Written Contributions to the EHR Advisory Committee Public Hearing on Employers' Views

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Invited Speakers:
"Employers' Views on the Preparation of SME&T Undergraduates"

Listed in order of Testimony. Titles indicate the speakers' positions at the time of the Hearing.

Baltimore Public Schools *Baltimore, Maryland*	**Walter G. Amprey** *Superintendent*
Columbia University *New York, New York*	**Eugene Galanter** *Professor of Psychology*
New York Hall of Science *New York, New York*	**Peggy Ruth Cole** *Director of Program Planning and Development*
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Hewlett Packard Company *Palo Alto, California*	**Alfred Moyé** *Manager, University Relations* **Robert W. Ritchie*** *Director, University Affairs*
Boeing Commercial Airplane Group *Seattle, Washington*	**John H. McMasters** *Senior Principal Engineer, Aerodynamics Engineering* **James D. Lang*** *Director, Technology Division, New Aircraft and Missile Products, McDonnell Douglas Aerospace, St. Louis, Missouri.*
National Alliance of Business *Washington, District of Columbia*	**Robert Jones** *Executive Vice President*
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Bell Atlantic Corporation *Arlington, Virginia*	**Patrick E. White** *Vice President, Strategy*

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Employers' Views on Desired Capabilities of Undergraduate Students Entering the Workforce

Walter G. Amprey

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I thank the National Science Foundation for this opportunity to testify on behalf of public education concerning the undergraduate preparation of students entering the workforce. Our "industry," public education, develops a "product" that ultimately must support a regional and national economy and must be the source of problem-solving ingenuity and innovation to meet the challenges of change. The university undergraduate product we depend upon to mold this "product" is the new teacher: either a science, mathematics, engineering, or technology (SME&T) major who often enters secondary education or a non-SME&T major. Even though these teachers receive formal instruction in content and methodology, they are not fully prepared to teach effectively as soon as they graduate.

Many new teachers arrive at their first assignments lacking sophisticated skills in writing, speaking, and computing. These are essential skills for success in any workplace. In addition to these "basic" skills, all graduates should be able to think logically and be able to show their students how to use higher level thinking skills.

Technological literacy is another basic requirement for successful citizens of the Information Age. All new teachers should be able to use technology and adapt to its roles and applications. They also should be able to appreciate the power of science, mathematics, engineering, and technology in everyday living and should understand how mathematics and science support, undergraduate, or clarify concepts in other disciplines such as art, music, and social studies and in diverse career fields.

Along with these "basic" skills, new teachers should understand organizational "culture" and the need for continuous improvement. When entering the workforce, all new teachers should be able to contribute to team efforts that focus on an organization's goals and respect their co-workers' abilities. New teachers should also enter the workforce seeking more education. They must understand that continuous study and research, both formal and informal, are essential, and that preparation for teaching does not end at college graduation or with a master's degree.

SME&T content are also essential for all new teachers. Non-SME&T majors, especially those, who will become elementary teachers, need broad-based knowledge of SME&T content, so they can integrate material into any subject area. They also need to be aware of career opportunities for their students and be able to direct students to appropriate course work for their career goals.

While all teachers should be technologically literate, those who become SME&T teachers should be able to use technology as a pedagogical tool in their classrooms on a regular basis. SME&T teachers also should be well grounded in modern pedagogy and be able to apply modern pedagogical techniques to their content areas.

In their content areas, SME&T teachers should know more about the subject materials than they are required to teach. For example, a pre-college mathematics teacher for senior high school should be able to teach freshman and sophomore courses at the college level. Similarly, a chemistry teacher should be able to handle undergraduate skills and concepts in addition to knowing the state-of-the-art equipment.

New SME&T teachers should have the benefit of sufficient practicum/internship experience before they graduate. After they graduate, these new teachers should have mentors who are experienced teachers as well as mentors who are based in business and industry. SME&T teachers cannot lose focus on the world of SME&T beyond the classroom.

In general, all SME&T majors must be able to adjust to the changing demands of the workplace and use the higher level skills of thinking in mathematics and science to be productive workers. As requirements of business and industry change and as corporate downsizing becomes a reality, graduates must have the transferable skills and flexibility that will provide them with successful livelihoods.

Undergraduate SME&T education for majors and non-majors is influenced by several trends. First, the increased requirements in mathematics and science in precollege education will require colleges to introduce more rigors in college-level courses. Second, the increased number of students in the pipeline for SME&T at the precollege level will increase the number SME&T majors at the college level. This will require more college SME&T faculty. Finally, the increased number of SME&T-literate precollege students will increase the number of majors in college and technical schools who will request training in SME&T-related fields.

Ideally, undergraduate SME&T education for potential teachers should be developed through collaborations of local school districts and universities. For example, the National Science Foundation funds the Maryland Collaborative for Teacher Preparation, an alliance of the University of Maryland system, Morgan State University, Baltimore City Community College, and three Maryland public school systems. This project focuses on elementary and middle school science and mathematics instruction and supports joint efforts to meet the needs of teachers new to the profession. Many informal collaborations coexist with such formal arrangements. Thus, individual public school staff members interact frequently with their colleagues on college faculties because of numerous projects that tie them together. In addition, a number of institutions of higher learning assist local districts in meeting their identified needs.

The standard school district/University interface, however, is the student teaching program, where young people preparing to be teachers work in classrooms under the joint guidance of a classroom teacher and a college professor. Because individual school systems are institutionally separate from the teacher training institution, school district needs are not always met as quickly or directly as possible since universities must meet their own goals and objectives. This "extended reaction time" sometimes keeps the teacher training institutions one step behind the needs of the school district. What is needed is a process for more rapid and direct implementation of system needs into college programs.

Improved articulation between school districts and teacher training programs also would reduce the need for "remedial" teacher training. Because so many new graduates need in-service training to perform satisfactorily, it appears that the training programs at the college level lack content and pedagogy or lack understanding of the needs of the school district. New teachers must be able to apply educational theory in their daily teaching practices. Too often, the practices demonstrated by professors in teacher preparation courses are not the state-of-the-art pedagogical methods that are needed for instruction in precollege classes.

SME&T curriculum for both majors and non-majors must be broadened and deepened if we are to improve elementary and secondary instruction. Preparation of secondary teachers, for example, usually includes almost as many courses as a SME&T major; however, new teachers should be up to the standard of all other graduating SME&T majors. Elementary teachers enter the workforce with very little content background in science and mathematics. Further, they are not challenged to become more prepared because “seasoned” administrators whose backgrounds may be lacking in science and mathematics content supervise them. Thus, a self-perpetuating cycle of "science and mathematics weak" elementary curricula establishes and maintains itself

Both pedagogy and curriculum can best be improved through the collaborations of precollege and undergraduate faculties. With such alliances, curricular and pedagogical innovations could better address the knowledge and performance bases of students -- and better prepares them for jobs and career paths.

Finally, as colleges and universities work with school districts to update and upgrade teacher preparation programs, states should re-evaluate their requirements for teacher certification. Currently, a limited number of SME&T courses is required, especially for elementary teachers. New standards should emphasize the integration of mathematics and science in other disciplines such as art and history where high-level skills in problem solving and decision making are required. States also need to increase their requirements for certification of mathematics and science teachers as more rigor is introduced in college and precollege courses. In general, certification requirements should give all potential teachers more practical and comprehensive "hands-on" experience in mathematics and science.

To meet the requirements of the 21st century workplace, we must work harder to disseminate needed improvements in educational practice. On the national level, roundtable discussions and other forums involving school districts and teacher education institutions could address problems. Direct local interaction on a regular basis can resolve problems as they occur. Collaboratives already address some of those needs, but superintendents and college administrators need to interact more frequently. This will prevent the bureaucratic needs of either institution from overwhelming the common goal of providing and employing a competent SME&T workforce in education.

Local districts such as the Baltimore City Public Schools look forward to continued partnership with the National Science Foundation, other federal agencies, and other funders. Specially funded programs have produced many positive outcomes. For example, more minority students enter the SME&T pipeline and consequently enter lucrative career paths where they have historically been under-represented. These programs have also provided the dollars to assist these young people as well as dollars to assist colleges and universities establish SME&T programs. NSF grants to colleges and universities have provided equipment -- and resulting technological literacy -- for students training to function successfully as scientists, engineers, or teachers. Specially funded projects have developed teacher-training programs, such as "STARS," featuring state-of-the-art hands-on/minds-on pedagogy. In the future, we hope organizations such as NSF will develop more collaboratives to help us meet critical needs.

In recent years, changes in our society have produced changes in the direction and practices of education. We have become more sophisticated. We have adopted the principle of ethnic and gender equity. We expect all students to know more and to perform at higher levels. The growth of technology and its application in the mathematics and science classroom require that new teachers be computer literate and that they be adaptable to new technologies and techniques as they appear. Because we expect students to know more, we expect new teachers to know more and be prepared to learn more throughout their careers. Also, as we implement performance-based instruction, cooperative learning, and "hands-on/minds-on" strategies, teachers must be prepared with an expanded "bag of tricks" so they can deliver a 21st century curriculum.

***Walter G. Amprey** has been Superintendent of Public Instruction of the Baltimore City Public Schools since 1991. From 1973 to 1991, he served in administrative positions in the Baltimore County Public Schools – associate superintendent for staff and community relations, associate superintendent for physical facilities, director of staff relations, and principal and assistant principal. In 1966, Dr, Amprey began his career in education in the Baltimore City Public Schools as a social studies teacher then served from 1971 to 1973 as a school administrator, He holds a doctorate in education from Temple University, a master's degree in educational administration and supervision from Johns Hopkins University and a master's degree in history/social science and a bachelor's degree in history/secondary education from Morgan State University. Dr. Amprey was honored as Maryland Superintendent of the Year, 1994-95, and served as president of the Large City Schools Superintendents of U.S. and Canada, 1995-96. Most recently, Dr. Amprey served with Reverend Jesse Jackson as facilitator of the Rainbow/PUSH Coalition's Public Policy Education Conference, "Closing the Gap," in Chicago, Illinois.*

Testimony to the NSF Undergraduate Review Subcommittee

Eugene Galanter

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Real improvement in science education (SME&T) at the baccalaureate level will require: a) revisions in instructor attitudes and interests; b) attention to multiple cognitive and motivational functions of students; c) revisions in standard modes of instruction; d) new evaluation procedures; e) augmentation of new technology; and finally f) serious longitudinal studies. I will attend mostly to items a - d. The last pair are technical issues that need attention by experts in these fields.

To begin with, instructors (clearly not all) must recognize that students don't think science or math is much fun. They are mainly forced into science by curricular or career path requirements, e.g., chemistry or biology for medicine, psychology for aspects of medicine or social or technical professions, and physics and math by those with self-recognized quantitative or computational skills for technical or scientific program management. Engineering students are self-selected for these skills, and comprise a less intense problem for engineering instructors. However, many of these students at research institutions are more interested in engineering science than real engineering. In my discipline (experimental psychology), students choose our introductory courses to satisfy (effortlessly they hope) a requirement, or to find a less demanding career with the cachet of science. They may then discover that some of the materials are daunting, or that the substantive materials barely speak to their interests.

I attack the question of how to advance science education at the undergraduate level by asking several questions. First: how many students really want to take science in college? The answer is very few. Which sciences do the students take? Our data show that except for pre-meds, they opt for the easiest, the least quantitative, and the most descriptive. The third question: Do these sciences provide opportunities for such students to engage seriously in the technical world: The answer, I am afraid, is maybe not. The fourth question is: What can we do? And that constitutes the heart of my suggestions. These suggestions must be tempered by the enormous revolutionary events that are occurring now in our colleges and universities. My colleague, Eli Noam in the Columbia Business School, has just published an article in *Science* on the demise of the university as the mechanism by which information transfer occurs. His point is that, in the past, the user went to the source. Now the source is distributed to the user. So what does the user need our real estate for? The consequence is that this will engender enormous changes, changes in which instrumentality's that we have never thought of as the educational base of our activities will become the instrumentality's by which information does flow to our consumers, if you will pardon that expression.

Back to our primary topics. Once instructors recognize these default attitudes of students – requirements or jobs – they can often loosen-up the relentless drive to provide technical materials that span a broad spectrum. They must remember that their own initiation required many years of hard work. Part of the difficulty is a failure to notice that our students are taking other courses as well as our own. The demands on their time can create a climate of anticipated failure. I will say more about this phenomenon later.

Students have limited experience. The kinds of experiences they have are not connected to atomic structure, to spiral nebulae, et cetera. They are connected to why can't my grandfather remember things any more? How is it that (I have been told) still images on a television screen look as if they are really people moving around? What is virtual reality? How can athletes do the stuff they do, and so on.

My own field of experimental psychology is useful for discussion because it covers an enormous class of phenomena, and also interlocks with biology, chemistry, and physics through neurosciences and psychophysics on one side, and the personal and social sciences on the other. As such it will serve to illustrate and informally substantiate my views on undergraduate SME&T in the large. To summarize the discussion to follow, I suggest that the paths to continuing progress in SME&T are:

- increasing relevance
- restructuring content
- modularization
- motivational design

In order to make science attractive to students who are not yet career driven, but who may be drawn into a career choice by their college experiences, our offerings must have *relevance.* This much-abused concept refers here to the ability of a course of study to raise and answer questions important to (the limited experience of) students. In the last ten years many curricular efforts have attempted to achieve this relevance, sometimes, unhappily, with a loss of precision. In my first attempt to make psychophysics an integral part of introductory psychology[1]. I opened with the question of how an airliner is guided to a safe landing during weather conditions that defeat direct visual control. Such tasks depend on translating visual codes into skilled action. In recent text materials[2] topics in signal delectability theory center on issues of radiological diagnoses of breast cancer, and failure of memory in recognizing faces. Such questions engage the student with problems they can understand. If science informs the answer, relevance is insured.

Are there enough relevant topics? Again in my own field consider a spectrum of subjects such as memory loss through aging or accident, virtual reality from apparent motion through full-fidelity simulations, individual differences in intelligence and other personal characteristics, cognitive development, social and political consequences of individual attitudes and prejudices, motor skills and athletics, sexual preferences and aversions, human error and its consequences; the list could continue to a score or more.

We are *restructuring* the content of early science education in psychology to motivate interest and to offer rational and more importantly –plausible – ways to understand and solve real problems. I mean to do this by making data collection one of the centers of effort to confront the questions of fact and theory. Students who collect their own data as compared with students who do problems in a book *own* the data in a way that the book never provides. When they are really your reaction times to stimuli of various kinds, then you may say, "hey, can I respond faster to red or green." Having those personal data becomes and intrinsic motivator that is critical to the continuing activities of the student. And so rather than follow some preferred sequence, including prerequisite course work, structure has been changed to show relevance. The tested retention of such

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[1] Eugene Galanter, *Contemporary Psychophysics,* in *New Directions in Psychology,* ed. by T. Newcomb. Holt, Rinehart and Winston, New York, 1962.
[2] Eugene Galanter, *Psych Tech Notes V. 2.1* Adams • Bannister • Cox, 1994.

information in our admittedly minimal current evaluations suggests enhancements suggest enhancements in understanding by a factor of six.

A third advance in my own field, and extendible to other disciplines, is the technique of *modularization.* This refers to the construction of independent sub-parts of a discipline along with its own auxiliary technical materials. Units of study do not need to be timed to coincide with rigid time frames. If we want to talk about memory and about lapses of memory, then, we could have a memory module, and that memory module might last for two lectures or four lectures or six lectures. It might include experiments to see how memory works, how it dissolves and disappears, et cetera.

Our current NSF support has helped us develop a variety of stand-alone quantitative modules on topics in the human sciences from biology to sociology. We have modules of varying duration on human genetics, evolution, psychophysics and decision theory, space and motion perception, and social psychology. We plan to construct additional modules on cognitive mechanisms in perception and action, motor organization, language and thought, theories of memory, virtual reality, human engineering and ergonomics, psychometrics, animal conditioning, learning and cognition, and quantitative sociology.

Each of these units is supported by quantitative material that undergirds the topic. We do not demand prerequisites in, say, calculus, statistics, algebra, or probability theory. Rather, we incorporate the required techniques in the module itself. Any single module is studied for its nominal duration, which currently ranges from 4 to 14 fifty-minute lecture/labs. The ancient bookkeeping of academe proscribes such plans. Our modules currently fill the standard semester time scale, and are given in a “rational" order. The ramifications of these historic constraints are reviewed later.

Table 3.1:

Theory of Intelligence	Goal Orientation	Confidence in Present Ability	Behavior Pattern
Entity Theory (IQ is fixed)	**Performance Goal** gain positive judgments avoid negative judgments	if **High**	**Mastery Oriented** seeks challenge, high persistence
		if **Low**	**Helplessness** avoid challenge, low persistence
Incremental Theory (IQ is malleable)	**Learning Goal** increase competence	**High** or **Low**	**Mastery Oriented** seek challenge, high persistence

From Dweck, C. Motivational processes affecting learning. *American Psychologist,* October 1986.

In psychology the computer has become the required instrument for experimental research and field data tabulation. It is our microscope, centrifuge, accelerator, or telescope. Few institutions provide adequate access to these machines for undergraduate use. In my own department of fifteen tenured faculty, our financially challenged administration has recognized the importance of such investment, and has provided 16 machines for undergraduate labs. These sequestered microcomputers have made "open" labs possible. Only one graduate (or often an advanced undergraduate) supervisor is needed, and the lab is available to students in several courses on an essentially ad lib. basis. There are *ca*. 600 undergraduates per semester in our course offerings, so the ratio is quite small. On the other hand only about 150 students need access to the machines. With increased curricular implementations, we anticipate that this 1:10 ratio will probably increase to 1:25, a figure that is probably close to optimum. As with any computer implementation, we are hampered by software limits. We have developed some experiments for use on our machines, and will be offering these materials on our Internet home page.

Just as lab equipment (in our case microcomputers) is often in short supply, so also are teaching materials. In the modules we are developing, primary sources are the vehicle of choice for students to read. However, for many undergraduates it is often necessary to provide some intellectual resources that may not be part of their apperceptive mass. To this end we need texts that can provide explicatory material to permit students to engage the primary source scientific writings that have cast light on the central issues they study. We are trying to provide such texts in our curriculum development program, but as any teacher will recognize, this task is enormously difficult and time consuming.

The limit imposed by academic bookkeeping prevents us from using new formats and methods creatively. With free standing modules on a variety of topics keyed to questions of obvious and direct importance, we need to allow students to select a group of such modules based on their own interests. If we intelligently metricize the credit value of each module, we can allow students to select from a menu of topics a personalized subset for study during a standard academic time period. Students might be expected to take a variety of admixed modules, any combination of which would be accepted by a registrar for appropriate academic credit. In combination with newly designed evaluation procedures that we are currently exercising, the entire task of selection (i.e., advising), pedagogy, and credentialing could be simplified and packaged to minimize student anxiety and time constraints. These revisions have direct implications for various sorts of distance learning, and other forms of non-institution based education.

The previous reference to evaluation needs expansion. In science education we have commonly used so-called objective test formats to evaluate student comprehension. Critics have charged that "constructive" tests better measure student knowledge. Indeed, this topic is quite current[3], but fails to recognize the cognitive continuum between, say, a true-false test and a constructive essay. We have developed several waypoints on this continuum, and is currently analyzing correlation between double blind scoring of quasi-constructive answers, and items on objective (four-alternative) examinations. Our preliminary findings support the view that the correlations are very high (*ca*. +.85). We score the objective tests by requiring students to eliminate incorrect answers. Originally we gave unit weight to each incorrect answer. Now we have installed our examinations on our Web page, and process the test data by more sophisticated statistics. We will shortly be able to differently weight the incorrect answers as “easier" or "harder," and in this fashion improve the ostensible validity of the score. Of course, all of these improvements are based on plausibility, and wait real longitudinal validation.

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[3] *Construction vs. Choice in Cognitive Measurement,* ed. by R. E. Bennett & W. C. Ward. LEA, Hillsdale, NJ, 1993.

Finally, the fourth topic – *motivation* – stands at the center of our efforts to bring science to those who are traditionally absent from the feast. Of the 186,013 baccalaureate degrees in science and engineering awarded in 1989, 9325 were awarded to blacks[4] (the data are similar in structure for Hispanics and Native Americans). Roughly 5 percent of the students are drawn from 13 percent of the population. We characterize this as a motivational deficit, not an intellectual one[5].

To attack this problem we must recognize the distinction between learning and performance. What we mean by the goals of learning are to increase confidence to act. What we mean by performance goals are to seek positive personal judgments. That is, performance means you have gotten such a good score on the test, or you have gotten such a bad score on the test. Either of those two can lead to problems down the road. When we can make clear that failure to learn is a natural part of learning, and if we ensure that the goals of learning are learning goals, then we may observe mastery after failure. There are now more than 50 studies that demonstrate that this is the case. We also believe that an entity theory of intellect can be replaced by an incremental theory, one where IQ is malleable. The format of our modules tries to accommodate these principles.

We know that failure in performance goals leads to hopelessness and rejection of the intellectual content. We must examine how we frame our material so students understand that it is not their performance that counts, but rather their ability to grasp the issues and solve the problem. And if they can't solve the problem, then that failure is intrinsic to actively searching for more information.

Let me conclude with some tangential remarks about how we might fix some parts of SME&T; in particular how some aspects of these revisions would work. Change would occur because students would do things. The teacher would say as little as possible. That is hard to implement. After all, because of my competence in language and delivery, I can amuse you, and it rewards me to see you smile, applaud, and so on. Teachers are mostly like that everywhere. However, the rewards to the teacher are mostly irrelevant to the student. What the student wants to know is how to do something, not to be told about something. In science, doing is everything. Ideas are cheap. It is work that is costly. We have concentrated too much on the transmission of ideas, and not enough on the transmission of effort, activity, and the way to do it.

Unless we are proactive in respect of the changes that have to occur, we are going to be left in the dust. But there are things we have to know, e.g., whether any of these revisions have consequence. I can talk about students being happier, students getting better grades, students inviting others to join the course, et cetera. But if we don't know how many students go to the right jobs or whatever, then all of this is just talk.

We need to plan major longitudinal studies to assess the consequences of science education. We must answer the hard questions: Do the things we are trying to do now have real consequences? To find such answers will require a coherent and well-organized research enterprise to see what happens 5, 10, and 15 years after these changes go into effect. In order to do this I think we must mount a federal enterprise with continuity in design and support. Management has to be administratively structured in such a way that students can be tracked into graduate school, the market place, and their later lives. Do we change from 3 percent entering technical work to 7 percent because of the changes we make now or not?

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[4] Adapted from *National Science Board, Science and Engineering Indicators*, Tenth Ed., 1991.
[5] Carol Dweck, Motivational processes affecting learning. *American Psychologist*. October 1986.

Finally what about our input? What is K-12 science education today? We know that an enormous problem is the turnoff that has occurred in the middle and senior high schools in science. Now, attempts to rectify that by talking about imitation science – I don't mean that in any disparaging way – but things like nature studies and fanciful ecology are not going to increase our entry quality, because the first time these kids take a college course that is serious about these issues, they are going to have to look at population densities and distribution functions of animals, and genetic structures, and they will say, "hey, where is the ecology." And we must answer it is in there somewhere, but we have to work to get to it. K-12 education, as you know, is run in a political environment that is essentially inviolate when it comes to attempts by people in collegiate education to impose anything. We have to suck them into it. We can't push it down. They will simply walk away. They may not have exactly the training that is needed to accommodate the materials we suggest they provide. In which case they are going to be very tough about saying, "well, I think the stuff I am teaching is much more important than what you are doing, and my kids love it, and they are doing very well, thank you, and furthermore 70 percent of the class got A's." To reach the common schools will be a much harder job than getting our own act together.

Professor Galanter received his Ph.D. from the University of Pennsylvania in 1953, and advanced from Instructor to Professor from 1952 to 1959. He was appointed a Research Fellow at Harvard from 1955 to 1957. He was a Fellow at the Center for Advanced Study in the Behavioral Sciences *in 1958-59. His work with George A. Miller and Karl Pribram on a new cognitive psychology was published in 1960 as* Plans and the Structure of Behavior. *Following his return from the* Center*, he began a collaboration that resulted in the three-volume* Handbook of Mathematical Psychology*, published during 1963-65. He completed his* Textbook of Elementary Psychology *in 1966. In addition to these books, and his three popular books in the* Kids and Computers *series published in 1982-84, he has contributed more than 100 reports, journal articles, and book chapters in the fields of psychophysics, mathematical psychology, aviation psychology, and utility measurement. Professor Galanter was made Chair of the Department of Psychology at the University of Washington in 1962. In 1966 he went to Columbia University as Joseph Klingenstein Professor of Social Psychology and Race Relations. He was named Professor of Psychology and Director of the Psychophysics Laboratory in Columbia University in 1967.*

Testimony Delivered to the National Science Foundation Review of Undergraduate Education Hearings on Employers Views on Desired Capabilities of Undergraduate Students Entering The Work Force

Peggy Ruth Cole

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Before coming to the New York Hall of Science 11 years ago, I was principal of an independent school in New York City, and before that a graduate faculty member of Bank Street College of Education, a teacher training institution also in New York City. I have 15 years of classroom teaching experience at both the elementary and secondary levels.

While I will limit my examples to issues related to our particular science center, I am also speaking on behalf of the 300 science-technology centers around the country serving over 76 million annual visitors including children, families, school groups, and teachers. Informal science institutions offer training to 150,000 teachers annually. All these institutions have an informal approach to science, mathematics, and technology in common. Unlike schools, they are discretionary environments where visitors chose to come and select their experiences based on interest, attraction, and a variety of other factors. To quote the late Frank Oppenheimer, founder of the Exploratorium in San Francisco, "Nobody flunks a museum."

Science centers have the potential to improve the undergraduate preparation of new teachers. We have an externally evaluated program in operation for 9 years, which is a model for other science centers. Our Science Teacher Career Ladder, a program within our Science Career Ladder, serving mostly women and minority youth, involves cooperation among the science center, colleges and universities and schools. Together, we provide a support and training package which colleges and universities cannot supply alone.

The program design is effective. A survey of almost 25 percent of our Career Ladder alumni showed that 34 percent of them are now teaching. And our record of attracting women and minorities to teaching is high. Of our Science Career Ladder alumni now teaching, 21 percent are African-American compared with a national average of 5 percent of current teachers; 14 percent are Asian compared with a national average of 1 percent; and 13 percent are Hispanic compared with a national average of 3 percent.

How does the program work? We employ 40 high school and 60 college youth annually as our floor staff. They work part time in a science- and technology-rich environment, and receive both pay and school credit for the experience.

Their job is to explain science to a broad public, from pre-schoolers through senior citizens. The stimuli for both Explainers and visitors are l70 hands-on interactive exhibits, ten on-floor demonstrations, and science activities delivered through workshops and special events. Our youth staff learn science and they learn how to teach science in an environment free from grades and exams, but rich with science phenomena. As a result, many discover both an interest in science and pleasure in sharing it with others. Consequently, the majority decides to become teachers.

These students have, on the whole, come through a school system that teaches science through the traditional avenues of textbooks, lecture/demonstrations, and structured laboratory experiences with a reward system centered on high grades. Most never see the real-world application of science and math and they rarely get to meet and interact with people who work in these fields while they are still in decision making positions that will effect their entire futures. The result, as we all know, is an early turnoff to math and science by the very population of women and minorities that will, by the year 2000, be the majority entering the workforce.

The Science Career Ladder is almost 10 years old. It has been a model for 12 other science centers around the country that have adapted aspects of the program. In the past decade we have worked with 20 colleges and universities and 14 local high schools. Almost without exception, we have been able to develop meaningful partnerships with Cooperative Education Departments who do not offer content course credit. In some cases we have developed relationships with Schools of Education but rarely with departments of academic science: physics, biology, chemistry, etc. The culture of undergraduate institutions is curriculum driven, departmentally structured, grade oriented – formal. The culture of science centers is content driven, discretionary, intergenerational, exploratory, visitor driven – informal. We are working hard to bridge this gap and to help colleges see our program as relevant and meaningful to their enterprise, but the academic structure that informs course development and credit makes it very hard.

As employers of youth, in a rapidly expanding industry, with a significant shortage of well-trained minority youth, we have learned to "grow our own." We identify women and minority youth who traditionally are not represented in science and technology fields, and offer them science-related employment to both serve our public and to prepare them for the workforce. And we are succeeding. In addition to producing science teachers, the 1994 survey showed that 9 percent are working in museums, and 15 percent are working in science and technology fields. The majority of our Career Ladder alumni are African American, Latino, or Asian, and the minority of white students includes recently immigrated ethnic groups. They are poor, often first generation college students.

What are the workplace literacy skills we are developing in our youth staff? Because these positions are authentic, paid, and essential to the functioning of the museum, our demands are those of any other employer. We expect punctuality, responsibility, appropriate dress and professional demeanor, teamwork, the ability to meet performance standards, and above all, knowledge of science. We pay for training and we expect students to learn the science needed to work with the public.

The science content we teach is directly related to our permanent, temporary and traveling exhibitions, and school and public programs. Interpreting our 170 permanent exhibitions demands a knowledge of anatomy, psychology of perception, optics, wave theory, resonance, atomic structures, physics of light and color, feedback systems, quantum physics, audio-technology, microbiology and chemistry. Delivering programs and interpreting traveling and temporary exhibits involves knowledge of astronomy, information technology, navigation, earth science, manufacturing technology, architecture, and the biology of AIDS. We also expect our youth staff to use instruments from scanning electronic microscopes to a functioning steam engine. Students tell us the skills they need to work at the New York Hall of Science test and exercise what they learn in the university in new and more interesting ways.

Career Ladder participants learn questioning techniques, how to adapt demonstrations for kindergartners and high school seniors, how to present the same content in different ways to meet different learning styles, how to use manipulatives to illustrate principles, how to attract and keep attention, and how to control large groups. Our Preschool Science Place is a laboratory for learning about early childhood development and how to work with very young children and their caretakers. Unlike traditional undergraduate pre-service students who get one or two student teaching placements, our Science Career Ladder participants interact with students at every grade level from preschool through graduate school, students with disabilities and learning problems, students who are intellectually gifted, and everyone in between. Many Career Ladder participants discover an affinity with a particular grade level or learning style as a result of their experiences at the Hall of Science. Our Career Ladder students get to observe teachers handling groups on class trips and they form ideas about teachers and teaching from a perspective unavailable in any other setting.

Some schools of Education offer field credit for the experience, one or two offer student teaching credit. Our experienced pre-service Career Ladder students work in our teacher training programs, interacting with classroom teachers as museum staff. But most importantly, our students are rewarded for exploration, discovery inquiry, experimentation, flexibility; the very attributes essential for good science teaching and learning and, unhappily rarely modeled in high schools and colleges.

In sum, the Science Career Ladder and similar programs around the country, are providing students with workplace skills and science, technology and math know-how within informal settings that supplement and enhance undergraduate education. The evidence is rapidly accumulating and it indicates that work experiences explaining science in an informal setting have a positive impact on career choice, science knowledge, and a sense of self-confidence and self esteem.

The major obstacle science centers face is neither designing nor implementing successful work-study programs for undergraduates. It is, rather, convincing the formal education community that experiences provided by science centers are legitimate and valuable ways to provide young people with skills, motivation, and know-how in science, mathematics and technology. At the moment, science center staff are included in reform efforts as advisors, committee members, and representatives of community-based organizations. But they are not taken seriously as an integral part of undergraduate teacher preparation despite the advantages I have just described.

These hearing are designed to help you assess what further needs and opportunities we see in undergraduate education reform. I would strongly recommend a National Science Foundation program that provides major funding for a few model programs which, like our Science Career Ladder, offer undergraduates carefully constructed, content rich experiences in informal science centers. If requirements for successful proposals included: 1) academic credit in the disciplines for participants; 2) college level administrative commitment to such programs; and 3) a planning team of college and science center staff; we could show the formal education community ways they might work with the informal science community to reach our mutual goals, which are the preparation and employment of a scientifically literate, and science- and technology-oriented workforce.

***Peggy Ruth Cole** is a senior staff member at the New York Hall of Science responsible for the planning and implementation of new programs and for the development department and its fundraising activities. She is the founder of the Science Career Ladder, the signature, minority access education program of the New York Hall of Science which is replicated nationally. Before joining the Hall, Dr. Cole was special project coordinator at the Chrysler Museum in NorfoL4 , Virginia and the conceptual advisor to the Staten Island Children's Museum's exhibition, " Once Upon An Island." She was Principal of the Fieldston Lower School in New York City from 1981-1983. Prior to this, for 12 years, Dr. Cole was a graduate faculty member of the Bank Street College of Education in New York City. She serves on the editorial board of* Curator*, the journal of the American Museum of Natural History. Dr. Cole is nationally active as a reviewer, author, and speaker in the field.*

Math, Science, and Technology Undergraduate Education in America: One Small Business Perspective

Israel Joseph Galvan

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Introduction

These are the personal views of one small business owner deeply involved in current and emerging technologies. However, I wish to emphasize that I claim no special expertise on education.

My name is Israel Joseph Galvan and I am President of GHG Corporation, a computer systems engineering company based in Houston, Texas. We have been in business since 1979 and employ about 200 people.

Criticism of the American educational system comes from a variety of directions. It has increased in volume and intensity and, worse, it has become a permanent issue in every political campaign. Whether the fundamental role and purpose of a university education is in need of a serious national debate is problematical. However, there appears to be some confusion and lack of a unifying principle in our educational system—a lack of clarity.

Arguably, the last serious debate on the role of the university occurred in the 1930's between the camps of Robert Maynard Hutchins, the traditionalist, and John Dewey, the progressive. These two giants proposed ideas that were fundamentally different, but their views were clear and unambiguous. Hutchins believed that the university should be a community of scholars, a place to train the intellect and to transmit a Great Tradition of culture. Dewey saw education as an experience and a process for coming to grips with and solving real world problems, a bridge between school and society. Hutchins opposed professional schools; Dewey embraced them. It is safe to say that a hybrid of Dewey's ideas won.

As it should be in any democracy, the debate on the nature and function of higher education continues, but the current issues are not as fundamental. The debate is less on the role and more on quality, efficiency, and economics. It is centered principally on delivery and implementation issues. The core of contemporary criticisms, I believe, validates our present educational system. Our educational system is sound. It is only in need of minor adjustments. Yet there are some aspects of our educational system that do require further clarification.

What is the role of our educational system in training our work force, as opposed to educating our work force? What is the role of our community college system? What is the relationship between our university system and our community college system?

These questions are beyond my simple musings. Contrasted to the complex problems visited on our educational system, I fear that this modest presentation may be too narrow and parochial. My intent is to simply share the personal observations and views of a small "high-tech" firm.

The Environment

The world is undergoing a transformation not seen since the Industrial Revolution, but at an increasingly faster rate. The time from idea to development to implementation has virtually disappeared. The forces driving this change began in the early 1960’s and were not anticipated. Our finest research institutions and our finest minds thought that the 1960’s were going to be the decade of nuclear energy. It was going to satisfy our every need for energy. Energy was going to be so cheap it would not have to be metered.

They were wrong, of course; it turned out to be the decade of the computer, with IBM as its corporate manifestation. For most of the next two decades, IBM became the corporate model for the world, emulated for its technical and business innovation. Little did we know that the heart of IBM's computer, the Central Processing Unit (CPU), consisting of a dozen circuit boards, would be replaced by another CPU the size of a dime. Driven by this new CPU, which is embedded in every facet of our lives, including our psyche, our world and our perceptions of that world changed, and continue to change before our very eyes. It has created, and is continuing to create, new industries. It has changed, and continues to change, existing industries. It has transformed, and is continuing to transform, every sector of our economy. It has eliminated, and is eliminating, jobs; created, and is creating, new jobs; and is contributing significantly to our country's anxieties and sense of uncertainty. Indeed, even IBM feels threatened. It is threatening the classic American corporate model and creating new ones. It has empowered the technician and the small business.

Much has been written and said about the economic importance and significance of the small business community. Small businesses:

- provided virtually all of the net new jobs from 1987 to 1992;
- were 99.7 percent of all employers in 1992;
- employed 53 percent of the private work force in 1992; and
- are the source of considerable innovation.

So says the U.S. Small Business Administration. And yet most of our national educational and economic policies do not reflect the uniqueness, diversity, and role of small business in the current transformation.

These are fast changing times; these are exciting times; and these are perilous times. However, there appears to be one universal constant: "Knowledge is Power.” For the present, this verity could possibly be restated "Mathematical, Scientific, and Technical Knowledge are Power.” And it is the role of our educational system and this board to insure that all Americans are armed with this knowledge. Of course, nothing much is at stake, except the economic well being of this country.

Small businesses, especially "high-tech" ones, live, operate, succeed, and fail in this environment. Most small businesses share common problems and concerns, but "high-tech" small businesses, I believe, have a number of unique concerns and problems intimately tied to undergraduate science, mathematics, and engineering education. Generally, the small business community has very little direct contact with the university community, except as a source of talent. In the university research and development world, cooperative agreements and sponsored research is the exclusive domain of the large corporation. The overhead cost of a typical university is daunting to any small business wishing to fund a research project.

The Real World

Recently, a colleague said that the three most important concerns of his business were: capital, capital, and capital. Hyperbole not withstanding, capital is always a problem, but equally important is good management and good people. This, of course, is true for any business, small or large. We both face a rapid and sustained force of technological change, and a diminishing life expectancy and relevancy of particular skills. It is challenging our abilities to maintain our skill base tuned to this change.

Unlike the large, well financed corporation, the small "high-tech" business has minimal redundancy in its skill base and less resources to keep that skill base continuously trained. The loss of a key employee can be devastating. Thus the recruitment, retention, and continuing training of a quality work force, while always important, has become critical. In this highly competitive market place, we can not afford to lose employees, lose our sense of unity, or disrupt the "team." We can not afford to treat employees as expendable commodities. We have to nurture them, train them, in short, value them. This is not without a significant financial burden and increasing pressure to make tough management decisions. Yet, we must remain competitive. We are still subject to all of the forces of a competitive market place: being raided by highly skilled professional recruitment agencies, market demands for increasingly narrow job descriptions, competitive compensation packages, and the bottom line.

For example, it is not unusual for us to have to pull a highly skilled computer scientist from a revenue generating project in order to send him or her to an expensive short course on some very specific emerging and proprietary technology. An alternative is to establish an internal training program with our own courses and instructors, and we have. But this is very expensive. Another option is to lay off employees when their substantial skills are not considered adequate for more narrowly defined skills. To retain a competitive posture, we are forced to make decisions at odds with our sense of fairness, our sense of community with our employees, and the long-term health of the firm. However, survival is basic and immediate. Though necessary, it is no longer sufficient to have a solid education in a particular technical discipline., thus demonstrating a compelling need for the development, implementation, and delivery of continuing education programs that keep pace with the changing technical environment.

This fact is equally true in non-degree technical fields. For example, the transition from mainframes to distributed workstations is abolishing the need for the traditional computer operator and other affiliated paraprofessionals. This same transition is creating new jobs such as local area network (LAN) administrators, managers, and other related jobs. However, instead of training the current work force, businesses are replacing them.

We expect recent college graduates to arrive at the work place fully armed and ready to contribute to the bottom line. Perhaps our expectations are misplaced. Perhaps it is the role of the business community to provide the necessary training. Additionally, it appears that recent college graduates generally lack practical, immediate skills; skills demanded by current market forces; skills such as being able to work in teams, being familiar with current technologies, and a fundamental understanding of systems engineering are glaring examples. Unfamiliarity with working in teams and with current technologies and systems thinking may be a manifestation of dated curriculums. The currency of detailed technical skills is important, but graduates also lack fundamental skills. Skills with the written and spoken language are deteriorating. In fact, it has become a cliché that scientists and engineers can not write. This paper is probably a good example.

In summary, the most glaring deficiencies in Math, Science, and Technology Undergraduate Education that I have observed are:

- Lack of team skills in recent recruits;
- Lack of communication skills, both oral and written;
- Lack of a dynamic and current curriculum and continuing education program; and
- Inability of small businesses to access the applied research and development capabilities of our educational system.

Modest Recommendations

The National Science Foundation should promote greater participation between the Small Business community and our educational institutions. More specifically, the Foundation should:

- Encourage the development of curricula allowing undergraduates to work on more relevant projects; projects that require multiple disciplines and an integrated team effort. This will allow them to experience a project through its entire life cycle. This will encourage teamwork, systems thinking, and significant practice in the development of their oral and writing skills.
- Encourage the continuous improvement and relevancy of the curricula.
- Encourage the development of a better, more relevant, and more accessible continuing education program. This program should be made available to non-degree technical people, post graduates, and even post doctoral students. Considerations should be given for small businesses to consult in the development of such a continuing program. In addition, small businesses should be considered in its implementation and delivery.
- Encourage an active partnership between small business and our university system. Undergraduates should be encouraged and allowed to work on small business sponsored projects and receive credit.
- Encourage and sponsor more relevant and applied research projects at the undergraduate and masters level. The small business community should be allowed and encouraged to participate, share cost, and benefit from the research.
- Encourage the small business community to sponsor application research without the burden of the educational institution's overhead. Perhaps, the Foundation could make overhead moneys available to the university community if they could match it with appropriate direct cost moneys.

- Finally, the Foundation should encourage the small business community to work more closely with the Community College System in the development of curricula more efficacious to small business and to the paraprofessional.

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Employers Views on Desired Capabilities of Undergraduates Entering the Workforce

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Introduction

We applaud NSF for having these hearings and for focusing on undergraduate science, math, engineering, and technology (SME&T) education. Significant change in how we educate in these critical areas is required, and NSF is uniquely positioned to take the leadership in encouraging this change. NSF is the Federal agency looked to by the Academy as having the general health of higher education as its focus, without the encumbrance of specific, narrowly defined missions, such as the Departments of Defense, Health, or Commerce.

The organization for this presentation is:

1. The Environment and Why it Requires Change in Undergraduate SME&T Education
2. The Characteristics Required of Graduates to Succeed in This Environment
3. The Kind of Undergraduate Education for There to be Such Graduates
4. Specific Programs to Move Towards These Kinds of Undergraduate Experiences
5. The Environment and Why it Requires Change in Undergraduate SME&T Education

The Environment and Why it Requires Change in Undergraduate SME&T Education

Our society is radically different from the one in which the current educational system developed. Changes in our world have had a major impact on our sense of what students need to learn and how the learning should be delivered to them. Increasingly, we are recognizing that mastering a body of knowledge is simply not enough. Students must acquire lifetime skills, such as critical thinking, quantitative reasoning, effective communications, along with such abilities as finding needed information and interacting well with others. We want graduates who have the capacity to learn not who know everything.

Some institutions are rethinking and redesigning their curricula to reflect the shift from teaching content to enabling students to develop life-long learning skills. Some faculty understands the implications of the information explosion and has re-engineered their courses accordingly.

An important, and not so subtle, change has been a shift from life-long job security to a more realistic hope for career security. This shift is not greatly appreciated because it places responsibility on employees to manage their careers; and to continue learning in order to avoid technological obsolescence.

Today's worker has to learn to survive and thrive in a world that is globally interdependent. Workers must be able to operate and communicate cross-functionally, cross-culturally and across geography.

Teamwork, group problem solving and collaboration characterize today's high-performance workplace. Learning in industry shifts from the classroom to peers and teams. Knowledge creation shifts from the individual to the organization where problem solving and decision-making skills are important components.

Characteristics Required of Graduates to Succeed in this Environment

This environment requires that all graduates have skills for continued learning. Workers must assume responsibility for managing their careers, for continuous upgrading of their skills and acquisition of new skills in order to be prepared for emerging opportunities. Managing one's career in this way is the way to guarantee career security--to position oneself to have a career for as long as one wants to work. The onus is on the individual.

To prepare students to be productively employed for life in science, math, engineering and technology, the undergraduate experience must consist of a solid foundation in mathematics and science fundamentals.

They must have an understanding of the modern, rapidly changing, high-performance workplace and knowledge of what is required to succeed and thrive in such a workplace.

They must have the flexibility to expect and embrace change throughout their careers, skills for and the commitment to working in teams, cutting across vastly different areas of expertise whether it is development, manufacturing, marketing, or whether it is with other people from around the globe.

Workers must have an appreciation for the global interdependence of our communities and have the ability to work across geographies. In particular, students planning for careers in science, math, engineering, and technology must be prepared to understand the business and social implications of the activities in which they will be engaged.

The Kind of Undergraduate Education for There to be Such Graduates

To prepare graduates, who have the above skills, schools must drastically change the undergraduate educational enterprise, especially in SME&T education.

An expectation of all undergraduates in the next millennium must be basic science and technology literacy, regardless of area of concentration. Information technology will increasingly impact our lives as citizens, voters, politicians, and parents. Without an understanding of issues arising from science and technology, it will be difficult to be a fully functioning member of a democracy dominated by technology and public understanding of science and technology will remain very low.

K-12 teachers must have better preparation in SME&T. K-12 teachers who are science, math, technology-illiterate, will not be able to encourage students to consider careers where SME&T skills are needed.

A much higher percentage of our populace must understand science, math, engineering, and technology to be successful in the workplace, and hence, to lead financially secure lives. For this reason, ways must be found to make SME&T education interesting and attractive for a much broader cross-section of our populace.

To make education interesting and attractive requires a shift to student-centered learning environments in which the faculty are guides, in contrast to the current, largely mass production, teacher-centered ones, in which the faculty are lecturers imparting information. Someone said it requires a shift from the sage on stage to the guide at your side.

It requires faculty who are knowledgeable of careers outside the academic world so that they can make their courses more relevant and advise students of career opportunities using SME&T knowledge in jobs that are not closely aligned with the narrow interests of most faculty.

Acquisition and application of a better understanding of the learning process and of different learning styles is required, especially those which may be the prevalent styles of segments of our society which have not traditionally been attracted into mathematical, scientific, and technological careers. We know a lot about how people learn, but too few faculty, especially in science and engineering, are using the results of research on learning in their courses. The knowledge is there, but our faculty does not use that knowledge.

Individualizing education will lead to much heavier reliance on current and shortly forthcoming technology, enabling learning experiences to be delivered on the learner's demand across space and time (just-in-time, anytime, any place learning). Faculty must become proficient at using the technology for education. They must have both the willingness and commitment to use technology and also the support and time from the university for professional development.

Undergraduate education programs must find and apply ways to impart basic written, visual and oral communication skills and skills in working in teams. In addition, students aiming for science, math, engineering careers need to learn about business and societal issues to be able to understand implications of decisions they make.

At a Hewlett-Packard sponsored conference in October, 1995, attended by 18 faculty involved in SME&T education, the topic of appropriate characteristics of institutions of higher learning in the year 2000 was discussed and debated. The conclusion of this group was that the college or university of five years from now must be learner-centered and include the following:

- Anytime, anyplace access
- Collaborative learning and problem solving
- Support for life-long learning
- Significantly improved learning outcomes
- Equity, access and success across all populations; and
- Economic viability and globally competitiveness

They also concluded that this requires a very different kind of academic environment: one, which has agile and change-oriented institutions. One which applies and integrates appropriate technologies, exhibits cooperation and resource-sharing among government, industrial, and other educational institutions, disseminates and applies best practices from elsewhere, effectively evaluates the results of its activities, and has a faculty reward structure which encourages these activities.

We absolutely agree with these conclusions.

Specific Programs to Move us Towards These Kinds of Undergraduate Programs

The discussion above indicates where the focus of Federal programs should be, and they should be designed to move as quickly as possible to the academic environment outlined above.

To reinvent institutions to be more agile and change oriented, those individuals within the institution who are change agents should be supported and rewarded. For example, a program of summer grants and awards to faculty for significant curricular development, application of best practices into their behavior, etc., could be developed.

To encourage use of technologies, infrastructure for learner-centered anytime, anyplace activities could be mounted. Faculty at the HP October 1995, workshop recommended leveraging funding by requiring matching funds from the institution. Faculty saw this as a way to get institutional commitment and begin to institutionalize successful programs. NSF might also require institutions to state how they intend to sustain funded programs through operating expenses or endowments for technology upgrades and enhancements.

To enhance collaboration, NSF might fund faculty time to work with industry to transfer insights from the corporate world to the academy. Much of the breakthrough research today is coming out of industry, and faculty would benefit from the experience. Similarly, encourage faculty to work with K - 12 teachers with, for example, summer funding to increase the number of high school graduates ready to pursue the undergraduate experience.

Faculty who attended the HP workshop ranked new models of collaboration -- among institutions, commercial-industrial collaboration, as well as collaboration with government – among their highest priorities. They also felt it was important to launch some grand experiments; especially grand experiments with multi-campus involvement. To disseminate best practices, NSF could fund centers for accumulating and distributing best practices much in the model of the Synthesis coalitions' NEEDS project, which is funded by NSF.

To develop and apply evaluation methods, NSF could fund research into evaluation of program design to enhance learning, especially learning in populations previously under-represented in SME&T programs.

To encourage modified faculty reward structures, NSF might consider awarding summer grants to faculty and administrators to create alternative ways to recognize faculty involved in educational innovation. Finally, on this point, NSF has special leverage with its research programs and could require descriptions from institutions as to the steps the institutions are taking to modify their faculty reward structure as a condition of (or at least as a significant factor in) the award of a research grant.

Conclusion

Thank you for the opportunity to appear today. Our environment mandates changes in SME&T education if we are to produce graduates who can succeed in today's rapidly changing information society. We applaud your interests and believe your focus can have a unique and positive influence on American higher education.

Alfred L. Moyé *became Hewlett-Packard's Director of University Affairs in May 1996. He leads HP's worldwide interaction with key universities, including the company's ongoing programs in such areas as research, recruiting, marketing, training grants and public advocacy. In addition, because of the crucial role of universities in developing skills and technologies needed to improve national competitiveness, Dr. Moyé leads the formulation and communication of HP's views on U.S. policies for technology and higher education. He was previously Manager of Engineering Education Performance Technology at Hewlett-Packard. Prior to joining HP in April 1984, Dr. Moyé was national educational sales manager and director of the Atari Institute for Education Research He was also vice president for academic affairs at Roosevelt University, Chicago, and vice chancellor for student affairs and associate professor of chemistry at the University of Pittsburgh. During the Carter Administration he served as deputy assistant secretary for higher and continuing education He has published an organic chemistry laboratory text and has authored several articles in chemistry and chemical education journals. He is an officer of the Board of Trustees of West Virginia Wesleyan College and the National Technological University, and a member of the Board of Visitors, Faculty of Arts and Sciences, University of Pittsburgh. He was recently elected to the Board of Trustees of the University of Pittsburgh. Dr. Moyé received his B.S. degree from West Virginia Wesleyan College and his Ph.D. from the University of Pittsburgh, both in chemistry. He is also recipient of five honorary doctorates.*

From January 1990 until his retirement in 1996, ***Robert W. Ritchie*** *served as the first Director of University Affairs at Hewlett-Packard Company. He led HP's worldwide interaction with higher education, including the company's on-going programs in such areas as research, recruiting, marketing, training, grants and public advocacy. Prior to becoming Director or University Affairs, Dr. Ritchie was Director of the Computer Systems Center in HP Laboratories from 1988 through 1989. From Science Laboratory of Xerox Corporation's Palo Alto Research Center. From 1962 to 1983, he was on the faculty of the University of Washington, first in mathematics and, subsequently, computer science. He formed the Department of Computer Science there in 1966, was its first chair, and then chaired the department again from 1977 to 1983, helping it achieve its current rating among the top ten in the country. While at the university, Dr. Ritchie also served as Associate Graduate Dean and Vice Provost of the University. From 1960 until joining the faculty at the University of Washington, he was John Wesley Young Research Instructor in Mathematics at Dartmouth College. He has served as the chair of the Committee on New Areas in Applied Mathematics of the Conference Board of Mathematical Sciences, chair of the Computing Research Board, and co-chair of NSF Workshop on Quality in Engineering Education.*

Enhancing Engineering and Manufacturing Education: Industry Needs, Industry Roles [6]

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The problem of how to provide quality-engineering education (as contrasted with training) in our universities, and the appropriate role of industry in this endeavor, has been a topic of controversy and debate for decades. Ever since the proliferation of research-oriented universities began in the early 1960s, a widening gulf has been developing between our colleges of engineering and the industries they support. It has become increasingly clear to those of us with an interest in industry-university interactions and recruiting that the curricula in most of the major universities in this country are now badly out of balance, with a too heavy emphasis on engineering science (analysis) and competition at the expense of design (creative synthesis), manufacturing and cooperative learning (teamwork). Despite an increasing number of recent refreshing signs of change, the current under-emphasis on the quality of undergraduate education is further cause for major concern with respect to the impact this may have on the overall competitiveness of our future industrial technical workforce. Of particular concern is the inadequate exposure to manufacturing issues given to most undergraduate engineering students. Design (engineering) and manufacturing are inextricably bound together in modern industrial practice, and this fact generally is not reflected in current engineering education programs in the majority of our research oriented universities. This situation poses a significant long-range problem for industry in this country unless sustained, cooperative actions are taken to restructure and rationalize the present system. Furthermore, industry needs a greatly increased level of continuing education and training, much of which could be provided by developing strong and continuous linkages with our universities and community colleges.

> *"Poor ... education wastes human potential If schools are sound...[students] will graduate with the knowledge, skills and motivation to help further build our nation, and with the foundation needed to help them enjoy full and productive lives.*
>
> *Frank Shrontz*
> *CEO, The Boeing Company*

[6] Presented at the 1995 American Society for Engineering Education Annual Conference and Exposition, Anaheim, CA June 25-28, 1995

"A scientist discovers that which exists. An engineer creates that which never was."
Theodore von Kármán

"In time, the ... public and possibly even the 'educated class' will come to appreciate that engineering is no more applied (and therefore second rate) science, than science is theoretical engineering."
C. R. Chaplin[1]

"The mind is not a receptacle; information is not education. Education is what remains after the information that has been taught has been forgotten. "
Robert M. Hutchins[2]
(after Benjamin Franklin)

The Current Situation

The state of education in this country, especially in science, engineering and technology, has become a matter of increasing concern to many of us. The recent National Research Council working paper (*Major Issues in Engineering Education*) of the Board on Engineering Education, as only one recent example, identifies many of the major issues that need to be addressed. While the problems we perceive encompass the whole system from pre-elementary through post-graduate education and training, the focus of the present paper is on needed changes in university undergraduate education programs. Our paper is sometimes strongly worded, but we believe that the assertions made can be adequately documented and defended. Extended discussions with a large number of our colleagues in industry, academia (including many students) and government show that while there are significant exceptions to what we have written, and continued denial that anything very basic is wrong with our current system of higher education, there is now an increasing degree of admission that the following observations have validity.

- Too many of the faculty and administrators in our colleges of engineering remain complacent. The primary message from academia continues to be: Give us more money and we will do more (of the same) good things.
    - Improvements in curriculum, etc. are always needed, but nothing basic is broken in the educational system we now have. Witness the number of foreign students in our graduate programs as only one measure of the success of the system.
    - Research money continues to come (from largely government sources) to those willing to work hard enough to get it, which is good because so many departments are now so heavily dependent on it. The fact that too much of this research is of very limited value to our industry seems to be irrelevant.
- From an aerospace industry vantage, as potential employers of the universities' graduates, we see vast opportunities for improvement. We are increasingly "dissatisfied customers."
    - New hires must serve excessively long apprenticeships (three-to-five years) before they become fully productive (i.e., we must fill significant gaps in their education's as well as provide job-specific training).

- We see too many new graduates with an inadequate grasp of what engineering (as contrasted with engineering science) is and how one practices it, particularly in the currently evolving industry environment. Too few of our engineering graduates seem to have any idea of how to work in teams or how to manufacture anything. Fewer still seem to understand the process of large-scale, complex system integration, which characterizes so much of what we do in our industry.

- Based on limited data available to us, academic success (as measured by test scores and grade point averages) shows little discernible correlation with subsequent performance on-the-job (as measured by salary growth and perceived value of an employee to a company). Those students who are judged the "best and brightest" on the basis of grade point average are Frequently those who have worked hardest in a highly competitive academic environment of separate, specialized courses, and are often least prepared to work cooperatively in teams to engineer an integrated complex system which is economically and operationally viable.

- Industry continues to be limited, and sometimes-underutilized partner in the engineering education process. Merely throwing money into the system is inadequate.

    - Industry recognizes its vested interest in education, but is largely preoccupied with staying in business while producing a proper return on the investment of its shareholders. Improving the national educational system is not in most corporate charters.

    - The modern international marketplace is highly competitive and volatile (particularly in the aerospace industry). Historically, industry has tended to be shortsighted in its planning, while longer-range forecasts have generally proved unreliable. The unknown consequences of the present era of world political and economic uncertainty only exacerbates the difficulty of making sustained, long-term commitments to "lower priority" supporting activities such as generic research and pre-employment education. At best, industry has too often been viewed as a "fair weather friend" by much of academe.

    - Discussing appropriate engineering education programs is made very difficult when a higher-level manager from a given company (with a background in one discipline, as practiced when he was an engineer years earlier) tells a dean of engineering one version of "what industry needs" while a working lead engineer from another discipline tells a department chairman quite another story. In the end, both stories get lost or the one closest to what the listener wants to hear gets heard. *Industry really would do all involved a great favor by developing and delivering a more coherent position to academia on this issue--even if the message is complicated or a mere statement of principles.* [A listing of the "Desired Attributes of an Engineering Graduate" is appended as on candidate for such an industry-wide message].

Much more than the above has been written [1-13] on the faults (and less frequently, the real virtues) of our educational system in general, and a large number of documents have been prepared recommending a wide range of reforms. The university system has proved remarkably resistant to many of these assaults, however, and little real change has been apparent until quite recently – spurred in part by the massive dislocations caused by the end of the Cold War and the concomitant "right-sizing" (downsizing) in our industry [l4] which has been further fueled by increasing international competition. In defense of our universities it also must be pointed out that the increasing complexity of our technology, the past availability of large sums of government money, the changing economics of maintaining a high quality (largely graduate student focused) academic and research program, a lack of adequate industry attention, and the perceived weaknesses of K-12 public education are in part responsible for the higher education system we have today – which in the face of greatly increased international competition, is no longer good enough. While it is easy enough to point fingers or blame "outside" causes for our current situation, the problems we now face remain ours to deal with. Since we all (industry, government and academe) share some measure of culpability for what we have created, we should now be able to go beyond the point of deciding "whose fault it is" and work together in a spirit of enlightened self interest to create a new system which better meets the future needs of all of us and our nation as a whole. Further studies of the problems we face are not needed; what we do need are practical plans and processes for cooperative act ion. These plans should be based on rigorous use of systems engineering principles to define requirements for and develop the design of, the new approaches needed. Appropriate metrics must also be developed and applied.

What We Need - Some Opportunities

What is needed is a long-term, sustainable and fully cooperative effort based on systems engineering principals aimed at producing the sort of education (the most valued product of the university system from an industry perspective) which will develop future engineers with the skills and attributes listed in the Appendix. This program would be based on:

- Recognition of the basic distinction between “engineering science" (analysis) and “engineering" (design/creative synthesis) in both the education and employment of our future engineers. “Design" and "engineering" are fundamentally synonymous[1,6] and thus we must accord design education the respect to which it is due.
- Recognition that what you design is what you have to (attempt to) build and therefore that design and manufacturing are inextricably bound together – both in professional practice and in university curricula.
- Recognition that no 4-year (or 5- or l0-year) university program is ever going to be able to produce a fully and permanently qualified professional engineer, and thus that efforts to cram "everything a student must know" into this time frame is futile. A student must be prepared for life-long learning and major new partnership efforts are required to provide continuing education at all stages of an individual's career.
- Recognition that our future prosperity depends on industry/university teamwork and cooperation at all levels, including student course work and in university faculty interactions.
- Development of a modern approach to teaching design and manufacturing as a fully integrated, team focused, part of the university curriculum (including such exposure in core engineering science courses) beginning at the beginning of a student's freshman year. Intrinsic in this is the recognition of the profound importance of systems engineering and information technology (far more than mere "computer literacy") both in the curriculum and as a means of educational program delivery.

- Providing our students a proper view of the context (the whole system) within which engineering is practiced. This context includes economics, history, manufacturing as well as environmental, legal and ethical aspects of our profession.
- Providing an appropriate hiring and reward system for engineering (design) and manufacturing educators within a given university structure, and which at least provides a faculty with sufficient experience and dedication to teach these topics well.
- Recognition of the distinction between education (a primary university function) and training, much of which must be viewed as an industry responsibility. We must understand the appropriate (and perhaps new) relations between our research universities and our community colleges in providing both initial and continuing educational and training services. The differing requirements and available resources of large corporations and smaller companies for training must also be recognized and dealt with.
- Proactive leadership and involvement from all relevant professional societies (e.g., AIAA, ASME, ASEE, SAE, etc.) in building processes to link industry, academia and government participants. Their traditional role should be expanded and integrated across societies in recognition of their members' current needs. Their role, along with ABET, in formalizing and enforcing educational standards provides strong leverage to develop and implement engineering curricula changes and to achieve results on a national level.

Roadblocks

It is easy enough to make lists of what we in industry need, but it must be clearly recognized that there are some serious stumbling blocks to be overcome in accomplishing the changes previously advocated. Some of the most obvious are:

- While many in both industry and academe now recognize the need to change, there is a serious discrepancy between our two cultures with respect to the sense of urgency we each feel regarding the rate at which changes must occur.
- Too many university administrators and faculty members have little or no knowledge of what industry does, how it does it, and what their graduates need to know to function effectively in an industrial environment.
- Too few in industry have an adequate understanding of how our current universities function, how the faculty reward system works, or the constraints under which faculty members must operate in the system we have.
- Design education generates little research revenue and leads to few publications in "the right journals." Manufacturing has been held in even lower esteem until quite recently since, in academic terms, it is perceived to lack “intellectual content."

What We Can Do - Recommendations for Action

Engineering education has become “big business” and there is much inertia and resistance to the sort of changes advocated here, which also echo recommendations in several recent national studies (i.e., those prepared under the auspices of the ASEE[15] and the NRC). Many believe that no further studies are needed. We need action. These actions include:

- Establishment of a process to develop an industry-wide position on: “What we (industry) want from our colleges of engineering and what we are prepared to do to help provide it.”

- A much better focused use of our "aid to education" resources (both money and people). This includes a balance between government-funded research and educational programs.
- A change in the university reward system that recognizes that quality teaching must be at least on parity with funded research with regard to faculty promotion and tenure.
- Changes in the degree structure to establish engineering as a true professional program and which are consistent with future industrial technical workforce needs.
- Greatly expanded faculty - industry exchange programs. The objective of such programs should be to provide faculty with first-hand knowledge of industry practice and issues which would allow them to devise curricula which are truly responsive to industry needs rather than to merely allow faculty to continue their usual research at another (industry) site. Models for such exchanges exist in NSF Grant Opportunities for Academic Liaison with Industry (GOALI) and the Boeing-A.D. Welliver Faculty Fellowship programs.
- No culture change of the magnitude we believe to be required can be accomplished in a single meeting or by conducting yet another study. Likewise, no single party, working in isolation, can resolve the diverse problems we confront What we must do is establish and support (at both national and local levels) processes which encourage individuals from industry, academe and government to work together on a sustained basis to address the practical aspects of how we are going to change. A national forum to include relevant professional societies, perhaps in the leadership role, should be sought to address these issues and to create the continuing process for discussion and resolution. Agreements on curricula options should be sought on a periodic basis. ABET accreditation criteria and the ABET accreditation process can be used as a mechanism for now to formalize and enforce the agreements.

Concluding Comments

The central message of this paper has been that the world is changing dramatically[14] in the wake of the Cold War, and just as broad sectors of industry are changing to meet new challenges and opportunities, our universities (particularly in technical education) must change as well. The needed changes we can foresee will not come as swiftly as some would wish, nor will they come easily. But change must come if we are to sustain our prosperity in an increasing complex and highly competitive international environment. Of the changes advocated in this paper, perhaps the most profound and sweeping must be the rethinking and implementation of appropriate partnerships between industry and academe in the education and training of engineers. In our view, it is no longer tenable (if indeed it ever was) to accept a practice in which a university "educates" a student to some level of competence, and thus having done its job and "completed" its task, turns this "finished product" over to an employer to do with as may be fitting. From now on we must truly prepare a student to become a "life long learner" - an individual who will require and actively seek continuing education as well as training opportunities for the entirety of his or her career. In this process, industry and academe (appropriately aided by government) must become active partners, each doing what it is best qualified to do in fully cooperative efforts from the beginning of the educational process. We all have much to gain if these new partnerships can be established, and much to lose if they are not.

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Appendix: DESIRED ATTRIBUTES OF AN ENGINEERING GRADUATE

- A good grasp of engineering science fundamentals.
    - Mathematics (including statistics)
    - Physical and life sciences
    - Information technology

- A good understanding of the design and manufacturing process (i.e., understand engineering).

- A basic understanding of the context in which engineering is practiced.
    - Economics
    - History
    - The environment
    - Customer and societal needs

- Possesses a multi-disciplinary, system perspective.

- Good communication skills.
    - Written
    - Verbal
    - Graphic
    - Listening

- High ethical standards.

- An ability to think both critically and creatively - independently and cooperatively.

- Flexibility - an ability and the self-confidence to adapt to rapid/major change.

- Curiosity and a desire to learn - for life.

- A profound understanding of the importance of team work

Note: This is a list of basic, durable *attributes* into which can be mapped specific *skills* reflecting the diversity of the overall engineering environment in which we in professional practice operate. In specifying desired attributes (i.e. desired outcomes of *the educational process*), we avoid specifying how a given university goes about meeting industry needs. Curriculum development is viewed as a university task to be done in cooperation with their "customers," and in recognition of their own local resources and constraints. Industry, as an important customer, must be an active partner in this process.

Testimony on the Views of Employers on Undergraduate Education in Science, Mathematics, Engineering, and Technology[7]

Robert T. Jones

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Washington, District of Columbia

Permit me to make three statements that generally characterize business community positions regarding higher education.

First, higher education should demonstrate greater understanding of the needs of the private sector. Too often higher education seems unaware of job requirements and changes in the workplace. I believe that maintaining a close connection between what goes on in our educational system and the rapidly changing work environment is essential.

Second, higher education curricula should reflect the changing conditions in the workplace. More students need to experience the challenges and rigor of contextualized learning.

Third, higher education should help develop the work ethic that will sustain students in their eventual careers. Note that many corporate leaders say that new employees are fine – even more responsive than they used to be. These same leaders point out that they screen a substantial number of potential applicants, selecting only the best from that pool. As long as that pool is large enough and active enough and vital enough, firms will always manage to hire the kind of people they need. We must however be concerned about all the rest, those who do not enjoy the skills needed for employment and advancement.

Corporate leaders tend to believe that the factual knowledge derived from undergraduate education can quickly become obsolete. Further, the life expectancy of new entrants in their first job is very short. Relatively inexperienced employees move on to another company or another function or task more rapidly than ever. Companies are also increasingly reluctant to hire recent college graduates. Before they invest in hiring on a long-term basis, they want to see degree holders with three to six years of work experience in the modern corporate system who can show an effective adaptation to the updated demands of the new workplace.

The typical employer no longer defines educational preparation solely on the basis of scientific knowledge or experience, or mathematical and technical competencies. Increasingly, employers are looking for the ability of new scientists to think clearly and communicate their thoughts, to write clearly, to negotiate, to listen, to work on teams, and to function effectively as part of a diverse work force. Employers' perceptions are that schools are not paying enough attention to the development of these skills. They do not seem to be taking business very seriously, nor listening to our cues that how we hire is now different.

I urge you to look at the hiring processes that companies are utilizing, to study carefully the methods of testing and interviewing. What are the broad and durable skills and competencies they

[7] This text is an edited version of Mr. Jones' verbal testimony to the EHR Advisory Committee on November 1, 1995.

seek? It is very clear that when applicants don't understand the needs of employers, they are not likely to be hired.

New employees are increasingly expected to demonstrate as one CEO calls it “boundary-less” skills. This all happens because of the changing nature of the way we work. Engineers and scientists are now “on the factory floor.” They are not isolated in a lab. Engineers and scientists now deal with customers and their ability to deal with customers is key to their being hired in the first place.

There is a growing perception that a college degree per se is of minimal value to business. Business is more concerned about the level of a job applicant's competencies, the breadth of that applicant's competencies, and the applicant's ability to assimilate, manage, and utilize information. How those skills are acquired -- whether during studies for an MBA or a MS in science or math, or as part of some other educational experience -- is not of great import.

Related to this focus on competencies rather than credentials is the increasing demand for certification programs. The demand is growing for continuing education programs that let employees re-enter the education community in order to update their skills, to stay current on new technology and procedures and to do so in short certifiable bites that employers can recognize. Simply taking people out of employment for two or three years for an advanced degree for the sake of improving skills and knowledge doesn't work effectively for many jobs. The way we traditionally boxed up these degrees doesn't match well with the needs of today’s work force. We will probably see within the next 24 months a very rapidly growing discussion about how we create certification programs where people can engage frequently and efficiently in continuing education.

In summary, business believes more strongly than ever that post-secondary and continuing education are crucial for all potential workers. How to sustain the strengths of our existing system while responding to the vibrancy of the business environment is a challenge that higher education must meet.

A nationally recognized expert in the workforce development field, ***Roberts Jones*** *has over thirty years of organizational management and public policy experience in the training and education field. As a lifelong advocate for investing in people, Mr. Jones is widely credited with helping place workforce development at the forefront of the nation’s public policy agenda. Prior to joining the Alliance, Mr. Jones was vice president of RJR Nabisco, Inc. Mr. Jones served both Presidents Reagan and Bush as Assistant Secretary of Labor, responsible for federal workforce development and training policy addressing the significant changes in work and the workplace. Jones played a key role in the Hudson Institute’s landmark research project and report,* Workforce 2000: Work and Workers for the 21st Century, *and was responsible for the Department of Labor’s SCANS Commission, which for the first time spelled out the skills necessary for success in the workplace. Mr. Jones was awarded the Presidential Distinguished Executive Award, the highest honor in the Federal government, in 1986. Mr. Jones received his B.S. in Psychology from the University of Redlands in Redlands, California, and performed graduate work in Public Administration at the American University in Washington, DC. He also served for four years in the United States Air Force.*

Testimony to the National Science Foundation Undergraduate Review Subcommittee: Employers Views on Desired Capabilities of Undergraduates Entering the Workforce

John L. Sisler

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Thank you for the opportunity of share views on undergraduate science, mathematics, engineering, and technology (SME&T) education from the perspective of an Energy Industry employer of graduates from these programs. As manager of E&P Training in Shell Exploration and Production Company, I am increasingly aware of the challenges and demands placed on BS and MS SME&T graduates in out technical professional workforce. How well our Company, Industry, and Nation surmounts this challenge is of critical importance to future success and survival in a global market place.

While this testimony is from the viewpoint of a large, primarily domestic oil and gas exploration company, many of the phenomena discussed appear to extend beyond the upstream portion of Energy Companies. They are reportedly commonplace throughout other portions of US Industry.

One characteristic of the upstream Energy Industry's technical professional workforce is the mixture of scientists and engineers. Geosciences (Geology and Geophysics) together with Physicists and Computer Scientists are combined with Electrical, Geological, and Petroleum Engineers to form the skill pool responsible for finding and delineating new hydrocarbon deposits. Engineering graduates become increasingly important in developing, producing, and managing existing oil and gas reservoirs through economic lives to eventual abandonment. These include Geological, Petroleum, Chemical, Electrical, Mechanical, and Civil Engineering graduates. They are integrated with the skill groups used to find and delineate who are also involved in the later phases of the E&P cycle. This workforce is predominately BS and MS level with a lesser number of Ph.D.s who typically transferred from Research into the operating organizations. The way work gets done by this mix of SME&T graduates across the spectrum of E&P activities has changed significantly in the last five years.

Organizational Characteristics

Changes in the job environment associated with organization redesign are profound. An ongoing process attempts to create work group structures that are focused, efficient, and responsive to change. Nearly all upstream US Energy companies, including Shell E&P Company, have experienced dramatic organizational changes. In most cases these resulted in somewhat smaller SME&T workforces and significantly fewer supervisors and managers. Work now being done often exceeds levels prior to the changes. Further change is very unlikely but a return to the type of work group structure characteristic of the past is very unlikely.

Integration

Currently, most U.S. Energy companies have emphasized integration at every organizational level. Formerly organizations were divided into separate groups based largely on skills and type of work performed. Exploration was typically separate from Production, and within each there were subdivisions such as Geology and Geophysics in Exploration, and similar splitting within Production into Operations and Engineering that was in turn split into various engineering scientific specialty groups. Today, multidisciplinary teams that are formed to accomplish a specific project or manage a group of assets within a defined geographic area do work. These teams are interlocked to form multi-disciplined project groups responsible for major business segments.

Today's integrated work team organization has far fewer managers and supervisors. Typically, supervisors lead large, diverse work teams and do not exercise the level of detailed control characteristic of past more hierarchical work structures. Someone will probably lead the SME&T graduate with a dissimilar educational specialty.

Leadership Style

The style characteristic of successful leaders today is one of coach and coordinator rather than command and control that was possible when past supervisors frequently were experts in subordinates' jobs. Some work was associated with personnel administration and the individuals now do development formerly done by managers and supervisors themselves. The SME&T graduate will probably find the leader not as deeply involved in how work is done, provided it is timely and correct. Today's leader is far more interested in results than style. Because of the size and diversity of typical work teams the leader today is rarely as involved in each individual's personal skill development as were past supervisors. Individuals are expected to be proactive in defining their needs and seeking our opportunities to grow. The leader's role is to enable and encourage, but not to be prescriptive.

Performance Measures

Performance measures for individuals in today's organizations attempt to focus on business-relevant results. Compensation is more directly tied to current business results. To a growing extent individual results are tied directly with Team results. In contrast, past performance measures too often dealt with style and activity level. These may have had only an indirect linkage with business objectives. The SME&T graduate is finding that it is increasingly difficult to prosper personally while the ship of which he or she is a crewmember sinks. Coming from an undergraduate system that exclusively recognizes individual achievements this change may cause some to question "fairness."

Skills

Skills needed to successfully function in today's work team environment are somewhat different from the past. Each person needs an awareness of the role and contributions of others on the team. In-depth specialized knowledge must be accompanied by skill at relating various parts to the whole and finding solutions to problems that formerly might have "fallen between the cracks" of the different specialties and departments. Skills such as communications and teamwork are essential. Unfortunately these are often given low priority during the SME&T professional's undergraduate education. Working together interdependently in a team to achieve a common goal rather than competitively to garner individual recognition is a very satisfying change for many, but one that does not come easily to some SME&T graduates who have thrived in their former arena.

Personal Characteristics

Along with the organizational changes there have been changes in expected personal characteristics of the Technical Professional workforce. Skill areas deemed important for success in the current and future work environments include many areas besides the traditional SME&T subjects.

Technical

Sold preparation in the relevant sciences and mathematics together with their application to create beneficial products remains the most valuable asset that a SME&T graduate can bring into our workforce. Without this, chances of success are slim. It is particularly important to gain a broad foundation during the undergraduate period. This will provide the means to adapt and thrive as changes occur that impact the various applications used in the workplace.

One characteristic often missing in graduates of US SME&T programs is ability to understand system versus segments. Too frequently graduates who have impressive transcripts from highly acclaimed universities exhibit limited understanding of how their segmented knowledge fits together. An ability to understand context and to fit pieces into a larger framework are essential in working in an integrated, multi-disciplined environment. Critical thinking has greater importance than problem solving.

Commercial

SME&T graduates are expected to possess more commercial acumen than in the past. The necessity for improved financial performance has caused accountability for profit and loss to be at much lower levels, frequently at the work team level. A vocabulary once restricted to Business School graduates is now routinely used by technical staff. Engineers and scientists are no longer as insulated from accounting, financing, and marketing.

Risk management is particularly important. SME&T graduates typically are expected to define uncertainty, develop risk assessment, and play a major role in managing risk.

While SME&T graduates are not expected to possess abilities to perform specialized commercial tasks, they do need to understand their importance and how they must be integrated with technical work to achieve business success. Clearly SME&T graduates need to respect the importance of the commercial context of their work.

Information Technology

Without question, advances in computing and information technology (IT) are enablers for many of the changes discussed here today. All SME&T graduates are expected to have skills that allow application of advances in IT to their work. In fact, many technical professionals in E&P spend the bulk of the time at work at workstations or PCs. Most are not developing new software, but are using increasingly integrated applications systems provided by others. Major concerns are with data management and getting work done in complex internal IT systems. Many find their undergraduate programs did not provide sufficient expertise in the personal productivity tools.

This is one area in which recent SME&T graduates as well as technicians have exerted leadership. Without their training that embraces IT as just another of the natural work tools, progress would have been much slower.

Teamwork

All SME&T graduates must possess teamwork skills. While many factors go into developing these, one that is partly a consequence of the undergraduate educational system stands above the rest. Respect for others who have different educational backgrounds is essential.

Academic divisions between sciences and engineering and further subdivisions within each too frequently imprint SME&T graduates with personal biases. These are obstacles to effective teamwork. Rivalry between academic schools, departments, and even specialties within a particular field, create stereotyping of various groups. Academic role models that participate in such activities are sending very wrong messages to their students. In today's business environment, one's leader and office mates may well be from one of the groups held in low regard by his or her academic role models. The need to respect others extends beyond the SME&T disciplines to include those in business, humanities, and other groups such as law, which must work together in teams.

Communication

Good communication skills are even more important today. In addition to the long-standing expectation that SME&T graduates be able to write and speak effectively, the challenge today is the audience. Former audiences were often composed of specialists who all spoke and understood their specialties' jargon. Today an important audience is the multi-disciplined work group and its leadership. Increasingly the SME&T graduate is also communicating with external customers and stakeholders who generally do not understand the "insider" language of science and technology. This becomes particularly important to those working with environmental issues.

Electronic tools are playing a bigger role as a means of communication. However, the skill needed is to understand the cycle of listening, understanding, creation and delivery of a clear message to a specific audience. These are independent of the tools and should be incorporated into SME&T undergraduate programs.

Leadership

More leadership skills are expected from everyone in flat organizations. Fewer opportunities exist for formal management jobs, but there are many more opportunities for individuals to hold ad hoc leadership roles. As mid-level managerial and coordinational jobs have disappeared, individuals in teams are doing some of the work. The leadership roles and skills are very closely associated with teamwork rather than exercise of the power of an organizational position.

Change Management

The final personal skill in this list is the ability to proactively participate in the processes used to continuously improve. Change Management is now a part of every SME&T graduate's responsibilities. Each must acknowledge that the future is unpredictable. Major changes and retaining flexibility to alter strategies will probably be needed to survive both as business and individuals.

Individuals who accept personal responsibility for their own deployment and take actions to grow personally and professionally will be more likely to succeed. The employer of SME&T graduates is no longer providing the level of security and development direction seen in the past.

Recommendations

1. Support programs, which are interdisciplinary and integrated. Do not restrict this to just the SME&T fields. Opportunities for undergraduate SME&T students to become involved must be provided.

2. Support programs that instill rigor and breadth in BS/MS SME&T studies. Focus on teaching and shaping those who constitute the bulk of our workforce. Meaningful recognition must be available to faculty and institutions that do this well.

3. Support programs that provide BS/MS students with the interpersonal/organizational/ teamwork skills now essential in today's workplace.

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Testimony on the Views of Employers on Undergraduate Education in Science, Mathematics, Engineering, and Technology[8]

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I certainly appreciate the opportunity to be here to talk to you about undergraduate needs, particularly with regards to the telecommunications industry.

As the telephone industry evolves, one of the first things I think we need more of is engineering programs designed to educate generalists, to produce graduates with almost the same kinds of skills that John Sisler of Shell Exploration and Production Company was just describing.

Very frequently, the kinds of issues that at least our undergraduate engineers face require participation in multidisciplinary teams, but more than that, they are often not focused on one specific area of technology. They cover a variety of different areas. I think that a program in undergraduate education designed to produce engineering "generalists" would perhaps better match that need.

Our situation is analogous to the issue of the best strategy for educating medical doctors. A general practitioner course of study often meets the greatest need of communities for medical services. General practitioners can be coupled with the selective use of specialists. In the past there was a tendency to stress the education of medical specialists. Now we realize the importance of general practitioners.

We clearly do have that need for specialists in telecommunications, but for the vast majority of jobs, a general program matches our needs much better than specialized programs. Where we do need specialists, a bachelor's degree or even a master's degree is often not enough to cover the field in depth. We really need to hire Ph.D. level scientists or engineers to get the best contributions in specialized areas.

Another aspect that I wanted to bring out is that telephone technology, like most high-tech, electronics-type fields, is undergoing pretty much a revolution. For example, just look at one aspect of this field over the last ten years, fiber optic transmission. Ten years ago, engineers were talking about multi-mode fiber with LEDs. That has shifted very quickly through a number of different technology stages. Today, ten years later, nobody ever talks about multi-mode fiber, and nobody talks about LEDs. Instead, the talk is about lasers, fiber amplifiers, and dispersion-shifted fibers. In other words, the field is moving so fast that it is pretty hard for me to imagine how the universities can really keep up with current technology.

In fact, if you look at most programs in engineering, you typically see that they are pretty much covering the same old topics, and that is surprising, given the pace at which the technology seems to be moving along.

[8] This text is an edited version of Dr. White's verbal testimony to the EHR Advisory Committee on November 1, 1995.

I think that there is certainly several impediments or several areas within teaching that need to be dealt with. Tenure policies, I think, need to be looked at to make sure they are really encouraging faculty to keep abreast of technical areas, and that universities continue to hire the best-equipped faculty or the faculty with the most knowledge in some of these new technology fields.

I also think that the types of research that are being funded also have an impact. If you pick up almost any journal these days, I would say at least two-thirds, maybe three-quarters, and in some cases even 100 percent of the selected papers seem to represent minor tweaks in insignificant technical areas, most of which isn't all that relevant to what industry really needs in terms of research.

If you have faculty who are moving in that direction, then you can easily see why there will be a widening gap between what the universities are actually teaching young engineers and what industry needs if we are to remain at the cutting edge.

The last thing I wanted to talk about in my prepared remarks – related to the plea I made at the outset for more a general education in engineering – is that I believe we should reexamine the lack of a foreign language requirement in most colleges and universities. Increasingly there is globalization of just about every aspect of industry. Too often we go to meetings with the French, Germans, and Japanese and find that they can speak English plus their own language. In negotiation, I think we are at a significant disadvantage in only knowing English.

I also would put in a plea that the types of elective options that are associated with engineering, currently drawing from a traditional liberal arts menu, might also sensibly include wider options, e.g., business-oriented courses, finance, economics, intellectual property law. These are all very vital aspects for a young engineer's education.

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