Technology Management Education:

ALTERNATIVE MODELS

Michael K. Badawy

Global competitive strategies are increasingly becoming technology-driven. Technology has become the great equalizer among companies and countries. Technological innovation cannot be achieved without corporate management devoting considerable energy and investment to developing effective linkages between science, engineering, and management.[1] Done well, these linkages can ultimately produce and provide products, processes, and services that represent a cohesive and distinctive corporate technological competence. This competence, then, becomes a primary tool for achieving the firm's competitive advantage.

The enormity of technology capital expenditures represents a significant indicator of the key role technology plays in the U.S. economy. Data from the National Science Foundation research studies project that the U.S. will have spent $184.4 billion on R&D and related technologies in 1997.[2] Of this amount, industry is projected to have spent $113.5 billion, most of which will have gone toward applied research and development. The estimated total U.S. R&D expenditures represent 2.49 percent of the gross domestic product and mark the largest increase since 1985. In terms of international comparisons, the fact that the U.S. spends more on R&D than Japan, Germany, France, and the United Kingdom combined clearly underscores the critical importance of technology as a core economic resource for enhancing corporate productivity and profitability.

The author would like to thank Dr. Afie M. Badawy for her guidance, critical insights, and comments on earlier drafts of this article. The feedback received from her as well as from the anonymous reviewers is greatly appreciated.

Effective management of technology calls for different managerial skills, techniques, styles, and ways of thinking.[3] The challenge facing management educators in determining what managers in the 21st century should know about technology is daunting. What is needed is a new breed of managers who are as adept in technology management as they are in traditional business skills. Technology-based corporations increasingly need a capacity for rapid innovation in strategies, products, processes, and services as distinct from traditional high-volume mass production or service companies of past decades. Managers of technology, therefore, need to acquire the knowledge and skills that will enable them to compete effectively in world markets.

However, there is a question whether traditional academic programs such as the Master of Business Administration (MBA) and the Master of Engineering Management (MEM) degree can, in fact, adequately prepare technologists for effective management of technology. My purpose in this article is to provide an understanding of alternate educational degree programs as models for developing managerial skills in technologists. Focusing on management education and taking an analytical scholarly research perspective, this article will explore the value of the MBA degree for technologists and compare it with the MEM degree. The article will address the foundations, structure, and content of a proposed Management of Technology (MOT) curriculum that can overcome the deficiencies of both the MBA and MEM programs. It will also examine the implications for management educators, technical professionals, and managers.

Research on the Uniqueness of and Need for Technology Management Education

The management of technology involves a broad spectrum of functional areas, including basic research, applied research, development, design, construction, manufacturing, operations, testing, maintenance, and technology transfer.[4] The concept of technology management is quite broad since it covers not only R&D, but also the management of product, process, and information technologies.[5] The management of technology is thus the practice of integrating technology strategy with business strategy in the company. This integration requires the deliberate coordination of the research, production, and service functions with the marketing, finance, and human resource functions of the firm.[6]

Current university degree program offerings provide technologists with two major possibilities or avenues for management education: the MBA and the MEM. Before undertaking a research-based critical assessment of each degree in the following two sections, we should first understand the nature, issues, and unique problems of managing technology. It is this uniqueness that mandates a different kind of educational program for developing managerial skills in technologists.

The idea that a good manager can manage anything regardless of its technological base is simplistic, misleading, and must be abandoned.[7] Corporate practices in the U.S. have long emphasized the need for general management skills in mid-level and top executives and have required no familiarity with the complex nature of the technologies that are supposed to be managed. The central question is: How can managers manage something they do not understand?

The point is not that CEOs and top executive staff must become technology specialists.[8] Rather, they must develop a high degree of empathy and a strong appreciation of the technologies they are investing in and the role of technology in corporate strategy.

> While it is not necessary for every manager to have a science or engineering degree, every manager does need to understand how technology relates to the strategic positioning of the firm, how to evaluate alternative technologies and investment choices, and how to shepherd scientific and technical concepts through the innovation and production processes to the market place. For more and more firms, effective performance in developing, adopting, and using technological innovation is becoming vital to success in the market place. A solid understanding of how to combine the technical, organizational, and human dimensions of the innovation process is at the heart of effective technology management.[9]

In short, without a thorough understanding of the essence of the management of technology, executives will end up with "tunnel vision."

Successful managers of technology invariably attribute their success largely to the ability to create a vision.[10] That is, they have a sense of the grand scheme of things that enables them to put individual technological developments into perspective. Top executives must have an idea of how technology will evolve, how it will manifest itself within the industry, and how the company will operate its business using technology in the future.[11] For these managers, rapid technological change holds little intimidation value. They understand what the evolving capabilities of these technologies are and how they can contribute to making their firms competitive. Successful technology executives' vision is clearly reflected in their values, strategies, and leadership styles.[12] In short, their vision is based on a knowledge of where technology has been and where it is going.

Often, however, executive action reflects inadequate strategic thinking, cluttered vision, and a lack of focus.[13] Instead of concentrating on what it can do best, a company gets into doing too many things, but none of them well. This gives top management a mistaken sense of synergy. Strategically, it would be far more effective to develop a presence and a technological capability in a focused market niche. This would enable the company to build a competitive advantage through focusing on the critical few rather than the trivial many. From the perspective of technology management education, this point is significant in that it demonstrates the necessity and importance of executive training in understanding the strategic role technology plays in shaping corporate direction and future.

Because this special training has been clearly lacking in MBA and MEM programs, there are many instances of poor practices in managing technology.

Top management must accept its primary role in technological innovation since the process of managing technology begins at the top.[14] Technology direction must emanate from senior management, which defines business strategy, allocates investment funds, and establishes corporate policy. If this is not done, these tasks default to others at lower organizational levels. Although research studies show that top management involvement is a necessary condition for developing a successful technology strategy, many technology-based companies in the United States are headed by top executives who don't have technology backgrounds.[15] Thus, they have insufficient understanding of linking business and technical priorities, managing technological strategy, and planning technology. Compared with Europe and Japan, more American managers come up through non-production jobs in finance, law, accounting, or marketing.

This situation has serious implications for technology management practice. Specifically, technological deficiencies in executive backgrounds did, in fact, make it difficult for U.S. companies to compete during 1970s and 1980s in technology-based global markets.[16] This led to some serious and well-documented outcomes with regard to corporate competitiveness.

Technology-based organizations draw heavily on the use of applied science and technological innovation. Examples of fields where these organizations typically function include electronics, computers, data processing, information technology, pharmaceuticals, optics, lasers, word processing, chemicals, communications, and instrumentation. Studies show that the context of technology-based organizations has several distinguishing features or characteristics. While these features are difficult to quantify, they nevertheless present a corporate profile that is distinctively different from traditional non-technology based organizations.[17] These features include:

- Technology-based organizations typically employ a large number of engineers, scientists, and other technical professionals. (It is estimated that over 1.8 million engineers were employed by U.S. industry in 1997.)[18]
- These organizations spend an enormous proportion of their resources on R&D and other technology-related activities.
- They essentially sell the knowledge, information talents, and expertise of their technical staff.
- They put a tremendous premium on the necessity of technological innovation as a tool for achieving competitive advantage.
- Inventions and innovations by the technical staff are usually protected by patents and other means of protecting intellectual property rights.
- Product, process, and information technology innovations are sources of strategic competitive advantage.

- Management systems, practices, and structures appropriate for these organizations are less formal and more fluid, organic, adaptive, and flexible than in traditional bureaucratic organizations. Systems, policies, rewards, and overall organizational environments must be conducive to creativity, experimentation, and innovation.
- They typically function within extremely dynamic, high-velocity, and turbulent environments characterized by rapid technological change, product and process substitution threats, and massive changes in science and technology.

Technical professionals represent the core competence of a technology-based organization.[19] The organization is driven by the talents, skills, and expertise of its knowledge workers. It is these workers who create the inventions and innovations in products and processes that change the industry. As technologies change, technology-based firms are challenged to continually maintain, develop, and expand their knowledge of workers' talents and skills.

Technical professionals are the most important asset in the technology management function. In organizations whose most valued product is essentially ideas, the importance of effective managing and utilization of human resources can not be overemphasized. With all the financial and physical resources a technology-based corporation has, it will have nothing to sell without the creativity, imagination, and innovativeness of its scientists, engineers, and other technical professionals.

The scholarly and professional literatures draw a profile of the technical professional "stereotype."[20] However, there are enormous variations both among and between different professional groups in terms of individual personalities and behavioral patterns.[21] The features this profile presents include:

- Technical professionals are well educated and usually hold advanced academic degrees and other professional credentials.
- They display a high degree of creativity, intelligence, and capacity for learning.
- They thrive on intellectually challenging assignments.
- They seek individual autonomy and flexibility as important elements of an organization's general work climate.
- They value their freedom in pursuing intellectual research streams and lines of inquiry.
- They have a high degree of curiosity with a deep desire in learning and acquiring knowledge for its own sake.
- They have strong personalities and individualized ways of thinking and value systems.
- They have a high propensity for risk-taking, experimentation, and trying new approaches to known phenomena.

TABLE 1. Differences Between R&D and Other Corporate Activities

Dimensions and Variables	Research and Development	Other Corporate Functions
1. Nature of task	Ambiguous, less programmed less defined	More programmed, more defined
2. Central management focus	People (labor-intensive industry)	Structure
3. Most important managerial skills	Social and interpersonal skills	Administrative (structural aspects of the organization)
4. Key management priorities	The R&D director is the chief technologist of the business	Marketing, production, and finance are the key functions with top priorities
5. Managerial leadership style	Participative	Directive

Furthermore, there are also well-documented studies showing that scientists, engineers, and other technical professionals tend to be different from other segments of the labor force.[22] As such, these differences set engineers and scientists apart from those working in other traditional individual activities such as marketing, purchasing, and personnel. These differences include: they have very long time horizons; their primary thrust is toward invention rather than sales; they often have a strong product (or discipline) orientation but not market orientation; and they tend to identify more with their professional peers than with their company.[23] While other corporate functions are fairly well defined, R&D activities are generally less structured, with a high degree of uncertainty of outcome, and with creativity required for their effective performance.[24] Table 1 provides the broad differences between R&D and other corporate functions.

Because of the salient differences between various professional groups and the varied definitions of the concept of a "professional," researchers have continued using this concept as an encompassing construct under which several types of employees are grouped.[25] The evidence on the need for a technology management education, however, remains compelling. There are five major forces that contribute to this: the necessity of understanding the complex problems of managing technology, the critical need for a broad vision of technology as an integral link in corporate strategy, managing technological innovation as a top-management responsibility, the context and core competence of technology-based organizations, and the unique characteristics of technical professionals. What is required of educational institutions is a different set of managerial concepts, competencies, and skills for the effective management of technology.

The Master of Business Administration Degree

The Value of the MBA for Technologists

The typical MBA curriculum is too theoretical and academic to provide technologists with the proper training and skills they are going to need to function effectively as managers.[26] There is also mounting evidence about the dissatisfaction of the corporate community with the quality of MBAs and the general performance of business schools.[27] This negative sentiment was made clear in a recent executive survey:

> Industry told us that we were teaching all the wrong things. They explained that academe is industry's only supplier with quality so bad that 100% of the incoming goods require rework—that is, more training. . . . One of the major concerns executive survey respondents had was that they have got engineers who understand technology, and they have business people who understand management. What they are missing are people who understand the interrelation of those two things—managing technology.[28]

The 1996 Report of the Faculty leadership Task Force of the American Assembly of Collegiate Schools of Business (AACSB) provides a glaring testimony on the changing global environment and the critical need for business schools to change their modes of operation in both undergraduate and graduate management educational programs.[29]

> The primary problem is that faculty skills are not aligned with the rapidly changing needs of business. Over time, business practice has advanced rapidly (e.g., TQM, re-engineering, cycle time reduction, diversity in the work force, customer satisfaction incentives, global strategy and managing technology). Although school and faculty competencies have advanced, the gap between practice and academic research and teaching has widened. The lack of business interaction, changing technologies, aging faculty and shortage of incentives to change have inhibited faculty initiative for change that is necessary to keep pace with a rapidly changing environment. Faculty should be leading the next generation of industry knowledge and practice, but, in some schools, this is not the case.[30]

The tremendous growth in "corporate university" programs is another recent indicator of the technical management community's dissatisfaction with the workings of the business school.[31] From 1968 to 1996, the number of corporate universities has grown from around 400 to 1000. Although these universities were once found primarily in the high-technology industry, they now are found in industries as diverse as financial services and health care.

The inadequate coverage of MOT in typical MBA curricula is a major concern. Technology can no longer be taught or viewed as a "black box." Russell Ackoff has issued a warning about another field of which MBA program architects should take a serious notice.[32] He traces the devolution of Operations Research from its original state as a *market-oriented* profession through the stage of *output-orientation* to its current state of *input-orientation*. He also traces the

devolution of OR/MS in the decade following World War II and correlates this devolution with the changing needs of U.S. industry, the inbreeding of faculty teaching OR/MS subjects, and the concomitant inbreeding of OR/MS journals. In Ackoff's words, "The field's introversion drove it into a catatonic state in which it died mercifully but is yet to be buried."[33] Henry Mintzberg's work echoes Ackoff's negative sentiment about MBA management education:

> Our schools of administration and management have designed their curricula to do other things. At one time most concentrated on teaching by the case study method, presumably in the belief that managers-to-be would benefit from practice in unstructured decision-making . . . but our study gives us reason to believe that this kind of instruction does not develop the wide array of talents managers need. In the 1960s many schools of management turned away from the case-study philosophy, devoting their attention instead to the teaching of theory. It is interesting to note that much of this theory deals, not with the job of managing per se, but with the underlying disciplines—economics, psychology, and mathematics. . . . All of this knowledge will be useful to the manager-to-be, but almost none of it relates directly to those things he will be called upon to do in the job of the manager. . . . We must recognize that although the management school gives students M.B.A. degrees, it does not in fact teach them how to manage. Hence these degrees can hardly be considered prerequisites for managing, and the world is full of highly competent managers who have never spent one day in a management course.[34]

The AACSB study report frames the above issues as part of a larger problem relating to relevance in management and university education in general:

> The growing gap between academic and business worlds and the lack of theory and relevance in research can be traced to deficits in underlying skills. Faculty are doing well on theory testing and construction and have made some progress on global thinking, but the greatest needs exist for improvement in multi disciplinary methods, new teaching technologies, technological awareness and innovative research. Additionally, the knowledge of best practices, business communication and creativity in problem-solving could benefit from skill enhancement. Much room exists for improvement in faculty skills and interests. If business schools could move faculty skill levels up, build ties to industry, and increase faculty ability and willingness to change, progress can be made in solving the problem of lack of alignment between academia and business needs.[35]

Further evidence that coverage of the management of technology in typical MBA curricula is lacking can be found in some of the basic features underlying typical MBA programs.[36] For example, MBA programs have generally taught the false theory that a good manager can manage anything, and that it is not necessary to have a technological understanding of the process one is trying to manage. Clearly this can lead to executives' technological illiteracy which, in turn, is responsible for a risk-aversion mentality. This orientation reinforces the false and shallow concept of the professional manager, a "pseudo-professional" who has no special expertise in any particular industry or technology but who nevertheless can step into an unfamiliar company and run it successfully

through strict application of financial controls, portfolio concepts, and a market-driven strategy.

Furthermore, MBA programs place a predominant emphasis on short-range results, quick fixes, quarterly earnings, and viewing R&D and technology functions as cost centers rather than investments in the corporate future. Executive performance is expressed and measured only in quantitative terms. Investments in technology are usually tied to explicit cost justifications of the type that discount assumed cash flows over the next few years.

These weaknesses and shortcomings of typical MBA programs can be addressed through specific areas or fields that can be covered in an MOT education program. As outlined in the 1991 report by the National Research Council, eight primary needs in technology management have been identified.[37]

- How to integrate technology into the overall strategic objectives of the firm.
- How to get into and out of technologies faster and more efficiently.
- How to assess/evaluate technology more efficiently.
- How to accomplish technology transfer.
- How to reduce new product development time.
- How to manage large, complex and interdisciplinary or interorganizational projects/systems.
- How to manage the organization's internal use of technology.
- How to leverage the effectiveness of technical professionals.

However, none of these topical areas are covered in current MBA curricula.

The Master of Engineering Management Degree

Program Features[38]

Engineering management (EM) has been defined as the discipline that focuses on making and implementing decisions for strategic and operational leadership in current and emerging technologies as well as their impacts on interrelated systems. A worldwide survey of engineering management programs in 1994 shows:[39]

- Academic institutions are using a variety of titles for this new discipline. Examples include industrial management, systems engineering, technology management, engineering science, production management, and manufacturing management. Although there are at least 46 different titles, engineering management is the most commonly used for these programs.
- As shown in Table 2, a total of 159 universities in twenty-five countries indicated having EM programs. One hundred and three of them are in

the U.S. and the remaining 56 are in 24 countries.

- The growth in university programs has been primarily on the graduate level. A total of 204 types of degrees were offered by these 159 educational institutions in 1994. These consisted of: 34 Bachelor's, 132 Master's, and 38 Ph.D. degrees. A comparison between 1990 and 1994 in the number of degree-granting programs provides some interesting findings. As the number of degrees offered by the programs has increased by 23% in 1994, the shift of emphasis toward the graduate degrees has become visible. The undergraduate programs have decreased both in absolute numbers and as a percentage of the total while the graduate programs have increased, with the master's degree representing the majority of the offerings.
- EM programs are offered predominantly by the engineering schools. Of the 159 world-wide programs, eighty-eight are located in engineering schools, 26 in business schools, and 32 are jointly administered.

TABLE 2. Distribution of Engineering Management Programs by Country*

Australia	9
Austria	1
Belgium	2
Brazil	1
Canada	8
Denmark	2
France	2
Germany	3
Hong Kong	1
Indonesia	1
Ireland	1
Israel	1
Japan	1
Mexico	1
New Zealand	1
Norway	1
Saudi Arabia	1
Scotland	1
Singapore	1
South Africa	4
Sweden	1
Switzerland	3
Taiwan	1
United Kingdom	7
USA	103
Total	**159**

Source: D.F. Kocaoglu, "Technology Management: Editorial Trends," in *IEEE Transactions on Engineering Management*, November 1994, p. 348.

While there are many common elements in the overall curriculum designs, there are considerable variations in the subjects and topics covered in each program.[40] At the graduate level, most of the programs have a built-in flexibility provided by a combination of core courses and electives. The four course clusters in graduate programs are:

- *Prerequisites* (primarily in the core, few electives): statistics, simulation, software engineering;
- *Fundamentals* (both in the core and the electives): operations research, accounting, economics, financial management, project management, behavioral science, organization theory, quality management, manufacturing management, I/O (industrial/organizational) psychology,

technology management, strategic planning, R&D management, communications;

- *Specialization* (mostly electives, few in the core): engineering specialty courses, M.I.S. (management information systems), personnel management, artificial intelligence/expert systems, database management, productivity management, technology forecasting, industrial relations, entrepreneurship, CAD/CAM, computer-aided engineering, technology marketing, technological innovation, engineering and public policy; and
- *Emerging Areas*: strategic management of technology, business/technology integration, technology planning, venture management, technology transfer, concurrent engineering, product development process.

Engineering management concerns the process of managing the engineering function itself. In short, engineering management is much narrower in scope and orientation than technology management. Thus, the thrust of the engineering management degree is not broad enough to cover the spectrum of issues and intricacies of managing technology as a strategic corporate resource.

Proposed Mechanisms for Educating Technologists in the Management of Technology

The Role of MOT in the Management Curriculum

Why is a curriculum in MOT needed? To answer this question, a more precise definition of MOT is necessary. The 1987 and 1991 reports by the National Research Council define MOT as linking "engineering, science, and management disciplines to address the issues involved in planning, development, and implementation of technological capabilities to shape and accomplish the strategic and operational objectives of an organization."[41] A survey of university courses by the JUPITER Consortium in the United Kingdom defined six categories of technology management education: technology strategy and planning; technology acquisition and transfer; organizing and implementing technology; technology support; technology for managers; and general technology management.[42] Another disciplinary perspective views MOT as comprising three distinct activities:[43]

- *Management of the Development of Technology:* This is the product development process. It is especially important in today's environment which features short product life-cycles, multinational vendoring, large-scale product management, multidisciplinary components, application of scientific principles over engineering know-how, and extensive use of design aids and tools.
- *Managing the Technology Itself*: This involves the management of highly-complex automated production process and systems having a low labor content, such as a chemical plant or an automated factory.

TABLE 3. Conceptualization of MOT: A Proposed Model

Phases/Spectrum	Process	Output
Technology planning and development	Basic research Applied research Development	New Knowledge Invention Innovation
Technology implementation	Product design Product development Process development Integration	Introduction and use of technology in products, manufacturing processes, and other corporate functions
Technology diffusion	Technology evaluation Technology marketing and distribution	New or improved products, processes, and services
Technological change	Technological forecasting Technology assessment Technology substitution	Reevaluating and coping with technology

- *Managing with Technology:* This is essentially the use of technology to solve a management problem. For example, the personal computer can increase a manager's efficiency and effectiveness; robots can reduce assembly time and cost; automating a machine tool can make it more competitive; and management information systems can provide a manager with information to make timely and better informed decisions.

Based upon the above, MOT can thus be defined as a field of study and a practice concerned with exploring and understanding technology as a corporate resource that determines both the strategic and operational capabilities of the firm in designing and developing products and services for maximum customer satisfaction, corporate productivity, profitability, and competitiveness. The distinguishing characteristics of MOT implicit in this definition include:

- MOT is an integrative field of study and an emerging discipline.
- MOT can be characterized as having four basic components: R&D management, product technology management, process technology management, and information technology management.[44]
- As a field of study, MOT has a distinctive scope and is much broader than production and operations management, industrial engineering, engineering management, and entrepreneurship.[45]
- MOT is an interdisciplinary field of study with a dual orientation: it is cross-disciplinary and problem driven.

TABLE 4. Scope and Boundaries of MOT

Horizontal Dimension (Breadth)	***Examples of Disciplines Involved***
R&D management	Mathematics
Product technology management	Economics
Process technology management	OR/MS/statistics
Information technology management	Industrial engineering
Vertical Dimension (Depth)	Management
Strategic	Political science
Operational (product level and project level)	Science and technology policy
Interfunctional	Operations management
System integration	Information technology
Level of Analysis	MIS/computer science
Corporate	Finance/accounting
Industry	Marketing
National	Manufacturing technology
Global	Organizational behavior
Context	Science/engineering disciplines
Low technology	***Other Areas Not Yet Apparent***
Medium technology	
High technology	

- The MOT field has a largely diffused and fragmented research base. This is a natural phase in the development of an evolving discipline.[46]
- Managing technology has a strong strategic orientation relating to the role of technology in corporate strategy.[47]
- As an integrative discipline, MOT has a vertical and a horizontal dimension. The *vertical* dimension represents the need for disciplinary *depth* and concerns the MOT internal core or foundations (i.e., strategic, operational, interfunctional). The *horizontal* dimension represents the need for disciplinary *breadth* and concerns building on theories and principles drawn from other fields, such as R&D management, product technology management, process technology management, and information technology management.[48]

Because of the evolving nature of the field of MOT, there are no established models. Tables 3 and 4 present useful information for conceptualization of MOT and identification of its scope and boundaries. An MOT degree for technologists is an appropriate means for gaining an effective understanding of the management of technology. While non-technical MBA managers may understand the technologies being employed by their firms, they don't have enough

background to develop intuition for which possible technologies now on the horizon are apt to become important and which are apt to be discarded. The result is that incumbent managers have no way to judge the merits of revolutionary changes (in, for example, production technologies), and as a result they procrastinate, waiting for it to become clear which technology is the best. By the time the answer is known, foreign firms may have a two- or three-year lead in understanding and employing those new technologies.

Richie Herink's research lends strong support to this position and makes an appealing case for a degree program in MOT.

> Managers of technology require a unique combination of technical, management, and business abilities in order to effectively design, develop, manufacture and distribute their firms' products and processes. These abilities are more critical than ever before, especially in today's climate of rapid technological change where new products are: increasingly complex; have shorter life-cycle; often involve many disciplines, many organizations, and many vendors; are required to integrate with products developed by other business units and companies; have more demanding criteria for performance, quality, cost and delivery; and require highly sophisticated assembly and manufacturing techniques and methodologies. Products and processes are being designed today for use into the third millennium. The departmentalization and discipline proliferation tendencies of universities emphasize knowledge in depth rather than in breadth, and consequently favor theory over practice. As a result, managers have no place to go to learn "how to run the store." This learning, therefore, largely takes place on the job via an oral tradition. What is needed is a new graduate degree program in the management of technology which represents a cooperative effort between industry and the university schools of business and engieering.[49]

Alternative Modes of MOT Educational Delivery

Existing Programs

A strong partnership between students, the university, and industry is needed if management education is to be effective. The alliance between the three parties is shaky, and its basic foundations need to be reexamined. There are several problem areas that warrant the concern of management and engineering educators and practitioners and require a reexamination of the assumptions, methods, and approaches employed by the university in doing its task.

How can the university help better prepare technologists for careers in management? In addition to the MBA and MEM degree programs, other strategies include:

- infusion of MOT training in existing curricula by broadening the scope and domain of engineering management programs and by creating a field of concentration in MOT within MBA programs;
- initiating graduate degree programs in MOT.

The problem with broadening the scope of the typical existing EM or MBA program is that the educational philosophy, objectives, ideologies, foundations, and program structure are quite different from what would be needed to make it an MOT graduate program. To be sure, the existing programs cannot be made broad enough to transform it into an MOT program. Furthermore, a sound MOT graduate program should not be developed and offered by either the engineering faculty or by the business faculty alone. It should be a joint partnership and an educational program that is offered and administered by the faculty in both colleges. This would ensure high quality and program integrity.

A Graduate Program in MOT

While the proposed program might overlap with some of the programs already available under a variety of names, it should, of course, be different from both EM and MBA programs. The philosophy, requirements, and content of the proposed program would, naturally, have to be left for the faculty of the concerned schools and would largely depend on their backgrounds, program objectives, and "market needs."

Because of the "newness" and evolving nature of MOT as an emerging discipline, providing a detailed blueprint of the proposed program would not be appropriate here. However, for the proposed program to be effective in overcoming the deficiencies inherent in both the MBA and EM degree programs, it should be designed to meet several criteria. It should:[50]

- be a joint sponsorship by both engineering and business colleges;
- seek heavy involvement from the industrial community in providing valuable input into the design and content of the program;
- provide a thorough and substantive coverage of the unique and complex problems of managing technology;
- maintain a profound balance between technology and management in program structure, content, and course coverage;
- take an action learning perspective with a strong skill development orientation;
- provide a balanced content combining learning-by-doing with cognitive learning through breadth in scope and depth in analysis.
- adopt a clinical positive (as opposed to normative) approach to management education, incorporating appropriate strategies for adult learning; and
- recognize the foundations of managerial skill development as essentially a self-development process.

Based on the available research studies, a university curriculum for a master's degree in management of technology is proposed in Table 5. Again, this is not a blueprint, but is meant to stimulate ideas and discussion among

TABLE 5. Proposed Curriculum for a Master's Degree in Management of Technology

Foundation Courses/Topics

1. Computer-based management support systems
2. Managerial accounting and technical systems
3. Technology and economic analysis
4. Financial management for technologists
5. Quantitative tools for decision making
6. Technology transfer
7. Emerging technology management models and techniques (TQM, concurrent engineering, cycle time management, robotics, etc.)
8. Techniques for new product development
9. Developing managerial skills of technical managers
10. Expert systems in technology management
11. Communication skills for technical people (verbal, nonverbal, written, etc.)

Core Courses/Topics

1. Leaership in technical organizations
2. Technology and organizational systems
3. R&D management
4. Managing cross-functional teams
5. Managing process technology
6. Managing product technology
7. Managing information technology
8. Human resource utilization systems in technology-based organizations
9. Managing technical professionals
10. Manufacturing systems and operations management
11. Marketing and selling technology
12. Managing technical projects
13. Technology/corporate interfacing
14. Developing interpersonal skills of technical managers
15. Technology and business unit strategy
16. Technology and innovation management
17. Strategic management of technology

Elective Courses/Topics

1. International aspects of managing technology
2. Design/manufacturing interface management
3. Technological alliances
4. Technology integration and functional interfaces (R&D, engineering, manufacturing, and marketing)
5. Analysis of emerging technologies
6. Technology forecasting
7. Technological entrepreneurship
8. Technology planning and venture management
9. Contract management
10. Patent and copyright law for technical managers
11. Technology assessment and social aspects of technology
12. Personnel management for technical professionals

university educators, researchers, and managers in this field.[51] In reviewing the proposed curriculum, it is important to keep the following in mind:

- The proposed areas are not necessarily separate program courses, but topical areas that can be combined into course packages.
- Three program tracks are proposed: *foundations* covering managerial tools and techniques, *core* areas, and *elective* areas.

TABLE 6. Selected Universities and Institutes with MOT Offerings: An International Listing

Bentley College	Northeastern University
Carleton University (Canada)	Northwestern University
Carnegie-Mellon University	Pepperdine University
Clarkson College	Polytechnic University of New York
Cranfield Institute of Technology (U.K.)	Portland State University
Case Western Reserve University	Rensselaer Polytechnic Institute
Catholic University (Belgium)	Rochester Institute of Technology
EuroPACE (European Program of Advanced Continuing Education) (France)	Stanford Univeristy
European Institute of Technology (Italy)	Stevens Institute of Technology
Fairleigh Dickinson University	Sussex University (U.K.)
George Washington University	University of California at Berkeley
Georgia Institute of Technology	University of Cincinnati
Harvard Business School	University of Colorado
Industrial Research Institute	University of Kiel (Germany)
International Institute for Management Development (Switzerland)	University of Manchester (U.K.)
JUPITER Consortium (U.K.)	University of Miami, Florida
Massachusetts Institute of Technology	University of Minnesota
McMaster University (Canada)	University of Southern California
National Technological University	University of Twente (Netherlands)
New Jersey Institute of Technology	Virginia Polytechnic Institute and State University
	Washington University

- The proposed areas revolve around the four components of MOT: R&D management; and managing product, process, and information technologies.
- The proposed areas cover the four major resources in an organization: financial, physical, human, and informational.
- Selection of appropriate topical areas for an academic degree in technology management must, in the final analysis, depend on the judgment of the faculty, university administrators, and the professional business community. It follows that the MOT program curriculum will vary among different colleges as a function of the program objectives, educational philosophy, distinctive competence of the school and its geographical location, market needs, and other community-based considerations.

TABLE 7. Selected Journals in Engineering and Technology Management: An International Listing

International Journal of Operations & Production Management	*R&D Management*
International Journal of Quality & Reliability Management	*Research Policy*
International Journal of Technology Management	*Research Technology Management*
Journal of Engineering and Technology Management (JET-M)	*Technology Analysis and Strategic Management*
Journal of Product Innovation Management	*Technology Review*
Product and Process Innovation	*Technological Forecasting & Social Change*
Project Management Journal	*Technovation*
	Transactions on Engineering Management

Where to Learn about MOT

University degree programs in MOT are emerging in Europe, and many U.S. colleges and institutes are also offering degrees, short courses, executive programs, and seminars in MOT. Collaborative efforts among faculties, involving multiple universities and multiple countries, are not uncommon.[52] As a newly emerging discipline, it will be some time before those program offerings mature and stabilize. Table 6 provides a partial listing of universities and institutes offering degrees or individual courses and seminars in MOT.

In addition to degree programs and seminar offerings, several specialized journals in engineering and technology management are available. These journals can provide technologists and scholars with a valuable source of current information, new developments, and research findings in MOT. A selected list appears in Table 7.

Conclusion

The implications of the proposed MOT programs are profound. While most managerial activities in other corporate functions are directed toward managing stability and conformity, managing technology and innovation is, by its very nature, directed toward managing change. Change is disruptive because it requires developing and dealing with new ways of doing things, new products, new markets, and new competitors. Indeed, it requires new ways of thinking.

The management of technology is an integrative process and not a functional activity like engineering management. It focuses on integrating the technology side of the house (i.e., R&D, engineering, manufacturing) with the business side of the house (i.e., marketing, finance, human resources). From this perspective, MOT has an important professional role to play in management education. This can then be the university's response to industry's need

TABLE 8. Management Educational Programs for Technologists: A Comparative Profile

Program Characteristics and Features	MBA	MEM	MOT
Target audience	Open. Technologists to learn about management	Technologists to learn about engineering management	Both technologists and managers to learn how to manage technology
Major thrust	Management	Technology	Management of technology
Orientation	Functional specialization	Functional specialization	Integrative with strategic orientation
Dominant mode of thinking	Product-driven	Process-driven	Technology as a strategic corporate resource
Education and research focus	Management disciplines	Technical disciplines	Cross-disciplinary, problem- and issue-driven
Domain	Business school	Engineering school	Joint
Correspondence to corporate functional structure	Business and management side of the house	Technology side of the house	Cuts across functional divisions and departmental structure

for technologists to learn about management and for non-technologist managers to learn about technology.

Table 8 compares the distinctive features of MBA, MEM, and MOT programs. While both the MBA and MEM degrees provide valuable knowledge of management concepts and principles, they will not adequately prepare graduates for dealing with the unique and complex problems of managing technology. An MOT curriculum can overcome their deficiencies and lead to more effective managers who can successfully address the strategic needs of competing in the global markets in the third millennium.

Notes

1. For a good discussion of this point, see Richard N. Osborn and John Hagedoorn, "The Institutionalization and Evolutionary Dynamics of Interoranizational Alliances and Networks," *Academy of Management Journal*, 40/2 (April 1997): 261-278.
2. National Science Foundation, *Science & Engineering Indicators* (Washington, D.C.: U.S. Government Printing Office, 1996).

3. See Yu-Ting Cheng and Andrew H. Van de Ven, "Learning the Innovation Journey: Order Out of Chaos?" *Organization Science*, 7/6 (November/December 1996): 593-614; Michael K. Badawy, *Management as a New Technology* (New York, NY: McGraw-Hill, 1993), chapters 1 and 2.
4. See, for example, Katherine J. Klein and Joann Spear Sorra, "The Challenge of Innovation Implementation," *Academy of Management Review*, 21/4 (October 1996): 1055-1080; J.F. Coates, J. Mahaffie, and Andy Hines, *2025: Scenarios of US and Global Society Reshaped by Science and Technology* (Greensboro, NC: Oakhill Press, 1997).
5. Michael K. Badawy and Afie M. Badawy, "Directions for Scholarly Research in Management of Technology," *Journal of Engineering and Technology Management*, 10/1&2 (June 1993): 1-5.
6. See M.A. Youndt, S.A. Snell, J.W. Dean, and D.P. Lepak, "Human Resource Management, Manufacturing Strategy, and Firm Performance," *Academy of Management Journal*, 39/4 (August 1996): 836-866; A. Subramanian, "Innovativeness: Redefining the Concept," *Journal of Engineering and Technology Management*, 13/3&4 (September/December 1996): 223-243.
7. For an excellent discussion, see Peter F. Drucker, "The Discipline of Innovation," *Harvard Business Review*, 63/3 (May/June 1985): 67-72; Robert Drazin and Claudia Bird Schoonhoven, "Community, Population and Organization Effects on Innovation: A Multilevel Perspective," *Academy of Management Journal*, 39/5 (October 1996): 1065-1083; Jan Bossak and Soichiro Nagashima, *Corporate Strategies for a Borderless World* (Tokyo: Asian Productivity Organization, 1997); John P. Kotter, *General Managers* (New York, NY: The Free Press, 1996).
8. Stephen C. Harper, "The Challenges Facing CEOs: Past, Present, and Future," *The Academy of Management Executive*, 6/3 (1992): 7-25; Donald C. Hambrick, "The Top Management Team: Key to Strategic Success," *California Management Review*, 30/1 (Fall 1987): 88-108; J. Macioriello, J. Burke, and D. Tilley, "Improving American Competitiveness: A Management System Perspective," *The Academy of Management Executive*, 3/4 (1989): 294-303; J.F. Mathis, "Turning R&D Managers into Technology Managers," *Research-Technology Management*, 35/1 (January/February1992): 35-38.
9. Michael L. Dertouzos, Richard K. Lester, and Robert M. Solow, *Made in America: Regaining the Productive Edge* (Cambridge, MA: MIT Press, 1989).
10. See Raymond E. Miles, Henry J. Coleman, Jr., and W.E. Douglas Creed, "Keys to Success in Corporate Redesign," *California Management Review*, 37/3 (Spring 1995): 128-145; John G. Irwin, James J. Hoffman, and Bruce T. Lamont, "The Effect of the Acquisition of Technological Innovations on Organizational Performance: A Resource-Based View," *Journal of Engineering and Technology Management*, 15/1 (March 1998).
11. For more on this point, see Leonard H. Lynn, John D. Aram, and N. Mohan Reddy, "Technology Communities and Innovation Communities," *Journal of Engineering and Technology Management*, 14/2 (June 1997): 129-145.
12. Peter F. Drucker, "The Information Executives Truly Need," *Harvard Business Review*, 73/1 (January/February 1995): 54-63; G.G. Dess, A.M.A. Rasheed, K.J. McLaughlin, and R.L. Priem, "The New Corporate Architecture," *The Academy of Management Executive*, 9/3 (August 1995): 7-20; Jay A. Conger, "The Brave New World of Leadership Training," *Organizational Dynamics*, 21/3 (Winter 1993): 46-58; Andrew H. Van de Ven, "A Community Perspective on the Emergence of Innovations," *Journal of Engineering and Technology Management*, 10/1&2 (June 1993): 23-51.
13. Dertouzos, op. cit., chapters 3, 4, and 5; Badawy, op. cit., chapter 1, pp. 3-34.

14. See, for example, Rita G. McGrath, "A Real Options Logic for Initiating Technology Positioning Investments," *The Academy of Management Review*, 22/4 (October 1997): 974-996; Jeanne H. Liedtka, "Collaborating Across Lines of Business for Competitive Advantage," *The Academy of Management Executive*, 10/2 (May 1996): 20-34; S. Ghoshal and C.A. Bartlett, "Changing the Role of Top Management: Beyond Structure to Processes," *Harvard Business Review*, 73/1 (January/February 1995): 86-96.
15. For an interesting discussion, see Deborah Dougherty and Edward H. Bowman, "The Effects of Organizational Downsizing on Product Innovation," *California Management Review*, 37/4 (Summer 1995): 28-44; William McKinley, Carol M. Sanchez, and Allen G. Schick, "Organizational Downsizing: Constraining, Cloning, Learning," *The Academy of Management Executive*, 9/3 (August 1995): 32-44; Ghoshal and Bartlett, op. cit.; Michael K. Badawy, "Technology and Strategic Advantage: Managing Corporate Technology Transfer in the U.S. and Japan," *International Journal of Technology Management* (1991), pp. 205-215.
16. Richie Herink, "Technology Management Education for the Third Millenium," *International Journal of Technology Management*, 10/3 (1995): 353-359.
17. See, for example, Sara L. Keck, "Top Management Team Structure: Differential Effect by Environmental Context," *Organization Science*, 8/2 (April 1997): 143-156; Eric H. Kessler and Alok K. Chakrabarti, "Innovation Speed: A Conceptual Model of Context, Antecedents, and Outcomes," *Academy of Management Review*, 21/4 (October 1996): 1143-1191.
18. Based on data and estimates provided by the Engineering Workforce Commission of the American Association of Engineering Societies.
19. See, for example, James Brian Quinn, Philip Anderson, and Sydney Finkelstein, "Leveraging Intellect," *Academy of Management Executive*, 10/3 (November 1996): 7-27; Brian Becker and Barry Gerhart, "The Impact of Human Resource Management on Organizational Performance: Progress and Prospects," *Academy of Management Journal*, 39/4 (August 1996): 779-801; C.A. Lengnick-Hall and M.L. Lengnick-Hall, "Strategic Human Resources Management: A Review of the Literature and a Proposed Typology," *Academy of Management Review*, 13/3 (1988): 454-470; Michael K. Badawy, "A New Paradigm for Understanding Management as a New Technology: A Research Agenda for *'Technocologists'*," *International Journal of Technology Management*, 12/5&6 (1996): 717-732.
20. Mary Ann Glynn, "Innovative Genius: A Framework for Relating Individual and Organizational Intelligences to Innovation," *Academy of Management Review*, 21/4 (October 1996): 1081-1111; T.M. Amabile, R. Conti, H. Coon, J. Lazerby, and M. Herron, "Assessing the Work Environment for Creativity," *Academy of Management Journal*, 39/5 (October 1996): 1154-1184; Michael Bonsign-Ore, "Four Forces of Career Change," *Engineering Management Review*, 25/1 (Spring 1997): 67-72.
21. See, for example, Ralph Katz, ed., *The Human Side of Managing Technological Innovation* (New York, NY: Oxford University Press, 1997); Cameron M. Ford, "A Theory of Individual Creative Action in Multiple Social Domains," *Academy of Management Review*, 21/4 (October 1996): 1112-1142; R. Cordero, G. F. Farris, and N. Di Tomaso, "Identifying and Developing Promotability in R&D Laboratories," *Journal of Engineering and Technology Management*, 11/1 (March 1994): 55-72; N. Di Tomaso, G. F. Farris, and R Codero, "Diversity in the Technical Workforce: Re-Thinking the Management of Scientists and Engineers," *Journal of Engineering and Technology Management*, 10/1&2 (June 1993): 101-128.
22. For an excellent discussion of this issue, see Brent B. Allred, Charles C. Snow, and Raymond Miles, "Characteristics of Managial Caeers in the 21st Century," *The Academy of Management Executive*, 10/4 (November 1996): 17-27; Shirou Fujita, *A Strategy for Corporate Innovation* (Tokyo: Asian Productivity Organization, 1997);

James E. Tingstad, "Why Do Technical Managers Ignore the Data?" *Research-Technology Management*, 35/1 (January/February 1992): 8-9; Michael K. Badawy, *Developing Managerial Skills in Engineers and Scientists*, Second Edition (New York, NY: Van Nostrand Reinhold, 1995); T.J. Allen, *Managing the Flow of Technology* (Cambridge, MA: MIT Press, 1984).

23. See Debra M. Amidon Rogers, "The Challenge of Fifth Generation R&D," *Research-Technology Management*, 39/4 (July/August 1996): 33-41; Lisa H. Pelled and Paul S. Adler, "Antecedents of Intergroup Conflict in Multifunctional Product Development Teams: A Conceptual Model," *IEEE Transactions on Engineering Management*, 4/1 (February 1994): 21-28.
24. Deborah Dougherty and Cynthia Hardy, "Sustained Product Innovation in Large Mature Organizations: Overcoming Innovation-to-Organization Problems," *Academy of Management Journal*, 39/5 (October 1996): 1120-1153; Claudia U. Ciborra, "The Platform Organization: Recombining Strategies, Structures, and Surprises," *Organization Science*, 7/2 (March/April 1996): 103-118.
25. Michael K. Badawy, "Practical Issues in Managing Technical Professionals," *International Journal of Technology Management*, 13/5&6 (1992): 428-442.
26. For an excellent critical evaluation of management education for technologists and MBA programs, see Richard T. Mowday, "Redefining Our Scholarly Values," *Academy of Management Review*, 22/2 (April 1997): 335-345; Jane C. Linder and H. Jeff Smith," The Complex Case of Management Education," *Harvard Business Review*, 70/5 (September/October 1992): 16-33; "Management Education: Passport to Prosperity," *The Economist*, March 2, 1991, pp. 6-28.
27. AACSB Report (1996), op. cit.; Linder and Smith, op. cit.; J.C. Mason, "Business Schools: Striving to Meet Customer Demand," *Management Review*, 81/9 (September 1992): 10-14; James Reeve, "Graduate Management Education in Transition," *Survey of Business*, 28/1 (Summer 1992): 3-5.
28. John H. Sheridan, "The New Breed of MBA," *Industry Week* (October 1993), pp. 11-16.
29. The American Assembly of Collegiate Schools of Business, *A Report of the AACSB Faculty Leadership Task Force*, April 1996, St. Louis, MO.
30. Ibid., p. 4.
31. Mowday, op. cit., p. 337.
32. Russell Ackoff, "Higher Education and Social Stratification," *Interfaces*, 24/4 (1994): 73-82; Russell Ackoff, "OR: A Post Mortem," *Operations Research*, 35/3 (1987): 471-474.
33. Ackoff (1987), op. cit.
34. Henry Mintzberg, *The Nature of Managerial Work* (New York, NY: Harper & Row, 1973), p. 186.
35. AACSB (1996), op. cit.
36. This discussion is partly based on Edgar H. Schein, "Career Anchors Revisited: Implications for Career Development in the 21 st Century," *The Academy of Management Executive*, 10/4 (November 1996): 80-88; the AACSB Report (1996), op. cit.; Mowday, op. cit.; William A.B. Purdon, "Increasing R&D Effectiveness: Researchers as Business People," *Research-Technology Management*, 39/4 (July/August 1996): 48-56; John P. Kotter, "Leading Change: Why Transformation Efforts Fail," *Harvard Business Review*, 73/3 (March/April 1995); Dertouzos et al., op. cit.
37. National Research Council, *Research on the Management of Technology* (Washington, D.C.: National Academy Press, 1991); National Research Council, *Management of Technology: The Hidden Competitive Advantage* (Washington, D.C.: National Academy Press, 1987).

38. Discussion in the section in based partly on D.F. Kocaoglu, "Technology Management: Educational Trends," *IEEE Transactions on Engineering Management*, 41/4 (November 1994): 347-349; D.F. Kocaoglu, "Research and Educational Characteristics of the Engineering Management Discipline," *IEEE Transactions on Engineering Management*, 37/3 (August 1990): 172-176.
39. Kocaoglu (1994), op. cit.
40. For an interesting discussion, see Arnold Reisman, "Technology Management: A Brief Review of the Last 40 years and Some Thoughts on Its Future," *IEEE Transactions on Engineering Management*, 41/4 (November 1994): 342-346; A. Bailetti and J. R. Callahan, "The Engineering Management Synthesis: Evidence from Graduate Programs in Telecommunications," *IEEE Transactions on Engineering Management*, 40/1 (February 1993): 30-39.
41. National Research Council report, op. cit.
42. William A. Weimer, "Education for Technology Management," *Research-Technology Management*. (May/June 1991): 41-45.
43. Herink, op. cit.
44. Badawy and Badawy, op. cit.
45. S.E. Herman and K.G. Provan, "An Emergent Theory of Structure and Outcomes in Small Firm Strategic Manufacturing Networks," *Academy of Management Journal*, 40/2 (April 1997): 368-403.
46. C. Marlene Fiol, "Squeezing Harder Doesn't Always Work: Continuing the Search for Consistency in Innovation Research," *Academy of Management Review*, 21/4 (October 1996): 1012-1021; Philip Anderson, "Toward Exemplary Research in the Management of Technology," *Journal of Engineering and Technology Management*, 10/1&2 (June 1993): 7-22.
47. For an excellent discussion, see Raghu Garud and David Ahlstrom, "Technology Assessment: A Socio-Cognitive Perspective," *Journal of Engineering and Technology Management*, 14/1 (March 1997); W.G. Egelhoff and C.S. Haklisch, "Strategy, Size of Firm, and the Use of Technological Alliances: An Exploratory Study," *Journal of Engineering and Technology Management*, 11/2 (June 1994): 117-148; Kim B. Clark, "What Strategy Can Do for Technology?" *Harvard Business Review*, 67/6 (November/December 1989): 94-98; Joseph Morone, "Strategic Use of Technology," *California Management Review*, 31/4 (Summer 1989): 91-110.
48. Abbie Griffin, "Modeling and Measuring Product Development Cycle Time Across Industries," *Journal of Engineering and Technology Management*, 14/1 (March 1997); Philip Anderson, op. cit.
49. Herink, op. cit.
50. Peter J. Frost, "Bridging Academia and Business," *Organization Science*, 8/3 (May/June 1997): 333-347; Mowday, op. cit.; Dertouzos et al., op. cit.
51. See, for example, the AACSB Report, op. cit.; Manuel London, "Redeployment and Continuous Learning in the 21st Century," *Academy of Management Executive*, 10/4 (November 1996): 67-79; Michael B. Arthur and Denise Rousseau, "A New Career Lexicon for the 21st Century," *Academy of Management Executive*, 10/4 (November 1996): 28-39.
52. Weimer, op. cit.; Trevor Grigg, "Entrepreneurship and Innovation at Universities: A Case Study of Higher Education in Australia," *Journal of Engineering and Technology Management*, 11/3&4 (December 1994): 273-298.