary use of the computer to create realtime graphics of an extraordinary nature.

Yet somewhere, amidst the emotional outburst for computing, is lost the important fact that much of the reason that we are capable of performing such feats of analysis is due to the fact that the mathematics behind these graphics endeavors was of a highly non-trivial nature; involving projective geometry, matrix theory, vector calculus, numerical analysis, partial differential equation theory, operator theory, and many other areas of high level mathematics.

Benefiting from the rediscovery and the subsequent application of the Radon-Nicodym theorem, medicine has computed tomography. Advances in the field of tomographic

medicine have lead to positron emission tomography, nuclear spin resonance tomography, field emission tomography, and the creation of a formal medical discipline called non-invasive medicine. Computers now control the infusion of all types of medication, and are on duty twenty-four hours a day. Computers pervade coronary care units and are used to monitor and to predict life-threatening arrhythmias. Major drug houses now use computers, in an effort to create new and more efficient drugs. A whole field called computer aided drug design/molecular modeling has come of age. These computer programs allow use to attempt to create medicines which will work on precise locations in the human body and they allow us to examine the possible side effects of the drug, in the human, before it is actually used on humans. Simple versions of these mainframe programs are now available for the IBM PC. In fact, one can now design molecules on one's home computer. Yet, the complexity and the importance of the mathematics behind this capability is lost in the excitement of the new software. Debye-Huckle theory, quantum calculations, and hidden line algorithms, whose mathematics is extremely sophisticated, are lost in the new fangled fun of slamming organic molecules together.

Management of large databases of information has become a science unto itself. Libraries, large businesses, medical houses, airlines, hospitals, and even the everyday homeowner are using database systems and database management techniques for handling their large/small volumes of information, in an organized manner. Within the field of medicine, a whole new specialization called *medical informatics* has sprung up. It deals with the simple problem of handling medical information. The advent of inexpensive home computers has brought video games, computerized education packages, and information management right into the home. Within the near future, we will be seeing the creation of an international video-net for delivering newspapers, mail, and performing banking in the home.

However, hiding in the background, unrecognized, is a wealth of mathematical rigor and depth; a depth, without which, these new technological advances could not have seen the light. We rarely hear of fuzzy set theory, of lambda calculus, of reliability theory, and of parsing theory and the theory of syntactical decomposition(usually hidden in the more general theory of grammars). We sometimes hear of queueing theory and of differential equations. Not so often do we hear of stochastic differential equations, stability theory, perturbation analysis, and a myriad of other mathematical disciplines through whose study we now have the technological capabilities of which we make such casual use.

The advent of the computer age has brought with it the development of factions within the mathematics community. As computers function in the world of discrete or finite mathematics, many current university mathematics and computer science instructors hold to the belief that we should replace the current calculus requirements with equivalent requirements for rigorous finite mathematics courses. Others believe that calculus, despite its obvious lack of "discreteness", is still a useful introduction to the rigors of mathematics. Whatever the case, and whomever is correct, computerization has heightened the awareness that mathematics and mathematics proficiency are of greatly increasing importance(Fiske,

1984; [14]; Turner, 1983).

The information age has arrived, bearing with it a whole new set of demands upon our lifestyles, our business and economics world, and our educational system. Mathematics is the language of that age. How we face the challenge will determine our technological proficiency and edge for decades to come (Pirsig, 1974; McGrath, 1983; [24]; [44]; [47]; Emmett, 1983).

2.0 The Crisis of Technology. Manifest in the sudden technologic explosion, which we now face, is a blatant lack of foresight for dealing with the onslaught of the very technology that we have created. The scientific surge of the early space exploration years has given way to a decreasing interest in science and mathematics as a whole. High salaries, offered by large corporations, snatch up the best undergraduates and Ph.D. candidates. Academics, not being able to compete with such salaries, loses its researchers and its teachers. And, in doing so, it loses its ability to maintain a *quality* education. The beauty of mathematics gives way to the high salary of computer science.

Still others have discovered that mathematics, while an obligatory part of their education, is not something necessary upon exiting the university and entering into the workforce. This is particularly true in the engineering disciplines. As an extra credit project, I ask my engineering students to interview senior, practicing, engineers. These engineers are asked to comment about their mathematics training, its day-to-day usefulness, and to examine — in retrospect — whether or not they really needed to take all of the mathematics that they had been forced to take as undergraduates. The response was overwhelming and bleak! Over a 5 year period of interviews, I found that 98% of the respondents said that they rarely used more than highschool algebra on a day-to-day basis! When asked whether they regretted taking the mathematics, they responded with statements of the form, "While I never really use it, it was good as a means of helping to discipline my thinking." (Reza, 1986; Crecelius, 1986; Gordon, Wells, and Durbin, 1986; and Meurer and Hagan, 1986). How can we, as educators, possibly compete with an attitude of this kind? If it is not economically necessary, than a student is not likely to make it a high priority item.

The reasons for the development of such attitudes are complex, many, and intertwined. Figure[1] illustrates a portion of this author's perception of the problem. From this figure, it is clear that the difficult economic times have precipitated and propagated a large portion of our problem. But we cannot blame it all on economics.

It is clear that the technological explosion has brought with it an educational crisis. Nowhere is this hotbed more readily apparent than in Japan's recent and overt announcement to the world that it will dominate the computer domain by the year 2000, and that by 1990 they will have developed the 5th generation computer; a computer which is truly artificially intelligent. The country whose schools were considered the finest in the world, whose universities drew students on an international basis, is rapidly losing ground to

the Far East and the European Bloc countries. Coming out of its 15 year plan to create a totally new educational system, the Soviet Union has created an educational environment which is supposedly unmatched in terms of the sophistication of its goals; among them domination of the field of robotics. The educational light of the United States wains faintly in the more radiant glow of the dedication seen amongst its major international competitors.

While many individuals are aware of the problems we are facing, few are truly aware of the overall magnitude of the various issues. Let us briefly examine some relevant statistics concerning teacher training, shortages, and student scores in mathematics and science.

- [1] In 1980, 28 states had mathematics teacher shortages, critical in 16 states.
- [2] In 1981, 48 states had shortages in physics teachers, critical in 27 states. Chicago had 1 certified physics teacher for every 2 public schools.
- [3] In 1981, half of all mathematics teachers, as well as science teachers — *nationally* — were unqualified or less than qualified; teaching on emergency certificates.
- [4] In the last decade, there has been a 77% decline in the number of secondary school mathematics teachers being trained, and there has been a concomitant 65% decrease in the number of secondary school science teachers being trained.
- [5] The popularity of mathematics has dropped from 48% liking it in third grade, to 18 % liking it in twelfth grade.
- [6] Average SAT scores in mathematics have decreased steadily from 502 in the Kennedy space race years(1963) to 466 in 1981.
- [7] Remedial mathematics enrollments in public four year colleges have increased more than 70% during the last five years.

That we must resolve our nation's mathematics and science crisis is a fact which we must all come to grips with. Fundamental structural changes in our educational system, both at the preschool, school-age, university, and graduate education levels, and in our very attitudes towards education must now be introduced if we are to avoid yielding our technological and intellectual lead to Japan and the European nations(Hight, 1950; Frazier, 1980; Watkins, 1983; [22-24]; Holmay, 1986; Darling-Hammond, 1986; Bowen, 1981; Brademus, 1983; Pelikan, 1983; [44]; [47]; Rice and Austin, 1983; Maeroff, 1985).

I am reminded of a comment Alexander Frazer(Professor Emeritus, Ohio State University(1980)) made; a quote which is all the more relevant and timely at this point.

*“What kind of person are we hoping to help come into being? ...
Unless we have a pretty good idea of where we are going, we may*

*have trouble finding our way – or even knowing when we get there,
if we ever do.”*

3.0 Identifying The Problems. Much has been written on the nature of the acquisition of mathematics by children and by young adults. We read of the fact that *“mathematics originates from the earliest physical, mental, emotional, and social activities of children by their seeing and understanding the world around them so that the number stems from experiences that the activities give.”*(Choat, 1978). We, as teachers, discuss the *numberness* of the number; hoping to transmit the powerful and sophisticated ideas built into the conceptual framework of mathematics.

Cognitive research into the nature of learning has provided numerous insights into the acquisition of knowledge. Recent research in language understanding and production is suggesting that processes that have much in common with qualitative analysis in the sciences play a role in comprehending and writing complex text of various kinds; a *humanities–science* link, if you will (more on this aspect in a moment). A recent experiment illustrates this fact in a most striking manner. Two groups of volunteers, musicians and mathematicians, were labeled with a radioactive sugar which is metabolized in the brain. After injection, they were placed inside of an NMR tomography unit. The musicians were asked to concentrate upon a musical track being played into a set of speakers near the tomography unit, the mathematicians were asked to concentrate upon a difficult mathematical problem of interest to them. Brain metabolic activity was subsequently mapped by the tomography units and compared between the two groups. Metabolic maps indicated that the musicians process music in the same portion of the brain in which mathematicians process mathematical problems. That is, there was a matching of the metabolic activity in the brains of both the musicians and the mathematicians. Is mathematics music? Or, perhaps, music is mathematical? Remember the eternal golden braid of Goedel, Escher, and Bach (Hofstadter, 1980). Like the practice of medicine, though we soon forget the fact in the rigor of the discipline, there is still a creative or artistic aspect to science and to mathematics. And, it is this creative component which is essential to the effective advancement of the field.

Students rarely see that mathematics is the language of nature and of art. DaVinci's ideal proportions are based upon mathematical constructs. The spiral of the nautilus and the spiral of the arabesque all relate to the logarithmic spiral of mathematics. The geodesic dome and the puff ball of the dandelion extol the solid geometry of nature, as do the snowflakes, the mineral crystals, and the pollen grains. It is impossible to escape the mathematical constructions of nature. There is the helix of DNA and the spiral of an opening flower bud. The hexagonal structure of the bee's hive reminds us of the efficiency of packing hexagons, minimizing work and materials necessary in construction. D'arcy Thompson was far ahead of his time in noticing the similarity transformations between the variety of fish forms, of bone structures, and of anatomic structures. His book, **On Growth And Form**, remains a classic to this day.

With all of this beauty, how is it that students look at mathematics as if it were a plague from space. Is it the way that we teach them? Or, perhaps, is it that mathematics requires a different logical sense?

Mathophobia! We hear this word, and the first thoughts which arise in our minds are *fear of mathematics*. Yet, as *polymath* translates to mean a person of many learnings; so *mathophobia* translates to mean a fear of learning (Papert, 1980). In fact, the status of mathematics in our contemporary culture is indicative of the acute dissociation, the *schizophrenic split* (Papert, 1980) between the humanities and the sciences.

Why then mathophobia? A number of factors contribute to this problem: (1) The dreaded uninspiring teacher, (2) The equally feared uninterested student, and perhaps, though not well documented, (3) Human physiology. Recent controversial medical studies on growth and development of the male and the female brain yield the startling and important fact that the *mathematics* section of the brain, in females, appears to develop at a later date (approximately eighth grade) than in the corresponding section of the male brain.

Intellectual capacity. Recent cognitive studies indicate that 50% of a child's intellectual or cognitive potential is fixed by age four, with an additional 30% fixed by age seven to eight. That is, 80% of the cognitive potential, in children, is fixed by the age of eight. Pause for a moment and reflect upon what grade, in school, these children are at the age of eight! We fail our children by not attending to their intellectual demands at a time when they openly insist upon that attention by being persistent, continual, and open questioners of the world around them.

This collection of comments concerning the various aspects of our educational physiology, of our development, and of our philosophy, while seemingly disjoint, is amazingly reminiscent of the problem of analyzing a biological or living organism. Reductionist philosophy hacks away, as we have done, at the biological problem; looking for a solution by reducing the problem to a collection of pieces and by subsequently analyzing those pieces. But, as any good biologist will inform you, you must — by the very nature of the organism — lose information when you destroy the organism. Consequently, the reductionist point of view can never truly appreciate and solve the problem. This is because the problem that we face is truly one of the *whole*.

As I stand back after 15 years of teaching, I realize two important facts. The problem that we face is not in the existence of the technology that surrounds us and which infiltrates our daily experience. Technology has, in actuality, only heightened our awareness as to how acute our educational problem really is. Rather, the problem lies in the fact that we are no longer a *learning society*. We have forgone the need to learn and question (Smith, 1988; Witten, 1983; Gardner, 1981) the world around us for the more primal necessities of personal economic survival. The times are hard, and nobody can really blame the reasons for the change. Yet, as educators who should stand unmoved amidst a sea of change, we have, instead, let ourselves be swept along with the tide of social and educational apathy

instead of standing our ground against the rising tides.

Times have changed, but the educator has forgotten the anthropology of his job and has become fixed in a quagmire of medicine man-like teaching methods. As society evolves, so too evolve the children of that society. And so too must evolve the educators in that society lest education most surely stagnate. It is this stagnation that we now see upon us in this country.

Generation after generation has been taught calculus in the same manner. Differentials, followed by integrals, followed by multivariables, followed by this and that, is the classical algorithm for mathematics teaching. There is no integration of this material with other courses that the students are taking. Material learned in multivariable calculus is rarely used in thermodynamics. Electromagnetism rarely uses line integrals. The hard sciences demand that we, as mathematicians, teach their students linear algebra, differential equations, vector calculus, and more. Yet, it is rarely made use of in the hard science courses.

And what about the way in which we teach calculus? Is there a better way? A way which makes more sense? I think that there is! But, it involves teaching the students to understand mathematics and not to memorize it. It involves a radical departure in methodology and in approach. Yet, the status quo, like the proverbial mountain, is exceptionally difficult to move. And, like the prophets, they are not heard in their own lands. And so, the old ways remain.

In a sense, our failure to see the need for change was prophesized by Silberman (in Meeker, 1974), when he said,

“ Students need to learn more than the basic skills. Children who have just started school may still be in the labor force in the year 2030 ... To be practical, an education should prepare a man for work that doesn't yet exist and whose nature cannot even be imagined. This can be done only by teaching children how to learn and by giving them the kind of intellectual discipline that will enable them to apply man's accumulated wisdom to new problems ... ”

Such wisdom was never more relevant as recent projections by the Futurist Society indicate that the average professional should be prepared, by the year 2000, to be changing jobs and/or careers as much as 10 times in a lifetime of working. The ability to survive and to adapt to such changes comes, not in one's ability to memorize facts, it comes in one's ability to learn and to adjust. It is this set of abilities that we have not passed on to our students.

Nowhere is the result of our failure to live up to these requires more manifest than at the college level. Incoming students are, in general, literary misfits and numerical incompetents. Two particular examples of these problems come to mind: the *black box engineer* and the *verbally deficient scientist*. Let me digress and discuss these two cases in a bit greater detail, for each illustrates the failure of our educational system

The black box engineering mentality is more easily categorized as *problem solving deficient*. Most educators will easily recognize his characteristics. This is the student who will ask the professor for the required formula(or formulae) necessary for the solution of the specified problem. This student will then quite successfully plug the numbers into the formula, affectionately cradle his pocket calculator in his hand while completing the requisite calculations, and obtain an answer. God forbid that the professor should give a test in which a calculator is not allowed or in which the student is required to explain how/why he used a certain set of formulae to solve the given problem. To make matters worse, try to explain to these students that the real world is not made up of problems which can be found in the textbooks. Those textbook problems have already been solved. That is the reason for their appearance in the textbook.

“When you go to work, your boss is not going to say to you: ‘Mr. Jones, please turn to page 100 of your differential equations book and do problems 1–10.’ He is going to give you some vague problem with which you must grapple. Your ability to problem solve, to see through the cobwebs and to turn the problem into a mathematical statement is what will allow you to survive.”

The real world is full of problems that remain to be solved, and these problems require that those who make the attempt must make it by extrapolation from their in-class knowledge and experience. We fail to teach our students how to analyze the problem and how to look for the required structure in the problem as a means of discovering how to solve the given problem. Nowhere is this problem more evident than when we ask students to do word problems or to execute proofs. Skills that they will need for future courses in mathematical analysis and mathematical modeling are not tackled early on in their careers. Then, when they leave the university, they are left to garner these necessary skills on their own.

I have had, over the years, many opportunities to sit in on highschool physics classes. In all of these classes, physics was taught in the following manner. First, the physics principle was discussed and, perhaps, demonstrated. Then, the appropriate formulae were introduced – with relevant examples. Unfortunately, students were not taught how to identify when a problem needed a certain physics principle. Hence, there was chaos in the class when the numbers in a problem were changed. We are failing our students when we fail to provoke them to thought.

I would mention two subcases of the black box mentality: (1) *The "but I only made a small arithmetic mistake" mentality* and (2) *The "why do I need to memorize this stuff when it is all in a book in which I can look it up if I need it" mentality*. Mentality (1) is easily trapped by asking him if he wished to drive over a bridge which was just a small arithmetic mistake away from the other side of the river, or by reminding him of the Kansas City Hyatt Hotel disaster. Mentality (2) is a bit more difficult to deal with. My usual response, to this student, is to remind him how difficult life would be if he had to look up the result of $1 + 1$ every time that he needed it.

The second major class of problem that I run into, at the university level, is the verbally deficient student. In order to be an effective scientist (mathematician, engineer, computer scientist, whatever), it is important that the student be able to communicate with other individuals. Because mathematics is a rigorous and logical discipline, it requires that its participants have clarity of thought. Clarity of thought is best illustrated by what mathematicians call *an elegant proof*. By *elegant proof*, we mean a proof that is terse, to the point, and direct. The logical sequence in the proof is immediately clear, and all of the structure in the proof is well organized. In the years that I have been teaching, I have seen the verbal and the writing skills of my classes become progressively weaker until they have reached a level such that I can barely understand what they are writing. Spelling mistakes run rampant in my upper level courses. Students cannot identify assumptions in a paper. Nor can they even cleanly or clearly summarize what they have read. They cannot do a library search. In fact, I have discovered that most students cannot easily follow the most explicit of directions. We are failing our students when we fail to teach them how to communicate with each other and with the outside world.

Science and mathematics (why we distinguish between them is still a mystery to me), are both inductive and deductive disciplines. And we are failing our students when we do nothing to develop these two aspects of their future needs. Geoffrey Davies (Professor of Earth Sciences and Planetary Sciences at Washington University) said it most elegantly when he said,

"I have concluded that most students have not been forced to think much about anything, be it science, history, or poetry. (Nevertheless, they often go on to graduate)."

The myriad of points that I have discussed draw upon a variety of areas to make a point; biology, physiology, physics, cognitive psychology, and computers. The point that I have tried to make is that we are failing our children and our students by not realizing the interplay of these factors in the development of their cognitive processes. And, we are failing them by letting them think that teaching is just the transmission of facts. If this were the case, how easy it would be to simply memorize the textbook for each class. Surely,

education is more than just memorization. We fail to address their creative potentials; to teach them how to learn.

"The principal goal of education is to create men who are capable of doing new things, not simply of repeating what other generations have done — men who are creative, inventive discoverers. The second goal of education is to form minds, which can be critical, can verify, and not accept everything they are offered."

Though I wish that I could take credit for that elegant statement, the credit belongs to the world renowned

4.0 Pandora's Hope. Despite the magnitude of the problems that we have outlined, there is a great deal of justification for a hopeful attitude. First of all, we have recognized that a problem exists. And, as the familiar axiom goes, the road to recovery begins with the recognition of the fact that one has a problem. We have already discussed some of the problems, let me now outline some of the possible solutions to those problems.

At the preschool and school age level, we should examine our teaching methods and philosophies. We should adopt the SOI teaching methods pioneered by Meeker. Meeker, whose extensive work in the area of the structure of the intellect has given her international standing, has developed a methodology for teaching children to think and not to parrot. Though these methods have been around since 1963, their power has only recently begun to be realized. Further, SOI testing must replace the various current testing genres such as the CTMM, Slosson, Binet, Leiter, DTA, and STEP examinations. SOI testing provides a deeper understanding of a child's *current* potential, as well as a child's *current* weaknesses (Meeker, 1968; Meeker, 1978).

A nationwide attack must be made upon the serious problem of the adequate handling of our gifted children. While we continually hear about the *exceptional* child, we rarely hear about the *gifted* child and his/her needs. And, as one of our most precious educational resources, how can we fail to address the needs of this group of students. Some educators believe that we should take a gifted student and shove him ahead until he becomes a classic demonstration of Murphy's Law, rising to his or her own level of incompetence. This is what *advanced programs* do. A gifted student is not necessarily uniformly gifted. Such students are often strong in just a few areas, functioning at age in the remaining other subjects. Yet, in an advanced program, we take our gifted student and push him ahead, ignoring his deficiencies. And, in the process, we can kill their desires for learning. We fail these children when we do not identify them and we fail them when we do not subsequently support their educational needs. By failing to identify them, we cannot meet their needs. As a natural consequence, gifted students often become disruptive and

therefore lose interest in academics. Others will become bored with school, seeing it as a waste of their time. Once identified, we fail them by acknowledging their capability. But, we do little else for them. Once-a-week meetings with a *gifted* teacher can do little to motivate the hourly needs of a truly gifted student. Daily meetings, addressing the gifted child's potentials, as well as his weaknesses, need to be arranged. Programs that deal with broadening and deepening the gifted child need to be developed (DeBono, 1968; Frazier, 1980; Meeker, 1968; Bettelheim, 1981).

Particular attention must be paid to school age children ages two through eight. Important cognitive development is happening during these years and we cannot fail to address it.

Recognized physiological differences such as the right-left brain development differential must not only be recognized (once validated), but also addressed within the context of our educational methodologies. In these times of sexual revolution and liberation, it may do well for us to recognize that during certain developmental stages, girls may have to be taught differently than boys.

Students should receive regular training in integration of science and humanities. Study of the history of mathematics and of science should become mandatory, as part of a general education in philosophy. The art of mathematics should be addressed throughout the student's education (Hofstadter, 1980; Lamon, 1972; Hunt, 1982; Edwards, 1979, Casazza and Franchi, 1985).

We must, as educational institutions promote mathematical projects in science fairs. Prizes should be awarded in this special category. Students should be shown that mathematics is a science, though it has the additional capacity to be a language of science.

The preceding points directly address our children and our students. However, as educators, we must address ourselves as well. I am particularly fond of the biblical quotation,

"How can you remove the speck from your brother's eye, without first removing the log from your own?"

In the years since 1963, we have let ourselves become fat and lazy as educators. We see the purpose of education to be one of information transfer rather than what it really is; giving our students the drive so that they never stop their learning, their striving to understand.

"... There is the story of a faculty member at a large university who, upon starting to teach a mathematics class had 35 students. By the time the class was over, 19 had taken the final and only 7 had passed. Of the 7 who passed, there were no A's, 2 B's, and the

rest were C's and D's. The chairman was not amused. Called the faculty member into his office, he proceeded to inform said faculty member that this grading scheme was not acceptable. The faculty member stuck to his guns, having a personal reputation for quality at stake. Later thatday, the faculty member found out that, of the 19 students taking the final, 17 had repeated the course at least once and 5 were repeating the course twice. Further, investigation showed that 14 of the 19 had come from the same section, in a preceding class. The young faculty member went to their past instructor and asked: 'How could you have passed these students?' He was told by the senior professor, 'I knew that you would flunk them!' "

Needless-to-say, the young faculty member has gone, the status quo remains, and the university lost an excellent teacher.

A timeless, seemingly endless parade of students passes annually through our classrooms. And in this endless sea of faces, we become inured, hardened, set in our ways. What should be a daily challenge to incite our students to learn, instead becomes a daily challenge to survive the onslaught of our student's and their problems. Perhaps, it was said best by Professor Carter A. Daniel of Rutgers(1979), when he wrote

"College has spoiled you by reading papers that don't deserve to be read, listening to comments that don't deserve a hearing, paying attention even to the lazy, ill-informed and rude. We had to do it, for the sake of education. But nobody will ever do it again. College has deprived you of adequate preparation for the last 50 years. It has failed you by being easy, free, forgiving, attentive, comfortable, interesting, unchallenging fun. Good luck tomorrow."

How did we, as educators, become this way? What logic allowed us to do this to our educational system? Was it because there weren't enough good students? Was it because we had to pass enough students? Has academics lost its separation from the business world, now becoming the *business of academics*? A prominent Judaic scholar and professor of religious studies at Brown delivered a stunning commencement address some time ago. Of interest is a portion of his opening remarks.

"We the faculty take no pride in our educational achievements

with you. We have prepared you for a world that does not exist, indeed, that cannot exist. You have spent four years supposing that failure leaves no record. You have learned at Brown that when your work goes poorly, the painless solution is to drop out. But starting now, in the world to which you go, failure marks you. Confronting difficulty by quitting leaves you changed. Outside Brown, quitters are no heroes.

With us, you could argue about why your errors were not errors, why mediocre work really was excellent, why you could take pride in routine and slipshod presentation But tomorrow, in the world to which you go, you had best not defend errors but learn from them. You will be ill-advised to demand praise for what does not deserve it, and abuse those who do not give it.

How did we allow our educational system to degenerate to the point where faculty, knowing better, still allow the aforementioned to occur? Perhaps, to paraphrase Pirsig (1984),

"We saw it and yet we didn't see it. Or rather we were trained (convinced, cajoled, or pummeled) not to see it. Conned, perhaps. The truth knocks on the door and you say, 'Go away, I'm looking for the truth,' and so it goes away."

The truth is that we have lost touch with our educational mission and now seek to regain that contact. The preschooler's hunger for learning gives way to the scholastic indifference and financial orientation of the upper grades, as schools fail to meet their needs and the obviousness of economic necessity and need for personal independence becomes increasingly prominent.

In all of our travels as educators, we forget the Piagetian goal of education; to create minds that can *think*, adapt to change, analyze, and critique. Embodied in this concept is the essence of creativity.

"I am a teacher. I love to teach! For if anyone can show someone on the ground how to see 1,000 miles, I can!"

Nowhere is our educational miscarriage more obvious than in the attitudes of our students. College is a means to an end; a meal ticket to be earned after four years of academic apathy. The degree is not an ensignia of knowledge, rather, it is a union card,

an education foodstamp if you will. Breadth of knowledge is rapidly being replaced by flagrant narrowness of mind, as we let our students get by with such wonders as two years of FORTRAN as a foreign language; one semester of English; marginal Mathematics (some high schools require Algebra as the last mathematics course); and no science in grades ten through twelve. I hear students talk about courses not being *relevant, where it's at, mainstream*, and I ask myself, "what do they know about the real world anyway?" Yet, we bend to their desires and teach courses to fit their envisioned needs. We fail them, because they cannot possibly know their needs; beyond their desire for financial stability. They let their desire for a meal ticket rule their educational experience.

Stop and think about the *breadth of knowledge*, the variety of interests, and the depth of understanding embodied in the likes of Newton, Leibnitz, Gauss, Whitehead, and Russell. Think of the honor and respect one accorded the *Renaissance man*. Such men are rare in these times of multiple adjective job descriptions and microspecialization. Such men, when they are identified, are often accused of being dilettantes, of not having an identifiable *niche*. I am reminded of one of the greatest of these dilettantes, Leonardo di Vinci.

It is impossible to feast upon a Bach Toccata or Fugue and not marvel at the mathematical precision and the artistic beauty embodied in the music. Here is an illustration of the glorious interrelationship between the *arts* and the *sciences*. My experiences as a classical ballet dancer have shown me that the rigors and the discipline of the dance are no less than those of mathematics and of physics; that the arts and the sciences complement each other. The delicate pirouette, superbly controlled by a prima ballerina, bears witness to the elegant physics of the gyroscope. The glory of the arabesque is seen in the logarithmic spiral and in the shell of the marine mollusc the Nautilus. We must train our students to see the unity of things.

No longer can we, the teachers, remain apathetic — enclosed within our set ways. Inciting students to thought requires energy, constant attention to developments in the world around us, and a willingness to go one step more when you feel that you have done all that you can do.

You must be an actor, a playwright, a director, a benevolent dictator, a mindreader, a voracious reader, and more. Each class must command your complete attention, drawing your capacity as a teacher to its limits. Your love of life, of learning, and the wonder and the curiosity that you have must be transmitted to your students. This is what is essential to their intellectual development. Remember, as with Johnathon Livingston Seagull,

"The gull sees farthest who flies highest."

On our love of life and of learning will soar the minds and the spirits of our students.

In following this philosophy, we will give our students a true sense of the importance of

knowledge. We will show them that a teacher is not just another person; we are important to each and every student. From our molding, our sculpting, spring the new generations of creative minds in the arts, the sciences, and the humanities. From us spring the new generations of philosophers, the new thinkers, the new teachers. The United States has lost touch with the importance of its teachers and of its educational system as a whole. School has become a synonym for daycare. This attitude is subsequently propagated to the children (who are highly skilled and sensitive judges of their parent's feelings). School is *not* daycare! And we, the educators, are not parents! The role of the educator transcends basic social skill development. We train minds. And, though we cannot change the past generations, we may yet create new attitudes and new respect in generations to come.

5.0 Closing Comments. We have seen the problems that our students face in our current educational system. And, we have seen how we might address some of these problems, both from the point of view of the students as well as from the teaching perspective. We have seen that, in order to survive, we must give the gift of the *joy of learning* to each of our students. We must teach them to understand that each of them has the capacity to think creatively. We must teach them to put aside those things that limit them; to *disturb the universe* and to *ask questions*. For, in each answer, there are yet still more questions remaining to be answered. We must reach into their minds, clearing away the cobwebs, creating clarity of thought and of analysis, driving them to ask questions – to think. We must show them that a teacher is human, we do not walk on water. And we do make mistakes. There is no shame in that. It is from mistakes that we learn. And when they can think no more, we draw them further, by posing the Socratic question; busying their thoughts once again with the need to think, to create, to extrapolate, to analyze.

There need be no fear of flying here. The only limits are the ones we set for ourselves and our students. And the fight that we must wage is one which can be won. We must show our students that there is no greater joy than the creation of a concept, the successful analysis of a problem, or the exultation of that momentary glimpse — that fleeting insight which leads to sudden understanding. The satisfaction accompanying the creative impulse is akin to the joy of having your own child and the sheer glory of watching its growth and development as it proceeds down a path to independence.

The technological rampage, of recent years, has destroyed much of the joy of learning; replacing it with the microprocessor equipped teachers. The microcomputer can be a teacher or it can create an environment, a microcosm for the learning experience. It can replace the teacher as an automated learning device, or it can create an environment rich with the necessary knowledge for a child to seek and to create; thereby living up to the Piagetian concept of education as it should be.

The choice we will now make, the philosophy we will all adhere to will set the course of education, in this country, for decades to come. We can give our students the minds to survive, or we can create another generation of information processing humanoids. The

choice seems clear to me. And, after all,

"A mind is such a terrible thing to waste!"

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