MANAGEMENT EDUCATION

ENGINEERING MANAGEMENT

TECHNOLOGY MANAGEMENT

Engineers have been candidates for managerial positions in industrial and government organizations for most of the twentieth century. During the latter half of the century, the percentage of engineers moving into managerial positions increased dramatically, and that trend has continued into the twenty-first century. About two-thirds of all individuals with engineering degrees now pursue a management career track, as opposed to design, research, or other career tracks, and about 85% of all engineers will, at some point in their careers, have managerial responsibility. With the current emphasis on integrating sophisticated information, communication, and automation technologies into engineered systems as well as into the processes for designing, manufacturing, and marketing those systems, adequate technological knowledge to understand the intricacies of these systems and processes is recognized as an important attribute of the managers whose task is to coordinate the processes. Hence, the percentage of individuals being promoted into managerial positions who have some form of technical background (engineers and applied scientists being prominent among that group) has been increasing over the past two decades. With the trend toward wider distribution of management functions, and in particular the emergence of the project form of organization in the high-tech industries, these managerial positions tend to have titles like project manager (or leader), program manager, product manager, systems manager, operations (or production) manager, and field office manager or assistant manager. Both the redistribution of management functions and their redefinition within a framework of integration has led to special needs for the management education of engineers.

A BRIEF HISTORY

During the first half of the twentieth century, most organizations relied heavily on on-the-job training and internal management training programs to prepare engineers and other employees for positions of management. While large organizations continue to staff training departments and organizations of all types contract for internal management training services, there emerged after World War II an awareness of the value of more formal management education. For those with engineering degrees, a master's degree in management, most notably the master of business administration (*MBA*), became the program of choice. Many employers selected certain individuals to enroll in these programs full time and set up reimbursement schemes to encourage others to enroll part time. By the late 1950s and early 1960s, the approaches and techniques being developed to manage new and complex military and space technologies, in particular, suggested a form of management education different from what was being offered through MBA programs. The new form needed to be designed specifically for those who were to become program and systems managers. For engineers and applied scientists, some early responses to this need included master's degree programs in engineering administration at George Washington University and in engineering management at the University of Missouri–Rolla, each of which evolved into its own department. Other programs began sprouting within existing departments (e.g., a master's degree in engineering management within the University of Pittsburgh's department of industrial engineering), and some departments changed their name when an engineering management program was added (e.g., the department of industrial engineering and engineering management at Stanford University and the department of operations research and engineering management at Southern Methodist University).

There are now, in the United States, more than one hundred master's degree programs in management that cater exclusively to engineers and applied scientists, as well as many technology and systems management programs for both engineers and non-engineers. Each of these programs has its own flavor, representing a variety of curricula, forms of staffing, and delivery modes. The importance of employing engineers with a managerial perspective has also led to the development of undergraduate programs, both majors and minors, and undergraduate management courses (required of engineers at some institutions) to provide that perspective. Non-degree certificate programs have recently become popular alternatives to master's degrees as a way to deliver management education in a shorter timeframe and in nontraditional formats.

The history that has created the current variety of management education programs presents, for the engineer, the problem of discerning the differences between the options. For the providers of management education, the absence of standardized curricula presents a problem of identity, which is important in developing employer credibility. The flavor of each type of program is influenced by the clientele to be served within the geographical region of the institution, and by the nature of that institution and its other academic programs. Some management education programs have a manufacturing orientation, others a project management orientation; some cater to the private sector, others to the public sector; some reflect a traditional business administration curriculum, others an industrial engineering curriculum, and still others a mix of the two. The American Assembly of Collegiate Schools of Business (*AACSB*) has, over the years, provided curricular guidance for management programs offered through schools of business. The Accreditation Board for Engineering and Technology (*ABET*) focuses its attention on undergraduate programs and has not served to provide curricular guidance for graduate management programs in schools of engineering. The American Society for Engineering Management (ASEM) runs a certification program for graduate programs in engineering and technology management. ASEM recognizes that these programs must reflect the rapidly changing needs for management education in a high-tech world and that a diversity of perspectives and

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program types can be desirable.

There is general agreement that management education has been and needs to continue to be multidisciplinary and interdisciplinary. This, by itself, presents special problems in staffing and delivering nontraditional management programs within the traditional university. There is also agreement regarding the high priority that should be placed in management education on continuing to develop communication skills, thinking and problem-solving skills, and interpersonal and team-building skills. This presents special problems when using distance learning technology, a common and increasingly used mode for delivering management education. There is disagreement on the extent to which the philosophy of management appropriate for the type of managerial position into which engineers are likely to move differs from the philosophy of management predominant in traditional education programs. Or, to put the same issue into the form of a question, Does the emergence of the project form of organization imply a need for a form of management education quite different from the traditional forms in order to reflect the new philosophy? And, if so, how can it be programmed, staffed, and delivered so that it creates an identity readily recognized and valued by students, teachers, educational administrators, and employers?

MANAGEMENT PHILOSOPHY

The term *management philosophy* is used here to refer to a system of motivating concepts, principles, and values, and hence a viewpoint on or way of thinking about the practice of management. Over time, discernible shifts in philosophies of management tend to be aligned with shifts in socioeconomic factors, organizational structures and processes, and/or technological breakthroughs. The currently emerging, although not yet completely defined, philosophy of management can be linked to the role of information and communication technologies in facilitating new, streamlined organizational structures, and of automation and simulation technologies in coordinating and customizing the processes of design, production, and delivery of an organization's goods and services, which themselves are increasingly incorporating those technologies. It is in this context that engineers are attractive prospects for managerial positions due to their familiarity and comfort level with the technology. The diversity of management education programs for engineers is a consequence of differences in perception of or approach to the emerging philosophy of management.

Organizational Trends

Although ad hoc project teams (work groups, task forces, program offices, etc.) have been a part of organizations for a long time, the matrix form of organization was the first formalization of a project-oriented structure. Companies in the military, aerospace, electronics, chemical, and other high-tech industries needed a way to free project managers from the usual chain of command, which involved reporting along functional lines of authority (e.g., engineering, manufacturing, marketing, and finance). The complexity of the technologies being employed required that all functions be considered simultaneously and without bias. By creating a line of reporting separate from these functional lines, this integration could occur. While functional management serves to maintain stability in organizations, project management serves as a change agent.

The matrix organization is not without its problems. Members of project teams typically have homes in functional departments, creating opportunities for conflict between functional and project managers. Also, projects are temporary, so when a project is completed there may or may not be a new project to which the project manager can move. Many organizations have lost some of their top management talent as a result of an uneven flow of projects. The multiple chains of command in the matrix organization also present a special problem of coordination. Computerized information systems, even in the early years, provided a means to facilitate the coordination of projects. With further advances in information and communication technology, a project form of organization that is significantly different from the matrix organization is becoming possible. The trend involves a redefinition and redistribution of traditional functions of management—both in the sense of functions like production, marketing, and finance and in the sense of functions like planning, organizing, and controlling. For example, management control is being redefined in terms like *dynamic coordination of teams* rather than in terms like *chain of command* and *span of control*. The redistribution of functions suggests a greater need for individuals with some management education, rather than less, as every member of a project team must develop an appreciation for all the functions and take responsibility for the success of the team. This is demanding a shift in thinking about management.

Management Paradigms

The popularity of the term *paradigm* can be traced to Thomas Kuhn and his book *The Structure of Scientific Revolutions* (1). As the use of the term spread, it was picked up by writers and thinkers in nonscientific disciplines, including management consultants and educators, who began using it to address the dramatic changes occurring in the marketplace and in society and the need for managers to embrace new ways of thinking in order for their organizations to survive. The word has now taken on the status of a buzzword, devaluing some of the original impact intended by Kuhn. The word *paradigm* can denote a model, a pattern, or an example. Kuhn preferred to use the word *exemplar* for example and saved *paradigm* for talking about a predominant pattern of thought or worldview within a profession, discipline, or sector of society. He specified two conditions for qualifying a change in thinking as a paradigm shift: First, the change has to be linked to an accomplishment of sufficient magnitude to attract a group of adherents away from competing patterns, and second, the new pattern must possess an open-endedness sufficient to give these adherents something to do.

Paradigm shifts are not, and cannot, be planned in the usual sense. They occur when they are needed, and they become needed when desirable concepts, tools, systems,

and processes cannot be implemented without them. Implementation of modern information, communication, and automation technologies, competition from international and multinational corporations (particularly in Pacific Rim countries), and socioeconomic changes in North America are cited as the factors that provide the impetus for recent shifts in management thinking and practice. Whether or not these changes qualify as a transformation of management paradigm remains for history to record.

The number of new management concepts, tools, and systems cited by educators, writers, and consultants over the past few decades is so great that it would not be possible or fruitful to list them here, and more are being created daily. The typical management section of one of the large chain bookstores typically contains 40 to 50 titles on management tools and philosophy, leadership style, and organizational change, with each claiming new ways of thinking. There are, however, a few writers whose ideas and language have become so widely known and used in both the rhetoric of everyday management life and actual management practice, that they deserve mention. The first three items in the following list offer a societal context in which new thinking is being stimulated; the remainder focus specifically on management thinking.

1. The Third Wave With the publication of his books *Future Shock* (2) and *The Third Wave* (3), Alvin Toffler has acquired the status of social visionary. Focusing on the impact of information, communication, and automation technologies, Toffler chronicles structural shifts in economic, political, and social systems worldwide that are having consequences on and creating new possibilities for national priorities, organizational transformation, individual work, and everyday life. The first wave was agricultural, the second industrial, and the third informational.
2. The Knowledge Society As Toffler is widely regarded as America's social visionary, Peter Drucker is widely regarded as its management visionary. Through a long history of books, Drucker has popularized certain ideas on management. In *Post-Capitalist Society* (4), he introduces the idea of the knowledge society and prophesizes that information and knowledge will soon replace labor, land, and capital as the most important (maybe the only important) resource (and product) of economic organizations.
3. The Age of Unreason/Paradox The British author Charles Handy has gone a step further in his books *The Age of Unreason* (5) and *The Age of Paradox* (6), examining the contradictions created by sudden and dramatic change and the implications of that on organizations of all types. As does Toffler and Drucker, Handy addresses educational institutions as well as economic and political ones, and the changes needed to manage these for the social good. The reader is led to conclude a need for new logic, a logic of change.
4. Systems Thinking The early history of systems thinking in management begins at the Tavistock Institute in London in the 1960s. It was here that experiments with a variety of corporations were conducted, employing ideas in democratic management and participative decision making. Emery and Trist (7) are credited with developing the sociotechnical systems approach to organizational change, stimulating their colleagues and sponsors to follow with books like *Towards a New Philosophy of Management* (8) and *Alternatives to Hierarchies* (9). In the United States, Russell Ackoff became a dominant advocate of systems thinking in management, building on his work with Emery, *On Purposeful Systems* (10), and popularizing it in books like *Redesigning the Future* (11), *Creating the Corporate Future* (12), and *The Democratic Corporation* (13). He developed idealized design as a tool for participative and consensus decision making and applied it to many types of organization. The concepts of the circular organization, the internal market economy, and the multidimensional approach to organizational design represent ways to implement democratic management. He offers a challenge to total quality management (see list item 6).
5. Change Management The first management book to reach the status of a national bestseller in the modern era was Peters and Waterman's *In Search of Excellence* (14). Based on case studies of successful and unsuccessful firms, the authors identify eight attributes of successful organizations that can serve as guidelines for change. Peters followed this with some sequels, including *A Passion for Excellence* (15) and *Thriving on Chaos* (16). Bradford and Cohen in *Managing for Excellence* (17) offered a practical approach to thinking about these changes, including the transformation of the role of the manager from that of technician and conductor to that of developer. They suggest that the role of developer requires a team approach to work and its organization. The idea of self-directed work teams has received substantial attention in recent years. (See Ref. 18.) Rosabeth Moss Kantor, also relying on a set of case studies, declared in *The Change Masters* (19) the importance of flat, team-based, entrepreneurial-style organizations for success with innovation and change. Additional case studies of highly successful companies can be found in Collins and Porras, *Built to Last* (20), and Collins, *Good to Great* (21).
6. Total Quality Management The apparent success of Japanese companies in the 1970s and 1980s has been attributed in part to the implementation of ideas developed by W. Edwards Deming of the United States. Deming was hired by the Japanese in the 1950s to apply statistical concepts of quality to design, production, and other processes in Japanese firms. The design quality and reliability of many of the products of those firms made them competitive in the global marketplace. As a result of his experiences in Japan, Deming extended his ideas to general management thinking. His 14 points of management presented in his *Out of the Crisis* (22) and in Scherkenbach's *The Deming Route to Quality and Productivity* (23) form the core concepts of total qual-

ity management (*TQM*). TQM has received attention in many corporate and government organizations in the United States and Europe. Implementation of TQM involves both the introduction of new tools (e.g., statistical process control, robust design, quality function deployment) and the development of a new culture oriented toward the customer and continuous improvement of products and processes. U.S. companies have attempted to use Deming's 14 points of management as a way to accomplish the latter, but few have been successful in implementing all of them. The primary obstacle appears to be the degree to which the reliance on numbers-based management systems inhibits a customer orientation and continuous improvement. These systems—namely, systems for work standards, training, purchasing, performance appraisal, production control, and financial management—are deeply embedded in the thinking about accepted ways to do business. Irrespective of the difficulties, Deming and TQM have influenced management thinking by raising awareness of the importance of satisfying customers, encouraging employee creativity, maintaining the flexibility to change quickly, building quality into the processes of design and production (rather than inspecting for quality in the end products), and focusing attention on variation in those processes.

7. Process Reengineering With Hammer and Champy's *Reengineering the Corporation* (24) and Champy's *Reengineering Management* (25), the idea of continuous improvement has met its greatest challenge. While the focus is still on building quality into the fundamental processes of a business and its organization, the thesis is that creating quality in a rapidly changing and turbulent world requires fundamental transformation of these processes and discontinuous thinking. These radical and dramatic transformations rely on breakthroughs, not on ideas for incremental improvements (or Kaizen). Considered one of the major process innovations in recent years is that of concurrent or simultaneous engineering—an approach to product development that emphasizes integration of the design, production, marketing, distribution, and other aspects of a product by considering them concurrently rather than sequentially. The idea is not only that interrelationships among these aspects are better addressed, but also that the time to market is less and the responsiveness to the customer greater.
8. The Learning Organization Argyris and Schon introduced the concept of organizational learning in their 1978 book by that title (26). It was then picked up by a number of authors, most notably Peter Senge in his book *The Fifth Discipline* (27). The learning organization is one in which learning holds a position of the highest priority in the strategic mission, as well as the daily operations, of the organization. The five disciplines of effective learning organizations are shared vision, mental models, team learning, personal mastery, and systems thinking. A related concept is that of the virtual organization, one that transcends the boundaries of any single organization by taking advantage of the collaborative possibilities offered by multiple organizations. The resulting organizational arrangement is not a physically defined entity, but a virtual one with the ability to respond more quickly, more frequently, and more innovatively than any of its component organizations could individually. This attribute has been given the name *agility*. (See Ref. 28.)
9. Nonlinear Dynamics and Chaos The theoretical foundations for the ideas just presented have not been well articulated. Systems theory is a recurring theme, but only in its system dynamics version does it reflect a rigor deserving of scientific status. The science of nonlinear dynamics and chaos has provided an additional foundation for management theory. Notable books that have explicated this theory include Wheatley's *Leadership and the New Science* (29), Priesmeyer's *Organizations and Chaos* (30), and Goldstein's *The Unshackled Organization* (31). Common themes include advocacy of self-organization (as opposed to planned change), flexibility as a criterion for decision making (as opposed to optimality), and variety generation (as opposed to efficiency and predictability). The shift in thinking from productivity to agility is consistent with a shift from a goal orientation to a process orientation, the latter requiring special attention to the dynamics of the organization and its operations. Strategic planning becomes an ongoing process of reevaluating and resetting goals, rather than an occasional exercise in evaluating strategies for achieving fixed goals. Paradoxes no longer need to be treated as aberrations; they become sources of creativity and transformation.
10. The Knowledge-Creating Company In their book by this title, Nonaka and Takeuchi (32) build on the ideas in nonlinear dynamics and make a case for an alternative view of the paradigm shift taking place. Rather than treating middle management as superfluous and advocating significant reductions in middle manager ranks, they regard middle management as acquiring a central role in the management and operations of the firm. They contend that the primary product of modern organizations is knowledge, and to think otherwise is to put the firm at a competitive disadvantage. Middle managers are the knowledge engineers of the organization. What is particularly noteworthy is that these authors are both professors in a Japanese university who have worked in industry and did their graduate education in the United States. Their contention that the success of Japanese companies in the 1970s and 1980s was based on skills and expertise in organizational knowledge creation is in contrast to the commonly held belief that success was attributable to the implementation of quality control, quality circles (bottom-up decision making), and lean management. While not in contradiction with these principles, knowledge creation does represent a perspective that perhaps has more po-

tential as a way of thinking about change in Western organizations than do ideas in books like Ouchi's *Theory Z* (33) and Pascale and Athos's *The Art of Japanese Management* (34).

While many of the ideas discussed in the preceding list are contradictory, there are also some common themes. These include a trend toward semiautonomous (self-directed) project teams or work groups; a focus on flexibility/agility in planning, design, production, and marketing; treatment of the entire life cycle of a product/service concurrently throughout its development; and recognition of the importance of information sharing, knowledge building, and learning in everyday activities. Organizations that embrace these notions tend to exhibit distributed, dynamic, networked, and multidimensional structures, and parallel, integrated, nonlinear, and circular processes. Where these organizations exist, they rely heavily on information, communication, and automation technologies to help maintain coordination. Intelligent systems are often used and will be increasingly used in the future.

Implications for Management Education

A case has been made by many (the aforementioned authors among them) that if shifts in management paradigms are occurring in industrial and government organizations, then shifts in the philosophy and delivery of management education should follow. These shifts, it is argued, should not be limited to changes in what is taught, but should include changes in how it is taught as well. What can be said at this time is that there are multiple strands of change occurring simultaneously, some of which could be viewed as contradictory. For example, one shift is being driven by information and communication technologies (particularly Internet-based technologies) and is directed at the ability to deliver courses to a greater number of geographically distributed students. While this mode of delivery has been heavily content oriented, the pressures from industry are for a more process-oriented form of education, directed at developing the new thinking, interpersonal, and communication skills suggested by the paradigm shift(s) discussed previously. Master's degrees and certificates in engineering management and the management of technology have been prime candidates for experiments with both content-oriented, online delivery and process-oriented, weekend/evening programs that make extensive use of case studies and group projects. While these divergent philosophies of management education continue to specify two quite different categories of program, they are beginning to merge into an integrated concept and approach.

EDUCATIONAL MODELS

There are at least three ways to distinguish different approaches to management education for engineers. There are different program types corresponding to educational level; different curricula depending on the student and employer market targeted; and different pedagogical approaches reflecting teaching styles and modes of delivery supported by different institutional types.

Program Types

Management education programs designed specifically for engineers and applied scientists began with master's degrees, including MBAs with concentrations in areas like industrial management and technology strategy, master's degrees in engineering management or engineering administration, management concentrations within industrial engineering master's programs, and master's degrees in the management of technology. MBAs are offered by business schools; master's degrees in engineering management/administration tend to be offered by engineering schools either as stand-alone programs or as programs within an engineering department, and may or may not involve participation of a business school; industrial engineering concentrations in management tend to favor a more quantitative approach than do the other programs; and management of technology programs tend to be offered as collaborative efforts between business and engineering schools. In all of these categories, there are some programs that are designed for full-time students and others designed for part-time, working professionals. While some of these programs do not require work experience for admission, others require two years or more of full-time work experience in an engineering environment since receiving the bachelor's degree, and virtually all regard such work experience as highly desirable. MBAs emphasize functional areas of business—particularly production, marketing, human resources, and finance—and integrate these through a policy perspective. Engineering management/administration programs emphasize the management of technical projects, programs, and operations, integrating functional areas of business throughout the curriculum. Management of technology programs tend to emphasize the strategic management of technology and technical resources.

Universities with ABET accredited undergraduate degrees in engineering management in the United States University of Missouri–Rolla, Stevens Institute of Technology, and U.S. Military Academy. These programs emphasize a curriculum in engineering fundamentals, a concentration in an engineering discipline, and a broad set of courses in management topics. Another trend in undergraduate programs is to offer a minor in engineering management. The undergraduate minor at Old Dominion University is a four-course sequence emphasizing decision making, quality control, economic analysis, project management, and team building. In contrast, the undergraduate minor in technology and management at the University of Illinois at Urbana–Champaign is offered jointly by the colleges of commerce/business and engineering and is open to students from both colleges. The curriculum consists of six courses, three of which combine the students of both colleges, and an industrially sponsored capstone project. The use of industrially sponsored projects in undergraduate engineering curricula is quite popular; such projects offer opportunities to expose students to the management and business aspects of the engineering profession.

Certificate programs as alternatives to degree programs are being introduced at both the post-bachelor's and post-master's levels. These programs allow greater flexibility in curriculum and format than do many degree programs, and employers are becoming increasingly supportive of programs with educational content that meets their needs, even if such programs cannot be accomplished within an official degree-granting structure. Case Western Reserve University's certificate in the management of technology has received strong support from industry. It can be anticipated that as the demand for continuing education in management beyond the master's degree continues to grow, professional doctoral programs (as opposed to research-oriented doctoral programs) that can be delivered in part-time and nontraditional formats will begin to emerge. Such programs will not require a research dissertation.

Curricular Content

The focus of the curricula of management programs varies substantially from one institution to another. There is general agreement that an introduction to the functional areas of finance, marketing, and production is important; however, in some programs this is accomplished in separate courses, while in others it is accomplished by integrating these subjects across the curriculum. Programs at institutions that reside in regions with a high concentration of federal government employers and government contractors tend to focus on program and contract management. Programs at institutions that reside in regions with high concentrations of industrial employers tend to focus more on manufacturing and/or project management. Programs associated with industrial engineering departments tend to favor either a manufacturing or an operations research focus. Programs associated with business schools tend to favor a strategic management focus. Programs within schools of engineering tend to be more technical and quantitative, although some programs have maintained a strong behavioral component in their curricula. Ongoing debate about the degree to which management curricula for engineers should be standardized is likely to continue.

Pedagogical Approaches

Just as there is a range of curricular content in management programs that target engineers and applied scientists, there is also a range of pedagogical approaches to the teaching and delivery of that curriculum. While there has been a move toward more project-based education in undergraduate engineering programs, the demand for master's programs in management that are accessible to the part-time student has mitigated the degree to which this occurs at the graduate level. Many master's programs do require a capstone project or thesis; and some on-campus programs, including those with weekend or other nontraditional formats, may permit a greater concentration of project work throughout the curriculum. Capstone projects conducted as individual study have a history in some programs of taking multiple semesters to complete.

At many institutions, master's degrees in engineering management have been targeted for delivery via distance learning technology. The latest trend is toward Internet-based delivery. This approach is primarily asynchronous, requiring a high level of motivation on the part of the student for successful completion to be realized. Asynchronous learning has been around for many years in the form of correspondence courses. Curricula developed for the World Wide Web offer many advantages over the traditional correspondence course. It remains to be seen if this form of delivery can be integrated with other modes of delivery to circumvent its drawbacks.

ISSUES IN MANAGEMENT EDUCATION

The changes that are occurring in the structure and management of economic organizations, and that will certainly continue to occur, are forcing institutions of higher education to reconsider the way they deliver educational products in general. The demand for management education, in particular, is such that a variety of innovative programs have been forthcoming in recent years. The growing political pressure to hold public institutions accountable, through demonstrations of the value of their services to the public, along with the tightening of budgets, has raised questions about the future role of the university in our society. The rise of the "virtual university" certainly suggests some profound changes. The predominant opinion at this time is that there is much of management education that can be delivered through a virtual university, much of it better (particularly when the visual capabilities of the various media are utilized) than what could be delivered through the traditional university; there are other needs of management education (like face-to-face group exercises and team-based projects) that have not been met as well in this way.

The following trends in the content of management education for engineers and applied scientists are regarded as significant:

1. The team-based project form of organization
2. The management of parallel and distributed (as opposed to sequential) processes
3. Global and multicultural perspectives on business
4. Entrepreneurship/intrapreneurship skills

The following trends in the process of management education for engineers and applied scientists are regarded as significant:

1. Industrial involvement in courses/projects
2. Interdisciplinary approaches to teaching
3. The use of educational technology
4. A mix of scheduled and asynchronous learning environments

The extent to which management education continues to embrace these trends will depend in great part on how institutions of higher education respond to their changing roles.

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