

## **EXECUTIVE SUMMARY**

**Seminar on  
Engineering Education for a Global Economy  
October 20-24, 2002  
Shanghai and Beijing  
People's Republic of China**

The Seminar on Engineering Education for a Global Economy was held on the campuses of Shanghai Jiao Tong University and Beihang University (BUAA). Beginning with an Opening Ceremony at the Jianguo Hotel in Shanghai on the evening of October 20, 2002, plenary sessions continued at Shanghai Jiao Tong University for the next two days. On the morning of October 23 the delegates adjourned to Beijing where the seminar continued with a Roundtable Policy Meeting on the afternoon of October 23. The seminar concluded on October 24 with plenary sessions all day and a closing ceremony that evening. The National Natural Science Foundation of China (NSFC) and the U.S. National Science Foundation (NSF) provided financial support for the seminar.

### **PURPOSE**

The Seminar on Engineering Education for a Global Economy was the fifth in a decade-long series of bi-lateral dialogues between representatives from the principal sectors of the science and technology enterprises in China and the United States. Its theme was selected to provide opportunities for broad-based, far-ranging discussions centered on the changing demands for engineering education in the knowledge-based global economy. Underlying the selection of this theme is the assumption that a deeper understanding of and appreciation for differing perspectives and approaches to the policy components of these issues are important. Improved understanding in both countries will result in better planning and implementation—nationally, bilaterally, and regionally—for the effective and balanced development of a global workforce.

### **PROGRAM TOPICAL AREAS**

The seminar was organized around three topical areas: I. Globalization of Engineering Education; II. Lifelong Learning & Distance Education; and III. Innovation and Creation in Engineering Education. Elements of all three topics were addressed in Shanghai and in Beijing, as are reflected in the Technical Program appended to this Executive Summary. This executive summary is organized mainly by topical area, not by geographical or temporal proximity of the presentations. There were also keynote addresses presented in Shanghai and Beijing, two each by U.S. and Chinese speakers. These are briefly noted in this executive summary.

## **OPENING CEREMONY REMARKS**

Remarks were presented at the opening ceremony in Shanghai by Xu Kuangdi (President, Chinese Academy of Engineering and former Mayor of Shanghai), Xie Shengwu (President, Shanghai Jiao Tong University), J. Thomas Ratchford (Professor at George Mason University Law School and Director of the China-U.S. S&T Policy Cooperation Program), and Yan Juanqi (Vice Mayor of Shanghai). Several themes recurred in these remarks. First, the importance of the China-U.S. bi-lateral relationship to global economic prosperity and world peace was noted. The role of engineers and scientists in maintaining a friendly relationship even in the face of challenging diplomatic problems was lauded. There were mutual concerns about the future of engineering talent because of a trend in both countries for an increasing number of talented students to enter fields such as finance and business. This in turn provides challenges to encourage better public understanding of engineering and science and to reform curricula and teaching methods in engineering.

## **SHANGHAI KEYNOTES**

The U.S. co-chair of the seminar, Edward Alton Parrish, was not able to attend for health reasons. His keynote address was presented in print. In it he identified the primary challenges facing engineering education in the years ahead: a thorough grounding in fundamentals with necessary depth in the appropriate discipline consistent with the degree sought and the highest professional competence; effective skills for success in life—the so-called “soft” skills (which include the ability to communicate orally and in writing; leadership and intellectual maturity; understanding of and appreciation for literary and aesthetic arts which enrich lives; ability to work in multicultural, interdisciplinary teams; appreciation for the impact of technology on society, including ethical, economic, political, safety issues); and sustainable lifelong learning skills. He went on to discuss how Worcester Polytechnic Institute is addressing the challenges.

The U.S. keynote in Shanghai was presented by Stephen Director. His theme was globalization of engineering education. The University of Michigan-Shanghai Jiao Tong University bilateral collaboration features several mechanical engineering education courses offered by Michigan faculty on the Shanghai Jiao Tong University campus. The importance of new topics and themes in engineering courses, such as a course on Global Product Development, was also noted. Such courses provide engineering graduate students with hands-on experience in the development of global products as well as the process of global development of products.

The Chinese keynote in Shanghai addressed the concepts of talents and education in the structure and reform of the educational system. Weng Shilie identified five major trends for education in the 21<sup>st</sup> century: integrating education, research and manufacturing; synthesizing science and technology; rationalizing social development; globalizing the economy; and realizing lifelong education. Good education requires knowledge, competence and quality. Engineering education has unique demands on the educational system because of the need to transmit knowledge of experimental practice. In engineering, “Genuine knowledge comes from practice.” In China, efforts are being made to strengthen experimental practice through provisions of better research facilities and experimental bases.

## **BEIJING KEYNOTES**

The Chinese Keynote in Beijing was presented by Wei Yu. The multidisciplinary requirements of modern life, and by extension the engineering professions, was emphasized in his address. Engineering education has to adapt to this trend just like other elements of everyday life. Within engineering this means that students in one specialty (such as mechanical engineering) need to become expert in other fields (such as computer science). In addition to changes in course content there are also revolutionary changes occurring in the way engineering knowledge is learned. Web-based learning is of special attraction, since it provides an opportunity to design courses (from kindergarten through university) that are carefully balanced between range and depth in the subjects offered.

The concept of “learning by doing” was applied to these diverse educational challenges and attention given both to principles and application. He went on to address the relevance some general educational reforms have for engineering education reform.

Public-policy impacts of globalizing engineering education were the topic of the U.S. keynote, presented by J. Thomas Ratchford. He pointed out that producing technology is only one element of the societal role of engineering. Transmitting engineering knowledge, both explicit and tacit, is just as important. After reviewing basic global trends in science and technology, such as investments in technology, value of technology, a more technology intensive economy, global convergence in technology and education, and the decreasing role of governments in technology development, this keynote went on to examine best practices for obtaining and utilizing knowledge. Finally, the interactions between policies specifically for engineering education and more general policies that broadly affect education were outlined and delegates were challenged to integrate technical and policy considerations in their own work.

## **CONCLUDING CEREMONY REMARKS**

The seminar officially closed on the evening of October 24. The concluding ceremony featured remarks by Zhou Bingkun (Vice President of NSFC); Li Wei, (President of Beihang University); Winfred Phillips (Vice President, University of Florida); Mrs. Wei Yu (Ministry of Education of China); and Shen Shituan ( Former President, Beihang University). These distinguished educational leaders of China and the U.S. noted the opportunities for continued cooperation that were identified in the seminar sessions and agreed to proceed to implement at least some of those opportunities in coming months and years. These remarks are reflected in the conclusions and recommendations sections noted below in this executive summary.

## **TOPIC I. GLOBALIZATION OF ENGINEERING EDUCATION**

The development of the global economy has produced more companies with multi-national bases. International cooperation and collaboration for engineering is becoming a common phenomenon in companies as well as universities and other organizations. Countries are establishing supportive public policy agendas, and mutual recognition of professional credentials is of growing

importance because engineers are more frequently moving from one place to another across national boundaries. Further, engineering designs need to take account of both local and global cultural perspectives. All these concerns have increased demands for educating new engineers with international perspectives.

The seminar addressed questions of what influence should globalization have in shaping policies related to engineering education and in the process of policy making at national and international levels. How should engineering education curricula and programs be adapted to match this changing environment? How should accreditation (and reciprocal recognition of credentials) in different countries be handled?

Speakers focused on the many challenges facing higher education, especially engineering education. Roberts Jones, for example, noted the need for substantial restructuring of the traditional institutional roles in preparing engineers. This theme of reform in engineering education was continued by Wang Sunyu, who emphasized its importance in enhancing industrial competition and enhancing the professional stature of engineers. Gretchen Kalonji emphasized the importance of international experiences for engineering students at both the undergraduate and the graduate levels. The successful Sichuan University-University of Washington joint program was cited for its contributions to enhanced educational and research experiences and to better understanding of cross-cultural education in engineering.

Ed Yang addressed university-industry issues and opportunities. He noted the growing importance of industry partnerships with universities in this age of globalization and new internet technologies. Globalization implies collaborations and mobility of the engineering workforce, trends that have accelerated in recent years. These trends across international borders in turn raise questions of equivalence in educational content and standards, professional qualifications and accreditation (of both institutions and individuals), as well as holistic education for more efficient global collaboration. New internet technologies provide opportunities for enhanced instructional efficiency. Industry and educational institutes should also strive to contribute toward improved productivity, innovative new business models and enhanced quality of life around the world. Winfred M. Phillips and Wu Qidi both raised relevant aspects of this complicated set of technical, policy and educational issues. This family of topics related to accreditation was perhaps the most strongly discussed at the seminar and is expected to lead to additional cooperative efforts in the future. One aspect of this set of topics was discussed by Yu Shouwen, specifically the internationalization of engineering education and the changes that have taken place in China's educational system as a consequence. Alexander DeAngelis noted this internationalization trend is consistent with an overall, rapidly increasing globalization of science and engineering research and education; NSF international programs reflect this trend. Chen Huai provided similar insights on the evolution of Chinese science and engineering toward a global structure.

## **TOPIC II. LIFELONG LEARNING & DISTANCE EDUCATION**

The rapid pace of technological change requires engineers to learn continuously throughout their careers. It is important to know how they can best achieve life-long learning, and how universities and companies can best provide opportunities for such learning. The seminar addressed this issue as well

as questions such as what role universities should play in retraining engineers for career changes later in life.

Lifelong learning (continuing education) has emerged as one of the highest priorities for engineering educators around the world. Speakers at the seminar addressed both the pedagogy of lifelong learning and its implementation. For example, Xie Qihua emphasized the importance of continuing education in facilitating technological innovation in a leading Chinese company, Baosteel. Pedagogy and implementing technology came together in the presentation by Huang Jin on e-learning and software engineering education. She outlined the interdependencies of various components of the “educational platform” to successful distance learning. Eric Hamilton pointed out three frontiers in e-learning: technological change, learning in distributed settings, and pedagogical developments at the intersections of these. Jane Prey noted the work of the Digital Library Initiative, an NSF effort to support development of excellent educational materials of students, teachers and the general public. Keh Tung described how a major U.S. company, General Motors, applies a variety of technologies and approaches to develop competitive talent. “Training the trainers” is an important element of this strategy. Jack Wilson reviewed how computing, communication and cognitive science advances have driven changes in engineering education. He described how new formats, such as computer based courses, have in turn led to changes in content of curricula.

### **TOPIC III. INNOVATION AND CREATION IN ENGINEERING EDUCATION**

The soul of engineering is innovation and creation. The rapid advancement of science and technology has made this issue even more crucial for engineering education. Increasingly, knowledge management systems and industry-university partnerships, as well as incubators and technology transfer offices, are playing significant roles.

Explicit knowledge is generally taught well and transferred easily. Implicit or tacit knowledge, frequently referred as “know-how,” is not taught well and becomes an even more difficult objective to implement in the global science and engineering environment. The seminar addressed questions like: how can the principles of knowledge management be applied to strengthen engineering education in the global economy? How can the community of engineering educators strengthen students' identity, encourage critical thinking and empower students with the capability of innovation and creation? What role can research parks play? What about the role of partnerships between universities and companies in preparing students to be future innovators?

Incorporating innovation in the engineering education curriculum has been an important element in the success of Shanghai Jiao Tong University. University President Shi Shengwu set the tone for seminar discussion of this topic by noting the roles of widening the teaching platform, hands-on experience, and a new credit system in fostering creativity among students. Jun Ke highlighted the role of engineering education in the development of China during the remainder of this century, and described a very exciting pilot program emphasizing undergraduate research undertaken at the University of Science and Technology, Beijing. The need for quality assurance in engineering education was the important theme addressed by Richard Anderson. By comparing the U.S. and European models, he was able to provide analysis relevant to China's interests in the globalization of engineering education.

Innovation and creation in engineering education was the theme of remarks by Zhou Zhewei. He addressed the needs of local companies as well as broader needs for continuing education. The need for engineers to identify social needs and to develop innovative products and services to address those needs is the heart of engineering entrepreneurship, according to Frank Huband. This is reflected in trends for engineers to learn “soft skills” such as negotiation, finance and marketing. Knowing what to learn is only part of the challenge, however. How students should be taught innovation and creativity is just as important. It is this question of “how” that was addressed by Xie Youbai, who concluded that students must master knowledge acquirement, integration and utilization, not just benefit from knowledge transfer. James Melsa noted that for this process to succeed, and for the “global skills” of students to be fully developed, a network of institutions (including companies) and individuals must be involved. He offered the Global Academic Industrial Network as one successful example.

## **CONCLUSIONS AND RECOMMENDATIONS**

The U.S. and Chinese participants learned a great deal from the formal presentations and, to an even greater degree, from the discussions and personal interactions. All in attendance thanked the U.S. National Science Foundation and the National Natural Science Foundation of China for making this possible.

### **Conclusions**

The participants learned that:

1. China and the U.S. share many objectives. The major interests and goals of the Chinese and U.S. engineering educators are mutual ones.
2. The major topics addressed at this seminar provide appropriate challenges for engineering educators in both communities. These include:
  - A. Globalization (Markets)
  - B. Education Reform (Innovation, Creation)
  - C. Continuing Education and e-Learning
  - D. Quality Assessment and Accreditation

An integrating theme of the globalization focus is economic opportunity. There is a clear indication that a continuing China-U.S. bilateral conversation on engineering education is important, and that it can be mutually beneficial and serve as an introduction to broader opportunities for reform of policies and practices. Both sides believe that technology is a critical resource for increasing economic opportunity, and that engineering education is a cornerstone of the structure of policies and practices that will assure the opportunity becomes a reality. As Beijing keynote speaker Tom Ratchford noted, (this was) “... a precedent setting bilateral conference on engineering education.”

### **Unfinished Business**

Moving forward, the delegates on both sides expressed the wish to seize the opportunity provided by this seminar to assist in the orderly development of our growing mutual interdependence.

The following four tasks have been identified as worthy of continued investment of time and effort of delegates from both countries.

1. Accreditation and Quality Assessment - Dr. Weng Shilie, Dr. Shen Shituan and their colleagues will discuss this interest with the Chinese Academy of Engineering and the Chinese Ministry of Education and contact the U.S. Accreditation Board for Engineering and Technology (ABET) to explore potential cooperation. The NSF and NSFC would be potential sources of support.

2. Globalization of Engineering Education - Industry and markets are global. Companies in the world economy require a high level of technology, as well as managerial and technological competence, to compete in the global marketplace. External constraints imposed by this global marketplace are similar in China and the US. Exchanges between institutions as well as individual study and training programs should be increased. There is mutual interest in developing strong players in the global industrial market. Engineering educators can play an important role in this process.

3. Lifelong Learning and Distance Education (Continuing Education and e-Learning) – The first China-US agreement emphasizing e-Learning opportunity was signed the week of this bilateral seminar on engineering education. China and the US are interested in extending existing programs in continuing education and in developing further economies of scale and access afforded by e-Learning. Further conversations on e-Learning are clearly desirable.

4. Innovation and Creation in Engineering Education (Engineering Education Reform) - China clearly has developed an intense technological focus over the last 20 years. Engineers are growing in numbers and in prestige. The debate over national funding priorities in China and in the U.S. should challenge the engineering communities in both countries to play a more participatory role in the policy process.

The themes of (1) Accreditation and Quality Assessment, (2) Globalization of Engineering Education, (3) Lifelong Learning and Distance Education, and (4) Innovation and Creation in Engineering Education are timely and important issues in both China and the United States. In the United States these issues, especially the last three, are especially relevant to the National Science Foundation (NSF), particularly in the Directorate for Education and Human Resources (EHR), whose mission includes the development and nurturing of a globally aware science and engineering workforce. In addition, while the focus of this seminar was on engineering education, the areas of common interest actually extend well beyond engineering to other postsecondary topics, and include some issues in K12 education.

The issue of Lifelong Learning and Distance Education is critical to the Workforce Priority Area that both NSF and the National Science and Technology Council at OSTP are pursuing. Eric Hamilton's paper in the Seminar Proceedings focuses on the lack of research currently available to document cost-effective approaches to distance education, and argues that even the existing research base will soon become outdated by developments in distance education technology and by a rapidly growing research base in understanding net-based learning and communication. China has a relatively small investment in distance education now compared to its population. Additionally, most of the distance education is relatively outdated by US standards, is based on (one-way) synchronous satellite presentations of lectures, and does not benefit from Internet platforms. Yet as the presentation from Huang Jin suggested at the end of the seminar, the basic features of current distance learning state-of-

the-art programs in the United States may be realized soon on Chinese language, internet-based platforms.

The research and evaluation questions that arise, though, from these current platforms and from the platforms that will be available in the next decade are enormous. It appears that one of the most promising areas of collaborative activity, with significant value-added for both countries, will center on research and evaluation of distance learning modes, both in formal higher education structures and in corporate/workplace settings.

Some collaborative activities are planned or have already taken place. NSF and the Office of Naval Research held a workshop on February 6-7 at California State University at San Bernardino designed to produce a research agenda in Distance Education. The NSFC sent a participant for this workshop as an initial step in spurring research collaboration between US and Chinese investigators. Additionally, partly as a result of the planning for the bilateral seminar, EHR suggested that distance education should be an area of emphasis adopted at the November 12-14 Executive Secretary's Meeting in Guilin of the US-China Joint High Level S&T Committee. There was agreement in Guilin that a workshop on distance education and digital libraries would be a promising topic for such a workshop.

There are other areas of common interest in evaluation of engineering education programs. The Chinese participants had an unusually sharp focus on expanding engineering education to include more content to accommodate global product design and project-based instruction. How to pack all that into a degree (or workplace) structure was a recurring question. At the same time, they are grappling with establishing an ABET-like structure for quality assurance in engineering programs. In addition, how do we establish benchmarks to measure or evaluate international collaborations? As part of a broader international strategy, NSF and NSFC should consider explicitly welcoming collaborative research and evaluation proposals. .

Another area of potential collaboration involves primary and secondary science education. It appears that some in the Ministry of Education are embracing inquiry-based science education reforms of the type that are now being called into question in the United States. Perhaps NSF should consider the possibility of inviting a distinguished, senior science and engineering educator from the Ministry of Education to visit the United States both to witness current U.S. approaches and thinking in this area and to lecture on China's reform efforts.

The seminar participants discussed ways to help build a forceful and coherent set of strategic collaborations from the many opportunities that are surfacing from the seminar. One of the ideas includes a Symposium on International Collaborations. There are some very interesting models of US-China collaboration in engineering education. Representatives of these models could profitably be brought together in a forum to explore best practices. Example models include those of the University of Michigan and Shanghai Jiaotong University in which students from the University of Michigan spend time in Shanghai, the University of Washington and Sichuan University in which undergraduates spend time in each others campuses, and the University of Iowa program. NSF's Education and Human Resources Directorate (EHR) and the East Asia and Pacific Program (EAP) of NSF's Office of International Science and Engineering could consider organizing such a forum. NSF's Division of Undergraduate Education (DUE) may be interested in Course, Curriculum, and Laboratory Improvement Program proposals to develop collaboration programs for courses and curriculum development, special projects and centers, etc, involving some extensions of models like

the ones from Michigan and Iowa State. NSF's Division of Research, Evaluation, and Communication (REC) should consider supporting evaluation activities associated with those collaborations.

It is imperative that China and the US share best practices in engineering education. Issues include the adaptability, communication skills, technical competence and life long learning ability of engineering graduates. In engineering curricula, care and efficiency are needed as we continue to add more and more material to the array of courses demanded of students. Industry internships and exchange programs are of special interest in both nations. By learning from each other it will perhaps be possible to create an ever- improving model for effective, lifelong engineering education.

### **Recommendations and Next Steps**

The seminar participants felt strongly that some issues dealt with need further work and that these issues are worthy of additional time and effort. Specific next steps in four areas were identified:

#### **1. Accreditation and Quality Assessment**

An important unresolved issue is accreditation and quality assessment. The prospect of the participants and/or the organizations they represent, assisting China in the development of a unified accreditation system for the various engineering disciplines generated considerable excitement during the seminar series. At the conclusion of the seminar in Beijing, it was expected that this assistance may begin with "pilot" evaluation programs based on the outcomes based assessment process developed by ABET. The focus of these visits would be the civil engineering discipline because the existing Chinese accreditation system is most advanced in this discipline.

Concurrent with the U.S. delegation's visit to China, Dr. Zhou Ji, the Chinese Vice Minister of Education, was visiting the ABET headquarters in Baltimore, Maryland. Dr. Zhou Ji was visiting ABET to determine the level of interest in ABET participating in the development of a comprehensive engineering accreditation program for China. Based on Dr. Zhou Ji's comments to Dr. George Peterson, the Executive Director of ABET, China desires to develop an accreditation system similar to ABET in the United States. The system envisioned would cover all of the engineering disciplines, and it would be controlled by the profession using volunteer peer reviewers. Dr. Zhou Ji thought this could be best accomplished by setting up a non-governmental accreditation entity.

The next step is for Dr. Zhou Ji, or his designated representative, to begin setting up the accreditation infrastructure in China. Once this organization is in place, it is suggested that it consider entering into a Memorandum of Understanding with ABET concerning a variety of joint activities. ABET is willing and anxious to assist in this endeavor.

#### **2. Globalization of Engineering Education**

There was a consensus to continue the discussions initiated at the seminar on current trends and practices related to globalization of engineering education. The accession of China to membership in the World Trade Organization (WTO) makes these conversation even more helpful. Future topical meetings may very well be indicated. NSF and the NSFC are logical partners in such an effort.

Specific steps that may be taken in response to the Shanghai/Beijing Seminar include:

- Appoint a collaboration team to continue correspondence. Coordination of further activity would include the Chinese Academy of Engineering and U.S. entities.
- Individuals to pursue this issue in more detail would include Jim Melsa and Shi Lie Weng. Gretchen Kalonji and Steve Director would be potential leaders on the U.S. side on exchange programs.

### **3. Continuing Education and e-Learning**

The following suggestions offer some reasonable “Next Steps” that could be taken collaboratively between NSF and NSFC to promote common understanding and problem-solving in approaches engineering education in the United States and China:

- Collaborative research and evaluation of distance learning modes in formal higher education and corporate/workplace settings
- Organizing a US-China Workshop on Distance Learning and Digital Libraries (adopted at the US-China Executive Secretaries Meeting in November 2002)
- Welcoming collaborative research and evaluation proposals that focus on evaluation of engineering education
  - Inviting a senior Chinese educator to visit strategically chosen sites in the United States to witness current US approaches to educational reforms and to lecture on China’s educational reforms
  - Inviting proposals to develop collaborative programs for courses and curriculum development, special projects and centers, involving extensions of the Michigan and Iowa State models.
- Organizing a workshop to explore best practices in US-China educational cooperation: e.g., the University of Michigan-Shanghai Jiaotong University , University of Washington-Sichuan University, and University of Iowa programs
- Inviting Course, Curriculum, and Laboratory Improvement Program proposals to develop collaboration programs for courses and curriculum development, special projects and centers, etc, involving some extensions of models like the ones from Michigan and Iowa State, and supporting evaluation activities associated with those collaborations.

It should also be noted that a strong opportunity results from the Ambow platform being available. This could be further investigated under the leadership of Jack Wilson and Huang Jin

### **4. Engineering Education Reform**

The continuous change underway in engineering education results in reforms that occur at an increasing pace. Many of those reforms are subsumed in the first three topics discussed above. There is, however, merit in addressing the overall trends in engineering education reform as a topic on its own.

Perhaps the best elements of a Sino - US curriculum, and the reforms they have resulted from, could be compared. The U.S. NSF can share best practices from its coalitions, and the NSFC and other Chinese institutions could do likewise. Gretchen Kalonji could provide leadership on the U.S. side, and the Dean of Undergraduate Education at Shanghai Jiaotong University, Liu Niancai, could do so for the Chinese. Part of their charge would be to define a future seminar topic.

# ISSUES FOR ENGINEERING EDUCATION

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## **Introduction**

The environment that engineers must face is considerably different today from that even a decade ago, and no doubt will change substantially in the future. For example, within the US, the National Science Board has called for every citizen to know more mathematics than ever before, have some understanding of technology and its impact on society, be able to use computing resources, and develop lifelong learning skills. In addition, employers are encouraging broad-based undergraduate programs for engineering students that will prepare them for significant job changes over the course of their careers. Similar positions are being taken within many countries, driven by globalization.

As a consequence, engineering educators in many countries appear to have agreed that their programs should lead to three principal outcomes: a thorough grounding in fundamentals with necessary depth in the appropriate discipline consistent with the degree sought and the highest professional competence; effective skills for success in life—the so-called “soft” skills (which include the ability to communicate orally and in writing; leadership and intellectual maturity; understanding of and appreciation for literary and aesthetic arts which enrich lives; ability to work in multicultural, interdisciplinary teams; appreciation for the impact of technology on society, including ethical, economic, political, safety issues); and sustainable lifelong learning skills. Disappearing national boundaries add to the complexities of developing appropriate curricular and extracurricular experiences for students such that these outcomes are achieved.

Another factor that will affect engineering graduates is that many will find themselves engaged in non-engineering fields. For example, an NSF reported that only 38 percent of those with engineering BS degrees were working as engineers. Another 48 percent were found to be in areas related to science and engineering, many of who were managing technology. There is little question but this trend will grow in the coming years.

Desirable attributes such as the ability for critical thinking as well as for conceptualizing long were associated with studies in the liberal arts. Engineering programs in the US, driven to some extent by the new ABET *Engineering Criteria*, increasingly are recognizing the value of making liberal arts studies an integral part of their curricula. However, simply adding course requirements is not sufficient to inculcate the necessary abilities in students.

This paper will examine these issues in some depth. Examples will be provided illustrating how Worcester Polytechnic Institute is addressing them.

## **Liberal Arts**

Generally speaking, a liberal arts education is intended to provide general intellectual ability rather than a particular skill. The term itself is derived from Medieval Latin, namely, *artēs liberālēs*,

which included studies in the trivium (grammar, logic, and rhetoric) and the quadrivium (geometry, astronomy, arithmetic, and music). Mastery of the trivium led to a BA degree, while additional study led to specialization in theology, law, medicine, or the four sciences of the quadrivium.

Modern liberal arts programs have evolved from this foundation and continue to focus on developing critical thinking skills, an ability to communicate, and the capacity for continuous learning. Driven by concerns from parents and students that such an education does not prepare graduates for immediate employment, liberal arts programs now are moving closer to technological programs, in that they are beginning to recognize the importance of integrating technology into the curriculum, as well as providing students opportunities for gaining international experience and helping them understand and appreciate cultural diversity. Thus, liberal arts studies and those in engineering programs are beginning to overlap.

A recent report from Wake Forest University presents results from a survey of liberal arts educators in the US. [1] Among the findings is a ranking of important attributes of a liberal arts education, and is repeated here in descending order:

- Develops critical thinking skills
- Develops abilities to think and communicate one's own thoughts
- Teaches a student how to learn and conceptualize
- Develops abilities to deal with issues and questions with no single answer
- Provides a broad picture of the world around them
- Provides greater appreciation of different perspectives
- Develops a more self-aware and informed citizen
- Develops core values and sensitivity to ethical issues
- Acquaints students with the major ways of knowing that have characterize human achievement
- Develops self-confidence
- Develops fluency in a foreign language

Engineering educators and employers likely would agree that most if not all of these are necessary attributes for engineers as well. In fact, many consider engineering education the new liberal arts because such studies are concerned with developing literacy and communication skills (trivium) and deal with the physical world (quadrivium). Furthermore, engineering education provides a foundation for careers in many other fields, including law, medicine, business, finance, technical sales, and the like.

Interestingly, ABET's *Engineering Criteria* may be interpreted in terms of *artēs liberālēs*. Criterion 3 Program Outcomes specifies eleven specific attributes that graduates of accredited engineering programs must attain at graduation. They can be arranged according to their membership in the trivium and quadrivium:

#### Trivium

- Ability to function on multidisciplinary teams
- Understand professional and ethical responsibilities
- Ability to communicate effectively
- Understand impact of engineering solutions in global and societal context
- Ability to engage in lifelong learning

- Knowledge of contemporary issues

#### Quadrivium

- Ability to apply knowledge of mathematics, science and engineering
- Ability to design and conduct experiments, analyze and interpret data
- Ability to design a system, component, or process to meet desired needs
- Ability to identify, formulate, and solve engineering problems
- Ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

In addition, Criterion 4 Professional Component requires a general education component to complement the technical content that is consistent with both program and institutional objectives. Consequently, there is some validity to the claim that a modern engineering education reflects a liberal education.

#### **Achieving the Outcomes**

Many of the outcomes presented above may be acquired as explicit knowledge [2] that can be learned from textbooks and associated studies. On the other hand, tacit knowledge is represented by know-how. It is very difficult to teach and to transfer, as it has to be done indirectly through metaphors and examples. In truth, it can be gained only through experience. In particular, developing the soft skills referred to earlier, especially in a global context, and inculcating ability for sustainable lifelong learning are challenges engineering educators face in having their students acquire this tacit knowledge. These are very difficult topics to teach in the traditional classroom paradigm.

At WPI, the move from a traditional curriculum to project-based education occurred some thirty years ago. The faculty eliminated prescribed sequences and prerequisites, allowing students to tailor their programs to meet individual needs. The entire educational experience was focused on outcomes—mastering subjects rather than passing specific courses. Thus, WPI changed its approach from teaching centric to learning centric, a focus that still exists today.

Academic programs at WPI are experiential in nature, providing many opportunities for students to learn by doing and thereby acquiring tacit knowledge. Three capstone projects are required for all students and are used to measure learning outcomes. The first is normally done in the sophomore year and involves a coherent sequence of courses in the humanities and arts, followed by a significant paper. This results in 18 hours of credits and ensures that every science, engineering, or management student has an academic minor in the humanities and arts. The second is an interdisciplinary project, equivalent to three courses in credits, nearly always done in teams of three or four students working with a faculty adviser during the student's junior year. It is particularly important as it is focused at the intersection of science and technology on the one hand and society on the other. It is here where students encounter questions involving ethics, safety, the environment, how to function and contribute to teams, and project management issues. Because these projects are interdisciplinary in nature and generally fall outside the domain of expertise of some are all team members (including the faculty advisor), they are excellent vehicles for learning to learn. Finally, there is the design project in the senior year, also worth the equivalent of three courses in credit. This is similar to a senior thesis found at other schools and involves the application of in-depth knowledge in a particular discipline. Many of

the junior and senior projects are defined and funded by external sponsors to whom both oral and written reports are presented.

More than 60 percent of WPI undergraduates complete one or more of these projects at centers located around the world. Because there are four seven-week terms during an academic year and the relationship between courses and projects, students may complete their projects without lengthening the time to their degree. As a result, WPI has had project sites located all around the world for more than 25 years, including London, Venice, Bangkok, Puerto Rico, Costa Rica, Ireland, Germany, Hong Kong, Madrid, and Taiwan. Some projects are completed in a single term, while others continue from team to team with the same in-country sponsors.

Because of these features, graduates of the University possess the attributes listed above, and are especially well prepared to function in a global, knowledge-based economy.

### **Conclusion**

There is little question that the role of technological universities in preparing future engineers will be even more important in the future than in the past. For example, half of the economic productivity in the USA since 1950 has been due to innovation and the underlying science and engineering. The knowledge-based societies of the 21st century will value even more highly research, innovation, and human capital as the principal assets of nations. The convergence of liberal arts and engineering programs will serve to improve the citizenry of the world by fostering a higher level of learning.

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## **GLOBALIZATION AND ENGINEERING EDUCATION**

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The Global Product Development course provides engineering graduate students with a hands-on experience in the development of global products as well as the global development of products. Both are important for future engineers. In this course, which has been offered jointly with Oxford University (UK) and Seoul National University (South Korea), faculty from all three universities lecture in a global classroom that is created using videoconferencing between the three institutions. In addition, students work in global teams throughout the semester to develop products for global markets. The course provides students with an understanding of time, space and cross-cultural barriers that need to be overcome in the new distributed workplace of global companies.

As part of the University of Michigan (UM), Shanghai Jiao Tong University (SJTU) collaboration, several mechanical engineering courses are being offered by UM faculty on the SJTU campus. One of the first courses taught to a selected group of SJTU students was Introduction to Design and Manufacturing (ME250). This is first of the three core courses in design/manufacturing for mechanical engineering undergraduates at the University of Michigan and provides students with an understanding and appreciation of various design and manufacturing issues, and their interplay, which lead to quality products. A key aspect of this course is a "hands-on" manufacturing experience and teamwork involving a semester-long group project. Teaching this course in SJTU provides a unique perspective on the similarities and differences between the UM and SJTU educational systems, student experiences and expectations and the academic culture.

# **CHALLENGES FACING ENGINEERING EDUCATION**

## **THE BUSINESS VIEW**

**Roberts T. Jones**

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Around the world, governments, the private sector, and the public are becoming increasingly aware of the positive impact of successful higher education on economic stability and national security. Moreover, the key to quality higher education is clearly related to successful engagement in high level math and science courses throughout the k-16 educational experience. Yet, today's students entering higher education are not well prepared in math and science and our universities are facing a drop off in the number of students taking engineering, science, and technology, degrees.

Further compounding the problem, our institutions of higher education are faced with the daunting challenges of meeting the escalating demands of a rapidly changing world. Engineering education in particular is faced with an ever changing set of expectations, definitions, new technologies, broadened applications, and widening range of preparation among entering students.

The growing gap between student preparation and engagement and the demands of an ever changing world suggest the need to reassess the structure, delivery, content, and achievement expectations of our higher education systems. What is certain and inexorable, is that the external pressures on our engineering education systems will not abate. Public and education policy leaders must come to understand that this not a one time issue. Rather we are called to transform the management of our education enterprise into a system of 'continuous improvement' which respects and reacts to the constantly changing external environment.

### **DEMAND AND SUPPLY**

In most industrialized nations and many emerging countries, the long term demographic trend suggest slower population and labor force growth contrasted with higher skill demand and increased job growth. In particular, the demand growth for engineers, computer, physical, nuclear, biological, and mathematical scientists are growing at experiential rates. Growth in these fields is projected to increase by over 50% over the next decade.

Yet, in the United States, the number of degrees granted in many of these fields has been dropping precipitously. Over the past ten years there has been a drop of over 15% in the various technical fields. While engineering degrees dropped 14%, computer science 22%, and math 26%, there were corresponding increases in such social science fields such as psychology at 77%. These gaps are expected to increase as the population ages and the working age labor force percentage shrinks. Meanwhile, developing technologies and newly competitive countries will continue to increase the demand much faster than the traditional supply system can produce degreed students.

Finally, it is important to recognize that this growing trend is relatively impervious to short term economic fluctuations. The issues arising from long term demographic shifts and slow growth in the supply chain need to be addressed regardless of the inevitable shifts in the economy.

### **GROWTH IN STUDENT ENROLLEMENT**

Both China and the United States are experiencing significant growth in higher education enrollments. While China has seen a 384% increase over the past few years it will face even steeper increases in the coming years due to its successful investments in primary and secondary education. The United States is approaching 75% of secondary school students entering post secondary education within two years of graduation. As these numbers continue to climb, universities will be faced with increasing numbers of students who are less prepared for rigorous degrees in engineering and science.

As we increase the student participation rate it is more apparent that many students have not had sufficient preparation in math, science, and technology. In the US less than 50% of our secondary school students have taken at least one high level math course and less than a third have had a rigorous science course before graduating. The quality of the curriculum and achievement is likely to weaken even more as we dip deeper into the pool of participating students. Increasingly universities and engineering schools will be faced with a series of challenges.

First, this issue in itself portends for fewer math and science majors. Without the necessary preparation, these students will migrate to less challenging fields. Second, universities will be faced with the pressure for increased investments in remedial programs. In order to survive the demands of higher education these students will need increased assistance not only in math and science, but in reading, writing, and general analytical skills. Third, universities will have an increased problem retaining students through degree completion. Many will drop out either from the University or from more rigorous majors. Statistics in the US show a direct correlation between increasing populations and decreasing retention rates.

All in all this challenge calls on the universities to build more active partnerships with the primary and secondary education systems in their countries. They must communicate the ever changing curriculum and achievement expectations, provide professional development opportunities for teachers, provide increased attention to teacher preparation, and assist in student support programs. Significant increases in the numbers of science and engineering students can only be achieved by effectively improving the supply system.

### **RESTRUCTURING CURRICULUM**

Increased knowledge, new technologies, and expanding regulatory standards affirm the need to significantly restructure the traditional engineering curriculum. It is simply impossible to “add” new courses and requirement with the advent of each new development. Schools are faced with the need to establish a system for continuously updating the curriculum, re-assessing the ‘basics’ versus the ‘specialty’, updating applications and case studies, updating their own technologies, and ensuring opportunities for the professoriate to maintain currency in their expertise.

Globalization brings a whole new set of variables. Engineering students will enter an employment world which is characterized by multi-national standards and applications as well as increasing numbers of international regulatory requirements. Whether included directly in the

curriculum or in the development of and in accessing new reference systems, engineering schools must ensure currency in the world of application.

Like other professions, engineers now find themselves having to apply their trade in a multifaceted environment with increased responsibility. There is growing pressure from employers to improve students interpersonal and communication skills, increase their knowledge of related fields and integrated applications, and to significantly increase their 'creative' abilities. Normally, these would all require additional courses and time on task, but now schools are faced with 'integrating' these new requirements into a traditional curriculum.

Finally, employers are expecting universities to prepare engineers for a world of life long learning. Graduates will be entering a dynamic workplace, profession, and economy and will need to possess the intellectual and psychological aptitudes to not only survive but thrive and grow in that environment.

### **NEW LEARNING MODALITIES**

Essentially, higher education is becoming a more customer driven enterprise. We are faced with increases in student populations of all ages, greater ethnic and intellectual diversity, growing numbers of life long and part time students, and the demand for increased efficiency in producing engineering graduates. This means we must have more efficient user friendly systems of learning opportunities. Integration of e-learning and web based systems is obvious and essential, not as alternative to traditional education, but as an integrated part of the learning process. We are experiencing increased impact and efficiency of contextual and application learning both during traditional education and extended learning environments.

There are growing questions about restructuring the basic three to four year degree program. Perhaps, smaller size 'certificate' programs that deliver specific skills and knowledge on a much faster and concentrated basis should be considered. These may be 'structured' as part of undergraduate and graduate degree programs but may be more suited to the delivery of many of the new and ever changing requirements. Such a system is evolving rapidly as in the life long learning market and may well be of value to basic engineering education.

With increases in diversity of preparation and backgrounds of students it becomes increasingly necessary to include a wider variety of learning experiences to address their needs. The assumption that one system works for all students and all curriculum is no longer valid.

### **STUDENT COMPETENCY**

The world of applied engineering has become increasingly dynamic and complex. Employers face constantly changing requirements and the need for graduates who can communicate their competencies and achievements in a manner that matches their expectations. It is insufficient to have graduated from a prestigious university, have a specific degree, or have spent specific time on task as means of communicating competencies. Completing the curriculum and graduating do not communicate the graduate's level of understanding of the world of application, technological competence, or communication skills. Universities now must provide evaluative insight to student achievement and to then create ways of communicating this to employers. This is not limited to 'testing' but may involve 'portfolios' or 'cap-stone' projects, or other means of assessment.

Further, employers, students, and schools are looking for ways to improve the communication of curriculum and competencies. Schools of engineering and employers need to be on the same agenda and maintain a communication upon which both can depend and students need to have the assurance that their educational experience has indeed be ‘relevant’ to those expectations.

### **TIME TO DEGREE COMPLETION**

The growing demands on the traditional engineering curriculum have resulted in a prolonged time frame for graduation. The average engineering student takes five to six years to graduate with Bachelors degree. Constantly adding new requirements and new courses in response to external demand has resulted in an overburdened system. Professors and classes are spread too thin and students spend extended time in order to complete the curriculum. In a market where engineers are in increasing demand students and employers grow increasingly frustrated.

The challenge is to recognize that the pressure for increased knowledge transfer will not abate but, in fact, will continually increase. The question then is how to re-engineer the standard curriculum, how to decide what ‘basics’ to teach in order for students to continue learning after graduation, and what ‘core’ competencies students need versus those which should gained outside the traditional system. This inevitably takes us back to the discussion on ‘certificate’ systems both during and after the standard degree program.

Ultimately, the increasing cost of higher education, the growing demand for graduates, and the need to increase student persistence suggest the need to design our systems to graduate all students on time.

### **CONCLUSION**

All of higher education, and especially engineering education, are being challenged to maintain pace with an external environment whose expectations of content, quality, application, technology, and achievement are rapidly escalating. Indeed, the challenge is how to design an engineering curriculum that is flexible, resilient, and responsive while maintaining the quality of education which has been the hallmark of the university.

The pressure of global markets and increased competition suggest that the engineering education must and will be transformed. It is inappropriate, inefficient, and impractical to leave this change solely to the markets or to governments. The challenge for universities is to confront this changing world with the honesty and intellectual integrity that have long been their hallmark, even if this process reveals the inescapable need for far reaching institutional transformation.

Finally, every nation which strives to maintain pace with the pressures of global impacts must ultimately focus on the effectiveness of its primary and secondary education system. High levels of math and science achievement must be our goal for ‘each and every’ child. This will ultimately determine the success of our engineering schools, our universities, and indeed, our economic security in a global market.

# Engineering Education and Internationalization of Engineering Education

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**Abstract:** This paper deals with the relation between engineering education and the internationalization of engineering education. The paper has first analyzed the changes which took place in China's engineering education system, brought out some problems in the engineering education which need to be solved, explored the way for training China's new engineers, and developed a framework and an outline of a new system for China's engineering education and the relationship of the tendency of the internationalization of education and the development of information technology in the fields of engineering education, so as to make it possible for further discussion and study.

**Key words:** Engineering Education, Internationalization of education, Information technology

## (1)

Engineers' qualification is an inevitable demand in an economic globalization. As a major planner and executive of engineering designing, experiments, quality control and management, an engineer must acquire high qualities and fineness, which are directly related to the economy and safety of engineering. Therefore, serious consideration should be given not only to common characteristics in engineers' qualification in various countries, but also to the special features of the Chinese history and its economic development, and the purpose and steps for implementing the Chinese engineers' qualification in hope of entering the global economic scope.

The engineering education should take it into its conscientious consideration what impact the establishment and enforcement of engineers' qualification will bring about on engineering education and what unshirkable task should be completed in making the engineering education ready for training well-qualified engineers and what kind of work should be done in higher engineering education and continuing education of engineering.

The socialist market economy will apply the market criteria to regulate the human resources of engineers. Therefore, the criteria and demands for engineers' qualification is in no doubt an invisible "baton", which affects a series of practices such as the selection of the students, setup of curriculum, social practice, examination, degree and employment as well, and will have profound impact on the basic elements such as teachers, students, teaching resources and environment.

In this paper, a discussion is focused on how an engineering system could be established, which will fit in well with the Chinese context, and could adapt itself well into self-properness and parallelism.

## ( 2 )

In order to predict the future, it is necessary to make a correct analysis of the present. In the 21<sup>st</sup> century, what will happen in the Chinese engineering education. The following will be the happenings.

Since 1949, China has established an engineering education system which can well fit into the Chinese context. This system contains the engineering education programs of higher learning for undergraduate education and special field of study, engineering education programs at graduate level characterized by master degree and bachelor degree, the engineering education specializing in continuing education, and long distance programs for engineering education including the programs of the university of the air in recent years. At present, there are about 2,100,000 engineers.

All in all there are about 200 universities and colleges which have engineering education as their main components for professional training programs in China, which has formed a system for training the students with a speciality, undergraduates with bachelor degree in engineering, graduates with master degree in engineering and some Ph.D students with doctoral degree in engineering. At the same time, continuing education system in engineering has developed a great deal, and the program for vocational and technical education has been set up for the students. Therefore, it can be said that the engineering education system of higher learning which can meet various needs of Chinese economic construction and social development at different levels has been well established in China. Meanwhile, this system is facing a serious challenge to adapt itself to the economic and social development of the 21<sup>st</sup> century.

It should be pointed out that China has trained over 200,000 engineers, whose continuing education is an important part of education system, which is worth drawing attention once for all. Some key enterprises have established their own training systems, and started to combine the continuing education with the promotion of engineers so as to promote the innovation of knowledge and technology, and to increase the vigor of the enterprises. In addition, the universities of the air set up in 1960's in China and China Education Research Internet (CERNET) have played an important role in engineering education. With the establishment of National Self-study Examination System, some diplomas in engineering fields can be offered, which has made it possible for a society to assist the engineering education through various channels.

Under the leadership of the State Council and State Education Ministry, a great reform has been completed in the engineering education system of higher learning. Due to the merger and reconstruction of the State Ministries and Departments into group corporations and companies, some of 30 universities and colleges of engineering, which used to be attached to Ministries of Machinery, Electronics, Transportation, Civil Construction, Aviation, Metallurgy, Military Industry, etc. have been put under the administration of State Education Ministry, and most of them have been placed under the administration of local governments or related economic sectors. This reform has helped the engineering education to combine itself well with the economic construction, and created a bright future for the engineering education to meet the demands of socialist market economy. In accordance

with the policy “Making the country strong through science and education”, the central government and local governments have increased the investment in education, and so the engineering education is faced with a new developing situation and high demands for its fine quality.

Global economy has brought about the issue of internationalization of education, and proposed the task for engineering education to fit the globalization well. The important change is that concept about engineering and engineers has been greatly changed. The engineering is turning to huge projects, and coordinated and cross-countries engineering projects are coming into being in this new century. The engineers have now got themselves away from the narrow labor division for technical engineers, research and development engineers, designing engineers, management engineers, etc. Now, the emphasis is placed on comprehensive qualities in an all round way for engineers on the basis of labor division, and new requirements have been proposed. Among these changes, the most important is the change in the educational ideology, which is brought about under the global economy. Therefore, the above-mentioned changes should be taken into consideration for the assessment of engineers’ qualification, and related engineering education.

### ( 3 )

In the view of the current situation of China’s engineering education, and in full consideration of new requirements from the new century’s global economy, China’s engineering education has some important issues which need to be studied and tackled.

A new engineering education system which can well meet the requirements of the developments of the new century should be established. On the basis of retraining programs and the analysis of the existing engineering education system, this new system will be more flexible in its transfer from one field to another, will be more characteristic in its personnel training programs, and will be more able to be self appropriate without the division of superiority and inferiority. It will require the authentication of the transfer, connection and matching of various types of engineering education at different levels. Besides, the continuing education of engineering and long distance education of engineering should be recognized at the human resources market and departments on the basis of strict evaluation.

The relatively narrow specialities (580 specialities in various fields of engineering in 1997) which used to be attached to the Industrial Departments and came out from Russian education system should be turned into fairly wider subjects (249 subjects merged in 1997), so as to turn the emphasis on the comprehensive qualities into reality, and combine graduate education of engineering with post-college education, and emphasis the importance of the engineering practice. It is expected that within 6 to 7 years, a new type of “semi-finished” engineers will be turned out in order to meet the requirements of engineers’ qualification.

In regard with the contents of education, the training which used to focus mainly on designing and techniques, should be turned into the training which will concentrate on wide knowledge education for the increase of the knowledge on economy, law, environmental protection, foreign languages, humanities, etc. What is more, the enterprises will be aware that the engineers of various types with excellent comprehensive qualities will be the victorious magic weapon in the market competition for modern enterprises. Those who can develop the new products with the systematic and intellectual property right, know well the regulations of international competition, and are good at the

management and linking all kinds of engineers working together are the most important personnel whom the enterprises badly need for the global economy. So it can be said that the day when the Chinese enterprises will pay really serious attention to engineers will come and will be regarded as the time for the engineering education to develop itself in the earnest and to meet the requirements of the global economy.

The point which should be particularly made here is that how the combination of engineering education with the practice of enterprises will be enhanced is the key factor for modern engineering education to improve its quality. In recent 20 years, a great development has taken place in China's engineering education, but from the viewpoint of the practical links and students' engineering practical ability, the engineering education has been somehow weakened. Some people say that the engineering education has been "softened", which could be explained in the following two aspects. First, the number of the hours assigned for engineering practice has been reduced owing to the uncertainty of the system reform and the lack of the education investment. Second, the number of the teachers with adequate engineering experience is not enough, and the experienced engineers from the enterprises can not enter universities for training programs. Therefore, some people said ironically that China has senior engineers similar to university full professors, but has few professors similar to senior engineers as far as their engineering experience is concerned. That is to say, university professors who train the semi-finished engineers lack the necessary engineering experience. So, how to train the qualified engineers has become a problem which needs to be faced squarely and solved.

Finally, what should be pointed is that engineering education is a systematic engineering project, which involves education, enterprises, human resources management, financial investment, scientific research, etc. If there were no such an engineering education system which could fit well the global economy and could finely coordinate the subsystems, and could shift the power to the legal representatives such as universities, enterprises or social medium organizations for running it at their will under the guidance of the education policy without much interference, the engineering education would not be able to adapt itself to the tomorrow of the global economy.

#### ( 4 )

On the basis of the above analysis, we hope to work out a way for the Chinese engineering training.

Since 1995, the author has written and published two papers in a journal of Researches in Higher Education of Engineering, analyzing "The Way for the Chinese Engineering Training" The initial purpose is to draw attention from the people to this issue. Today, I would like to discuss it once again to get more attention and further discussion.

In order to carry out the work of authentication of engineers' qualification, retraining program should be conducted among 1000000 engineers and senior engineers in China according to the international standards on the basis of the Chinese real situation. It can be learned from the experimental work on the training of architectures and structural engineers. All the universities and colleges, continuing education departments of enterprises and training departments should make efforts to engage themselves in the training and retraining programs. This is the demand from the global economy on the make-up of missed lessons for engineering education, and this is a national task which should be fulfilled in the view of systematic engineering and under the central leadership

of the state departments concerned. It will be involved in the Chinese Academy of Engineering, State Education Ministry, Human Resources Ministry and other departments concerned. Therefore, an overall consideration and planning should be made in advance and all the preparations should be performed first.

Second, under the guidance of the education department, a general plan should be worked out for various institutions of higher learning, continuing education departments, TV universities, vocational schools in accordance with the division of labor based on specialization and demands at various levels. On the basis of the experiments and the different division of labor, the requirements for different universities and colleges should be clarified, the guided standards for quality evaluation should be formulated, the requirements for connection between different universities and colleges should be set up, and a system for various channels to academic education and degree for engineering education should be established.

Third, at the demand for widening the basic knowledge and specialization, engineering education should fit in well with the curriculum designed to meet the needs of 21<sup>st</sup> century for the personnel training of comprehensive qualities. The most important point is that the demand for the amount and value of the engineering practice should be well decided and completed. The minimum amount of engineering practice and the number of the credits for engineering education at different stages should be clearly verified.

Concerning the high-level engineering personnel training, the quality should be greatly improved, the scope of the training program should be extended, and the practice requirements should be fixed for the master students in engineering during their study at university. In addition, personnel training programs in various enterprises should be well combined with the graduate programs and post-doctoral programs at university. In this way, enterprises will be able to possess their own intellectual property right and approaches to develop themselves.

When the continuing programs for training present engineers are carried out, it is necessary to develop remote engineering education and full-time engineering education programs. All the universities and colleges should try to provide various training courses at different levels, and the human resources departments should work out the new regulations for authentication of engineering qualification. The government should set up a virtual university at a large scale according to the huge demand from the society. As for China with a vast land, unbalanced economic development in different areas, and huge population, the virtual university is a way to turn out thousands and thousands of qualified engineers. Undoubtedly, the success in a popularized engineering education will certainly lie in this way of society-running schools and life-long learning, and personnel training through information technology. The “Free University”, and the “Phoenix University”(on line) which have recently developed in the world can well meet the different needs of personnel market. It is regarded as a fast, fine and economical approach for engineers’ training program in order to integrate into today’s global engineering education. The support and demand from enterprises for this approach is the key factor which could decide whether it will succeed or not. The government should issue a favorable policy concerning the regulations and tax for these enterprises which are engaged in the engineering education, on the basis of which international cooperation on the authentication of engineers’ qualification can be implemented.

As a time for the global economy is drawing close to us, we can not afford to wait.

In order to integrate into this global economy, it is important and necessary to develop and retain the engineering education system with its own Chinese characters. Therefore, we need to be determined to push ahead the improvement of engineers' qualification. Based on this work, a framework and criteria for the evaluation on engineering education should be formulated. Under the government's macro-control, the initiative from the enterprises and universities should be brought into full play, and a new way for Chinese-characterized engineering education should be paved in order to meet the requirements of the modern construction in China.

The internationalization of education is primarily determined by the intrinsic nature of education while the economic globalization decided the international feature of education. We had made it a point to gear our education to the needs of modernization, the world and the future. Historically, China has gained a good tradition of active cultural assimilation and culture exchange with other nationalities and countries. It is our goal to achieve the exchange and integration of excellent Chinese civilization with the advanced civilization of the world.

The internationalization of engineering education implies that, in the broad setting of the world economic development and education reform, it is an understanding and an action as well. It is a strive to spread the best of an education and culture while absorbing and borrowing from advanced cultures and to foster talents in international exchange, cooperation and competition. In essence, it is an interactive assimilation by means of exchanging, absorbing, and borrowing useful elements from each other. During the process of this assimilation, we maintain our self-respect and characteristics. The cooperation will only keep us from falling behind. Because the goal of this process is to boost one country's social and economic progress, to exchange cultural and educational exchange between nations and to maintain world peace and development. The education internationalization is to be achieved through worldwide mobility of personnel, namely teaching faculty and students, sharing of information and education resources to a considerable degree, mutual recognition. Of degrees and qualifications as well as their compatibility.

Apart from the international feature of education, we should also recognize its diversity. The cooperation and exchange go hand in hand with the competition worldwide in the area of teachers, job market, student sources, education resources etc. We understand that as a social phenomenon, education always associates with the interest of a nation or a state, and that each country is working at internationally acceptable measures to practice education sovereignty and to develop an education with its own national characteristics. This actually is to strike a balance between globalization and localization.

As far as engineering education is concerned, we should develop a diversified system in terms of investment in education, encourage community education and joint venture. We should also strengthen the effort of information technology application and speed up the high- and- new technology renovation in conventional industries and engineering fields. The government should focus on the adoption of education laws and regulations, the establishment of engineering education system as well as its evaluation and accreditation mechanism, stressing moral education, and eventually the formation of an education system which can meet the requirements of national development and education internationalization.

When we talk about the engineers' qualification and engineering education, it must be pointed out that to invigorate economy we must develop engineering education, become more concerned about it, and respect engineers and their work. Our government has set up the strategic policy, "making the country strong through science and education". So the realization of the science and education is actually meant engineering, which emphasizes the innovation, and intellectual property right. The engineering creates values, and can make the country strong and prosperous. In the course of the establishment of socialist market economy, it is the inexorable law in the human resource market to get rid of the gap between knowledge of intellectuals and their values gradually. When the values of engineers are respected, and their work and status are acknowledged in the society, then the success of China's engineering education will be able to mark its own practical value. The engineering education is an inexorable reflection of economic development and the real value of engineering and technology. This is because there is no example in the world showing that the economy developed without the respect to the value of the engineers' work. Therefore, if science and technology are well respected, engineering is well developed, and economy is invigorated, and if the first priority is well given to the humans and engineers are highly respected, China's engineering education and its huge team of engineers will be able to come out to the world with a completely new outlook.

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# **ACCREDITATION AND MOBILITY OF ENGINEERS IN THE GLOBAL MARKETPLACE**

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**ABSTRACT:** Engineering is a global profession, with multinational and transnational corporations employing engineers around the world. The United States Accreditation Board for Engineering and Technology (ABET) has addressed the issues of quality assurance outside the United States through consultations, program evaluations and mutual recognition agreements in response to requests within the United States and throughout the world. ABET has long cooperated with engineering organizations and societies beyond its borders.

An important part of the current ABET mission is to emphasize the international engineering educational quality assurance through the development of accreditation systems. ABET has worked closely with engineering societies and groups of engineering educators to assist in the development of effective accreditation systems based on the principles of self-assessment, peer review and stakeholder involvement in the development of criteria. ABET has met with representatives from numerous countries, sponsored a series of international workshops on accreditation system development, provided materials and speakers for symposia outside the United States, and encouraged observers on site visits, at training programs and to decision-making meetings. To formalize this process, ABET has entered memoranda of understanding (MOU's) with organizations in several countries.

Further, the assessment of the educational credentials of engineers to work in the global marketplace is a concern of employers, attorneys, graduate schools and licensing/registration bodies. To address this need, ABET has established a service to evaluate the educational credentials of engineers who attended institutions outside the United States. Engineering Credentials Evaluation International (ECEI) evaluates credentials using the ABET engineering criteria in effect at the time the applicant graduated. Mutual recognition agreements and substantial equivalency recognition form a basis for evaluating educational credentials.

Quality assurance in engineering education, regardless of the arena, will continue to be of importance worldwide. Accreditation and cooperation are key.

## **INTRODUCTION**

When confronted with a challenge, engineers have always been able to rely on their technical proficiency and ingenuity. They have built computers that are small but powerful, reusable space

vehicles, and a tunnel under the English Channel - often after skeptics said it could not be done. Today, however, engineers face a new challenge with no convenient technical solution: globalization.

Few would contest that the rapid spread of free markets combined with the telecommunications "shrinking" of the world is having a progressively more pronounced effect on the engineering profession. Increased global competition requires engineers to couple technical innovations with sensitivity to the world marketplace. Global telecommunications opens the door for engineers to work at home or abroad. And mega-mergers such as the union of Daimler Benz with Chrysler prompt corporations to bring engineers together across national and cultural boundaries. The question for engineering educators is an obvious one. What is the best way to prepare students to succeed in a dynamic, increasingly international workplace?

The short answer is educators must strive to prepare engineers to work anytime, anyplace and anywhere. ABET does not and should not dictate the content of universities' programs. But our policies and philosophies furthering international cooperation and our new engineering accreditation criteria, Engineering Criteria 2000, can assist institutions as they plan strategies for the international arena.

## **PROGRAMS**

ABET currently has several policies aimed directly at the international community. When asked, we evaluate programs outside the United States, recognizing those that are comparable in content and educational experience as "substantially equivalent" to ABET-accredited U.S. programs. Additionally, ABET has signed a number of agreements with other countries recognizing their accreditation systems as comparable to ABET's system. ABET also exchanges information and provides assistance to countries in the midst of developing accreditation systems. When combined, these practices have the desired impact: they facilitate the ability of engineers and engineering educators to work in a global environment.

Our efforts go further. One of ABET's underlying philosophies is that the best judges of the quality and effectiveness of engineering programs are engineers themselves. Thus, we strive to encourage the spread worldwide of accreditation systems based on concepts of peer review and self-assessment. Practicing engineers and engineering educators help to create similar standards and expectations from country to country. Educators in one peer-reviewed system may approach electrical engineering programs differently from educators in another, but the outcomes will be similar - and graduates will have skills that are useful internationally.

Additionally, peer-reviewed systems create the most effective and efficient mechanisms for changing educational standards and goals to meet changing demands. Governments and their agencies may not recognize the skills required for a developing market in, say, flat-screens or nanoengineering, but engineers certainly will. As markets become more global, engineer-piloted accreditation systems will evolve in sync. Among other countries, Japan, Malaysia and Argentina are all in the midst of developing peer-based review systems.

ABET has another underlying philosophy that speaks to the international arena: that the social sciences and humanities are important elements of an engineer's education. With more and more engineers on the payrolls of international companies or working abroad, the merit of such a wide

background is obvious. Encouragingly, we are starting to see more institutions outside the U.S. put in place a similar emphasis on this non-technical side of engineering professionalism.

ABET is active on a number of other fronts, including promoting discussions and resolutions relating to engineering and mobility. Especially noteworthy is ABET's Engineering Criteria 2000, or EC2000. This major change to ABET's accreditation criteria expands the emphasis from technical training to also include communications and teamwork skills. Broadly speaking, EC2000 also shifts the focus from what is taught to what is learned, making institutions accountable for the success of their graduates in whatever workplace they find themselves in. Areas of student achievement range from the very technical "an ability to design a system, component process to meet desired needs" to the very internationally-targeted "understand the impact of engineering solutions in a global and societal context."

Engineers helped bring about the era globalization by designing and building the computers and telecommunications equipment that are its backbone. Now, engineering educators must ensure all engineers are prepared to work in a global environment. With its emphasis on international cooperation, peer-reviewed systems and EC2000, ABET is helping to lead the way.

# INTERNATIONALIZATION OF ENGINEERING EDUCATION

**Wu Qidi**

**Tongji University**

*The internationalization of higher education is a major global trend nowadays. With the ongoing opening of the Chinese education market following China's accession to the World Trade Organization (WTO), educational service in China is increasingly integrated into the global tide, which brings great challenges as well as opportunities for Chinese tertiary education with its engineering education gaining the lion's share. Tackling the two issues of engineering professional accreditation and engineer's qualification registration, this paper attempts to render some thoughts regarding the internationalization of engineering education in China.*

## **1. Urgency of Internationalization of Chinese Engineering Education**

Economic globalization is a general trend of the contemporary world. With increasingly frequent transnational flow of commodity, service, capital, technology and information, mankind has entered into a new era, characterized by interdependence, interaction, mutual influence and mutual stimulation between one another. China's final entry into the World Trade Organization (WTO) signifies that the world's largest human resource and education market is further merged into global competition. Educational internationalization requires education in all the countries to be adjusted, reformed, integrated and synchronized with the international practices so that they can be more comparable for mutual recognition. Of course, some "rules of the game" are needed for that matter.

With the quickened pace at which Chinese engineering enterprises and science and technology staff march into the world community, together with increasing opportunities for them to provide educational and professional engineering services, it is all the more necessary and urgent for Chinese engineering education to match the practices of engineering education in other countries. As engineering education has quite unified norms and high application generality in its teaching content, methodology and technical requirements, it is more likely for the educated objects to be involved in a transnational job market and professional practice; and thus, it is more necessary and possible for engineering education to take a leading position in realizing internationalization.

## **2. Foreign Engineering Professional Accreditation and Qualification Registration Systems Readily Available for Reference**

Currently, mutual recognition of engineering professional accreditation and mutual recognition of professional qualification registration is being promoted in the international community, to which the Chinese engineering education circle should attach due importance. The accreditation of engineering programs and engineer's qualification registration are both interrelated and independent, therefore, it is our belief that internationalization of the present engineering education should start

with its professional accreditation with continued efforts to encourage mutual recognition of engineer's qualification registration in the international community.

With an early beginning, the developed countries have already established a set of quite mature systems and methods for professional accreditation and qualification registration in engineering education.

It is known to all that accreditation of engineering programs are mostly undertaken by non-governmental agencies such as authoritative professional societies. For instance, the Accreditation Board of Engineering and Technology (ABET) jointly established by professional engineering associations and societies, undertakes the accreditation of American engineering programs. While ensuring the quality of education, ABET also encourages curriculum innovation and reforms of accreditation procedures. Meanwhile, engineer's qualification registration is carried out by local registrars. The requirements for the registered engineers include educational background, typically a bachelor of engineering degree accredited by ABET, approved relevant work experience, fundamental examinations (FE) and professional examinations (PE). In the U.K. the quality of higher education is controlled by Quality Assurance Agency (QAA), which formulates the framework of diploma and degree qualification, benchmarks for each subject, and the guidelines for program specification. Professional accreditation and engineer's qualification registration are delegated to the Engineering Council, and the entire set of accreditation procedure consists of self-evaluation by individual universities, the external supervision system and professional society assessment mechanism.

With the rapid development of engineering internationalization, the international mobility of engineers has become commonplace, resulting in further requirements for multilateral engineering accreditation. In 1989 the authentication organizations from the U.S., Australia, Ireland, New Zealand, the U.K. and Canada signed the Washington Accord, which gives recognition to the uniformity of accreditation system and quality of engineering education for signatory states and recognizes each other's professional accreditation organizations and their accreditation conclusions. In 1997, the Engineer's Mobility Forum was established to promote the mutual recognition of registered engineers' qualification, thereby laying a solid foundation for engineering education internationalization and international recognition of registered engineers' qualification. The Washington Accord was later joined by several other countries and regions, including Hong Kong Special Administrative Region of China. Moreover, the Asia-Pacific Economic Cooperation Organization (APEC) is currently exploring the possibility of registration of APEC engineers.

### **3. The Establishment and Development of Engineering Accreditation and Professional Qualification Registration System**

The reform of Chinese engineering education and professional qualification registration is organized and promoted by the government and participated by the competent departments, the Chinese Academy of Engineering, universities and colleges, professional associations and societies. The criteria are formulated on the basis of the actual situations in China with reference to the accreditation and registration requirements commonly accepted in the international community. Now accreditations have been carried out for such programs as architecture, urban planning, civil engineering, building environment and facilities, and project management. The accreditation of software engineering program is beginning right now followed by those of many other engineering programs. In these accreditation activities, foreign methods and norms are referred to. For example,

American standards are adopted in the exams for Class A registered architects, and the standards for registered structural engineers in Britain are referred to in the registration of structural engineers in China. At the same time, work has been done to promote mutual recognition of such qualifications between China, the United States and the U.K.

The reform toward a linkage between engineering education accreditation and engineers' qualification registration started in the civil engineering discipline. Because of our superior strength in the civil engineering discipline, Tongji University has initiated and promoted this experiment since the early 1980s, and this effort has been actively supported by the Ministry of Construction. We sponsored the establishment of various accreditation committees and have taken an active role in the activities of these committees. 1993 witnessed the founding of the National Board for Civil Engineering Accreditation (NBCEA), as the result of which a series of documents, including the Charter for the Board, the Accreditation Criteria for Bachelor's Degree Education, the Accreditation Procedures and Methods, and Guidelines for Accreditation and Inspection Team. Since 1995 accreditations have been conducted for 26 civil engineering programs in related Chinese universities. TJU has taken a leading position in the civil engineering discipline in China, whose curriculum for this discipline has met the internationally accepted requirements. Compared with its foreign counterparts, the field work arrangements for students at Tongji University are more practical. In the graduation design assignments, the students, supervised by the teachers, participate in actual engineering designs and obtain first-hand experiences of actual projects. All this prepares them for a quick adaptation to their jobs after graduation, and that is why they have always been so well accepted in society. Currently, similar professional accreditation and qualification registration have been extended to architecture and urban planning disciplines in TJU, and are being extended to other engineering disciplines.

#### **4. Promoting Professional Accreditation and International Recognition of Academic Certificates, Degrees and Engineer's Qualifications**

China's accreditation of civil engineering education and the registration of civil engineers, architects and urban planners have aroused the attention of the international engineering education community, especially that of the professional accreditation agencies in the U.K. and the U.S.A. There has been quite a long time of cooperation between the engineering accreditation organizations of China and the U.K. They mutually dispatch inspectors to take part in accreditation activities and committee meetings and jointly hold international conferences on civil engineering education and professional registration. On the basis of mutual understanding, an agreement of mutual recognition was signed in March, 1998, which specifies mutual recognition of civil engineering programs accredited by NBCEA and the first degree programs of civil and structural engineering accredited by Joint Board of Moderators (JBM), holding that they are up to the teaching requirements Chinese registered structural engineers and the British Civil Engineering Association (BCEA) members. The degrees and teaching of the civil engineering program at Tongji University has already been recognized by JBM and NBCEA. ABET had sent observers to take part in the accreditation activities of engineering education in China, and has conducted in-depth and constructive discussions with NBCEA on mutual recognition of first degree accreditation in civil engineering and on China's accession to the Washington Accord.

Organized by the Ministry of Education and the Ministry of Construction, the civil engineering and architecture disciplines in Tongji University have successfully passed several accreditations by international experts, and have been granted a 6-year exemption from accreditation after each assessment.

While exploring the possibility of internationally accepted accreditation for engineering disciplines, TJU has made active efforts to achieve mutual recognition of engineering certificates and degrees. Since last year, the Ministry of Education of China has signed mutual degree recognition agreements with France and Germany, thereby paved the way toward compatibility of educational degrees between China and member states of OCED (Organization for Economic Cooperation and Development). This is of vital importance for China to further integrate into the international education market. But for countries where free market economies are practiced, only having the governmental agreements is far from being sufficient. Only when we obtain the approval from universities, relevant professional associations and societies can we realize true "market entry". Guided by such a concept, TJU in recent years has been endeavoring to start up extensive cooperation with famous universities and the business community abroad. Successful practices in TJU include Sino-German College (CDHK) Sino-French Institute of Engineering and Management (IFCIM), both of which are turning out postgraduate students. The German partners for CDHK include Technical University Munich and Ruhr-University Bochum and the cooperation is in the field of Electronic Engineering and Mechanical Engineering. The curriculum is jointly designed and students are co-supervised by Chinese and German professors. During their study, students will have to spend six months to 1 year in Germany continuing their academic studies and doing field work. Upon graduation they will be conferred mutually accepted degrees. The French partner for IFCIM is Paris-Tech Group, a group of ten elite encoles in France. ENPC is the major partner in engineering disciplines, with disciplines covering electronic engineering, environmental engineering and transportation engineering. After students obtained their bachelor's degrees, they have to study for 3 years with one year spent in France. Upon graduation, the students will be conferred two master's degrees, one from TJU and another from ENPC. Since the curriculum is jointly designed, the teaching is carried out by teachers from both sides; it is easy to realize mutual recognition of academic certificates and degrees. Now the cooperation is extended from civil engineering, architecture and urban planning to electronic, mechanical and environmental engineering disciplines. But at present, the issue of engineer's qualification appraisal has not yet been solved, nonetheless, breakthroughs have been made, and procedures for mutual recognition in this field has been simplified.

## **5. Suggestions**

1) Exchange and cooperation between engineering education institutions and their international counterparts should be strengthened. Sino-foreign joint educational programs should be encouraged.

2) An accreditation and registration agency should be established in China. This should not be limited to civil engineering, architecture and urban planning, but be extended to all engineering disciplines. And this agency should acquire its due authority.

3) Such an agency should try as early as possible to integrate itself into the international accreditation and registration agencies, and actively participate in the formulation of "game rules".

Engineering education is a very important component of higher education, the aim of which is to turn out qualified engineers. The profession of engineers is a very important profession in human

society, and they should enjoy the same respect as scientists and educators. Engineers should not only be educated in engineering knowledge, but should also possess good morality and humanity spirit. I'm fully convinced that education in science and technology should be coordinated with than in humanities, and this is one of the major objectives of tasks of modern engineering education.

# **REINVENTING THE PARTNERSHIP WITH HIGHER EDUCATION IN THE GLOBALIZATION AGE**

**Ed Yang**

**VP, Strategic Architectures**

**Office of Strategy and Technology  
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**Hewlett-Packard Company**

## **ABSTRACT**

The information technology industry has been presented with a wonderful opportunity to partner – again – with higher education at a time when global information sharing is uniquely possible. Over the past decades, the constant and accelerating trend has been for vastly increased pervasiveness of information access and technologies. Multinational companies have a special opportunity and responsibility to seize this moment to collaborate with universities so that together they can maximize the benefits these new technologies and systems can deliver.

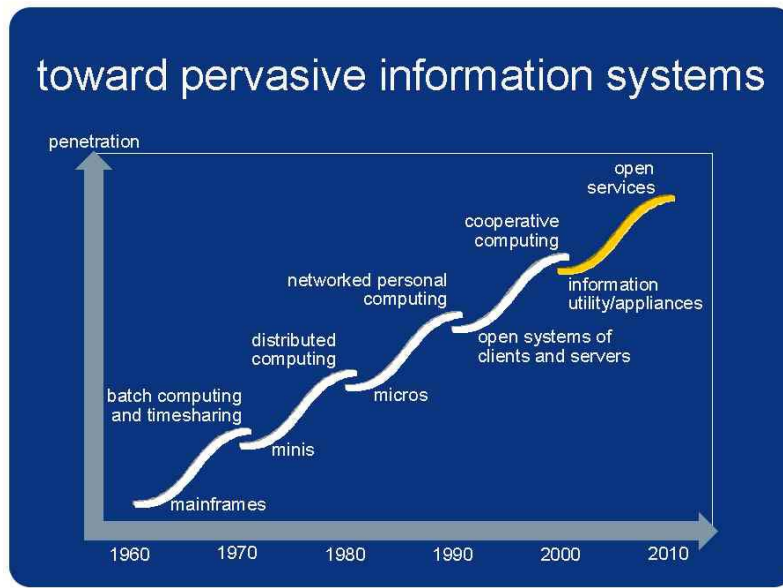
The traditional relationships between three critical contingencies -- universities, communities and industry-- must be reinvented to adapt to the world as it exists today. This paper examines the opportunities and challenges presented by this demand for reinvention by examining:

- Mega-trends
- Perspectives from a multinational company
- University-industry collaboration: opportunities and examples
- Conclusion

This paper presents a unique perspective of new opportunities and describes some first-hand experiences related to HP's global engineering and education partnerships. HP is a multinational company for over six decades, with business operations located in over 120 countries.

## **Mega-Trend**

The dominant trend in industry has been the movement towards pervasive information systems. The following graph shows the trend over the last 50 years towards this ever-increasing pervasiveness. We have moved from a few large expensive computer systems performing batch computing on a time-share basis to our present state of widely available, low-cost computing resources that are interconnected to a degree almost unimaginable only ten years ago.

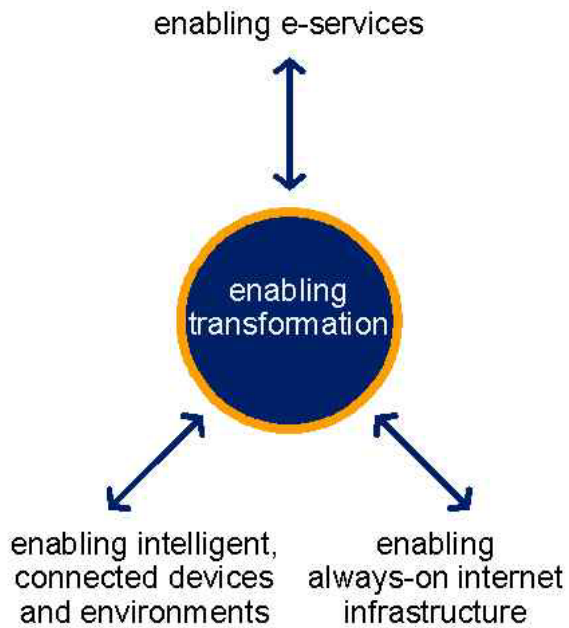


This trend continues and, despite the occasional economic flutters, promises to rapidly make the distribution and availability of information even more pervasive. This pervasiveness will be extended with new models based on dynamic open services built on top of an information utility infrastructure that is accessible through highly personalized and easy-to-use appliances. This trend presents a tremendous opportunity for a powerful partnership between higher education and the information system industry.

### **End-to-End Transformation**

The trends illustrated in the preceding chart promise to facilitate end-to-end transformation of information systems by:

- Enabling e-services
- Enabling intelligent, connected devices and environments
- Enabling always-on internet infrastructure



### **New Environments and Implications**

The ongoing end-to-end transformation of information systems implies entry into a number of paradigm-shifting environments that include:

- global connectivity
- global information access
- web-based business processes
- engineering collaboration platforms
- new customer-vendor interaction models
- mobility – anytime, anywhere
- blurring of boundaries between home, business and education IT
- digital content – new media
- new business models

### **Perspective of a Multi-National Company**

I am speaking as a representative of Hewlett-Packard, which is a leading multinational company. At HP, we feel an obligation to be a good corporate citizen and we have therefore defined a clear statement of our objective as a ‘multinational citizen’:

*“to honor our obligations to society by being an economic, intellectual and social asset to each nation and each community in which we operate”*

One key way that we fulfill this obligation is by focusing on education.

### **Why Focus on Education?**

The connection between being a good corporate citizen and being focused on education may not be immediately obvious, but has been clearly identified by HP's CEO:

*“The future of our success will significantly depend on how we prepare our young people. They come in all sizes, all shapes, all colors, all backgrounds, and all nations.*

*If we want the world to fulfill its real potential we have to make all of our children truly prepared. It's not only the right thing to do, it's good business.”* - Carly Fiorina, CEO Hewlett-Packard

Thus, our focus on education is not only the ethically proper path, it also makes sound business sense.

### **Invention and the Power of Diversity**

The core of HP's culture is invention, which goes beyond traditional research and development. We believe that diversity is a key strategy that drives creativity and invention. HP's CEO defined this relationship:

*“Invention – which is at the heart and soul of what HP has been about and must continue to be about – invention depends on creativity. Diversity drives creativity. No child can be left behind. Today, in HP educational programs, we are growing a quarter of a million new inventors – and we plan to do more.”* - Carly Fiorina, CEO Hewlett-Packard

### **Social and Economic Balance**

At HP, we are convinced that a successful future comes from finding the best balance between social needs and economic goals. Again, our CEO has said:

*“The Internet and related technologies hold the promise of rapid, sustainable economic growth that directly benefits everyone on the planet. However, the same forces could also exacerbate social and economic disparities. How much of each the world will see depends to some degree on how companies like HP approach sustainability and the deployment of technology across markets, cultures and continents.”* - Carly Fiorina, CEO Hewlett-Packard

### **University-Industry Collaboration**

Collaborations with universities around the world have played critical roles in HP's success as well as advancing the education systems and technologies. We continue to look for innovative ways to significantly enhance the collaboration and further expand into new geographies, particularly the Asia-Pacific area.

### **Asia Pacific University Activity**

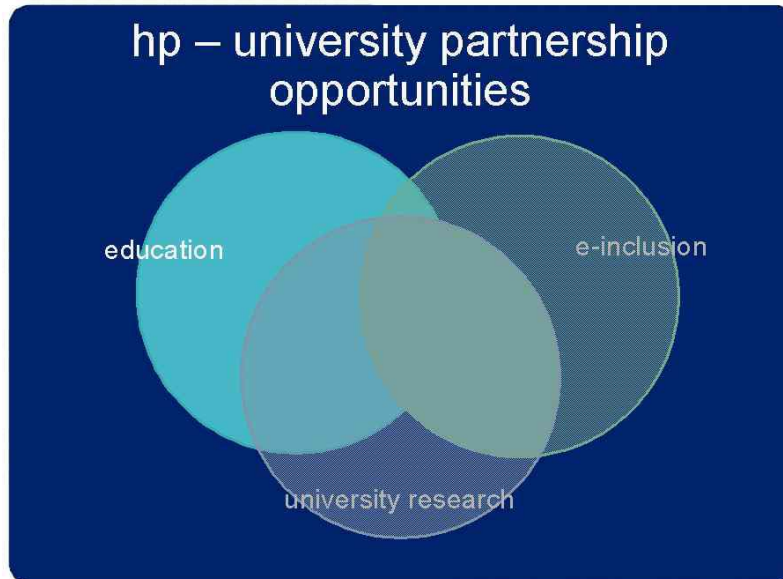
**For the fast-growing Asia Pacific region, we are now invigorating our focus and have committed to the following strategic objectives:**

- Develop new partnerships
- Identify new models for university engagement in emerging markets

- Advance international transferability of degrees, expansion of access, and new ways of teaching and learning by using technology

### **HP – University Partnership Opportunities**

The following figure illustrates the three broad and complementary areas where we have identified opportunities for the partnership between HP and the university community.



- Education: includes a full lifecycle approach from kindergarten to career, a holistic education beyond technical, and support for a mobile campus
- University research: supporting and promoting joint research by industry and educational communities with new research subjects and new collaborative methods.
- e-inclusion: actively applying technology to bring communities together into a *digital village*.

### **Education Programs**

The essence of HP’s education programs is to invest in schools and universities in ways that connect and improve the educational systems in communities. There are three key ways that we will accomplish this:

- transforming teaching and learning through technology
- increasing student success in math and science
- increasing underrepresented students in high-tech careers
- 

### **Holistic Education**

In order for our educational programs to succeed and provide maximum value to the community, they must be implemented holistically. A holistic educational approach seeks for a long-term win-win equation with:

- social and economic balance
- emphasis on:
  - technical skills

- ethical and social values
- business and management skills
- environmental awareness

### **Mobile Technology Solutions for Campus**

HP has awarded advanced mobile technology solutions to more than ten U.S. universities to accelerate new ways of teaching and learning. The grants include HP hardware and software products, consulting expertise and increased direct participation of HP employees.

University students and faculty are prime users and developers of leading-edge technology. And now, the university community is in the midst of a teaching and learning revolution driven by technology. The goal of this program is to support the creation of teaching-and-learning test beds that incorporate HP mobile technology solutions. This is accomplished by:

- transforming teaching and learning through technology
- deploying wireless infrastructure and access devices with high-bandwidth wireless capability
- assisting in end-to-end design and deployment know-how
- connecting students all the time with classrooms, instructors and peers
- complete & submit assignments from anywhere
- locate peers, classrooms, labs, instructors, etc.
- access online background information and other resources
- collaborate with peers more easily
- allowing us to understand how to integrate technologies with real-world and how to refine technologies

### **Current Educational Investments**

HP has awarded mobile technology solutions to the following U.S. universities:

- Carnegie Mellon University
- Cornell University
- Georgia Tech University
- Indiana University - Bloomington
- Massachusetts Institute of Technology
- Morgan State University
- Oregon State University
- Purdue University
- University of California, Davis
- University of California, Los Angeles
- University of California, San Diego
- University of Illinois at Urbana-Champaign
- University of New Mexico
- University of Texas, Austin
- University of Wisconsin, Madison

### **Global University/Industry Research**

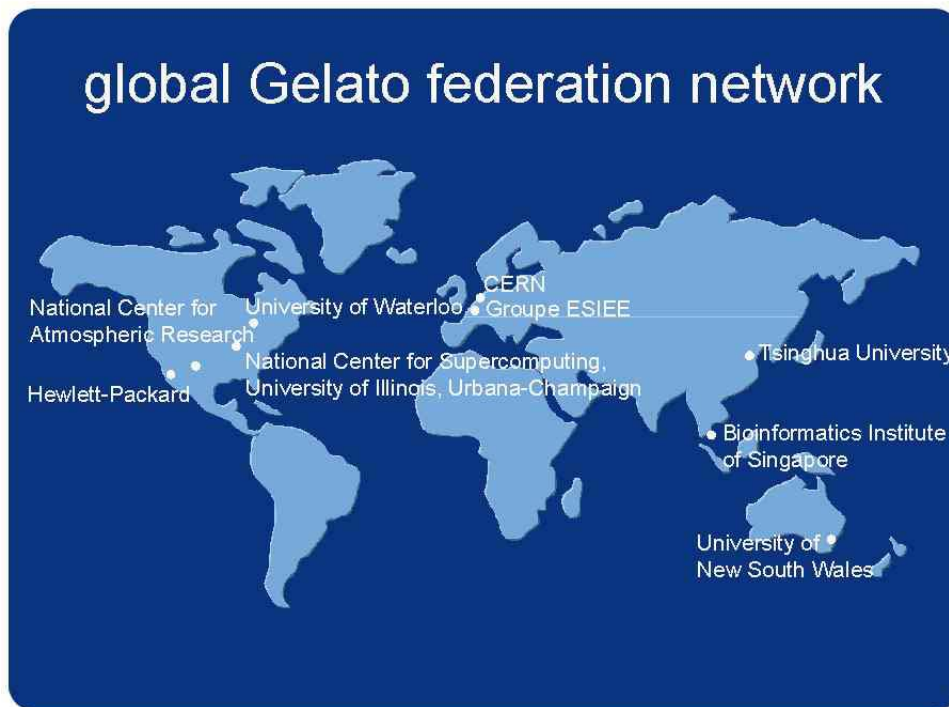
The second prong of our 3-pronged partnership with universities is to promote research cooperation between the information technology industry and the global university community. Some of the examples include Grid Computing, new platforms such as the Itanium CPU chips, operating systems such as Linux, and so on. The essence of this research is embodied in a project we call Gelato.

#### **What is Gelato?**

Co-founded by HP and seven of the world's leading research institutions, Gelato:

- is an international federation of research organizations
- enables scalable, open-source Linux computing on Itanium
- addresses real-world problems in academic, government and industrial research
- includes players in Asia Pacific such as:
  - Tsinghua University
  - Bio-Informatics Institute of Singapore
  - University of New South Wales

The following map illustrates the global Gelato Federation network.



#### **e-Inclusion: the Digital Village Vision**

The HP vision is that all people should have access to the social and economic opportunities of the digital age. We believe that, through technology, we can help underserved communities to:

- participate in today's digital society
- enhance people's lives

- demonstrate market-value of underserved communities for technology-based businesses
- help develop products and programs to engage local residents
- ensure sustainable and meaningful applications

### **Southern California Tribal Community – A Real-World Example**

HP has already applied this vision of a digital village to help change the lives of a Native American tribal community in Southern California. Here are the parameters of the situation:

**Center of gravity:** Wireless access

**Population:** 7,675 (37% children, 12% seniors)

**Geography:** Rural

**Demographics:**

50% Native American

20% Latino

29% below poverty

50% unemployment

**Location:** 17 reservations scattered over 150 miles, stretching from Mexican border to northern San Diego county

The approach used to bring this community together was to provide wireless access to connect 17 scattered tribes to each other and to the Internet. Here are the details of the holistic application of technology and education:

**Technology:** High speed broadband connection for all reservations

**Economic development:** Business incubators; career networks; job training

**Community:** Interactive tribal calendars; people share stories, pictures and experiences

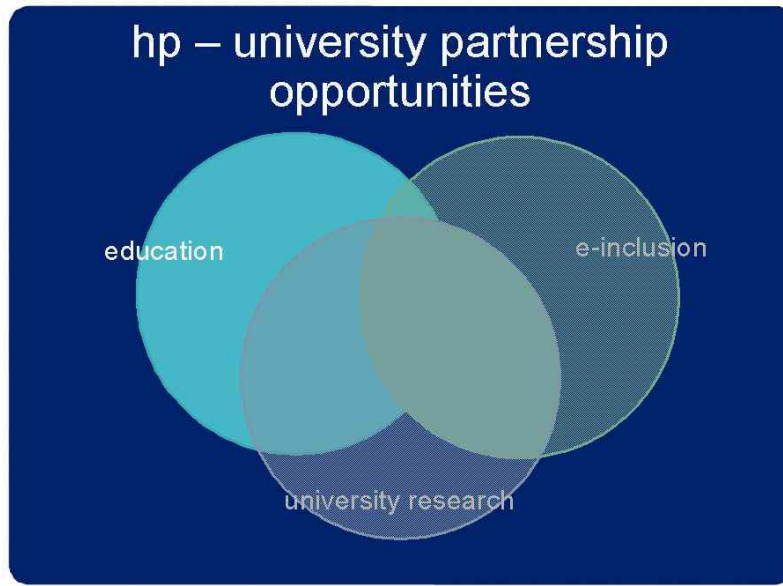
**Education:** Culture and language curricula; tutoring/mentoring

**Culture:** Maintain and express tradition

**Collaboration:** Strong local university partnership

**Conclusions**

I hope I have shared our vision of a new collaborative model between universities and global enterprises in the IT industry such as HP. There are many new opportunities and responsibilities.



For education, we want to apply the most advanced technologies to enhance the efficiency of the education systems. And we want to apply a holistic approach to these education systems to optimize their contribution to societies and the world.

For research, there is an abundance of new ways to connect the universities and enterprises for more effective collaborations and joint research. Additionally, there are many new research subjects emerging. We plan to push for expanded collaboration in these emerging areas.

Lastly, there are significant opportunities for university and enterprise partnerships to accelerate the development of underserved communities by applying technologies to improve business models, create new business models and, most importantly, enhance the quality of life in our communities. These partnership opportunities present a unique opening for corporations and the high tech industry to maximize our fulfillment of the social responsibilities to the communities where we live and serve.

# CONTINUING ENGINEERING EDUCATION FACILITATES ENTERPRISE'S TECHNOLOGICAL INNOVATION

**Xie Qihua**

**President of Shanghai Baosteel Group Corporation**

*This paper expounds the functions and roles of continuing engineering education (CEE) played by Shanghai Baosteel Group Corporation (hereinafter referred to as Baosteel) in facilitating the growth of the enterprise and enhancing its capability of the technological innovation. The practice and advancement of Baosteel's continuing engineering education reflects the fact that great importance has been attached by the Baosteel leadership to the constant updating of enterprise's operative perspectives as well as its technical creativity.*

The economic competition nowadays is seemingly a rivalry for economic resources, product quality and market shares while substantially a competition for talents and technologies. The key for an enterprise to keep a sustainable growth and a long-term dominant position lies in its possession of talents who are capable of technological innovations. Therefore, a first-rate enterprise is based on a contingent of elite. Institutes of higher learning are the cradles for the nurturing of enterprises' talents. With the rapid development of science and technology as well as the emerging of new types of subjects and courses due to the disciplinary cross, penetration and integration, advanced education can, nevertheless, no longer provide engineering personnel with an overall and lifelong training. Professionals should, however, receive constant in-service engineering education within their enterprises. Only this, can they remain the advancement of their knowledge and the rationality of their knowledge structure. CEE has thus become an essential part of the modern engineering education system and a magic weapon for the enterprise to achieve successes.

## **1. Retrospect of Baosteel's Continuing Engineering Education**

A synchronized development with the construction and production of the Group, Baosteel's CEE has experienced the stages of start-up, growth and flourishing, and become an important pillar for the development of Baosteel's production, management, scientific research and the exploitation of human resources.

Baosteel Education & Training Center, with a nationwide first-class teaching facilities and a contingent of excellent full-and part-time faculty members, is an executive organ for the implementation of CEE. It has through practice formulated an enterprise educational management and teaching system of "unified planning, overall responsibility, division of work with cooperation, and small detachment of picked staff with high efficiency".

### **1.1. Enterprise Teaching System, An Integration of Personnel, Production and**

## **Research, Is Fundamental Prerequisite of A Guaranteed CEE**

CEE tends to help professionals enhance their abilities of practical problems solution, decision-making and innovation in terms of enterprise's production and scientific research. Some important adjustments have been made to perform CEE's function. For instance, Two institutes, Institute for Continuing Engineering Education and Institute for Economy & management, were set up while Baosteel Workers' University was eliminated. A contingent of experienced full-and part-time faculty members of great attainments have by far fostered a great number of capable full-and part-time engineers who are good at training affairs, decision-making and management. ISO9001 Quality Management System has been implemented in the process of education and training. Besides, an enterprise education and teaching system has been established. All these adjustments have helped promote all-round development of Baosteel's CEE and its teaching quality as well.

At the same time, a cooperative system jointly run by Baosteel Personnel Sector, Production & Research Sector as well as Education & Training Sector is to put forth macro orientation according to Baosteel's status quo, its development and the needs for the cultivation of talents. All sub-units training requirements would be put forward directly to the Education & Training Sector. The latter would stick to the on-the-spot investigation and then undertake some comprehensive balance, coordination and implementation. Such flat operative system has not only seen a quick and effective result but also reflected the needs of CEE by the enterprise and its professionals.

### **1.2. Learning, Digesting, Mastering and Developing Baosteel's Technological Resources Are Major Tasks of CEE**

Many advanced technologies from different countries have been introduced during the Phase I, II, and III Projects construction. To well manage the corporation, employees have been organized to learn, digest and master these advanced technologies, and some of which cannot be found in any textbooks. So popularizing these state-of-the-art technologies has become a rare source and task for CEE. Some senior technicians who have participated in the technical negotiations, equipment installations and adjustments as well as production supervision have been invited to do the work of compilation of teaching materials, dissemination of new knowledge and training affairs on the basis of assimilation and absorption of the introduced technologies. As a result, their work has been highly spoken of.

Based on the advanced worksite technology, Baosteel CEE bears the features of practicality and advancement. It is beneficial for employees through their studies to grasp new technologies and conduct innovations. All professionals have warmly embraced CEE.

### **1.3. Close Combination of Production, Instruction and Research Is An Important Approach and Orientation for CEE**

Cooperation with institutes of higher learning that are rich in teaching and human resources is an effective way to facilitate the enterprise's education, which can complement each other. In addition, the direct involvement of the professionals in the production and research can stimulate the transformation of scientific findings into real productivity, promote enterprise's creative activities, and in turn enrich institutes of higher learning with new technology and know-how.

At present, Baosteel has good links with over 50 universities nationwide. Special cooperative projects have been jointly run with different institutes of higher learning, which have greatly helped

Baosteel in the field of CEE. For example, the Group established multi-tiered, all-round cooperation with Northeast University a decade ago. The Center for CEE, jointly set up with Northeast University and on the basis of Baosteel's needs, has conducted in a planned way various educational activities such as R&D, the digestion, absorption and creation of the major introduced projects, the nurturing of in-service postgraduates and high-level technical professionals.

#### **1.4. Effective Incentive & Restraint Mechanisms Are Strong Driving Forces to Deepen Development of CEE**

The rapid advancement of science and technology has shortened the knowledge's semi-degenerate period. Though the public's consciousness of the importance of study is increasingly upgrading, effective incentive and restraint mechanisms would stimulate the positiveness of people's learning motivation.

Competing for posts is not only an incentive mechanism but also a restraint one. For instance, the scientific and technological personnel in Baosteel have been required to have a good command of foreign languages. Otherwise, they could have little chance to get promoted, to climb up along the corporate ladder or to study abroad. Under such mechanism, the massive staff members have voluntarily embarked on the further study of foreign languages.

Various practices have proved that effective incentive and restraint mechanisms can serve as a catalyst to not only enhance employees' initiative and positiveness, but also upgrade the calibre of staff and strengthen the core competence of the enterprise as well.

#### **1.5. Internationalization of CEE Is An Effective Means to Enhance CEE's Levels.**

Featuring advancement, practicality and purposefulness, CEE has emphasized the close combination of all kinds of special training, research and studies with worksite production, technological problem tackling, development and application of new technology, new process and new products, as well as transformation of scientific findings into production.

To narrow the gap between itself and the world-advanced enterprises, Baosteel is quite aware of the importance of creating favorable environment for its talents to broaden their views and to look on to the global cutting-edge scientific and productive achievements. Baosteel has paid much attention to the internationalization of CEE and has successively established fine cooperative relations with some overseas enterprises, universities, institutions for scientific research and organizations for consultations in such countries as the United States, Britain, Germany, Japan, Canada, the Netherlands and South Korea. Early or late, more than 270 backbones of scientific and technological contingents of the Group have been sent abroad either for further studies or as visiting scholars. In turn, overseas experts and professors have been invited to give lectures to Baosteel employees, and academic exchange seminars have also been held.

## **2. Rethinking of Baosteel CEE**

The world is changing profoundly and we are in the era of economic globalization and scientific upgrading. Under such new environment, what we have to do is to emancipate our minds and update our perspectives.

### **2.1. Tasks of CEE in The New Era**

The main task of CEE is to update, supplement and enhance the knowledge and know-how of those once well educated scientific and technological personnel in Baosteel. It is a vital approach to improve the talents' calibre, to maintain vigor and vitality of the engineering & technological force and to enhance enterprise's international competitive momentum.

Baosteelneese, through CEE, have grasped the advanced technology, process and equipment, which helped guarantee the successful completion of the corporation's production as well as a stable and high-efficient operation. Both the labor productivity in kind and product quality have been up to the world advanced level. Baosteel is now building itself into a steel brand product base and a research base for developing new process, new technology and new materials. The Group holds that priority should be put on CEE while forging ahead towards its magnificent goal of "becoming a world first-rate enterprise with world first-class level".

To become a steel giant with international competitive strength, Baosteel needs a contingent of internationalized talents of high calibre. The nurturing of such talents would be the main task of CEE in the new era. And the emphasis is to be on the development of talents' intelligence, the optimization of their knowledge and competence structure, and the upgrading of their internationalized quality. Baosteel is determined to gain international competitive advantages by strengthening its technological innovation, manufacturing brand products, and obtaining autonomous intellectual property rights.

Employees at two different levels are expected to be the trainees of CEE. The first level covers newly recruited university graduates who would grow later into "Baosteelneese" from "campus students". They will be educated in the fields of Baosteel culture, management, technology, process and products. They will also be involved in such training programs as the application of informatized technology and the enforcement of foreign languages. They are required to get familiar with and abide by Baosteel culture and managerial system. The command of Baosteel's process and technology and the improvement of their capabilities of international exchange and cooperation would help get themselves ready to join the team of middle-and high-level technicians. The second tier of CEE's prospective trainees includes Baosteel's middle and senior technicians who are to become innovation-makers" from "technology assimilators". The final aim for the trainees at this level is to improve their technological innovative capabilities and master world advanced technologies in their own academic fields. They are expected to study and research on new technology, new process and new products by getting involved in the scientific research subjects, technical renovation projects and international academic exchange activities.

## **2.2. Intensifying Research and Innovation of CEE**

During its development, CEE has accumulated plenty of precious experiences and effective means. Baosteel should, however, continuously conduct innovations and create some feasible, time-synchronized and enterprise-satisfactory modes and methods.

### **2.2.1. Compilation of A CEE Guide to Subjects**

A CEE Guide to Subjects serves as a macro orientation for the training of technical professionals, which is conducive not only to the adjustment and optimization of the internal talent's structure and their knowledge structure, but also to the development of talents for the Personnel Sector and the implementation of training for the Education Sector. It is an essential work of CEE.

More than 140 internal experts, subject leaders and technological backbones under the

coordination of Baosteel Personnel Sector, R & D Sector and Educational Sector completed the compilation of the Shanghai Baosteel CEE Guide to Specialized Technological Subjects at the beginning of 2002 after 10-month work. The Guide bears such characteristics as the concerted involvement by multi-sectors, the combination of Baosteel's status quo and its development orientation, the objective reflection of the requirements to the talents and the needs of education and training for different employees. The Guide had laid a foundation for the further development of CEE.

### **2.2.2. Development of CEE's Brand Subjects**

Like the growth of an enterprise, the development of CEE should see its own brand subjects and strong fields. Brand subjects mean high quality and constant innovation.

Baosteel has once tapped some better training modes such as "4+1" which contains 4-unit research work and one technological paper. The 4-unit research work has covered the contents of "Management Innovation", "Thinking Training", "Widening of Technical Abilities" and "Cutting-edge Technologies". The teaching methodology used in the process of training has included theoretical lectures, case analysis, and questions-and answers with experts. Emphasis has been put on the interactive teaching, and studies of trainees' own accord instead of passive learning. The technological content, innovative ideology, productive applicability, and economic profitability have been considered as the vital elements in the evaluation of academic papers. Among the merits of such kind of training are high knowledge starting point, large amounts of technological contents, close linkage with the worksite production and the proper combination of theory with practice.

Baosteel is convinced that the further exploitation of its brand subjects and the widening of its strong fields would certainly lead its CEE to a new height.

### **2.2.3. Creating A Brand New Study Environment and Mode by Developing Online & Distance Learning**

Quickening and realizing the educational informatization and modernization is an important tactic to promote the development of education. Baosteel has clearly defined that the development of online education and training should be brought into line with the Group's plan on the development of informatization. So far, a digital and networked suppositional Baosteel Education & Training Center has taken into shape. A distance Education network has been formed with the Baosteel Education & Training Center as its main part, radiating programs to all Baosteel's subsidiaries, communities where the corporation's employees live, families and institutes of higher learning. Baosteel has realized its aim of providing its employees with online classes anytime, anywhere and for any course studies.

With a perspective of informatization and modernization, the Group is to formulate its further plan, system and mechanism on the development of educational informatization. To build the corporation into a learning-oriented enterprise and to establish a lifelong study system for all employees, Baosteel is determined to further tap educational resources, to strengthen its information management, to further improve the knowledge and ability of those who are engaged in the educational and training information and to intensify functions of the educational informatization.

## **3. Conclusion**

In the era of fierce competition, can enterprises stay ahead only when they undertake

constant innovations and create their own brand products and have their own patents. CEE is now regarded not only as a vital bridge of the latest knowledge transmission, but also as a cradle in terms of scientific innovations which are considered as an important part of CEE. We have to further enhance the function of CEE on the basis of practice, updating our perspectives and perfecting our measurements.

Finally, I would like to cite remarks by Mr. Zhou Guangzhao, an academician from the Chinese Academy of Sciences: It is time for us to shift our attention from the construction of some concrete projects to the fostering of talents. There will be no prospects for enterprises without the support of science and technology. And men will be of no innovative talents without the support of knowledge. Scientific and technological personnel devoting themselves to scientific innovations should make constant progress and advancement in the enterprises advocating learning and innovation. As for the enterprises, they should create, on the basis of sustainable development by relying on talents, an educational system in the face of market, economic globalization and knowledge economy so as to open the gate to the knowledge economy for their laborers and for the enterprises as well.

# THE CONCEPT OF TALENTS AND THE CONCEPT OF EDUCATION

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In my paper "Prospects for the Higher Education of Engineering in the 21<sup>st</sup> Century" written in 1997, I gave a description of the five major trends which will have great impact on the economic, social and cultural development:

- (1) The trend of integrating education, scientific research and manufacturing;
- (2) The trend of synthesizing science and technology;
- (3) The trend of rationalizing social development;
- (4) The trend of globalizing economic development;
- (5) The trend of realizing lifelong education.

In today's world, the cycle of the transformation from science to technology, and the materialization from technology to products has become shorter and shorter. The three originally separated social activities—knowledge discovery, knowledge communication and knowledge materialization — are increasingly closely combined together. At the same time, science and technology have gradually turned from the tendency of disciplinary disintegration in 1940's to disciplinary integration due to the uniformity of the objective world.

The whole world today is focusing on the sustainable development of human society. Huge amounts of investment are being put into healing the traumatic environment, and the international standards such as the standard of discharge of CO<sub>2</sub>; are made to protect the normal human activities, therefore, the relation between mankind and nature can be developed more rationally, and the human community can move on to the road from petroleum civilization to ecological civilization, and henceforward the earth can one day become a more comfortable habitat for mankind!

From the beginning of 1980's, China started to be merged into world economy as she carried out the policy of reform and opening to the outside world. China's admission to WTO in 2001 signifies her greater involvement in the world market and wider opening of China's market to the outside world. The admission to the World Trade Organization is the major event in the process of China's joining the global economy. Globalization demands China's wider opening to the outside world and further deepening other reform, and the ultimate aim is to make ourselves gradually more adaptable to the changes in world economy.

The realization of lifelong education is not only the need out of our work, but also the need to diversify and enrich the content of human life in the new century. Just as it is said, the human society in the 21<sup>st</sup> century will be the one with harmonious integration of creative labor, active learning and leisurely entertainment.

All these major development trends will inevitably transform our concepts of talents and education, and therefore to promote the reform in the higher education of engineering.

**1. The concept of talents**

Many countries in the world are making research of the quality the 21<sup>st</sup> century engineers should hold and the corresponding target of training in engineering education, and have thus expressed quite a number of ideas and thoughts. For example, China put forward the requirement of "qualified new-age-talents with higher level and greater creativity" in the National Technological Innovation Conference held in 1999;

The Drexel University from USA suggested the demand of "new century talents"; The Arizona University and 32 American enterprises have made the 12 criteria for the quality of engineering personnel; Technical University Berlin has put forward the demand for engineers from the angle of technology and management; the American National Research Institute and the Commission of Engineering Education, USA published "Engineering education facing the changing world" and "Report on the system design of engineering education adaptability"; Tokyo Institute Technology and Zhikuba University promoted "social, comprehensive, large engineering mode". The above mentioned suggestions have expressed the similar understanding, that is, the engineers of the 21<sup>st</sup> century should no longer be the purely technological workers, instead they should be the personnel with comprehensive talents. The knowledge, competence and the quality they should be equipped with can be grouped into three areas.

**1-1 Engineering science and technology**

They should be equipped with the solid foundation in mathematics and natural sciences (including life science); with strong foundation and training in engineering principles and engineering practice; with very new specialized knowledge; with the ability to recognize and define problems, to apply relevant engineering principles and experimental methods, design calculation methods to solve problems; with historical and social perspectives towards the role of technology; and with the broad vision of interdisciplinary approach.

**1-2 Humanities and social sciences**

In engineering education we lay emphasis on the humanities and social sciences, which reflects the synthetic overlapping of disciplines and it is also the inevitable demand from the uniformity of the objective world.

What are the humanities and social sciences? The connotation of the humanities and social sciences are quite extensive and wide-ranging, and they are often mixed at different levels. The humanities include literature, philosophy, arts, ethics, linguistics and archeology; and social sciences include anthropology, sociology, psychology, geography, socio-statistics, pedagogy, the science of enterprise/business management, public administration, mass communication, psychotherapy; as to history, political science, economics and the science of law, they belong to both the humanities and social sciences.

The humanities	Literature, philosophy, arts, ethics linguistics, archeology
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Social sciences	Anthropology, sociology, psychology, geography, pedagogy, the science of business/enterprise management, public administration, mass communication, socio-statistics, psychotherapy
The humanities & social sciences	Political science, economics, history, the science of law

(From *Encyclopedia Britannica* and *Ci Hai*)

The essence of engineering is to create, to invent, to design and to construct, and in the process of engineering construction human will, imagination and emotion are integrated to transform nature and shape the human society. For example, in the construction of the magnificent Three Gorge Dam project, a great number of technical difficulties and obstacles have to be overcome, however, the starting point and the ultimate purpose of this engineering project is closely related to human and social progress. The influence of the level of the knowledge of humanities and social sciences of the engineers, as the executors and implementers of the engineering project, upon the quality and the level of the project, and eventually upon the progress of the society, can never be underestimated.

One of the views holds that, the humanities and social sciences should hold a core position in engineering education. However, the more appropriate expression should be as follows: An engineer should be equipped with the knowledge of literature, arts, language, politics, economy, business management, and so he or she could have the ability to locate properly the engineering issue in the overall social system and survey it with the integration of politics, economy, law, ecology, psychology, and even ethics.

### 1-3 Personal cultivation

Engineering technicians should develop morally, intellectually and physically. S/he should have noble morality, strong physique, high social responsibility, team spirit to cooperate with colleagues, the devotion to be devoted to lifelong learning, and the linguistic competence to communicate.

The above requirements in science, culture, ideology and morality are the concept of qualified talents in the new age.

Contrasted to the traditional views, the changes in the concept of talents are quite outstanding. Take the Shanghai Jiao Tong University as an example. When we were studying in the University in 1950s, the prevailing view was "So long as you have mastered mathematics, physics and chemistry, you don't have to worry about wherever you go." Such kind of view had had enormous impact upon the development of the young generation then, as well as the teaching program, content and methods in colleges and universities. Today, the requirement is no longer restricted to mathematics, physics and chemistry, but covering almost all the aspects of academic study. Therefore, in Shanghai Jiao Tong University today, the requirements for talented personnel have been summarized as "solid theoretical basis, comprehensive multi-disciplinary knowledge and global-oriented characteristics". Under the guidance of Comrade Jiang Zemin's instruction that "Innovation is the soul of national progress," "innovation-oriented spirit" is added to the requirements.

The educators in the world have also raised the concept of comprehensive talented personnel. They have gone as far as to say that the mere mastery of narrow skill and technology will only make graduates the servants to the advancers of new ideas, fighters in the market and financial controllers.

The new concept of talents has revealed some contradictions and difficulties at certain stages of learning, particularly in the organization of education in the period of higher institution. To settle and to overcome these contradictions requires us to establish the correct concept of education. The concept of education serves the concept of talents, however, the two concepts belong to two different fields. The former is the requirement for the talented personnel, and the latter is about how to organize education.

## **2. The concept of education**

How to organize the higher education of engineering? Different colleges and universities have their own specific approaches and operational characteristics. It is only natural to "let a hundred flowers blossom". However, after a period of practice, some colleges and universities have developed faster, and some others would have moved relatively slowly. Therefore to make a summary of the experience accumulated from the concept of education is necessary and essential. Only eight years after its establishment, the China-Europe International Business School (CEIBS) has entered the top 100 in the world in the education of MBA and the top 50 (ranking 29<sup>th</sup>) in the training of EMBA. It is worthwhile to summarize and popularize their experiences and achievements accumulated in their organization of education. As a matter of fact, various proposals and schemes of running colleges and universities and training plans all aim at correctly settling the problems and overcoming difficulties under the guidance of the concept of talents. At present, the major difficulties are contradictions between: 1) the basic knowledge and professional knowledge; 2) the humanities, social sciences and technological and natural sciences; 3) teaching and researching; 4) theory and practice, knowledge and competence; 5) national and international; 6) teaching methods; and 7) the environment for cultivating talented personnel.

### **2-1 Basic knowledge and professional knowledge**

With the rapid development of science in the world today, the cycle of knowledge updating has become shorter and shorter. However, if viewed holistically from the sum total of knowledge, it has a relatively steady core, as well as an ever changing outer layer. For example, thermodynamics is the theoretical foundation of the research of energy and power machinery, its changes over the past decades mainly are shown in the deepening of the irreversible process, nevertheless, many theories of irreversible process are in fact not new discoveries, its basic ideas were put forward 50 years ago. Compared to the methods which deal with specific engineering issues with the application of thermodynamics, this part of the basic idea is relatively steady and has a longer life cycle. Take aerodynamics as another example. In this field we mainly study the internal flowing with the application of aerodynamics. In 1940s, with the methods of the external flowing to study the blades of the turbo-machine as the isolated aerofoil; in the beginning of 1950s, soon after the invention of computers, the method of 3 dimensional flow was developed greatly. The further development will focus on the settlement of issues involved in no steady flow, flowing, and heat-transfer coupling, the interaction of shock wave and boundary layer, the control of flowing process. The rich accomplishments achieved over the past 50 years have gradually perfected the working of turbo machine; however, all these changes are based on the basic cores of theories, such as conservation of mass, conservation of momentum, energy conservation, boundary layer theory, supersonic flow, laminar flow, etc.

In the period of university study, students should be required to firmly grasp these knowledge cores. In 1996, the Chinese Academy of Engineering organized an investigation of engineering education in the areas of Beijing and Tianjin in northern China, and the results show that, over 70% of the engineering personnel hold that, what they have benefited most from the instruction and training received from the universities is the study of the basic theories.

The professional knowledge is necessary and important, and its major role is to let students know the history and its frontier of that specific field of research, and learn through the application of the basic theory the ideas and methods useful in the settlement of the specific problems in the field of engineering, and afterwards use it in other similar cases and situations. Today a prevailing idea is that the field of professional knowledge should be broadened so as to improve the adaptability of students. However, this does not mean that students of power machinery should master everything about diesel engine, steam turbine, gas turbine, and steam boiler, and as a matter of fact, it's almost impossible. "To cut one finger is a more deadly blow than to wound ten fingers." "Disintegrating leads to deepening, deepening to comprehensive understanding, and understanding to integrating." Only by going deeper in a specific/individual field, can we reach the level of comprehending by analogy/grasping the whole category through the understanding of a typical example.

## **2-2 The humanities, social sciences and technological sciences**

Professor Zhou Yuanqing points out, " To change the once prevalent situation of overstating specialized education, undermining the education in the humanities and the obvious utilitarianism, and to improve students' level in the fields of morality, civility, culture, professional knowledge, physique and psycho health, and to focus on the education in the three fields of knowledge learning, competence cultivating and improving qualities, the Ministry of Education has systematically organized the activity to strengthen the work in improving cultural and civic education. Through the experiment over the past few years, the basic targets of training and requirements have been clarified, and some successful experience has been accumulated. Now this program is being popularized to all the colleges and universities in China." Professor Wang Dazhong pointed out in his "On some issues in establishing world first rate universities in China" that , "In the designing of school curriculum, emphasis should be laid on the education of the humanities and extensive knowledge, and liberal education should be promoted," Professor Yang Shuzi in his "System integration and overall promotion. The reform of education in mechanical engineering in the 21<sup>st</sup> century" defines the mode of educating personnel in mechanical engineering as "broad-caliber specialized education based on liberal education," The foundation of liberal education includes both the foundation of natural sciences and the basics of humanities and social sciences (such as the serial courses related to Marxism, ideological education and civic and moral education, serial courses relevant to humanities, arts and social sciences; foreign languages, physical education, military training, voluntary labor and social investigation. Professor Ke Jun points out that, "Foundational courses in humanities and social sciences should be arranged in engineering education. In the course of cultural education, engineering perspectives and economic perspectives should also be cultivated, as well as the devotion to one's professional career, responsibility, the spirit of hard struggle, the establishment of noble morality, professional morality. It is also necessary to strengthen listening, speaking, reading, writing and communicative competence in both foreign languages and our native tongue." All these views express the concern over the weakening of education in humanities in colleges and universities, and have

formed some insightful ideas about the arrangement of curriculum in humanities and social sciences, and what problems should and could be solved in the education of humanities; some of the programs have already been put into practice.

What should be emphasized here is, the education of humanities in the program should not be understood narrowly as just to offer a few courses, increase a little more knowledge, and lay a foundation in a certain field. The cultivation of many good qualities will rely on teachers' verbal instruction and personal example and nurturing influence of teachers' professional styles, the training in practical work (including field practice, design and research), meanwhile, in the process of engineering education, the economic, social and cultural viewpoints should be conveyed appropriately. The method of case study should be promoted in the education of engineering courses, and through the concrete examples in a given field which have had significant social influence; the comprehensive and lively education can be carried out.

### **2-3 Education and scientific research**

The institutions of higher learning should place scientific research at a key position. All the institutions of higher learning should carry out scientific research, including the research in the field of education; only in this way can the colleges and universities become the birthplace of new knowledge, new science and technologies, and new industries; only in this way can the universities and colleges implement the guiding principle of quality education, the essence of which is to cultivate students' originality and practical competence; and only in this way can the universities and colleges occupy an important position in a country's system of innovation. Of course, there will be differences between colleges and universities in the quantity, quality, depth and range of scope in scientific research and some of the universities can be built into research-type universities. However, the institutions of higher learning whose major orientation is not research should also devote some of its force to scientific research. The problem to be solved today is to promote the complementary interaction between teaching and research, and to make the educational work of undergraduates and scientific research both the indispensable parts in colleges and universities. As far as the education of undergraduates is concerned, colleges and universities should make full use of the huge resources of postgraduates and research projects to strengthen the quality of the undergraduate education and to optimize the environment of undergraduate education; as far as the scientific research is concerned, when scientists are together with intelligent, enthusiastic young students who are full of imagination, they will surely get new inspiration and to form new creativity.

The focus of universities' research should be basic research and applied basic research. Today many universities are undertaking a lot of "horizontal" research projects to contribute to the development of products for enterprises. However, with the development of R&D centers in China's enterprises, the research level of the universities in China will surely move upstream in science and technology. After China's admission to WTO, the competition between enterprises will be much fiercer, and such trend of upward research will be ever stronger. Therefore the engineering-oriented universities should give support to the R&D of enterprises from their basic research.

There should be a freer and looser environment for the scientific research in universities, and broader space for rapid development of free thinking. More posts for scientific research should be provided. In a word, research and teaching are basically complementary and mutually beneficial, they should not be considered antagonistic. The institutions of higher learning will surely improve both the

level of research and the quality of education through taking the advantage of both teaching and research.

#### **2-4 Theory and practice, knowledge and competence**

In the inspection of the implementation of the "Projects 2 II", I have visited quite a number of engineering-oriented colleges and universities. I have found that, in the process of construction of Projects 211, many universities have focused on the construction of bases for engineering practice. For example, Shanghai Jiao Tong University has built 10 national level teaching centers for basic experiments and experiment bases for postgraduates in the construction of platforms for basic education, and in the construction of platforms for specialized education, specialized experimental bases with complete sets of equipment. Universities such as Southeast University, South China University for Science and Technology, North Jiao Tong University, Southwest Jiao Tong University have also made great progress in the construction of experimental bases in the construction of "Projects 2 II". Such progress should be fully acknowledged in the education of engineering.

For a period of time, the actual implementation of experimental practice has been weakened and the equipment in experiment bases have been outdated with the shortage of fund, the practice in factories and plants has become difficult to carry out, the sector of design has been ignored, and the quality of engineering education has been severely lowered. Today the general approach is to pay great attention to training and practice. As a matter of fact, we are undertaking a regressive road back to engineering and practice.

The significance of practice to the education of engineering is as follows:

- (1) A large amount of knowledge, particularly the tacit knowledge, is often acquired and understood in the process of practice.
- (2) Practice is one of the major links in training and formation of competence and abilities.
- (3) Strengthening practice teaching is one of the keys in the establishment of educational system to cultivate talented personnel with innovative abilities.

As is known to all, "Genuine knowledge comes from practice." However, the erroneous tendency occurred time and again in history, so what we often see is the consequence of "losing contact with reality" and "paying more attention to theory whereas less attention to practice," One of the reasons might be the difficulties in the building of practice bases and the organization of practice teaching, therefore it has often been ignored. Therefore, today we should support the regressing to practice with greater force. The institutions of higher learning in China should have a number of well-known practice bases, which serve both the training and education of talented personnel and also contribute to the development of scientific research.

The four points discussed above are most important in all these issues. However, education is always a cause with prospects towards the future and it is always offering talents for the future. And talking of future, it has always had a certain degree of unpredictability. The views formed out of the past practice will not necessary be completely correct, but they can surely serve as the starting point for discussion and can be used as referential points.

# NEW CENTURY REFORM AND DEVELOPMENT OF ENGINEERING EDUCATION IN CHINA

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In the second half of last century, engineering education in our country faced fast development as well as many reforms, among which, there are two notable transformations: One is the overall readjustment of schools right after the foundation of New China; the other is the shift of direction and the large-scale consolidation of schools since the reform and opening to the outside world. During the former readjustment, a large number of engineering colleges based on classified specialties were established and in the latter reform, engineering colleges were dissolved massively by consolidation or development into comprehensive universities.

The social environment has changed a lot in the new century, which is mainly embodied by the new technological revolution, the two shifts in the economy of our country, the universal engineering education reform and China's entry to WTO.

Accordingly, there are great changes in the demand for engineering education both in quantity and quality. In the aspect of quantity, the structure problem including vertical layered structure and horizontal specialty structure is more protruding, and it is clarified that the quality of engineering education consists of the three elements of knowledge, ability and morality.

After the discussion on current situation and problems, ten problems are put forwarded in engineering education, which include objective, nature, characteristic, subject, system, assessment, status of undergraduate education, moral education, information and industrialization, among which, problems of objective, nature and characteristic aim at engineering education itself while other problems are general to the whole of education and problems like industrialization and information are both general and characteristic of engineering education.

In the end, it is stated that the direction of engineering education development is integration, diversification and internationalization. Analysis of integration in many aspects is conducted in both content and method.

## **I. Background**

The background of the reform and development of engineering education in the new century mainly includes the following aspects:

**1. New Technological Revolution.** The new technological revolution represented by information technology is just unfolding. Though the situation in the information industry has been severe since last year, i.e. the bubbles shattering, the developing tendency of information technology

itself and its gradual deepening application is unquestionable. Shattering of the bubbles will make the function of information technology more practical and more effective in the development of society.

**2. Economic Development.** It was ten years ago that the two shifts were proposed in China, which is far to be accomplished. That is, the economic system shifts from planned economy to market economy and the economic growth mode shift from extensive mode to intensive mode. Great achievement has been gained in the shift of economic system though it is still far to be completed while the shift of economic growth mode is only in the starting stage and has a long way to go.

**3. Changes in Educational System.** Great changes have taken place in the entire educational system since the policy of the reform and opening, especially in the past few years.

**4. China's Entry into WTO.** China obtained formally the membership of WTO last year, which makes the internationalization of talents and education unavoidable. Researches on engineering education should be based on the above background.

## **II. Demand**

The first aspect to approach in the research on educational system is demand. I think concept of demand has two aspects: quantity and quality, which have many problems worth studying.

1. Quantity problem. The problem of quantity also has two aspects: the aggregate and the structure. Quantity does not mean as simply as we need one million, two million, three million or ten million talents. In the recent planning on talents by the authority concerned in China, it is stated that we now have fifty million qualified personnel in various fields. The number is rather considerable. Besides the aggregate and absolute quantity, the problem frequently talked about is proportion. It is known that we have been talking about the proportion of college students to the total population, gross school entrance rate and the increase of the rate. Proportional problem deserves consideration, but it should not be merely concluded as proportion to the population. Though proportion to the population is very important and is also a rather basic indicator such as the entrance rate of the compulsory nine-year education, the ratio of illiterate and half-illiterate and etc. However, we should also consider other proportions when viewing specific kind of education.

It was proposed in the research on engineering education reform by Academy of Engineering several years ago that when considering what kind of talents are needed in engineering, we should take into account the industrial scale and the proportion of economic scale and industrial scale. There is a certain proportion between how large our economic scale is and how many people we need. There might be other problems in other education and conditions differ in different countries. For instance, in our country, the proportion of industry to the aggregate economy and economic structure is large, and therefore the proportion of our engineering students is as much as nearly 40%, far exceeding that in the US, which is only about 10%. We all know that the number of lawyers in the US ranks the first in the world and it is said that half of the lawyers in the world are in the US. This means that social structures in different countries are not the same. Proportion of industry in the economy of the US is below 20% while it is over 40% in our country.

Therefore, other proportions besides that to the total population, as well as the relations with the social development, are also to be considered overall.

The quality problem also includes two aspects: the vertical structure, i.e. layered structure, and the horizontal structure or specialty structure. Do we need people in a single level or different levels?

Obviously, the society needs people in different levels. The serious lack of senior technical workers has been revealed recently. Many places advertise for technical workers and the remuneration offered is better than that offered to those with bachelor and even master degrees. However, they cannot find the qualified workers they need. Evidently, it is questionable thinking only what we want, applying the single and same criterion to our young people and requiring them to become people of the same type.

The software industry is a hot topic now. People needed in the software industry are in the two extremes. One extreme is specialist capable of systems design or entire software design, while the other extreme is software workers or so-called software blue collars. Students with bachelor and master degrees cannot undertake the entire systems design upon graduation. There is no training on software system design in our educational system and teachers themselves have no similar experience at all. How can they teach students that ? On the one hand, it is difficult to bring up top qualified people directly from schools and on the other hand, we do not cultivate people in lower levels, either, so the vertical structure is a big problem.

Horizontal structure or specialty structure is also a problem. The proportion between different departments and especially problem of cross specialties are worth studying. The current specialty classification makes it hard to give rise to new specialties. For example, the specialty of Logistics in the undergraduate education was cancelled during the reform. However, people specializing in Logistics are now in great demand everywhere and a few qualified specialists are quite popular. Teachers in some schools are also invited to make plans and consultation.

I talked about it with people in the higher authority to get some help. The first question he asked me is which department Logistics belongs to. I was not clear about that. Then he asked me whether it belongs to department of arts or science and engineering, which was also hard to answer. I told that it was probably a cross specialty. Colleges of engineering may stress contents on engineering while the colleges of arts may focus on those on arts. Then I said: Just because it is hard to tell which department it belongs to, it needs developing and it is a cross specialty. The current classification method is harmful to the development of our cross specialties. Some schools in the US offer the specialty of Financial Engineering and it is heard that the same specialty is also offered here in some places. Which department does Financial Engineering belongs to - Finance or Engineering, Economics or Engineering? It is hard to define.

2. Quality problem. The other aspect of demand is quality, which is widely recognized in the world. It includes three elements: knowledge, ability and morality. There may be some different formulations and words other than these. The English words for "Neng Li" are also different. Some use "capability" and "ability" while others use "skills". They are all ways of saying "Neng Li". One is knowledge, another is ability and the third is morality. Morality is thought highly as well in the capitalist countries, though their practice may be different from ours.

### **III. Current Status**

What is the current status of our education? Generally speaking, there are two major changes in engineering education after the founding of our People's Republic of China.

The first change is the readjustment of colleges and departments according to the Soviet pattern. Some elders among the present might have experienced it. Those who are older might be teachers at that time and the major were still students. A series of specialized colleges were established during the

readjustment and among them, engineering colleges took up a rather large proportion. That is learned from the Soviet pattern, which was basically the same as the German pattern, i.e., the educational system stressing training of practically qualified personnel. This pattern had been effective in the development of the large-scale industrialization after the founding of our People's Republic, while at the same time it brought about many problems.

The second change took place after the reform and opening to the outside world. After extensive speculation, the former pattern was assessed as disadvantageous. Some specialties are classified even more finely and subtly than that in the Soviet Union. This could be very harmful to the cross of specialties. Thus it is thought necessary to return to the original US pattern, which we followed before the liberation. Then the scope of specialties is expanded and some specialties are integrated. In recent years, schools are integrated in large scale, during which comprehensive universities are established. The major changes include three aspects: integration of schools, expansion of student enrollment and change in management system. I think all of you specializing in education would have more knowledge and understanding on this than me. The change in management system is mainly the dissolution of schools subordinate to ministries and commissions with only a few exceptions. Schools can only be operated in two levels: the Ministry of Education and the provincial and municipal governments.

We should admit that after the founding of our new China, a large quantity of people has attained education, and the demand in this 50 years has been mostly satisfied. It is not easy to comment on quality. Except the returned scientists, those who have fulfilled the economic and technological achievements including the "Two Bombs and One Satellite" were all cultivated by ourselves. It proves that the quality of our education has reached a certain level.

#### **IV. Problems**

1. Quantity Problem. Opinions on the current aggregate are completely divergent. The principal one is that the current aggregate is not enough, the starting point of which is that its proportion to the total population in our country is far smaller than that in the developed countries. Our education should provide opportunity for everyone to enjoy it and the access to higher education for all the young people. In this point of view, the number is far to be enough. It has been the prevailing idea, especially in the last few years. There might be some alteration this year, since the speed of enrollment expansion has slowed down. The opposing opinion is that there is still a large gap between our economic development level and that of developed countries. Can our social resources support the education system in the similar scale to that in developed countries? In particular, our primary education is so weak that many in the countryside cannot afford to go to primary school for the compulsory nine-year education. The proportion of our higher education expenditures to the whole educational budget is the highest in the world. During the Two Conferences this year, there are strong appeals for attention on agriculture, rural areas and peasants, including the education in rural areas. Why do the peasants have to pay for the primary education themselves while the government undertakes that in cities? The average income in rural areas is only one third of that in urban areas. We have been talking about shaking off poverty and fostering agriculture. However, even the primary education has to be bought by peasants themselves, which is greatly unfair. That is the problem in allocating educational resources. Another problem is on the sources of educational resources.

Certainly there should be some growth of sources, but is there some limit to that growth? To what extent can the sources be augmented and the demand be satisfied?

2. Quality Problem. I think problems exist in all the three elements of quality.

1) **Obsolete Knowledge.** Obsolete knowledge is a problem for both traditional specialties and new specialties. The traditional specialties have experienced lots of changes in dozens of years, but many teaching materials and textbooks are not fully updated, still less in new specialties. There is distance between our education and the technological development and we just cannot keep up with it. Thus the problem of obsolete knowledge emerges.

2) **Lack of Ability.** Practical content in teaching is in decrease under the dominant idea and the hands-on practice is far less. Even for the theoretical thing such as designing, there are mostly simulated questions with less combination with practice. Besides the hands-on ability, the thinking ability of the students is also very poor, because Methodology, thinking method or Logic was not covered in schools or even in the entire teaching field. Of course, there still remains the problem of poor self-studying ability and etc.

3) **Empty and Vague Morality.** We have moral education and have attached great importance unswervingly to it in form. It is concluded into "Two Courses", but their content is too empty and vague to be effective in the formation of young people's morality.

3. Educational System. The problem in educational system is critical. Though the credit system has been introduced for many years, a credit system in the real sense has not been built up and it is the year-number system with something like credit system that prevails. Transfer from one school to another or from one department to another is not approved. Recently, the software institute in Tsinghua University transferred some students from other institutes, but this transfer based on plans, not on the will of students. Late Mr. Zhang Wei had placed emphasis on the opening-up of different educational channels. Can they be opened up? For instance, now people often talk about higher vocational education. Will he be allowed to participate in the entrance examination for postgraduate after graduation from vocational school? He will not be allowed to. Therefore, students have only one channel to go down for their education, which is very disadvantageous to their growth.

4. Management problem. The quality of management is relatively low, or as we call it, inefficient. With the consolidation of schools, there appear directors of institutes under the university president. An administrative level multiplies and the president is busier than before, making it more difficult to handle affairs.

## V. Discussion

Here I would like to raise some problems for your discussion. Some ideas may not be right. We can discuss it together.

1. Objective. Which is the goal in our engineering education - to cultivate engineers or scientists? It was mentioned that due to the lack of practical content at school, it is hard for the graduates of four-year higher education to undertake engineer's work directly. So we proposed to cultivate primary engineers. The pattern in our whole school system is still a pattern of science, and thus most of the masters we have are masters of Science. We have only a few masters of engineering, but they are all on the job. What on earth is the training pattern of our engineering education? We need some engineering scientists in projects, but only a small portion. Most needed should be engineers or primary engineers. It is known that engineer and scientist are two different vocations with different .

tasks. The task of scientists is to explore the world and to discover while the task of engineers is to transform the world and to create. So it is a problem unsolved. There is consensus of opinions on the problem within our Educational Committee of Chinese Academy of Engineering, but in the entire educational circle, the problem remains unsolved.

2. Nature. Whether it is engineering education or science education is closely related to the above problem. We, including the older generations, even the next generation, have been attaching superiority and inferiority respectively to science and engineering. I will cite an example. It may seem ridiculous to you. What is the translation of MIT into Chinese? “Ma Sheng Li Gong Xue Yuan” (Massachusetts Institute of Science and Engineering). We do not use the word "institute" any more now since we are establishing universities and we look down upon institutes, but things were not the same at that time, so the word "institute" was translated by its original meaning. Then what about "Li Gong"? What is "Li" and what is "Gong" in English? There is no "Science" or "Engineering" at all in its original name literally. The correct translation of its name is “Ma Sheng Ji Shu Xue Yuan” (Massachusetts Institute of Technology). Moreover, we translated Caltech into "Jia Zhou Li Gong Xue Yuan" (California Institute of Science and Engineering). Obviously it is actually "Jia Zhou Ji Shu Xue Yuan" (California Institute of Technology). Whatever the translation is, Caltech has already produced famous masters of Science and a good number of well-known and excellent engineers. Our seniors might think that the Institute of Technology did not sound very good when they translated it into Chinese and then put it into Institute of Science and Engineering. Although it is only a noun and does not matter a bit, the idea reflected lasts until today. Schools of higher education keep on changing names, from institute to university, and adding words sounding superior to their names. What is the superior word in their mind? - Science. They think "Science" is superior to "Technology" and "Engineering". Therefore, how to form an engineering education system with the objective of training engineers ourselves is worth studying.

3. Characteristic. Here we have several relations. The first one is the relation between theory and practice. Can we handle this relation well? The second one is the relation between exploration and application. Science is mainly to explore while engineering is mainly to apply and solve the practical problems. The third one is the relation between analysis and synthesis. Generally speaking, the analysis is the method often resorted to in science, while our engineering people employ the method of synthesis. Any modern project with certain scales is not a project on a single subject. Can you tell what project an aircraft is? Now we call it an aeronautical project. Besides, the electronic equipment on a fighter surpassed the body itself in value. Can you tell what project it is? It bases on Aerodynamics for flight. However, flying with nothing inside cannot solve any problem. Thus engineering in its nature is synthesis.

4. Subject. Which is the subject of education - teachers or students? There were many ideas on it before, which held that the subject should be teachers. This has changed gradually to the current view regarding students as the subject. Whether students have learned and what they have learned is the result that matters. It is not the same kind of thing that a great teacher produces a brilliant student. Students taught by one great teacher might not be equally brilliant. Their conditions are different.

5. System. System has two aspects: structure and institution. Structure is a problem of being singularized and diversified. Should all schools become the same and keep up with Tsinghua University and Peking University or should they have different patterns? We visited California State University and they introduced to us upon our arriving: Our university is not a UC, which stands for

the universities concentrated on research in the United States and we only meet the practical need. The education in the US has three levels - the UC, the state university and the so-called community college. They have clear positioning of themselves. Yet here in our country schools in the lower level are always thinking to catch up with those in the higher layer and to reach the same level with them. This explains the "Project" everywhere and school expansions. What is first-class university and how many first-class universities will be set up? I am not sure about that. Nor am I about the number of universities in the project of "211". In the aspect of institution, is it standard, inflexible or flexible? This is worth studying.

6. Assessment. In what way should we assess schools and education? We got some experiences on it this time. The assessment of education in the United States has change a lot in the recent years. In their new 2000 standard of assessment, their focus changes to assessing what students have learned rather than what teachers have taught. In our previous assessment, it was examined how many courses you offer, how you teach and how your facilities are. For example, it was inspected here whether the running track is 300 meters long or 400 meters long, which I quite dislike . Only the 400-meter running track can produce good students while the 300-meter track cannot? Problems alike are all caused by assessment made on conditions of facilities. The new assessment should focus on what students have learned. The above is the problem of the assessment system.

7. Status of Undergraduate Education. What is the status of undergraduate education especially in a UC? The United States overlooked this problem before, but has reverted now. They are putting great emphasis on this problem nowadays and have taken many measures to make the undergraduate student grow faster and attain more knowledge in their limited school time.

8. Problem of Morality. We should make it clear first whether moral education is the teaching of knowledge or the guidance of spirit. Now it seems to be the teaching of knowledge. Of course it is certain that moral education needs some fundamental knowledge. If one knows nothing about the history and geography of his country, like some contestant in the recent singing contest who had no idea about the returning time of Hong Kong to our country, he can say nothing about moral foundation. However, morality is still a spiritual problem fundamentally. Then is it only a course or does it run through the entire school life? Suppose it is a course. Then morality is taught in class and you can do whatever you want after class. Is that good? Prof. Li Zhengdao told his experience in a lesson last year. While Filmy was his tutor in those days, it was decided that every week the two of them had to spend half a day talking with each other. The topics could be very extensive, anything besides the specialty. In this way, the tutor can teach by precept and example and thus influence and guide his students. We, nevertheless, sum up moral education as one course and the spread of knowledge. I do not mean that knowledge spread is unnecessary, but what is morality? It is a question to be clarified. A tutor now can have dozens of postgraduate student. Can he influence them and teach by precept and example? Even in the teaching of knowledge, can he really fulfill that?

9. Informationalization Is Informationalization the means or the purpose? We have experiences on it during our visit to Phoenix University On-line. The university has 100 thousand graduates, but it has not built any facilities for itself. They use Internet and establish 24-hour contact between students and tutors by e-mail. The student can get in touch with the tutors at any time. We also have Informationalization in our distance education, but what we do first is to build advanced wide-band network. The US not only has wide-band network, but also their wide-band network has very fast

speed. But it does not work in the same way as ours. We often take the purpose as the means. We have built a lot of networks, but what about our education? It is hard to say.

10. Industrialization. There are problems in the industrialization of education, but I do not intend to talk much about industrialization itself. When viewing industrialization, we must consider two markets. One is the educational service market, which is often talked about in the educational circle - how many people would like to spend how much money to have what kind of education and can they be allowed. This has close relations with the second market -talents market. What is the talents market like? I read in a newspaper a survey on the demand and supply of talents in some place. It is reported that the specialty of Computer ranks the first both in demand and in supply, yet it is also said that this specialty is still the first in the extent that supply exceeds demand. This is a report in a newspaper and I have no idea about its reliability, but it shows that the educational service market must keep a close eye on the talents market. The education itself has a long-time delay, since the two markets function separately and the enrollment of students and employment of the graduates are operated separately, between which there is quite a long time. What will happen in five years or ten years? Is it predictable? Education costs a lot nowadays and the parents save their money to let their children enter school? What is it for? They hope their children will find good jobs in the future, not simply enhance individual qualities. As to what kind of job their children will find, it is a matter of the future. Nevertheless, after several years their children graduate. Can they find good jobs? What will the relations between the two markets result in, if they are not considered together. There will be significant consequences of the enrollment expansion in the next two years. I hope there will be no serious problem, but the reality does not always follow our kind wishes.

## **VI. Direction**

The problem of direction of educational development is composed of three aspects.

1. Integration. There are two aspects included in integration: the content and the method.

For the content:

(1) The integration of natural science with arts and the humanities. Conditions for our engineers nowadays are not the same as before. They need much knowledge on arts and the humanities in market economy and as the foundation for moral education.

(2) The integration of science with technology.

(3) The integration of theory with practice.

(4) The integration of technology with management.

(5) The integration of knowledge, ability with morality. The above integrations need to be considered and correlated comprehensively.

For the method:

(1) The relation between teaching and learning, the two of which should be closely integrated. Someone said that since there is distance education, we could offer enlarged classes with a greater number of students - hundreds or even thousands. One teacher gives lectures, to which students around the country can have the access. This is one method, but is it the basic method? We should think about it. This idea mainly base on the fact that the number of our high-level teachers is too small. However, I am afraid that with the development of education the scale of the class would become even smaller. Like what I mentioned just now, in the Phoenix University On-line, there seems to be the same demand - thousands of students taking a lesson at the same time, but actually its class

scale is smaller than the average, only made up of about ten students. Teachers can handle students through the net and communicate with them whenever necessary, while the students can also have contacts with one another, so the scale of their class is very small. This is the integration of teaching and learning.

(2) How to combine undergraduate with postgraduate.

(3) How to integrate schools with society.

(4) How to combine education within schools with distance education. There are no engineering courses in Phoenix University. They are quite prudent on it since engineering needs a lot of experimental conditions. Though there is stimulated practice, but it cannot completely substitute for the actual practice. The face-to-face education contains the combination of knowledge, ability and morality. How can you conduct moral education without face-to-face communication? Distance education can be good and effective, but can it replace face-to-face education? I don't think so.

(5) How to combine school education with continuing education and life-long learning.

2. Diversification. The educational levels, specialties and institutions need to be diversified.

3. Internationalization. Internationalization contains three aspects. First, we should absorb all the useful experience of other countries. As long as the experience is beneficial to us, we should assimilate it regardless of where it comes from, but we should avoid blind learning at the same time. Secondly, we can establish cooperative relations in education. The control on education is quite strict in our country, but there are still some educational cooperation conducted without the permission of the Ministry of Education, which is actually fairly effective and is promising for some development in the future. Thirdly, the flow of talents. Can the talents acclimate themselves to the internationalization? This is a big problem. So is our foreign language teaching. I do not think highly of our foreign language teaching. We are spending so much time teaching foreign language, from primary schools and now from grade 1 of primary schools in some places all the way to the graduation from college, but what is the effect? Some cannot do the conversation and cannot understand the reading materials well. Let alone writing in foreign language. How can we adapt to the international flow of talents? How can we fulfill the work better? How can our people go and work abroad? Those are all problems.

Today I shared with you some of my opinions and mainly raised some questions for discussion. Engineering education is a problem of vital importance, which concerns the whole interests of our country. The progress of our society and the prosperity of our country rely on economics development, while economic development relies on technology and technological development relies on talents. Talents depend on education. Therefore, education is a problem that determines the final destiny of our country.