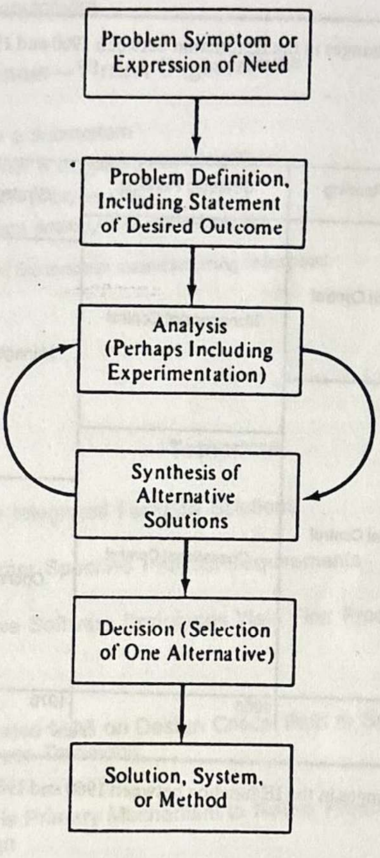
CHAPTER 1
INDUSTRIAL ENGINEERING AS A PROFESSION

TUNING IN:

Engineering is:



. Basic engineering process.

(1) Associated with a profession is a significant body of special knowledge.
(2) Preparation for a profession includes an internship-like training period following the formal education.
(3) The standards of a profession, including a code of ethics, are maintained at a high level through a self-policing system of controls over those practicing the profession.
(4) Each member of a profession recognizes his responsibilities to society over and above responsibilities to his client or to other members of the profession.

Industrial Engineering is

"Concerned with the design, improvement, installation of integrated systems of men, materials, equipment and energy. It draws upon specialised knowledge and skill in mathematical, physical and social sciences together with principles & methods of engineering analysis & design to specify, predict evaluate the results to be obtained" (Zadin, Industrial Engineering Handbook, 2001)

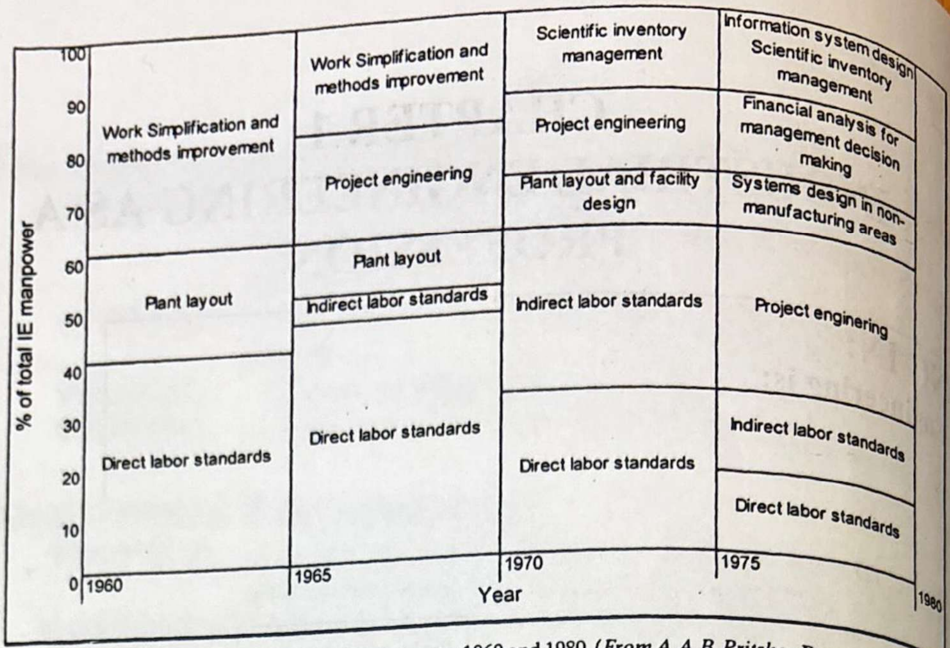
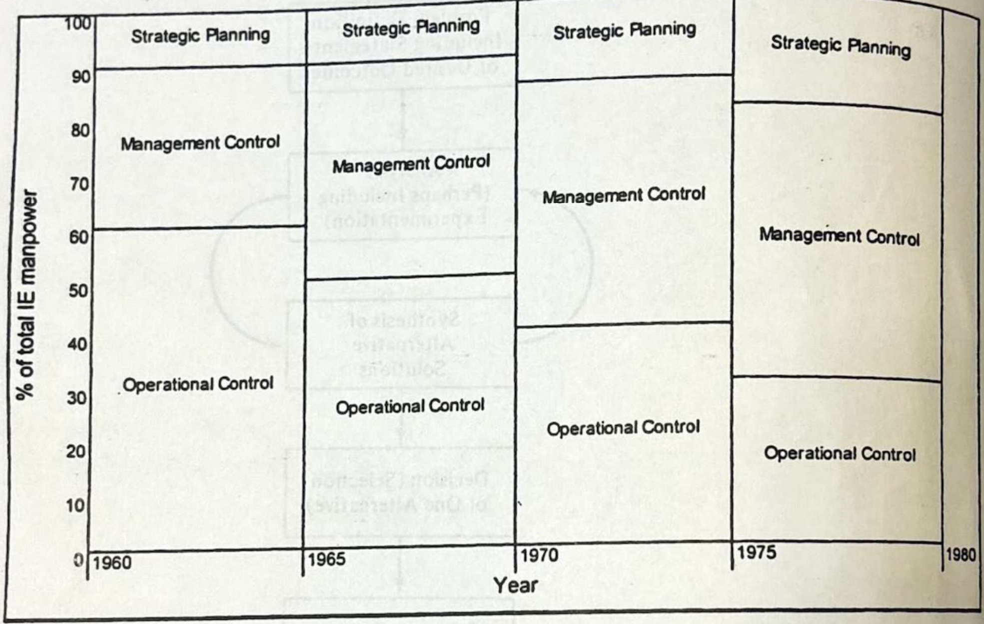


FIGURE [illegible] Changes in the IE function between 1960 and 1980. (*From A.A.B. Pritsker,* Papers, Experiences, Perspectives *[5]*.)



Changes in the IE function between 1960 and 1980. (*From A.A.B. Pritsker,* Papers, Experiences, Perspectives *[5]*.)

Enabling Technology	Concurrent Manufacturing	Integration of Human & Technical Resources	Conversion of Information to Knowledge	Environmental Compatibility	Reconfigurable Enterprises	Innovative Processes
Adaptable and reconfigurable systems	X	X	X		X	X
Waste-free processes				X		X
New materials processes				X		X
Biotechnology for manufacturing				X		X
Enterprise modeling & simulation	X	X	X	X	X	X
Information Technology	X	X	X	X	X	X
Improved design methodologies	X			X	X	
Machine-human interface		X	X		X	
Education & Training		X	X			
Collaboration software systems	X				X	

[illegible]1.1 Applicability of priority technology areas to the grand challenges. (*From* Visionary Manufacturing Challenges for 2020 *[8]*.)

Enriching Customers with Total Solution-Products

FROM		TO
Product	⇒	Product + Service + Information
Product lines	⇒	Fragmented niche products
Point solutions	⇒	Total integrated package solutions
Supplying product	⇒	Integrating with customer's processes

Knowledge-Driven Enterprise

FROM		TO
Product is an aim	⇒	Product is a platform
Sale is one-time event	⇒	Sale is over lifetime
Information confidential	⇒	Information shared and confidential

Adaptive Organization

FROM		TO
Departments	⇒	Teams
Command & control	⇒	Empowerment
Managing	⇒	Leading
Hard tooling	⇒	Soft(ware) tooling
Passive equipment	⇒	Smart equipment

Cooperating to Enhance Competitiveness—Virtual Organization

FROM		TO
Supply a component	⇒	Supply a subsystem
One company at a time	⇒	Customer & suppliers work together
Price = cost + margin	⇒	Margin = price − cost
Arm's length	⇒	Common destiny with stakeholders

The four principal dimensions of the modern manufacturing enterprise.

Today		Tomorrow
Point Solutions	⇒	Totally Integrated Package Solutions
Customer Order (Off the Shf)	⇒	Customer Specifies Product Requirements
Successive Hardware Prototypes	⇒	Iterative Software Prototypes Yield First Production Unit
Stand-Alone M&S	⇒	Integrated M&S on Design Critical Path to Support All Business Decisions
M&S Augments Design Proces	⇒	M&S is Primary Mechanism to Refine Product/Process Design
Models Costly & Time-Consuming to Create, Difficult to Share	⇒	Libraries of Usable Models Easily Accessible
Models Not Available or Affordable	⇒	Availability of Models Driven by New Business Model
M&S Tools Proprietary or Closed	⇒	Interoperable, Networked M&S Tools
Discrete Event-Based Simulation of Manufacturing Processes	⇒	3-D M&S Incorporating Time, Dimensional Variation, & Physical Properties
Hard Tooling	⇒	Hard & Soft Tooling
Fixed Capacity Difficult to Adapt	⇒	M&S Tools Enable Management of Variable Capacity
On-the-Job Training	⇒	Hybrid & Virtual Prototyping Simulators Provide Embedded Manufacturing Education & Training
Controlled Intellectual Property	⇒	M&S Libraries & Tools Enable Collaboration & Sharing of Intellectual Property

1.3.

Transition for modeling and simulation. (*From* Next-Generation Manufacturing Project *report [4]. Used with permission.*)

Industrial engineering education for the 21st century
Badiru, Adedeji B; Baxi, Herschel J
Industrial Engineering; Jul 1994; 26, 7; Academic Research Library
pg. 66

EDUCATION

INDUSTRIAL ENGINEERING EDUCATION FOR THE 21ST CENTURY

By Adedeji B. Badiru and Herschel J. Baxi of the University of Oklahoma

The 21st century is just a few years away. Strategic planners all over the world are using the year 2000 as the focal point for future business activities. Are we all ready for that time? Is industrial engineering education ready for that time? As the industrial world prepares to meet the technological challenges of the 21st century, there is a need to focus on the people who will take it there. People will be the most important component of the "man-machine-material" systems competing in the next century. IEs should play a crucial role in preparing organizations for the 21st century through their roles as change initiators and facilitators. Improvements are needed in IE undergraduate education if that role is to be successfully carried out.

Undergraduate education is the foundation for professional practice. Undergraduate programs are the basis for entry into graduate schools and other professional fields. To facilitate this transition, urgent improvements are needed in education strategies. Several educators have recognized that the way engineering is practiced has changed dramatically over the years and an upgrade is needed in engineering education. Educators, employers and practitioners are calling for a better integration of science with the concepts of design and practice throughout the engineering curriculum. Such an integration should be a key component of any education reform in preparation for the 21st century.

Hurried attempts to improve education are being made in many areas. We now have terms like "total quality management for Academia," "just-in-time education," and "continuous education improvement." Unfortunately, many of these represent mere rhetorics that are not backed by practical implementation models. IE should take the lead in reforming its own curriculum so that it can help to develop practical implementation models that can be used by other disciplines. Many educators and administrators are searching for ways to transform improvement rhetorics and slogans into action. Models developed by IEs can provide the answers.

> *Educators, employers and practitioners are calling for a better integration of science with the concepts of design and practice throughout the engineering curriculum.*

Quality in IE education

Incorporating quality concepts into education is a goal that should be pursued at national, state, local and institution levels. Existing models of total quality management (TQM) and continuous process improvement (CPI) can be adopted for curriculum improvement. However, because of the unique nature of academia, re-definition of TQM will be necessary so that the approach will be compatible with the academic process. For example, in industry, the idea of zero defects makes sense. But in academia, we cannot proclaim zero defects in our graduates since their success on the job cannot be guaranteed. Nonetheless, the basic concepts of improving product quality are applicable to improving any education process. Clynes, while reflecting on discussions he participated in at a National Research Council colloquium on engineering education, said "Teaching quality, like a company's customer service, can never be too good and always needs attention for improvement." This is true. A careful review of IE curriculum will reveal areas for improvement. This will help avoid stale curricula that may not meet the current needs of the society.

Theory and practice

Teaching determines the crux of research while research determines the crux of teaching. Integration of teaching and research is required for effective professional practice. The need to incorporate some aspect of practice into engineering education has been addressed widely in the literature. Pritsker recommends that professors must combine research interests with teaching responsibilities. The declining state of university education was described by Samuelson with respect to waste, lax academic standards and mediocre teaching and scholarship. These specific problems have been cited in the literature:

- Increasing undergraduate attrition despite falling academic standards at many schools. Decreasing teaching loads in favor of increasing dedication to research;
- Migration of full professors from undergraduate teaching in favor of graduate teaching and research;
- Watered down contents of undergraduate courses in the attempt to achieve retention goals; and
- Decreasing relevance of undergraduate courses to real-world practice.

Curriculum integration

Curriculum integration (interdisciplinary approach) should be used to address the problems cited above. Curriculum integration should be a priority in reforming education programs. Students must understand the way the world around them works and be capable of becoming responsible contributors to the society. Interdisciplinary education offers a more holistic approach to achieving this goal. Interdisciplinary course and curriculum improvement should link separate but related subjects to provide students with comprehensive skills so they can adapt to the changing world. One form of interdisciplinary integration involves projects in which students from more than one academic department participate in joint industrial projects. This facilitates sharing of views from different angles.

Role of the IE

Enhanced IE education will prepare students to lead efforts to integrate entities in manufacturing and service organizations of the 21st century. The IE profession, as a whole, faces an important challenge in educating future IEs for this leadership role. The current IE curriculum provides good exposure to its many unique facets. Individual courses at both undergraduate and graduate levels in many institutions are comprehensive. Yet there are some fundamental deficiencies as discussed below.

The academic curriculum rarely emphasizes the fundamental philosophy of IE itself. That philosophy is a holistic approach to design, development and implementation of integrated systems of men, machines and materials. Students go through courses in operations research, manufacturing, human factors and so on without understanding the interrelationships between these areas and the synergistic impact this integrated approach has on man-machine systems.

IE is quickly losing its identity as a value-adding profession. The basic cause of this problem is that many IEs graduate without resolving the question of identity related to the following questions:

- What separates an IE from other engineers? and
- What contribution does the profession make to an organization?"

The root of this identity problem lies in the structured and isolated approach of various IE courses. This results in specialization that is too narrow. For example, graduates today tend to associate more with focused professional societies rather than the general IE. This is a disturbing drift that may destroy the identity of IE as we now know it.

There is a big difference between academic and industrial approaches to performance evaluation. The academic community evaluates its members by the number of publications and research grants. By contrast, industry measures performance in terms of real contributions to organizational goals. This has had a detrimental effect on the learning interaction that faculty and students must share for students to graduate with professional loyalty, technical competence and capability of integrating theoretical concepts and industrial practice effectively.

In the attempt to prepare students for graduate level education, the academic curriculum often has a strong mathematical orientation. Though a required approach, it develops a very structured approach to problem solving among students. Consequently, students expect all problems to have well-defined inputs, processing modules and outputs. Thus, when faced with complex, ill-defined, and unstructured problems that are common in the real world, many new graduates perform poorly. Chisman points out that the bulk of teaching should be done for undergraduate students since over 85 percent of them go into industry, not on to graduate school. Unfortunately, attempts to improve curriculum is often tilted in favor of research-oriented education, thereby depriving the majority of the students of the skills they need to survive in the business world.

Many young graduates mistakenly perceive their expected roles as being part of the management personnel, having little or no direct association with shop-floor activities. Such views impede hands-on experience and prevent the identification of root causes of industrial problems. Consequently, this leads to the development of solutions that are short-term, unrealistic, and/or inadequate. The growing reliance of simulation models that cannot be practically validated in real-world settings is one obvious symptom of this problem.

Like many other engineering curricula, IE is growing within an isolated shell. Students do not realize the importance of developing solutions beneficial to a system rather than for individual components. Many new graduates take a long time to become productive in developing solutions that require multidisciplinary approaches.

Ethics in education

Professional morality and responsibility should be introduced early to IE students. Lessons on ethics should be incorporated into curriculum improvement approaches. IE graduates should be familiar with engineering code of ethics so that they can uphold and advance the integrity, honor and dignity of their professions by:

- using their knowledge and skill for the enhancement of human welfare;
- being honest, loyal, and impartial in serving the public, their employers and clients;
- striving to increase the competence and prestige of their professions; and
- supporting the professional and technical societies of their disciplines.

Some points to consider when developing curriculum improvement approaches are:

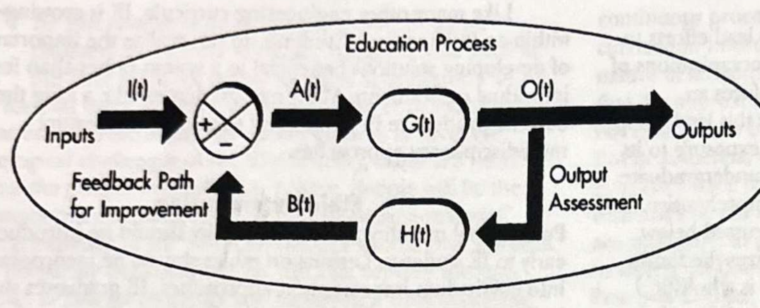
- Education should not just be a matter of taking courses, getting grades and moving on. Lifelong lessons should be a basic component of every education process. These lessons can only be achieved through a systems view of education. The politics of practice should be explained to students so that they are not shocked and frustrated when they go from the classroom to the boardroom.
- Universities face a variety of real-world multi-disciplinary problems that are often similar to industrial operations problems. These problems could be used as test cases for solution approaches. IE students could form consulting teams and develop effective solutions to such problems.
- Schools should increase their interaction with local industries when such industries are available. This will facilitate more realistic and relevant joint projects for students and industry professionals.
- The versatility of IEs in interacting with other groups in the industrial environment can be further enhanced by encouraging students to take more cross-disciplinary courses in disciplines such as mechanical engineering, computer science, business, etc.
- Students must keep in mind that the computer is just a tool and not the solution approach. For example, a word processor is a clerical tool that cannot compose a report by itself without the creative writing ability of the user. Likewise, a spreadsheet is an analytical tool that cannot perform accurate calculations without accurate inputs.

Curriculum assessment

Performance measures and benchmarks are needed for assessing the effectiveness of IE education. The effectiveness of curriculum can be measured in terms of the outgoing quality of students. This can be tracked by conducting surveys of employers to determine the relative performance of graduates. The feedback model presented in Figure 1 can be used for that purpose.

The primary responsibility of a curriculum improvement team is to ensure proper forward and backward flow of information and knowledge between the academic institution and industry. The percentage of students passing the engineer-in-training (EIT) exam can also be used as a performance measure. The percentage of students going on to graduate programs and staying on to graduate will also be a valuable measure of performance. Entrance questionnaires and exit questionnaires can also be used to judge students' perception of the improved curriculum.

Curriculum Improvement Feedback Model



I(t) = Set of Inputs
A(t) = Feedback Loop Actuator
G(t) = Forward Transfer Process
O(t) = Output of System
H(t) = Feedback Control Process
B(t) = Feedback Information

FIGURE 1

Conclusions

Significant changes are occurring in the world. These changes can come in terms of technological, economic, social and political developments. To adapt to these changes and still be productive contributors to the society, IE students must be prepared to be more versatile than their predecessors. This preparation requires significant changes in the contents and delivery of IE education. Educators and administrators institute plans immediately for reforming IE education in preparation for the landmark expectations of the 21st century. Efforts to improve IE education now will eventually lead to the development of leadership roles that other disciplines can emulate. This is a worthwhile service to the whole society that IE educators and professionals should not overlook.

For further reading

Anderson, Martin, "Measures for Improving Quality of U.S. Higher Education," *The Dallas Morning News*, September 20, 1992.

Badiru, Adedeji B., "An Academic-Industry Interface Could Expand The Practice of Industrial Engineering," *Industrial Engineering*, Vol. 23, No. 5, May 1991.

Badiru, Adedeji B., "Training The IE For A Management Role," *Industrial Engineering*, Vol. 19, No. 12, December 1987.

Blum, Debra E., "MIT Head Calls for 'Transformation' of Engineering Education; Hits Accreditors," *Chronicle of Higher Education*, July 1, 1992.

Brown, K. F., "Technical Ethics," *Engineering Education*, Vol. 73, 1983.

Cambel, B. A. and A. S. Schuh, "Proposed: An Academic Program in Engineering Ethics," *Engineering Education*, Vol. 78, 1989.

Chisman, James A., "Ivory Tower Research," *ORIMS TODAY*, April 1993.

Cole, William, "By Rewarding Mediocrity, We Discourage Excellence," *Chronicle of Higher Education*, January 6, 1993.

Cook, Thomas, "Improving the Relationship Between Academia and Industry: A Challenge for the '90s," *ORIMS Today*, October 1990, Vol. 17, No. 5.

Crynes, Billy L., "Changing Missions," *Sooner Engineer*, Vol. 2, No. 1, Spring 1993.

Davidson, Harold O., "Practice or Perish," *ORIMS Today*, October 1992, Vol. 19, No. 5.

Draeger, Margaret A., "Industrial Engineer Offers Ideas for Improvement in IE Education," *Industrial Engineering*, December 1992.

Ferguson, Eugene S., "How Engineers Lose Touch," *Invention & Technology*, Winter 1993.

Ferguson, Gary A., "Looking Beyond The Name To Demonstrate Real IE Value," *Industrial Engineering*, December, Vol. 24, No. 12, 1992.

Koshland, Daniel E., "Teaching and Research," *Science*, January 1991, Vol. 251, No. 4991.

Kraebber, Henry W., "Strengthening Manufacturing Education with Inputs from Industry," *Industrial Engineering*, January 1993.

Larson, Richard, "Curriculum Corrections: Teaching Operations Research as Research on Operations," *ORIMS Today*, April 1992, Vol. 19, No. 2.

Martin, W. M. and R. Schinzinger, *Ethics in Engineering*, New York: McGraw-Hill, 1983.

PRISM, "Real World 101: What Some Engineers in Industry Want Your Students, and You, to Know," *ASEE Prism*, October 1992.

Pritsker, A. Alan B., "Teach What You Use and Research What You Teach," *Industrial Engineering*, February 1993.

Purcell, James D., "Curricula for a Changing World," *Technological Horizon in Education (THE) Journal*, 1992.

Samaras, Patricia W., "Integrating The First Two Years," ASEE Prism, November 1991.

Samuelson, Robert J., "The Low State of Higher Ed," *Washington Post National Weekly*, Sept. 7-13, 1992.

Schmitt, Roland W., "Engineering Education: Opportunities for the Future," *National Academy of Engineering News and Notes*, Vol. 20, No. 2, Fall 1990.

Sheahan, Bonney H. and John A. White, "Quo Vadis, Undergraduate Engineering Education?" *Engineering Education*, Dec 1990.

Unger, H. S., *Controlling Technology: Ethics and the Responsible Engineer*, New York: Holt, Rinehart, Winston, 1982.

White, John A., "TQM: It's Time, Academia," *IEEE Education News*, Vol. 3, No. 2, November 1990.

Adedeji B. Badiru, Ph.D., is an associate professor of IE at the University of Oklahoma, Norman, Okla. **Herschel J. Baxi** is an IE graduate student at the University of Oklahoma.

CONVERSATION: Why have you chosen this profession?
WRITING : "Choose an industry and explain how you would contribute to the improvement of that industry as an industrial engineer."