Session 2266

Factors for Change in Mechanical Engineering Education

B. K. Hodge, Robert P. Taylor
Mississippi State University

Abstract

The combination of world events and technological advances is likely to result in the most profound changes in engineering education since the post World War II period. Factors for change in mechanical engineering education are postulated and described.

Background

The story of engineering education is change. A very interesting and readable account (Grayson, 1993) of the history of engineering education was distributed at the 1993 ASEE Annual Meeting during the centennial celebration of the society. Indeed, the Proceedings of that meeting contain a number of history-related papers in virtually every division. Reading the Grayson history or any of the many history-related papers in the 1993 ASEE Annual Proceedings illustrates just how profound and continuous change has been in engineering education. Thus far in the twentieth century the most profound change in engineering education occurred after World War II and at the start of the Cold War.

World War II illustrated the enormous impact research and development in science and engineering could have in the battlefield environment. Many engineers, especially those in academe or from academe, also observed that physicists played a dominant role in research and development activities. Many of these engineers concluded that the reason physicists played such an important role was the education in the basic sciences and mathematics that typified the undergraduate education of physicists. As a result the years after World War II saw profound changes in engineering education with the inclusion of more mathematics, a much firmer grounding in the basic engineering sciences, and the rapid assimilation of technological innovations. The Cold War of the decades after World War II continued to require large number of engineers with training suitable for the defense industry. Indeed, a number of engineering educators have viewed engineering education from 1945 to the early 1990's as primarily structured to supply the education needed for defense, and later space-based, activities.

However, with the end of the Cold War, significant activity relating to a major change in engineering education has been and is currently taking place. Within the next few years, engineering education seems likely to undergo as significant a change as at mid century. Moreover, in addition to structural changes in engineering education, technological developments related to the so-called information superhighway could combine to make turn-of-the-century changes in engineering education more profound than those at mid century. This paper explores some of the factors portending change in the undergraduate education of mechanical engineers.

Factors for Change

Changes in mechanical engineering (ME) education will be viewed in this paper as driven by various factors. The factors listed in this section were determined by the authors. Others would likely develop a different lists of factors, although certainly any list would contain many common factors. The list of factors examined in this paper are split between those concerned with tactics, changes that can immediately be made in the everyday practice of mechanical engineering education, and those concerned with strategy, longterm changes and directions in mechanical engineering education. One of the purposes of this paper is to elicit response and commentary from other ME educators.

As with any profession, mechanical engineering is subject to requirements and demands of practicing members. These requirements and demands are eventually communicated to ME educators and form part of the input into curriculum and course changes. Also as with any profession, mechanical engineering must adapt to the effects of technological innovations. Mechanical engineering, if viability is to be maintained, must integrate such innovations into practice and, ultimately, education. These innovations must be recognized by ME educators and eventually placed in their proper place in curricula and courses.

Table 1 lists the factors identified by the authors as being likely to cause changes in mechanical engineering education. The factors listed in the table are not in any specific order of priority. The delineation of factors in this section is followed in the next section with some comments and discussion for each factor.

Discussion of Factors

The authors postulate that the factors listed in Table 1 are driving potentials for change in mechanical engineering education. An examination of each factor is provided in this section.

<u>Factor 1: Cold war over</u>

Not since the conversion of United States industry to a war footing in the early 1940's has such a massive shift of engineering manpower from one sector to another taken place; this time, however, the shift is from the defense-related industry to more civilian-oriented sectors. If, as many ME educators believe, engineering education in the latter part of the twentieth century was educationally oriented to provide engineering expertise to the defense and space industries, then continuing, significant changes in ME education to reflect demands for different expertise can be expected.

Table 1. Factors for Change in Mechanical Engineering Education

NUMBER	FACTOR
1	Cold war over
2	Computers
3	Changing nature of the job market
4	ASEE
5	ME career expectations and prestige
6	Industry expects ME education to be more responsive to industry's needs
7	No more amateur programming
8	Computer applications and utilization
9	Reduced hours for BS degree
10	Teaching/research balance for faculty
11	International considerations
12	Back to basics
13	ABET
14	Lifelong learning
15	Remote instruction
16	Design education
17	Team projects
18	MTV generation
19	Ethics
20	WWW versus the library
21	Faculty aging
22	Curriculum difficulty
23	NSF coalitions
24	Curriculum emphasis and pressures
25	Assessment and accountability
26	Money

Factor 2: Computers

The dominant external influence on all aspects of engineering in the last half of this century has been the ever-increasing capability and availability of computers. Mechanical engineering has not been an exception as the profession as well as ME educators have struggled to both ascertain what the computer can do for mechanical engineering and what the implications are for ME education. One only has to examine the proceedings of any engineering education conference to sense that struggle. The integration and use of computers in ME can be divided into at least three phases. Phase 1, the 1960's and 1970's, consisted of exploratory attempts, based generally around code development on main-frame machines. The second phase, the 1980's, saw the decentralization of computing power and availability by the personal computer and networks. Phase 3, the 1990's, has so far been characterized by significant desktop computing power and sophisticated, user-friendly, applications software. Phase 3 has moved the mechanical engineer from code development to applications, a trend likely to continue and accelerate. Computer applications will become even more pervasive in analysis, design, and experimentation in the next few years.

Factor 3: Changing nature of the iob market

Driven in part by the end of the Cold War, the employment pattern of entry-level mechanical engineers has shifted over the last few years. At Mississippi State University (MSU) a much larger percentage of the graduating class is accepting employment with small companies and with local, rather than national or international, companies. Many of these entry-level jobs will require that the engineer perform a wide range of tasks involving the entire gamut of mechanical engineering. If these graduates are to succeed, then they must have had an ME education that covers at least the basics of most traditional mechanical engineering topics. The changing nature of the job market presents mechanical engineering educators with hard choices: how can more be taught about more in less time (see Factor 9)? Small companies generally do not have long-term training programs, unlike large corporations. Thus, ME's accepting employment with small companies must have sufficient depth and breath to be effective when hired. In the future more engineers who initially accept employment with larger companies may be hired away by smaller companies that require special engineering expertise.

Factor 4: ASEE

The ASEE needs to be more effective in attracting, holding, and using young faculty members. In too many institutions, new faculty are warned not to concentrate on the education function and tend to avoid ASEE activities. The ASEE does offer considerable opportunities for publications and interactions with other faculty members from different institutions. ASEE members have a window of opportunity to help make the ASEE more effective and viable as the education function is now increasing in importance in many schools. This represents an opportunity.

Factor 5: ME career expectations and nrestige

Engineering as a profession suffers from lack of prestige. Part of the reason is that the details of what engineers do are generally hidden; part is that as a profession we have not been very effective in public relations; and part is because only a BS is required for entry.

Mechanical engineers have a perceptual problem. The great diversity and opportunity in mechanical engineering need to be explained, since the profession is not viewed as a glamorous one. Highly qualified students sometimes shy away from ME and major in other engineering disciplines simply because the name is no longer descriptive of what ME's do. The name cannot be changed, but the awareness of prospective students about what mechanical engineering really is and what diverse things mechanical engineers do can be enhanced.

Factor 6: Industrv expects ME education to be more responsive to industrv's needs

This has always been an important consideration for ME education, but enhanced industry expectations and fundamental changes in the engineering workplace requirements have exacerbated the need for response. With the end of the Cold War, downsizing of many industries, and the "reengineering" of many companies, requirements for ME's have changed (see Factor 3).

Factor 7: No more amateur nrogramming

Mechanical engineers, especially at the BS entry level, are likely to do little or no coding or code development. The combination of sophisticated software with many man-years of development, spreadsheets, arithmetic systems such as MATHCAD or MATLAB, and company-developed programs have all but eliminated programming in the everyday engineering workplace. Baker et al. (1996), who coined the term amateur programming, pointed out that previous practices might have engineers developing simple codes for diverse, changing applications, but that practice is likely over.

Factor 8: Commuter annlications and utilization

The trend in the engineering workplace will be for more use of sophisticated software systems (see Factor 2), for more use of computers in data acquisition and analysis, and for more use of computers in information retrieval (see Factor 20). If Factor 7 is what will not occur, then Factor 8 is what will occur on a ever-increasing scale. The narrative of Factor 7 is also appropriate for this factor.

Factor 9: Reduced hours for BS degree

Turf battles, provincialism, and technological advances have resulted in engineering curricula that are stuffed, overcrowded, and unwieldy. In most universities, hour requirements for engineering graduates are higher than for the remainder of the university (at MSU 139 hours are required in engineering compared to 128 in most other majors). Many of the trends discussed bear directly on this issue. The authors believe that the basic problem is trying to keep the BS degree as the entry level for engineering. A more general BS degree with an MS or professional degree as the entry-level requirement for engineering employment makes sense. Alas, pressures from industry, state legislatures, students, and faculty are likely to result in the BS degree remaining the entry-level degree in engineering. The problem of producing competent engineers with a BS degree will be exacerbated by demands from many sectors to align real hour requirements more closely with the remainder of the university. The problem of teaching more about more in less time was delineated in the Factor 3 discussion.

Factor 10: Teaching/research balance for facultv

Especially at large, well-known universities, the post World War II years have been characterized by expectations, demands, and rewards for research productivity. Undergraduate engineering education has been perceived as being less important than research. The tension between research and education has been a source of considerable friction for many ME faculties. A number of events are altering the relationship between research and teaching for many faculty members. For state-supported universities, many state legislators do not understand research funding and are overtly hostile to what they perceive as reduced class time. Cutbacks in many federally-sponsored programs have made research funding more difficult to secure. Student retention and student recruitment have focused the attention of many university administrators on more effective teaching.

Factor 11: International considerations

The world is getting ever smaller, and the economies of many nations are becoming more dependent on each other. Multinational corporations are playing an increasing role in manufacturing, distributing, and hiring of entry-level engineers. Skills and masteries not heretofore important in engineering education are in great demand by multinational corporations. Foreign language proficiency, world geography, communication skills, and understanding of diverse cultures are among topics of importance for many engineers.

Factor 12: Back to basics

The increasingly sophisticated analysis and design computer programs and capabilities present a quandary for engineering education: How can students be taught to assess the correctness and utility of answers from sophisticated, general computer codes? Petroski (1994) provides compelling arguments for increased attention to basics in engineering education. As employment patterns shift (see Factor 3) to smaller companies with fewer engineers, understanding of the basics becomes more of a requirement for success for mechanical engineers in the workplace.

Factor 13: ABET

Few engineering programs can afford to ignore accreditation, so maintaining accreditation, while not a new factor, is a continuing one. For better or worse, ABET will continue to provide the system for engineering and engineering technology accreditation. ABET has certainly fostered standards and has attempted to be innovative, but at times bean counting has been a problem and consistency is always a problem when different ABET teams visit different institutions. ABET Criteria 2000 has as a stated goal to focus more on the results of the educational process (...than the contents?...) and to provide a greater flexibility for engineering programs to meet institutional objectives. The proposed criteria are included in the following topics: (1) students, (2) program educational objectives, (3) program outcomes and assessment, (4) professional component, (5) faculty, (6) facilities, (7) institutional support and financial resources, and (8) program criteria. Assessment plays a more significant role than in previous ABET criteria statements. The authors believe that ABET Criteria 2000 will lead directly to a national standardized test for all engineering seniors. If ABET Criteria 2000 is adopted, then “bean counting” will be reduced, but consistency from one ME program to another ME program will be more difficult to maintain as institutions will have much greater flexibility in prescribing ME curricula requirements.

Factor 14: Lifelong. learning

This is not a new factor affecting ME, but rather one that will become much more important. Successful mechanical engineers have always enhanced their skills and developed professionally. However, in the future, such activities will be a prerequisite to remain employed as an engineer. What part will the WWW play?

Factor 15: Remote instruction

Undergraduate courses, graduate courses, continuing education short courses, skill-oriented instruction, or virtually any other instructional need is likely to be available via some remote arrangement. The remote arrangement may be by satellite, closed-circuit television, compressed video, compact disks, the WWW, or video tape. A significant unanswered question is how conventional means of delivering material integrate with remote instruction. A single statics course could be presented by the "best" statics instructor in the United States and every statics student at every university could be enrolled. This is not going to happen, but the issue of how remote instruction affects engineering education is certainly unanswered. Various coalitions, cooperating schools, and other entities are already sharing course and instructors via remote media. A number of questions can be raised: Who teaches?; Who grades?; Who takes the course?; Who gets paid?; What institution gets credit for the course?; How do ABET and other accrediting agencies view various remote instruction arrangements?

Factor 16: Design education

Expectations for design capabilities of entry-level engineers seem to be changing. At a recent meeting of the Mississippi State University Department of Mechanical Engineering's Advisory Committee, understanding of fundamentals was a clear point of suggested emphasis. ABET requirements have likewise changed from a design "bean-counting" exercise to a more integrated assessment. A number of mechanical engineering educators are increasingly dubious of how effective the current teaching of design is for undergraduates. Since design is what distinguishes an engineering education from a science education, design will continue to be a significant part of an engineering education, but how design is taught is likely to change.

Factor 17: Team projects

Teamwork in engineering is increasingly in demand. Thus, the trend toward team projects in engineering education is likely to become more prevalent. Students may not particularly like projects, but they seem to realize that they need practice working in teams. Hodge et al. (1991) found that although ME students disliked team projects, they appreciated the need for such exposure.

Factor 18: MTV generation

Have the learning styles of ME students changed over the years? Although the authors have the results of no studies carried out with validated assessment instruments, the anecdotal observations are that current ME undergraduate students at MSU are less inclined to accept the necessity to master details. Are these observations a part of the “sound bite” culture often associated with the television media and the short attention spans to which most programming is aimed?

The learning styles of students are different. No matter what learning styles inventory instrument is used, most engineering professors’ learning styles would be clustered in same general pattern. Since most professors teach in styles that complement their learning styles, engineering lectures have typically had more appeal to students with certain learning styles. University administrators and engineering educators have increasing concern that students with learning styles markedly different from the usual for engineering professors drop out of engineering to pursue other majors and careers. Does this happen? Is engineering education excluding by default greater diversity in the profession? A more fundamental question might be how well individuals with different learning styles from those of the usual engineer might fare in engineering careers.

Factor 19: Ethics

The perceived value of any profession to the public rests in part with the ethical conduct by members of that profession. In many surveys, engineering is usually assessed to possess relatively high ethical standards. ABET considers ethics to be important enough to be specifically mentioned as a requirement for accreditation. However, formal instruction in ethics is usually viewed as a collateral topic by many in engineering education. The ethical standards of our society are viewed by many as deteriorating. If mechanical engineering is to prosper and gain respect as a recognized profession, then engineering educators must devote more attention to ethics and exhibit working examples of ethical behavior in day-to-day responsibilities.

Factor 20: WWW versus the library

Especially for practicing MEs, access to information electronically will be, if not already is, the norm; hard copy forms such as books, journals, and trade publications will become less important. For engineering education, mastering the information superhighway will be more important than mastering the library. This must affect what is taught and how it is taught.

Factor 21: Faculty aging

Both problems and opportunities exist as the average age of faculty members in a department increases. Senior faculty members represent years of accrued wisdom, expertise, and understanding and are often nearly indispensable in reaching consensus on controversial issues.

Loss of a number of productive faculty in a short period can be devastating to a department and can introduce instability in both research and education functions. New faculty, on the other hand, bring fresh ideas, energy, and youth to a department. As faculty who joined academe in the 1960’s and 1970’s leave, departmental personnel changes will occur, and unless managed properly, can adversely affect ongoing programs and goals.

Factor 22: Curriculum difficulty

This is not new as most engineers can remember the dire statistical information on engineering major success rates gleefully related during their freshman years. Retention may be a problem in engineering education, but engineering must develop acceptable competence with the BS degree. Whatever else engineering education does, it must retain the goal of competence by maintaining standards. A weakened BS degree in engineering is not in either the profession's or the country's best interests.

Factor 23: NSF coalitions

In a effort to "reengineer" engineering education, the NSF has sponsored and funded several engineering-education coalitions. A number of sessions and papers at the last few ASEE annual meetings have been devoted to plans, achievements, problems, and experiences of various coalitions and/or coalition member institutions. The results and experiences of these coalitions should provide guidance for change and the process of change.

Factor 24: Curriculum emphasis and nressures

The future of engineering education will include fewer hours (many state legislatures have already decreed a set number of hours, generally fewer than in unregulated engineering curricula, for curricula in state-supported schools). University core curricula committees are demanding more and more hours in existing curricula; engineering curricula problems are not viewed with much sympathy by most of the university community. See also the discussion for Factors 3 and 9.

Factor 25: Assessment and accountabilitv

For many engineering programs assessment and accountability are either already here or on the way. ABET is increasingly emphasizing the role of assessment. Indeed, the new ABET Criteria 2000 (see the discussion for Factor 13), under consideration, has as a stated goal to focus more on the results of the process. Regional accrediting agencies often key their visits and requirements to assessment and accountability. State legislatures, in times of decreasing support of higher education, have grasped accountability as the tool to wrest control of institutions of higher learning. All is not bad or gloom and doom, but changes will have to be made particularly for bureaucracies interested in only a single quantitative assessment number. Is as discussed in Factor 13 a nationally-normed test for seniors in engineering a likelihood?

Factor 26: Money

For at least a decade, the golden days of unquestioned expansion in higher education have been over. Indeed, the last few years have seen reductions and department eliminations in a number of engineering colleges and schools. The increasing paucity of federal and state funds is a trend that is likely to exist for a number of years. For state-supported engineering schools, the best strategy may be to tie engineering education to economic development. A trend of concern for public institutions is that over the last decade, many state-supported schools have in reality moved from state supported to state assisted as smaller and smaller percentages of their overall budgets have come from appropriated monies.

Conclusions

The factors presented and discussed in the preceding sections represent the ideas and thought of the authors. However, many of the factors delineated would also be contained on lists made by any other engineering educators. Of course, additional and different factors might also be included in other individuals' lists.

Important changes are likely to occur in engineering education in the near future. Within the next few years, changes in engineering education could be as significant as change was at mid century. As mechanical engineering educators we must devote considerable energy to outlining the paths that ME curricula and courses must take in the future.

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