Trends in Engineering Education - An International Perspective

F. A. Kulacki, Executive Director
Technology-Based Engineering Education Consortium
Department of Mechanical Engieering, University of Minnesota
Minneapolis, Minnesota 55455 USA
and
E. R. Krueger, President
Krueger and Associates
Bend, Oregon, USA

Abstract *- This paper presents a critical overview of contemporary international trends in engineering education. An analysis is presented of engineering curricula, educational delivery systems, engineering programs in developed and developing nations, and major challenges facing engineering education worldwide. Our intent is to synthesize the many ideas under the broad categories that have been presented at two recent world conferences on engineering education held in the United Kingdom in 1991 and in the Untied States in 1995. Based on this analysis of the contemporary situation, we present our perspectives on the immediate future and the possible scenarios facing engineering schools over next generation.*

Introduction

Two world conferences on engineering education held in 1993 and 1995 have brought focus to several issues, problems and opportunities that appear to be universal regardless of the federal and private systems of higher education in place around the world. Moreover, concerns over the education of the engineering workforce seem to pervade both developed and developing countries. Thus, with these two conferences as underpinnings, we analyze the current state of affairs and draw some general conclusions on the course that engineering education appears to be taking at the present time.

We note that transnational issues in engineering education have been a topic of discussion for some years, and several national and international associations and professional societies have from time to time addressed over arching issues and concerns. The United Nations has been a particularly active participant in the international dialog, and the International Liaison Group for Engineering Education has been a prominent promoter of international conferences on the subject. The World Bank has recently initiated developmental projects in several underdeveloped nations in Sub-Sahara Africa. Also, industry in the developed countries has become more interested in the future path that engineering educators chart for their schools given the relation between high value-added products and engineering know-how.

It seems that we are a particularly good point in time to draw together some of the trends that we have seen develop over the past tent to fifteen years. The ICEE's offer the potential to synthesize developments, to systematize them, and to serve as a technology transfer agent for engineering schools in various regions of the world.

The Framework

The framework of our discussion here comprises global high-technology industry and the engineering schools. Both are reflected in the focal areas touched upon by the two world conferences. To set the stage for our discussion of emergent trends in engineering education, we briefly comment here on two highly relevant factors: the early-21st Century picture for competitive industries and engineering degree trends.

The technical environment into which engineers will emerge in the next few years will be characterized by knowledge-based industries with high value added products, a high reliance on the application of fundamental science in product development, and a development-to-design-to-manufacturing process relying on a high level of simulation and information flow.

This is not to say that industries dealing with natural resources, infrastructure, and environmental quality will wither. Rather it is that advanced and developing economies will ultimately be based on "brain power" where the economies of scale and simple automation will not be sufficient for survival. In addition, the rapid growth of technologies that quickly disseminate knowledge and provide ready access to information and data have the potential to alter permanently the form and possibly the substance of engineering work during the next generation.

The engineering workforce (engineers and technologists) appears to be increasing globally despite current declines in the US and Europe[1]. Most of the increase has occurred in the

[1] Engineering degree trends in the United States have been carefully monitored for some time. Degree data for the 1985-1994 period have been summarized by Clarke and Kulacki [1996] and show a steady decline of the baccalaureate degree production. Annually, the degrees awarded at the end of the period were some 17% lower that for the base period. Technology degrees (two- and four-year) have remained at about one-sixth the number of baccalaureates. Overall degree production (BS, MS, and Ph.D.) in

Pacific Rim and in other Asian counties. The newly industrialized countries in this region have apparently made a long-term, strategic commitment to increase the engineering workforce. Current population and degree production data suggest that the worldwide engineering workforce in the next generation will be largely Asian in its cultural origin. The contribution of India to the international workforce will also be a significant factor, but the contribution of Central and South America remains to be determined over the long run.

Although the distinction between engineers and engineering technologists is maintained in the US and Europe, engineering and engineering technology are generally combined in a national system of higher education in other countries. The distinction between degree holders is therefore sometimes difficult to determine. Figure 1 illustrates trends in degree production in the US and selected Asian and European countries.

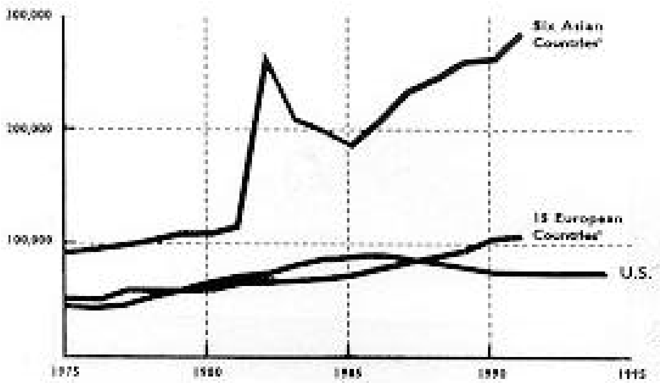

Figure 1. Projected worldwide production of engineering baccalaureates. A variety of sources have been used here, including data from the Engineering Workforce Commission, UNESCO, and the National Science Foundation (Johnson, 1993). This graph is taken from an article that appeared in the ASEE Prism in 1996.

The World Conferences on Engineering Education

The world conferences on engineering education held in the United Kingdom and the US in 1992 and 1995 respectively focused of very similar themes and thus represent a benchmark on the current state of engineering education in the 1990s and also a departure point for focal actions in the first decade of the next century. An all together different set of voices expressed surprisingly the same issues and areas of concern in a 1989 conference of limited scope held at the Ohio State University.

The emerging common theme of the 1992 and 1995 conferences may be said to be “restructuring engineering education to meet world needs”. Within this over arching idea, special topical foci included: educational development based on the productivity, the quality and accessibility of engineering, a concern for the environment, the use of technology, an understanding of the changing role of the faculty, innovation within the curriculum, and the formation of an action based agenda on international collaboration. Keynote lectures were focused on the articulation of engineering education with the needs of national and regional economic development, curricular design and reform, the impact of technology--especially computer-aided design and analysis--on the educational process and engineering itself, and the role of the engineer in the next century.

What we can say at this point is that a new context for engineering education worldwide is beginning to emerge. It is based on a paragon defined by three broad themes:

- **Education on any subject at any depth, any time and any place.**
- **Education tailored and styled to the individual learner’s skills.**
- **Integration of tomorrow’s research into tomorrow’s instruction.**

Each of these forms the basis for a number of the individual actions aimed at curricular reform, altering the role of the faculty, etc. Each of the focal areas of activity mentioned above are framed by elements of the larger educational process. It *is* a complex problem with no simple solutions and no clearly defined path of development. But what we have seen over the past ten years is that a “good news” versus “not so good news” kind of picture is coming into focus for the engineering schools, the faculty, and industries of all kinds.

The Good News

A worldwide movement toward the application of information technology to education - From the very developed nations to those emerging from the primary levels of agriculture, manufacturing, and design, the use of computing and communications technologies of all kinds is increasing as fast as the schools can install and implement campus wide information systems, workstations, and personal desktop computing. The raw capabilities of hardware and software have far outdistanced the adaptation of those capacities to engineering education in any sort of pervasive manner.

Irreversible changes in Eastern Europe, Africa, the Pacific Rim, and China - The change in the political landscape of these regions and the opening up of economies to embrace free market principles (even if slowly and with federal supervision) has meant that engineering schools and technical institutes are expected to play the same roles as their counterparts in the developed capitalist economies. Concurrently, we have observed almost universal activity related to a comparative analysis of the curriculum within the context of curriculum development.

---

the US has been generally steady during the period, with increases in graduate degrees compensating for the decline in baccalaureates.

A growing understanding on the part of national governments of the role of engineering education in the welfare of the state - National governments in both developing and developed nations have expressed through the world conference an understanding of the connection between the quality of their system of engineering education and key measures of national well being, e.g., economic progress and the sustainability of the national infrastructure. In more than one keynote lecture and contributed paper, the relation between the work of the engineering schools and the wealth creation process has been heard. Moreover, the fundamental idea that innovation is an incremental process appears to be more understood and appreciated.

The Not So Good News

Curriculum structures are slow to change. - Despite the efforts of many individual faculty members, administrators of engineering schools, and sometimes national governments, engineering curricula tend to remain faculty centered and content driven. Pedagogic approaches to learning that were established some fifty years ago yet control the educational process and shape the curriculum. In the US, the curriculum in place today was established in the 1950s and refined via several national commissions and the accreditation process throughout the 1960s. It is only with the advent of new accreditation guidelines that the potential for reshaping the curriculum has been created. However, the majority of the engineering schools in the US will not be too very much affected by the new guidelines until well into the next decade.

The future roles of the faculty are not well defined. - The future roles of the faculty of engineering have not been clearly enough defined in light of generally admitted potential for changes in engineering education. Currently the faculty are experts who provide information in a compartmentalized curriculum. Perhaps the future shape of engineering education will require them to embrace activities as mentors and facilitators in an environment where engineering judgment and the synthesis of knowledge are at the center of the learning process remains to be seen. In any event, a major shift toward a student centered educational process based on andragogy is perhaps needed before any significant redefiniton of faculty roles can take place. Also, the extent to which substantive curriculum reform takes place is needed as a prerequisite to altering faculty roles and work.

Faculty obsolescence will continue to be a factor in educational reform efforts. - While it is difficult to generalize across the many educational systems in place around the world, we believe that faculty obsolescence will be as much of an issue over the next 15 years as both the curriculum and the roles the faculty play in the learning process. In some nations, reductions of state support to the universities will ultimately mean a reduction in the numbers of faculty members and their support staff. In seniority-based systems of employment (we include here the tenure system of the US and lead professor system of Europe), an inevitable aging of the faculty will take place. The result will be a faculty with a skill set that is somewhat out of step with the requirements of engineering practice in the future. There are, of course, several remedies here, but a full discussion of them are beyond the scope of the present paper.

Baccalaureate and masters/professional degree programs need better definition. - With the advance of technology, it is not clear that baccalaureate programs can either expand or otherwise revise their content to accommodate new knowledge. We are perhaps at a point where the baccalaureate is insufficient for entrants into the workforce who wish to work at the forefront of product development, design, applied research, etc. In all nations, this issue needs thorough discussion, and models of engineering education need to be developed that recognize both the general and professional nature of engineering.

The intersection of science and engineering will alter the educational mission - This is arguably the most important issue for engineering schools worldwide. What we have witnessed over the past generation are two trends in engineering that are at times in opposition. The first is a dramatic altering of the basis of modern engineering because of breakthroughs--incremental and paradigm shifting--in fundamental scientific knowledge and the advance of computationally based tools for engineering. The second is an external pressure on engineering schools to produce students with readily applicable skills to meet the needs of industry. The first results in engineering education that is aimed at the long term while the latter begets a kind of vocationalism that was the end point of engineering education in the early years of the current century.[2] We believe that the first will eventually win out because it will be more relevant to the long-term survivability of industry and national economies.

We do not minimize the need for an engineering workforce that can perform over the entire spectrum of technical tasks needed in society. The schools should fundamentally address their educational mission and type of graduates they wish to produce. This outcomes oriented approach will enrich the engineering educational system worldwide and provide the varied technical skill sets needed for all types of economies and regions whatever their stage of development.

The use of technology in instruction is spotty. - Despite the many papers presented at not only the world conferences but also at other learning educational conferences (e.g., the Frontiers in Education Conference, the Annual Meetings of the Technology-Based Engineering Education Consortium), the use of computer-based instructional techniques is "spotty"

[2] This was the case in the US and most likely Europe. The shift in the US toward engineering science that gained momentum after 1945 fundamentally altered engineering schools. We note that in countries where economic transformation is underway, e.g., China, a system of technical education exist that includes a large number of institutes that provide training for specific technologies or industries rather than broadly-based engineering education.

at best. We draw a distinction here between technology as such and technique. Hardware and software currently exists that provide faculty and students with sophisticated tools for computation, simulation, and visualization -- this is the technology. However, the use of these tools in any sort of uniform way and in a manner that deeply affects how content is delivered and learning takes place is not at all apparent. Several schools have made tentative steps toward the use of technology, but our assessment is that technology-based educational processes are yet viewed as a supplement to traditional classroom lectures and laboratories. The need for the next several years is for effective dissemination agent for workable developments and techniques, as well as standards for instructional software.[3]

The Future Agenda

Three focal areas, or thrusts, have become apparent from our experience with the world conferences:

- Engineering education has assumed a truly global purpose and character.
- A new technological paradigm appears to be emerging.
- A restructuring of the educational delivery system is both needed and of deep concern.

Each of these deserves comment and some elaboration on possible future developments.

Global Aspects - Over the past ten years or so, each of us has interacted extensively with a variety of leaders in industry and education from around the world. The common message that they send to educators is while ready-to-use-skills are highly desirable, education of a generic nature is much more preferred. The long-term viability of an industry requires technical talent that is adaptable, flexible, and has a capacity to learn. These drivers are all the more important given a future in which international manufacturing and marketing and engineering with cross-cultural skills will e be demand.

While systems of engineering education meet these requirements to a varying degree, we are convinced that the message has gotten across to both the engineering schools and their benefactors (governments or donors). This, of course, places the schools in an interesting and challenging position. Our comments on the faculty, the curriculum, and educational delivery are relevant here.

An emerging new technological paradigm - A new educational paradigm us just beginning to emerge but is gathering momentum in a variety of settings. There are great differences worldwide as to how this paradigm is being conceptualized and applied within the engineering schools, but several elements are generally accepted. These include multi-media, computing, communications, software standards, standardized software, electronic publication, universal data sets, and universal design bases. We are at the very start of a period where each of these elements will be imbedded into the vocabulary of the educational process and given unique attributes in the development of engineering curricula.

Restructuring of the educational delivery system - There is general consensus that the engineering curriculum that has evolved during the 20th Century needs to be restructured to meet new societal needs and a transforming industrial scene. While integration of curricular elements and even entire programs of instruction is underway in many schools worldwide, there is surprisingly little commonality of approach and the sharing of methods and educational philosophies. This area, we believe, will require repeated and extended discussion a worldwide basis if engineering education is to achieve the reforms envisioned by industrial, governmental, and educational leaders.

The delivery system need to emphasize fundamentals at the undergraduate level, provide for an increased breadth of knowledge, focus on the learner, address life-long learning needs, and provide to a great an extent as possible cross cultural experiences.

The Forecast

We have touched on a large number of issues here that have been made visible by the world conferences and related experiences over the past decade. Our purpose has been to offer a framework for future activity rather than to offer solutions on any one particular issue or problem. The worldwide engineering education system is just too complicated and varied for general solution seeking.

We are assured, however, that movement toward the paragon of engineering education as we describe it here is universal and touches both developed and developing countries alike. Rates of progress toward a very different future and the endpoints of reform processes will vary rather greatly across the world. This is to be expected and in fact assures a richness and diversity in educational approaches that are as much needed as software standards and general agreement on the attributes of graduates.

Based on what the world conferences have told us, engineering education is generally moving toward an information rich, student centered future in which learning can be conveniently extended beyond the engineering school. In this environment the distinction between formal post-graduate education and life-long learning will diminish, and engineering knowledge will be provided to practitioners and students alike on an as-needed basis. Within this framework, we expect that the requirements on the engineering faculties around the world will be much more demanding because of the seamless amalgamation of scientific knowledge,

[3] The World Wide Web may in part answer the need here. Communication protocols are established and the use of hyper-text markup language is universal. The few authoring tools that are either freely distributed or commercially available are quite powerful and generally accessible worldwide. Perhaps the WWW may provide the vehicle on which ubiquitous reform can go forward.

techniques of engineering practice and international design standards.

References

Duggan, T.V., (Ed.), *Proceedings, Third World Conference on Engineering Education*, Vols. 1 - 3, Computational Mechanics Publications, Boston, 1992.

Clarke, R. W., and Kulacki, F.A., "International Engineering: Tins our Engineering School Never Told You," *Mechanical Engineering Education for Global Practice*, Proceedings of the 1997 ASME Mechanical Engineering Department Heads Conference, American Society of Mechanical Engineers, New York, 1997, pp. 27-38.

Glower, D.E., (Ed.), Proceedings of the International Symposium for Engineering Deans and Industry Leaders, College of Engineering, The Ohio State University, 1989.

Johnson, J. M., "Human Resources for Science and Technology: The Asian Region," National Science Foundation, NSF93-303, Washington, 1993.

Knoweles, M., The Modern Practice of Adult Education, Cambridge, The Adult Education Company, New York, 1980

Krueger, E. R., and Kulacki, F. A., (Eds.), *Proceedings, Fourth World Conference on Engineering Education*, Vols. 1-4, William C. Norris Institute, Bloomington, 1995.

Simrall, H. C., e*t al.*, "Challenge for the Future: Professional Schools of Engineering," National Society of Professional Engineers, Washington, 1976.

__________, "Engineering Education, Designing and AdaptiveSystem," National Research Council, Washington, June, 1995