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Combining High-Tech with Business Sense for Learning Success

HIGHER EDUCATION for the Information Age

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Grand opportunity is like a bus that makes only one stop. If we do not get on board quickly, then we could miss it forever. The opportunity to prepare for the Information Age is now. The impact of new multimedia-oriented technologies is starting to change job environments. These changes are affecting everything from professionals' concerns about job security to students' decisions to enter the workforce instead of pursuing doctoral degrees. Also, with the marketable value of traditional school education not as long lasting as it used to be, life-long learning becomes a must for life-long employability. In this article we discuss these challenges and some of the skills that will be necessary for both future and current engineers to deal with them.

Entering the Information Age

The first industrial revolution occurred in the beginning of 19th Century. Invention of engines ended the agriculture age of 8,000 years or so—the Industrial Age was born. Machines provided large horse-power to ease the burden of human workers. Productivity was increased several fold. At the end of the 19th Century, electricity was harvested, which helped to trigger the second industrial revolution. Lighting by electricity allowed us to continue activities past sunset. Telephony became popular and connected remote people in a more convenient way.

The recent third industrial revolution was spurred by the rapid advances of computer, communication, and consumer electronics technologies—we have entered the Information Age. Biotechnology and smart materials have also started to make

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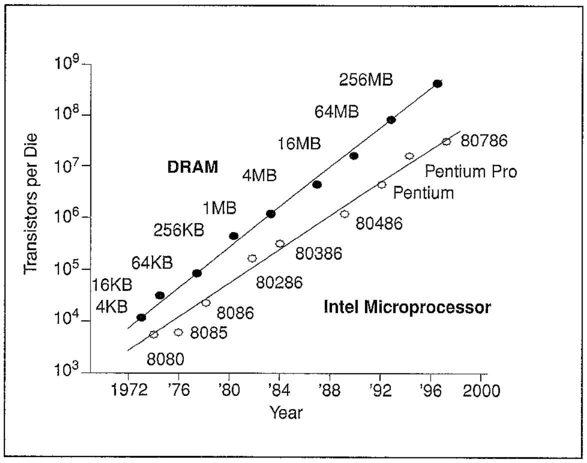
Table 1. Roadmap data on logic processors from the Semiconductor Industry Association.

Year	Feature Size	No. of Transistors	Clock Speed	Wafer Size
1995	0.35 μm	4 M	210 MHz	6"
1998	0.25 μm	7 M	350 MHz	8"
2001	0.18 μm	13 M	560 MHz	12"
2004	0.13 μm	25 M	680 MHz	12"
2007	0.10 μm	50 M	800 MHz	12"
2010	0.07 μm	90 M	900 MHz	16"



1. The prediction of circuit density based on Moore's Law.

significant contribution to our life. From the beginning of civilization, successful entrepreneurship has relied on three important ingredients: land, capital, and people. However, in the Information Age, high-tech know-how becomes the dominant source for creation of wealth. What to teach and how to teach it effectively need to be carefully examined as the new generation of children becomes more computer-literate than the old faculty members who have been in school for decades.

The Booming Microelectronic Industry

The silicon-based microelectronics industry helps to implement compact products for computer, communication, and consumer electronics applications and has become the major driving force of the second half of the 20th Century. Microelectronic fabrication technologies are under constant improvement, basically following Moore's Law of shortening the minimum transistor size by half every 18 months. In 1998, the state-of-the-art fabrication technology is around 0.25 μm for logic processors, and the laboratory experiments are conducted with 0.18 μm or even more advanced technologies. Each fabrication plant requires a US$ 1 Billion or larger investment. To explore the full strength of a new technology, efficient use of human resource and management skills is of great importance.

Continuous improvement on microprocessor performance has been driven by advances in fabrication technology and system-level architecture innovations, including advanced compiler, cache hierarchy, and superscalar/superpipeline processing. The continuous reduction in device dimension allows higher packing density of components and faster data-processing speed. Table 1 lists the roadmap data from Semiconductor Industry Association.

Over the past two decades, a dramatic improvement in operating speed and reduction in feature sizes of silicon-based electronic devices has occurred. Moore's Law can be used to predict the trend of the increase of very-large-scale integration (VLSI) chip complexity and computing performance [1]. Advances in chip-making technology are expected to continue to shrink the size of transistors in microchips over the next decade and allow the corresponding increase in the number of transistors per chip. From the roadmap provided by Semiconductor Industry Association, the minimum feature size in the year 2010 will be around 0.07 micrometers, and about 90 million transistors will be integrated in a cubic centimeter. Figure 1 shows the plots of microprocessor and dynamic random access memory products over the past two decades. The circuit complexity has doubled every 18 months. By the end of this century, an advanced DRAM chip could include one billion transistors [2].

Impact of Multimedia

At the early stage of computer invention, a computer occupied a large air-conditioned room and it required specially trained operators to handle. With the invention of the integrated circuit (IC) and an improved operating system, the size of computer was significantly reduced while its processing power was tremendously increased. Thus, the computer has entered our daily life and has provided valuable assistance to the business world. It is no longer specialized equipment for the scientific and/or engineering effort. It is no longer necessary for the user to write science/engineering-oriented source codes to access the computer. Nowadays, software packages and more convenient/efficient human-machine interfaces such as touch-screen/icon and speech/pen-based input/output are used to communicate with the very powerful, compact, and inexpensive laptop computers or portable electronic devices.

Multimedia has the potential to become one of the most powerful forms for communicating ideas, searching for information, and experiencing new concepts than any communication media ever developed. This is facilitated by the fact that multimedia incorporates and even combines every known type of media: text, speech, audio, image, video. Multimedia is a truly interdisciplinary field that takes advantage of the rapid developments in signal and information processing, telecommunication, computer engineering, microelectronics, consumer electronics, and electronic commerce. It has been widely used in business, entertainment, and education as it provides timely information and live interaction to users [3].

Multimedia will significantly enhance standard educational techniques. With the help of a large-screen projector and multimedia playback system, the teacher can use multimedia titles to enhance classroom presentation and stimulate questions. The students can further explore topics at home using a multimedia platform. In the home entertainment area, a high-definition television (HDTV) monitor serves as the system display. It offers good image resolution and a wide screen aspect ratio. New services like home shopping, remote electronic banking, medical diagnosing, and video-on-demand can be conveniently supported. Customized information, which is tailored to one's interests and tastes, can also be available through the interactive network. Digitalization of media is changing the audio/video landscape with multiplication of channels available to the consumer. In addition to surfing the internet for useful information, the system can be modified to provide audio web surfing for drivers who cannot afford to watch the video display while on the street or highway [4].

What to teach and how to teach it effectively need to be carefully examined.

Challenges Due to Diminishing Boundaries

With rapid advances of multimedia technologies in the Information Age, traditional boundaries between various academic disciplines have started to diminish.

Discipline Boundaries

Existing boundaries among various disciplines were established decades ago. However, with the impact of multimedia technology, these boundaries have started to disappear. People other than those trained in electrical engineering or computer science now have ability to conduct research and development tasks in multimedia; professionals in cinema-TV, literature, social science, and business can also prevail in this exciting field. Interdisciplinary curricula are very popular with the new generation of students. Figure 2 shows the relationship of various disciplines for success in the high-tech world [5].

Academic Degree Boundaries

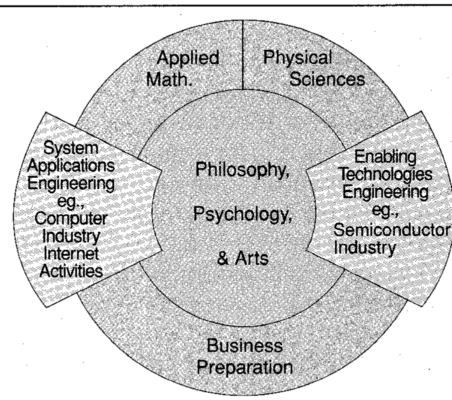
In the conventional sophisticated and pyramid structure, university graduates were hired by companies and compensated according to their academic degrees and the field of training. In the Information Age, there are lots of examples of college graduates or even high-school graduates who make a big splash in business. Advanced degrees such as doctoral or master's degrees can no longer guarantee high-quality jobs and better career growth opportunities. The success stories of Bill Gates of Microsoft, Inc., and executives at Netscape and Yahoo are famous examples.

Life-Long Employability for High-Tech People?

Why are high-tech engineers laid off? A typical answer is that they happened to be at the wrong place at the wrong time. The company may have decided to hire less-experienced engineers at lower salaries to replace the senior personnel. Employment may have also been terminated because the industry introduced more efficient technology required to develop new product lines and services.

Life-long employability means people are employable until they want to stop practicing in their chosen profession or when they reach the official retirement age. However, according to a report in the August 1997 *IEEE Institute*, a typical unemployed high-tech person is usually more than 50 years old, has more than 20 years of professional experience, holds an advanced degree, and has been searching for a job in a professional field for more than a year. This phenomenon can be related to productivity of the individual and the economics of doing business in a worldwide competitive market. As pointed out by human-behavioral experts, some people who work in a company for several years in a similar function job become secure, complacent, and inflexible. They are hard to motivate to perform at the most productive level.

Training of engineering students to meet the new challenges of a global workforce has been one major subject that the United States' National Science Foundation has focussed on. According to Olin Foundation president Lawrence Milas, traditional engineering students have been trained in too narrow a specialty.



2. Relationship of various disciplines for success in a modern high-tech world.

Table 2. Number of students indicating ability or deficiency in a specific performance category.

	Ability (Strength)	Deficiency (Needs improvement)
Ability to cope with challenges	17	8
Breadth of technical knowledge	11	7
Computer skills	13	8
Maturity/stability	15	14
Motivation/determination	14	7
Oral presentation/communication	2	23
Technical competence	16	6
Written report preparation	3	12

They are unable to adapt or recycle themselves later in their careers. IEEE president Joseph Bordogna suggested making students part of a team because they perform better in that way. Being trained in a scientific field is no longer the best approach. Young engineers need to know how to connect with or understand those in other positions because the jobs have become more complex. In addition to technical issues, a successful product is to be developed with careful consideration of finance, safety, environmental and public-policy matters. New engineers need to learn how to be versatile and competitive in a global market economy. Multidisciplinary training is a must. Diversity in views, approaches, and backgrounds are critical, as pointed out by Bordogna.

Traditional boundaries between various academic disciplines have started to diminish with the rapid advances of multimedia technologies.

Including Business Sense as Early as Possible

As we are fast approaching the 21st Century, some attributes and skills would be very useful for engineering professionals who are eager to excel. Those attributes and skills apply to both engineers and engineering management.

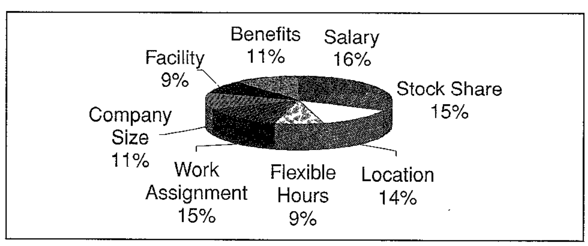
A solid technical base is a necessary, but not totally sufficient condition for success. In the Information Age, wide use of multimedia-based systems has changed our job environment permanently. A person cannot dream of being loyal to the same company for 40 years and ask in return to have that company take good care of him/her. The common scenario in industry now is downsizing, outsourcing, and short-term assignments. Life-time jobs cannot be expected and even life-long employability could be questionable. In some states, the meaning of tenure awarded to senior faculty in universities is under study. There have been proposals to conduct periodic review of tenured faculty for possible layoffs that could destroy the fundamental meaning of academic tenure.

Wally Read has tips for engineering professionals on how to succeed, as reported by Gus Gaynor [6]. His suggestions can be summarized as (1) a solid technological base, (2) work ethic, (3) soft-skills, (4) global outlook, (5) modern business awareness, (6) communication skills, (7) team play, (8) value networking, (9) aggressiveness, (10) career destiny, and (11) flexibility and adaptability. Some of the suggestions are obvious, while others need to be elaborated. Technological competence is a good start. In addition to being problem solvers, engineers need to be problem finders too. With regard to work ethic, we are to approach our work systematically and make adequate preparation to minimize any last-minute surprises. The key emphasis includes both effectiveness and efficiency. The work is to be done at the lowest possible cost that meets the required standard within the reasonable time period. Soft-skills for handling interpersonal relationships are typically not covered in the regular university curriculum. However, they play a fundamental role in determining the success or failure of a work effort. The role of engineering function continues to change. We have to focus on integration of people, technology, and the management system in order to achieve significant success in enterprise.

A global outlook will help to find solutions that are better than those from local constraints. Resources at various regions of the world can be made available through personal, business, and technical alliances to shorten the work effort. Here, a distributed system approach can be utilized that is usually better than a centralized approach. With regard to modern business practice, engineers need to recognize their role in sustaining business excellence. There will be dedicated choices that balance the engineering effort and business decisions.

Communication is of fundamental importance. IEEE chooses to emphasize "Networking the World," which clearly reflects the importance of communication. This is the area that corporate executives constantly suggest to engineering schools for strengthening student training. Team play is indispensable because projects have become more interdisciplinary so that engineers need to know the requirements of other operating functions. We have to understand the needs of business without sacrificing the technology standards. The word "company" means a group of people who work together with a shared goal. It is difficult for an individual to achieve success on large-scale complex projects. If you are a manager or director, recruiting capable employees for your team can benefit tremendously from references provided through established personal networks. On the other hand, such networks can also help you find a new position that better matches your accumulated skills and capability.

Being aggressive is not to offend people. It is to be viewed in a very positive sense, and it actually correlates with being energetic, proactive, enterprising, innovative, and ambitious. One has to take calculated risks in order to achieve more than what he/she routinely deserves. We need to have clear and definite career goals of our own. No one else is going to make that choice for us. The institution can provide some help, but the ultimate responsibility is ours. To be flexible and adaptive can help engineers in the Information Age to stay employable because the work environment will definitely change during the 40-year time period. The above suggestions, which were first made by Wally Read, are very valuable to engineers of the 21st Century.



3. Factors that affect the first job choice.

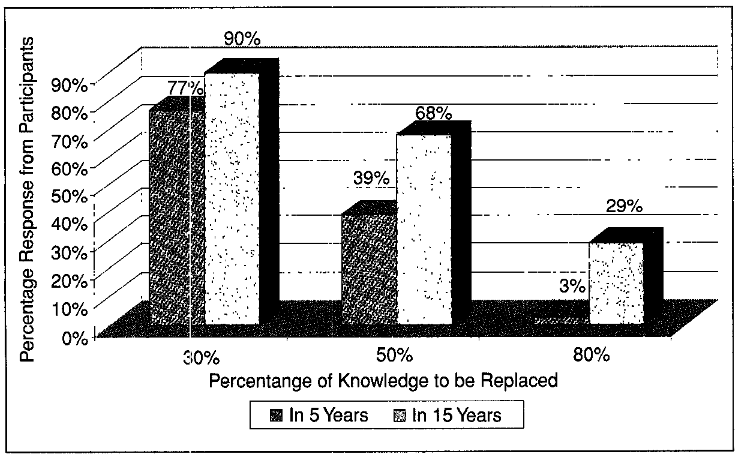
Solving the Puzzle of Higher Education

> We have to focus on integration of people, technology, and the management system.

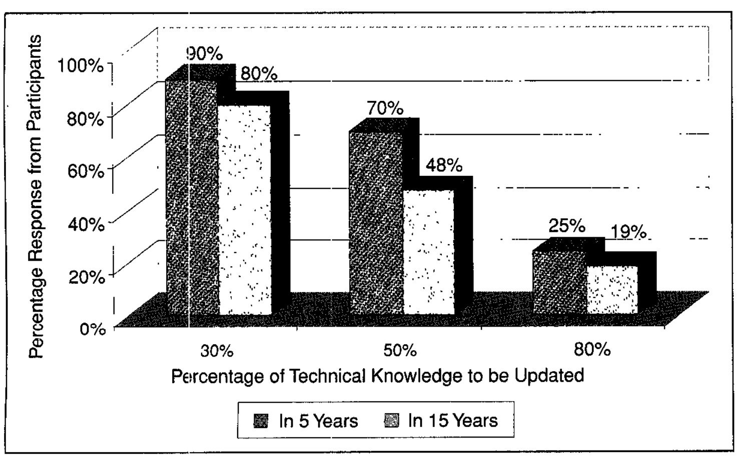
With the impact of multimedia technologies, the younger generation apparently worries about the useful duration and true value of acquired knowledge from a university education. The fear is that the knowledge learned in the classroom could be mostly outdated before the students enter the professional world. The fundamental questions for higher education are what to teach and how to teach it in order to help the graduates succeed in this new environment. This evolving phenomenon has not reached steady-state yet! Therefore, a suitable solution should be one with adaptive capability. The adaptive-system approaches associated with neural-network, fuzzy-system, or even genetic-algorithm methods are most appropriate in helping analyze the collected data.

We directly interacted with graduate students for first-hand data to gauge their views and perspectives about jobs and careers. Several oral interaction sessions were organized for graduate students who were majoring in electrical engineering or computer science in the Fall 1997 semester. At the beginning of the interaction, the students were given thorough guidance to become familiar with the purpose of the whole process of helping them become better prepared to fit into the business world. The students then played an active role during the oral interaction to express their views and concerns. A question set was prepared for the participants and the results are shown in Figs. 3-5.

Thirty-two students participated in the study. Table 2 lists the number of students indicating an ability or deficiency in specific performance categories. Each student could make multiple choices. Notice that oral presentation/communication, written report preparation, and maturity/stability need major efforts for improvement. Figure 4 shows that 77% of students feel that more than 30% of useful knowledge in general fields needs to be replaced by taking business-related courses while only 3% of students agree that more than 80% of useful knowledge has to be replaced in the next 5 years. However, if the same question was asked for the long period of 15 years, then 29% of students feel that more than 80% of useful knowledge needs to be replaced. The survey results on useful knowledge in a technical field are shown in Fig. 5. Notice that 90% of students feel that 30% of the technical knowledge needs to be replaced in the next 5 years.



4. Useful knowledge needs to be replaced by attending business school.



5. Useful knowledge needs to be updated by acquiring new technical knowledge.

To Ph.D. or Not to Ph.D.?

The pursuit of a Ph.D. degree is worthy of careful examination. For engineering students, this means another four or five years of hard work with low payment in contrast to the lucrative compensation received by a master's-degree graduate working in a high-tech company in the Silicon Valley or other similar places. Ten to 20 years ago, Ph.D.-degree holders could easily find teaching jobs in academia or comfortable research positions in corporate laboratories such as Bell Labs, Hewlett-Packard Labs, or the IBM T.J. Watson Center. Today, the situation is very different. Teaching positions are hard to find not only in United States, but also in other regions of the world such as Korea or Taiwan. Most of the corporate research laboratories are tied to divisions to assist the revenue-generating process in order to justify their existence. If we use the integrated-circuit and computer-system fields as an example, then the majority of Ph.D. graduates have joined industry for development of new products.

If their training during Ph.D. study was of a traditional format, these graduates do not have much of an advantage over the experienced master's-degree graduates who joined industry earlier. The devotion of multiple-year Ph.D. study just leads to a loss of seniority in industry. Many of their ex-classmates who started to work after obtaining master's degrees may have already become managers who serve as supervisors to the newly graduated Ph.D. students. This situation has contributed to the trend that a reduced number of students are interested in pursuing the Ph.D. degree in United States, China, Taiwan, and Korea.

Ph.D. students need to start the innovative approach at the very early stage of their study.

With the problems clearly identified, solutions are starting to appear. Governmental grant support has started to emphasize technology transfer. In the past, faculty who helped start new high-tech companies tried to hide the fact from their peers since they worried about being viewed as not being dedicated enough to academia. Nowadays, these faculty members are very proud of their off-campus efforts, and they provide a good method for effective technology transfer. Ph.D. students should not delay thinking about how to effectively contribute until they complete the degree requirements. They need to start the innovative approach at the very early stage of the Ph.D. study. Well-talented industrial people such as Bill Gates do not have to stay in the education system for too long. Those who pursue the Ph.D. are the group who believe they are talented but need additional chances to excel. Thus, the period of Ph.D. study provides the chance to further discover and exercise the quasi-genius talents. They should not wait until this period is over and the degree is granted, because at that moment about half of the most exciting period in their advantageous professional career has passed. Ph.D. study is a time period for exploring revolution in either technical subjects or problem finding/solving methods with an emphasis on philosophical aspects. Ph.D. students need to be given the opportunity to become true leaders of tomorrow, rather than super-master (or post-master) degree holders of yesterday.

Conclusions

Managing higher-education priorities is an important and critical task at schools and universities in this multimedia-oriented Information Age. A lot of challenges and problems have to be identified and then possibly solved by a cross-discipline team effort. The new generation of engineering professionals needs to know not only the scientific and engineering principles, but also have extensive knowledge about arts, literature, and social sciences. They need far-reaching vision for the future in order to understand grand challenges on the technical-level, the system-level, and the social aspects of topics that are of importance to the modern society.

One solution is to emphasize fundamental courses such as mathematics and physics with new interpretation to correlate with real-world applications. It is important to include system-oriented topics in the curriculum so that students know how to apply the basic principles. Key focus should be placed on the analysis and design skills, and effective communication is essential to address any large-scale problems.

We will continue our effort in this exciting field because it is very challenging and fascinating. Interaction with colleagues and those interested in this adventure will be greatly welcomed.

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