1994 Distinguished Teacher of the Year

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OK, So Tell Me about Physics!

I feel very humble to have been selected as the Distinguished Teacher of the Year for 1993-94. There are a number of teaching awards at FAU, including those under the somewhat controversial Teaching Incentive Program, but this award is truly special because it is the only one that is selected by students. I do not want to appear presumptuous, but I would like to think that the choice is not made on the basis of numbers of courses nor numbers of students taught, but the results in the classroom itself. I am deeply, deeply grateful and I thank the students involved for the time and effort they put in. I thank also all of the undergraduate and graduate students who have made my teaching duties so enjoyable for the short time I have been at FAU. I am delighted to see some of you here today.

On reviewing the list of previous Distinguished Teachers, I noted that no member of the physics department has received the award. I don't know why that should be, although explaining entropy or teaching classical mechanics to an unwilling audience can be very challenging! Consequently, with Dr. Shen Li Qiu receiving the Researcher of the Year Award, the Physics Department has, indeed, been dealt a double honor here today. Many people consider physics to be difficult, dry, irrelevant and so on, and physicists to be boring, perhaps even strange. Actually, as my students will confirm, I take these preconceived notions as the focus for stories and anecdotes I relate during my classes about some of the more famous physicists – people like Galileo, the father of "real" physics, who as an undergraduate was given the nickname "Wrangler" by both faculty and students because of his inquisitive and argumentative nature, and who, because he rejected Aristotle's ideas, could not pass undergraduate exams as his answers were therefore “wrong”; like Tycho Brahe, who lost a good deal of his nose in a duel and fashioned a “pseudo” nose out of wax, gold and silver; and recent Nobel Prize winners like Erwin Schrodinger, who had what one can only describe as a highly unusual family arrangement, and Richard Feynman, anti-establishment figure, raconteur, bon-vivant, painter, bongo player – who once wrote an opera backed by drums – but an original and brilliant researcher and much-adored teacher. You see, physicists can lead interesting lives! And now I would like to share some personal views about physics with you.

The evolution of modern physics began, not surprisingly, in Renaissance Italy; it had been, after all, the birthplace of the poetry of Dante and Petrarch, the writings of Machiavelli, the art of da Vinci, Boticelli, Cellini and Michelangelo, the music of Desprez and da Palestrina – and even of the celebrated culinary craft and cookbooks of da Como, di Messisbugo and Scappi!

The Renaissance brought about a brilliant revival in learning and so it was appropriate there should be a "re-birth" of scientific enquiry and understanding. After centuries of investigations by Greek scientist-philosophers like Archimedes and Aristotle, the study of the physical sciences essentially stood still throughout the period of the Roman Empire and the Middle Ages. Aristotle's writings had been translated into Arabic and Latin, and his work was taken to be authoritative in all matters by the Church and State, and opposition to his scientific principles ran the risk of severe penalty – even death. That is why, to me, the accomplishments of the scientists during the late Renaissance are so remarkable.

OK, so what is physics? *Physics in Perspective*, published in 1972 by the National Academy of Sciences, tells us that physics is the knowledge of inanimate nature. Some aspects of nature, like the shape of Florida or a spiral arm of a galaxy, for example, are neither universal nor permanent. But the fact is, the forces that created both Florida and the spiral arm of stars and dust obey universal laws. Discovering that has enabled us to understand more about nature, and as we gain more knowledge what appears complicated initially can be seen as essentially simple and, in a deep sense, orderly. Physics is concerned with questions that generally cannot be decided by thought alone. Answers are sought by testing ideas through experiment; in fact, the questions themselves are often generated by observation. But there is every reason to believe that the answers, once found, have a permanent and universal validity. All the evidence indicates that physics is the same everywhere in the observable universe. It differs from the fine arts, literature and philosophy because it is *self-testing, self-correcting* and *objective.* The final arbiter is evidence obtained through experimentation, observation and measurement, not authority nor opinion. In fact, physics is the parent of the physical sciences.

But isn't it expensive? Physics is a *practical* subject based on experimentation and observation. "Big Science," such as the space program or the now doomed Super-Conducting Super-Collider project, can be very costly, but big discoveries don't have to be; many have been made in "little science." The "big science" versus "little science" debate will always be with us, and I maintain that is one very good reason why everyone should be exposed to science. We all become tax-payers and voters – possibly parliamentarians – and we may be called upon to pass judgment on some piece of science-based legislation. It is unfortunate, but nevertheless true, that the people making decisions about funding levels are, more likely as not, scientifically ignorant. Everyone concedes that fundamental scientific knowledge is worth the cost if it contributes to human welfare by promoting, even indirectly, the advance of technology or medicine. However, let me make two points. First, an inability to foresee a specific practical application does not prove there will not be one. Consider, for instance, the scientists working on the purification and growth of silicon crystals some 60 or 70 years ago; they had no inkling of the semi-conductor revolution they were generating. So, in a present state of ignorance it would be as presumptuous to dismiss the possibility of useful applications as it would be to guarantee them. Second, understanding "things" is essential to a society and to the development of its culture. The marvelous thing about fundamental scientific knowledge is that it is an indestructible public resource, usable and understandable to anyone who makes the effort. It is a thing of beauty, pride, power and pleasure; yes, to quote a bumper sticker I once saw, "Physics is fun!" However, when teaching students, one has to be careful not to trivialize it; difficulty inspires exploration, which itself becomes thrilling and pleasurable. You see, knowledge of scientific laws makes for economy of thought and greatly

simplifies our bewilderingly complex universe. Research is an essential ingredient here because – and few people appreciate this – it leads inevitably not to more complicated models and theories but to simpler and clearer pictures. Research is a powerful stimulator of fresh ideas; for example, I am now teaching things in the classroom that just a decade or so ago were either unknown or much too complex for students to comprehend. Of course, a clear link between research and teaching is not confined to physics – indeed, that is why we must pursue research. If we do not, we are short-changing future students.

Well, what about the negative aspects? Physics enables us to do and make all manner of things good and bad, depending on one's perspective. Scientific knowledge is the enabling process, but it does not carry any instructions on how it should be used. Richard Feynman took part in the development of the first atomic bomb at Los Alamos, but in later life he became rather critical of his role. At a meeting in 1955, he quoted this proverb from the Buddhist religion: *To every man* is *given the key to the gates of heaven; the same key opens the gates to hell.* Feynman went on to reason, "What then is the value of the key … ? It is true that if we lack clear instructions that enable us to determine which is the gate to heaven and which is the gate to hell, the key may be a dangerous object to use. But the key obviously has value; how can we enter heaven without it? Instructions would be of no value without the key. So it is evident that, in spite of the fact that it can produce enormous horror, science is of value because it can produce something [good]."

So why don't more people study physics? Well, physics is not an easy subject; it requires a high degree of dedication. Also, more money and jobs can be found in other fields. However, in my opinion, it is teaching that is a major problem, not necessarily the quality nor type of teaching but the increasing lack of importance attached to science – and particularly the analytical sciences – in the curriculum. Be in no doubt, to remain at the forefront of a rapidly changing world our society requires thinkers not simply memorizers, and we must cater to that need. Physics is truly a core subject, but we are allowing its impact to become diluted by the introduction of more peripheral subjects; interesting maybe, but not essential. One can contrast this with the emphasis that other nations place on science. In Japan and Germany, for example, many more students graduate with science and engineering degrees relative to, say, law, than in the U.S., and most CEOs in those countries have degrees in science or engineering, whereas here most CEOs majored in business or accountancy. I know through my own experience in teaching non-science majors, there are many students who become very interested in the basic questions that physics addresses. They realize that although sometimes the language may be abstract and mathematical, physics can transform their appreciation of topics whose dimensions range from the atomic world to the whole universe. It is a pity that this awareness comes so late.

There is so much more I would like to say about physics because it is my life and passion, but I have to close. Before doing so I would like to share some thoughts with you about teaching. I haven't developed a particular philosophy myself, but from time to time I've come across statements that seem to parallel my own feelings. For instance, some while ago I read that *an ordinary teacher weighs and bags ideas like potatoes; a skilled teacher opens them up like a flower from a bud,* and that struck me as extraordinarily poignant and something we teachers should remember each time we face our students. During an interview, Richard Feynman once said:

"I don't really believe I can do without teaching!" And I know exactly what he meant. But I would add: *The reason is because I enjoy interacting with students whether they be non-science majors or graduate students, and I feast on the intellectual stimulation that brings. Knowledge is an incredible resource; to pass it on to the next generation is an awesome but truly satisfying duty.*

And in conclusion, I would like to share with you the words on my final view-graph for the students in my Physical Science course. It is based on the epilogue that Richard Feynman gave at the end of his lectures on physics at Cal Tech some years ago, but with minor changes I think it pretty much sums up my own approach to teaching:

To those of you who have understood everything, may I say I have done nothing but shown you things. To the others, if I have made you dislike the subject, I'm sorry. I just hope I haven't caused you any serious trouble nor turned you off for life. I hope you find someday that, after all, it's not as bad as it looks! .... My main purpose has not been to prepare you for an examination – not even to prepare you to serve industry nor the military. I just wanted to give you some appreciation of the world and the scientist's way of looking at it, which, I believe, is a major part of the true culture of modern times. There are probably teachers of other subjects here who would disagree, but I believe they are completely wrong!
Thank you.