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MR. RICHARD T. NALLE, JR.: The next subject is education in priorities for the second century, and specifically science education. This is one close to our heart because, as you know, the Franklin Institute is deeply involved in science education.

Again, I'm going to be very brief on the introductions. Dr. John Linvill will be our first speaker. He has a long background in education and research. He's currently professor of integrated systems and a Director of the Center for Integrated Systems at Stanford University, and he is also a fellow of IEEE.

His discussant will be Dr. John Slaughter, Chancellor of the University of Maryland, and also a fellow of IEEE.

First, Dr. Linvill.

MR. JOHN G. LINVILL: Well, greetings, fellow members of the IEEE. It's a real pleasure to have this opportunity to talk to you about priorities in engineering education for the second century of the IEEE.

Engineering education through the first century of the IEEE reflected the evolution of the electrical engineering profession during that century.

. The birth of the profession occurred with the development of electrical power. The vacuum tube brought radio and electronics. Computing machines changed from mechanical to electromechanical to electronic to digital electronic form. Particularly with World War II the emphasis on electronics vastly expanded and the government came into the education scene with levels of support and long-term involvement which have never occurred before. But the most rapid change during the first century was reserved for the last part of it. The transistor and integrated circuit combined with computing and information processing brought a rate of change previously never equaled.

At the end of the first century, the relative importance of electronics and electrical engineering has greatly increased from its start a century ago, and the rate of change of technology and its applications are growing at an unprecedented rate. Rapid growth and dynamic change represent the initial conditions for engineering education as we enter the second century of the IEEE. To match the growing importance of electronics and electrical engineering in general, the educational community, including its support base in the government and in industry, must establish the appropriate priorities for the second century and implement plans to act vigorously in accordance with these priorities.

Now one can identify many important directions and important goals for engineering education. Many of these correspond to the goals which have been established and are accepted these days in the education community, but the situation is significantly different looking into the next century than it was looking through the first century. I want to put emphasis on three major directions for engineering education, in a word to identify three priorities for the next century. I will state them first in introductory terms and then deal with them in sequence.

The rapidity of change in electrical technology has continuously shortened the effective lifetime of an engineering education, particularly the master's degree level of that education with the result that education must be an ongoing process throughout professional life. A dominant priority for engineering education is adaptation of the professional to change from the beginning and throughout his professional career. In a word, we must change education to educate for change. That is the first priority I will discuss.

Electronics has brought powerful tools for education. Television and the video screens of computers impact all parts of American life. They have come into the educational process by intent or automatically. The tools technology has created must be used imaginatively by the engineering sector to promote the education of new and practicing professionals. An important priority for engineering education is to utilize technology to enhance technological education. That is my second priority for the second century.

Today engineering education is going through a significant crisis. There is a severe shortage of faculty members qualified and interested to pursue an academic career. Those academically qualified for the teaching profession have recently found it more attractive to pursue careers in industry. An incentive system for education is lacking in which productivity and excellence in the profession are sufficiently rewarded to make academic careers attractive. In fact, the entire educational system would strongly benefit from a significant incentive system both for faculty members and for other sectors as I will explain shortly. So my third and I think the most important priority is the provision of an incentive system for engineering education for the next century.

Now let me turn to these priorities one at a time.

A significant measure of the present rate of change in technology is the fact that for a period of 20 years the number of elements on a silicon chip has doubled each year while the price of the chip remained constant. This relationship which was first pointed out by Gordon Moore, presently Chairman of Intel Corporation, has been frequently referred to as Moore's Law. The result is that the effectiveness of an integrated circuit chip changed rapidly by a factor of about a million over that period of time. The impact on the computer, on telecommunications, on electronics in general has been profound. The microprocessor -- the computer on a chip -- evolved in this environment changing rapidly both the power of the electronic systems which are possible and the way in which these systems are designed and used.

Now the engineering curriculum at the M.S. level is the part most affected by changing technology and itself has exhibited corresponding change. The undergraduate curriculum necessarily involves large components of mathematics and science and these changed relatively less rapidly. The new parts of the M.S. curriculum are of key importance to practicing professionals since these new parts provide their agenda for study to maintain and build a professional competence on a dynamic life-long basis.

For example, the design of systems involving microprocessors is presently only a decade old in the curriculum and the courses in the layout of large scale and very large scale integrated circuits is only half a decade old. The breadth of utility of microprocessors and custom ICs means that the electronics professional must learn to use these implements whenever it was that he received his own master's degree.

Now could I have the first view foil.

Here I simply have a look at education for engineering. And I don't want to slight the importance of primary and secondary schools. There's a crisis in a program worthy in its own right going on on that scene. I think it's important. It is the raw material with which we in the university community work.

I've indicated that the undergraduate program is important but it's relatively less rapidly changing, and I've focused attention on the master's degree which is really the working professional degree these days. The characteristics of it are that it is the most rapidly changing sector. It's the most necessary to technological process. The working degree for the real engineer is a master's degree. The troublesome thing of course is that a master's degree once mented does not really remain workable for an extended time. It must continuously be refreshed.

And of course, finally, that degree is important to the largest spectrum of engineers. Doctoral education and research is important, will continue to be so, but there is no doubt that the major work for the educator is going to be the master's degree.

Now we can shut it off for a moment.

Electronics professionals literally face a challenge of a continual process of education which must be life long. The industry which employs them must face a challenge of maintenance of the effectiveness of its work force, the central component of its base of competitiveness. The question, how can life-long education be most effectively carried out and who will be responsible for the process and system, is of course a major issue for individual professionals, for the society, and certainly for the educational institutions.

One possible answer to that question was provided in 1982 in a centennial study at MIT which was reported in "Life-Long Cooperative Education" written by Professors Bruce, Seibert, Smullen under the chairmanship of R. M. Fonnel. The proposal of the MIT study is that industry and the university must cooperate in the life-long education of the professional engineer. Moreover, the MIT study recommends a method of tutored video tape instruction initiated by Professor Gibbons of Stanford for providing that education.

In tutored video tape instruction, video tapes are made from regular classes paced by a live, learning audience trying to understand what the professor means and helping him out when he's in trouble. The video tapes are played in TVI before a small group, typically about ten or less, by a tutor. When one of that small group doesn't understand a point, he asks a question and the tape is stopped by the tutor who facilitates a discussion of the matter not understood but does not immediately answer the question or give them any lecture. When a point is understood, the tape is started again. Gibbons' supposition that course material would be effectively learned in these little intellectual communities, as he called them, formed by the viewers and the tutor was really verified by a large number of tests in which the video tape viewers (actually a set of groups from Hewlett-Packard) took the same quizzes and same examinations as the regular class. The viewers performed just as well as regular students.

Moreover, there's economic gain. Since the same lecture material is presented to a larger audience and of course the tape can be viewed anywhere that a tutor is located with a video player, the method is receiving further interest these days and I think is a promising way to solve part of the problem ahead of us.

Of course, there are other important means to implement ongoing professional education in this environment of change. The program and publication functions of the IEEE play a very important part. In conjunction with major regular meetings, tutorials and workshops on forefront technology have become commonplace. They play an important role in the education process and should strongly continue. The importance and effectiveness of short courses is apparent from the fact that groups of professionals, frequently educators, have made successful side businesses conducting them.

Well, how should professionals, you in this room, view this environment of change in which we now exist? How do you view the business of being a professional who is also a student, a pair of roles intertwined for a whole of a career? In one word, I think enthusiastically. It's not the imposition of a drudgery upon the profession but the injection into it of an exciting, continuously renewing experience.

It's clear that some of the learning must represent an investment of the professional himself. In other words, he's going to spend some of his evenings doing this. Some of it will be provided by the employer, and some of it represents a new investment of society at large through the governmental system. All three sectors -- the individual, his company, and his government -- will in the long term significantly benefit by the process set up. The benefits of the outcome of the technical professional work force will return a handsome benefit to all sectors making its investment.

Now let me turn to the priority, technology to enhance technological education. In the June issue of Spectrum which looked at technology and the individual beyond 1984, two significant papers were presented reagrding technology in education.

Professor van Volkenberg in his article entitled "Technology As a Tool for Teaching EE" has made a compelling case for the attractiveness of technological aids for education. He points out numerous examples of the effective use of electronic recording, both video and audio, in the education process. In addition, he shows a significant impact which the introduction of the computer as a teaching aid already has made.

In the end he concludes -- and I certainly agree -- that the use of technological aids increases the efficiency of education. That means that the number of effectively taught students per professional teacher will certainly increase.

In the same issue Professor Cert of Carnegie-Mellon in "The New Teacher's Pet: The Computer" points up the use of the computer in the broader base of secondary and undergraduate education. Cert believes that increased access to computers with short response time removes the major limitation which has prevented computer education in the past from achieving the success that he now anticipates. The creation of software by computed aided education is a major task. The consortium of universities organized by Carnegie-Mellon to build and share a software base is itself an important step.

Now graduate education in technology, particularly that part involving experimental research, requires experimental equipment which is expensive and which changes rapidly. At the same time, there is no effective substitute for hands-on experience in this part of the learning process. In the experimental research arena, the same class of equipment is necessary in the university as in the industrial research laboratory. The cost of equipping and maintaining a research laboratory on integrated circuits or semiconductor physics is comparable per doctoral student to the cost per technical professional in the corresponding industrial research laboratory. Now that is an overwhelming burden of a new kind -- an important one which we must meet. The implication is clear that a new higher level of capital investment is essential in the graduate schools presently and those for the future.

Now an alternative method of achieving hands-on contact with the professional implements is for the student to have this contact in conjunction with an industrial operation. One sees in this situation a merging of the educational operation with the industrial operation. A moment ago I said that industry has to get into education because it has an ongoing work force which continually has to be reeducated. Now we see that the university has to provide an environment much like the industrial environment to do an effective job of teaching. I think it's clear that the functions of industry and the university are on a path of merging. They have many goals in common.

Technological education by its very nature will have a content which is essentially more industrial than has ever been so before. At the same time, professionals in industry must have a continual educational experience to remain effective in their professional careers.

The inescapable result of this situation is, of course, that the functions of industry and the university must be merged at least in some degree. One doesn't have to go all the way. We have examples in the past of industries which ran their own educational systems. In general they found it typically too costly and less effective. And of course, in the same way, the university which sticks strictly to nonexperimental work is quickly out of sight.

If the process of cooperative education is done with vision and effectiveness, each sector will benefit by the presence of the other. The confluence of industry and technological education occurs primarily beyond the bachelor's degree. There has been and will continue to be significant interaction between the industry and university in certain undergraduate programs but changes here are small in prospect compared to those applying to the master's level.

Now let me turn to the third priority -- incentive systems for education. There are two aspects of incentive systems which I want to discuss. First, I shall talk about an incentive system for teachers.

The shortage of faculty members, particularly professors in the area of computer science and systems, is strong evidence that the education profession has lost comparative attractiveness to industrial careers. An American Electronics Association blue ribbon committee characterized this situation as industry having eaten its own seed corn. For the technical industry in particular but for all of society as well, the problem of faculty shortage is a very serious one. What we as a society must do is to establish incentives which make the teaching career attractive to the most able professionals inclined toward such a career.

Up to a certain level, regular salary is a primary incentive. The investment of larger amounts of money for teachers' salaries is essential for the educational system. Only by providing suitable salaries can society make outstanding teaching careers attractive to new Ph.Ds. Graduate students preparing for a career in education must be able to project an economic scale which does not imply financial sacrifice.

In the presence of an adequate base salary, external income from consulting, publishing, and lecturing, of course, are effective and attractive incentives in their own right. But there are other important incentives to educators in addition to salary.

Social recognition of outstanding performance of educators by professional societies, by government and industrial entities all have a powerful role in stimulating outstanding performance. Our professional societies and government agencies can focus additional attention on the education profession to bring it effectively to the attention of graduate students.

Again, the American Electronics Association has established a very attractive fellowship program whereby its member companies have provided forgivable loans to selected candidates. The loans are repaid by years of service as faculty members. And incidentally, a number of companies have done essentially the same kind of program as that established in the AEA. Though these programs are new, the positive effect can already be detected at Stanford in the response of our graduate students. More and more students there see an attractive career in the teaching profession.

Finally, let me say that a university creatively administered offers a very attractive life a faculty member. Many of us in the academic community find the continual contact with growing and inquiring minds a unique, stimulating experience. The university atmosphere is a significant attraction to the academic profession when the most serious impediment (an absolutely too low salary) is removed.

Now let me turn to the incentives for a different player in the education game. That player is industry.

Throughout this presentation I have pointed out the projected large increase in the interaction between industry and the university in engineering. I'd like to point out to you that there is a user/supplier relationship that we don't frequently put down on explicit terms in education and industry.

Could I have the next viewgraph please.

On this view foil I have indicated what industry's needs are. They need fundamental research, selected and prepared candidates for employment, imaginative, speculative projects, and effective education materials. The university needs state of the art technology, powerful research equipment, professionals addressing current problems, market for educational materials. You could say what the university needs the industry is a supplier for. What industry needs the university is a supplier for. There's only one little constraint in this system, and that's the bottom line there.

Security for proprietary advantage is essential in industry, at least it's been felt to be very essential in industry. And in the university, if we have any deity, it is openness of communication. So around the base of these two conflicting requirements, we have to work out an appropriate supplier/buyer relationship.

That's enough for the view foil. Thanks.

Of course, the bottom line question is this: who bears the cost of industrial involvement with education? Is it an unavoidable tax on industry for the benefit of society at large? Or must our public tax system in some way reimburse industry for this important contribution?

First of all, I firmly believe that participation in the education process must have incentives to the industries participating to assure that participation be of high quality and of continuing duration. There's no free lunch and there's no free education. At the same time, industrial involvement in the educational process brings a significant benefit to industry when the relationship is carried out in an effective way.

Contact with the graduate population being produced in the university gives the industrial partner facilitated access to the ideas which are generated there and facilitated access to the students as emerging professionals when they're ready to enter the employment arena. The worth to technological industry of an early and effective contact with a Noyce, a Pierce, or a von Noiman is of very great value indeed. To the outstanding individual, contact with an effective industrial employer has great rewards as well. When a creative individual is placed in an industrial position configured to exercise his creative talents to the limit, society at large is the major winner.

But who must insure that incentives to industry that I recommend be in place? Finally, it is the educators and the government entities that support education that must insure that the incentives for industry are there. These can be tax incentives provided through our political system. They can be the benefits implicitly available in the user/supplier relationship which I described. When the appropriate incentive system is in operation for all players, our educational system will show effectiveness far beyond what we have experienced in the first century.

Thank you very much.

(Applause)

DR. JOHN B. SLAUGHTER: I'd like to thank Ed David for inviting me to be a part of this program this afternoon. I particularly appreciate the opportunity to appear on the same segment of the program with Dr. John Linvill.

This paper addressed three of the most important issues in engineering education. There were: One, engineering education must develop a method to educate the professionals for change. Two, engineering education must utilize technology to enhance technological education. And three, we must develop an incentive system to interest engineer in becoming educators.

Note the emphasis on change in all three of his points. These are certainly priorities for engineering education, not all of the priorities by any stretch of the imagination but arguably the most important ones. I want to mention briefly a few others that engineering education must deal with in my opinion, but first let me comment on Dr. Linvill's point about incentives.

Paul Gray, the President of MIT, said that one of the major problems facing education today is that an academic career is becoming increasingly less attractive -- a point which John Linvill made very clearly. It is my belief that higher education needs to steal a page or two from Peters and Waterman's successful book, "In Search of Excellence." That book which points out eight principles practiced in abundance by America's most successful corporations provides us with a rare opportunity to compare and contrast how academic institutions deal with challenges, with opportunities, and incentives.

I argue that there is no systemic reason why the same successful approaches cannot be employed in higher education. Professors, researchers, students, football coaches, housekeepers, provosts and deans need supporting environments, incentives to excel, rewards if they do, room to take risks, opportunities to practice entrepreneurship, a sense of community, and reasons to feel pride in themselves and the institution of which they are a part. Too few educational institutions in my mind have shown the willingness to move away from those practices that prevent them from being the 3Ms, the Wangs, the Intels, and the IBMs of academia.

For over 30 years I have heard the argument that engineers by necessity are trained rather than educated. I think the charge is badly overdrawn, but to an extent it is true. Thirty years ago, if it was true at that time, it was much less important. Today, however, I believe it is more worthy of our concern. As our knowledge of science and technology expands almost without bounds, the five years of undergraduate education required of most engineers compels us to provide our students with more, not less, mathematics, physics, chemistry, and metallury. But the expanding set of social, economic, and cultural interrelationships associated with our rush toward high technology calls for a much deeper and more professional understanding of these issues as well.

A well trained but undereducated engineer has limitations -- limitations that are present in his or her designs, theories, and products. I believe that education must learn to deal with this reality.

Roger G. Smith, the Chairman of the Board of General Motors, spoke of the importance of these considerations when he said that business is not so much the movement of products as it is the relationships between human beings. That view was echoed by Charles O. Brown, Chairman of the Board of AT&T, who said that "my own experience has shown that it is conceptual issues and problems in business, the humanistic concerns if you will, that are the most difficult to deal with and the most crucial to resolve. And so there's a place," he continued to say, "a central place, for the humanities and the liberal arts."

That's the good news. The bad news is that the good news is not better known.

No discourse on education priorities in the future can be considered complete in my opinion until we deal with this issue. It is more important perhaps than those topics that occupy much of our time and concern now -- industry/university cooperation, new instrumentation in our laboratories, new computers in our classrooms. At some point educators must come to grips with the need for engineering students to have a greater appreciation for both Milton and molecules, Carlisle and chemistry, Picasso and potassium. In an ever changing society such as the high speed, high pressure, high technology one that we're helping to build, there will be a greater need than ever before for those persons who take our places 50 years from now to have a better education and better abilities in the humanities and the social sciences than do we.

Finally, I remained concerned about the slow progress we as a profession are making in improving the presence and the quality of that presence of women and minorities in engineering. A look around this hall confirms that our generation has not been very successful in that regard. I would hypothesize that at the beginning of the 21st century, women will have a more commanding presence in engineering based upon their present enrollment in our colleges of engineering, but I am not at all sanguine that blacks, Hispanics, or American Indians will be more evident than is currently the case.

In the 1970s business and industry took the lead to increase the number of minorities graduating from our engineering schools from between 1 and 2 percent of the total to some higher level. That effort was successful in doubling the number of minorities but that effort has now plateaued and in fact has even wilted because of a large number of economic and political reasons.

The engineering profession itself has never mounted a major effort in this regard and in fact has tended to discount the argument that there is any reason to be concerned. The responsibility in the future, therefore, in my opinion is one that will have to be carried largely by the educational community from pre-school to doctoral levels.

The reason this is important is not because of some appeal to our conscience or the need to satisfy some affirmative action laws. It is important because our nation needs all the intellectual skills it can muster to deal with the pressing technical, economic, and social problems that face us. We are dealing with problems faced by our industrial and production capacity, problems that will not be solved unless all of America's potential, not a portion of it, has a fuller opportunity to contribute.

All of us have become painfully aware of the problems in our public education system which were highlighted by the numerous reports that came out in 1983. Encouraging has been the response of school boards, administrations, and the public toward improving those schools. I trust that that momentum will continue.

Higher education is beginning to respond as well. The new cooperation will, I believe, produce much improvement. But we need to recognize that serious disparities still exist, disparities that impair many disadvantaged young persons from the necessary exposure to science and engineering that can ignite that spark that will make it possible for them to pursue these fields of discovery.

Priorities for education are great. They underlie all the other priorities that are before us. They include producing the finest scientists and engineers, a knowledgeable well-informed citizenry, and a national climate of enlightenment and tolerance. The future of our country depends to a large extent upon our commitment to meet those priorities.

Thank you.

MR. NALLE: Thank you, Dr. Slaughter, and thank you, Dr. Linvill.

We're getting back on schedule and I thought what I would do now is take a....the refreshments are out there. If we take a quick break and be back here by 25 of, we'll be able to have an extended question and answer period at the end of the last presentation. That will get all our speakers on and have a good question and answer period at the end.

So if you'll be back here by 25 of, we'll continue with the presentations.