PART 1

Core Concepts

A Research Architecture for Technology Management Education

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INTRODUCTION AND BACKGROUND

The objective of this chapter is to provide an understanding of why current educational programs in technology and innovation management are essentially flawed. We are employing twentieth-century tools and techniques for solving twenty-first-century challenges. Existing programs do not adequately prepare technical professional for successful careers in management of technology. Focusing on management education and taking an analytical research perspective, the chapter will provide some innovative paradigms and models for effective technology and innovation management education. Finally, the implications, issues, and challenges facing universities and management educators, technical professionals, and managers will be addressed.

Similar to engineering and medicine, effective management requires both knowledge and practice. Knowledge without practice breeds a blue-sky theorist. Practice without knowledge breeds a trial-and-error layperson. Knowledge and practice breed a well-grounded, competent practitioner (Badawy 1995). One justification for this approach is that managing—like engineering and medicine—is an applied professional discipline in which theory and practice must be closely intertwined. There is a question, however, 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 technical professionals for effective management of technology.

Effective management of technology calls for different ways of thinking, leadership styles, techniques, and managerial skills (Badawy 1993, 2007, 2008). The challenge facing management educators in determining what managers in the twenty-first 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 achieve a competitive advantage in the global digital economy.

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. 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.

Technology plays a critically vital role in the highly competitive global economy. This is reflected in data showing that the U.S. R&D expenditures were $342.0 billion in 2006. Of that amount, industry projected research and development was $232.7 billion, or 67.86 percent (National Science Foundation 2007). On a global scale, understanding that the United States spends more on research and development than Japan, Germany, France, and the United Kingdom combined clearly underscores the enormous importance of technology as a core economic resource for enhancing corporate productivity and profitability (Florida 2004; Welsh et al. 2008)

SCOPE, STRUCTURE, CONTEXT, AND RESEARCH LIMITATIONS

This chapter has been organized into eight sections. Sections 3 and 4 provide an assessment of the state of the art and what we know about educating technical professionals for management. Sections 5 and 6 provide an analytical perspective for alternative delivery systems for MOT education along with a conceptual design of MOT as a discipline and a practice. Section 7 articulates a proposed analytical research-based architecture and disciplinary foundations for designing technology and innovation management educational curricula. Finally, a 10-item action agenda addressing issues and future directions is presented in Section 8.

In an attempt to place this chapter in the proper perspective, readers need to understand the scope, domain, context, and limitations of this article, which are briefly articulated here:

- Definitions of the concepts of a *handbook* and *architecture* are in order. Simply stated, the concept of a handbook is used here to refer to a manual intended as a reference book providing information on a particular subject. The implication is that the content of the handbook should be sufficiently broad to accommodate the varied professional backgrounds, interests, and expectations of the readership. On the other hand, a research architecture is used here to refer to a stand-alone piece targeted toward providing the building blocks based on what is available in the literature, and proposing an action agenda for future research.
- This research-based chapter is squarely rooted in the MOT literature. Similar to other conceptual research schemes, the configuration is a stand-alone article providing the building blocks of the proposed research architecture, which is built on the state of the art and the results of the available research investigations.
- As an evidence-based chapter, it integrates, synthesizes, builds, and expands on research findings from the most recent literature citations and sources available. It also contributes to the research literature by articulating the author's position based on his own work for the last three decades. Then, taking explicit positions on the issues addressed, and raising constructive questions that are very critical for advancing the MOT field as a discipline and a practice.
- Readers need to keep in mind the significant role and importance of conceptual research for the MOT field development. It is extremely valuable in building and establishing the foundations of research and education in any emerging field of study. This point becomes clearer if you as a reader would just reflect on the following question: Where would the fields of management and MOT be today without the core monumental foundations and contributions of some of the twentieth-century giants such as Frederick Taylor, Max Weber, Herbert Simon, Peter Drucker, and W. Edwards Deming?
- This chapter provides the readership with a helpful taxonomy by taking an informed critical view of the entire MOT education landscape, and providing and synthesizing evidence-based research, then offers a comprehensive classification and categorization of the traditional and newly emerging paradigms, and ends up with an action agenda of issues and directions for future research.
- There are five tables embedded in the text. Based on survey results undertaken by the major publishers of some of my books and articles, using tables, figures, and diagrams as presentation media is usually highly valued by technical professionals and their managers with largely visual styles. Given that substance must overshadow appearance, the table format enables us to get the point across in a relatively limited space, thus increasing efficiency, clarity, and understanding. In short, the quality of the presentation is largely enhanced by the high functionality of the tables.
- Despite the brevity of the material presented in the tables, it represents a vital added value to the overall contribution of the chapter. While I fully recognize that the material presented in some of the tables is somewhat too long, cutting down this material would compromise the integrity of the complex phenomena discussed, and undermine the chapter.
- It is not the intent of this chapter to present models of actual MOT curricula, schools, or degree programs. All these elements plus many more items were already thoroughly and extensively covered in both the author's previous work as well as those of others. Duplicating this material again here would be pointless.
- A certain degree of stereotyping is probably a standard limitation of evidence-based research studies. Since conceptual research-based papers are not often based on a single empirical study, discussion in some parts of the chapter might have the appearance of a certain degree of stereotyping. This is because discussion is evidence-based and is drawn from multiple studies and sources. Since there are no research studies without limitations, this is a limitation of this research.

WHAT DO WE KNOW ABOUT EDUCATING TECHNICAL PROFESSIONALS FOR MANAGEMENT? STATE OF THE ART

Technology management is the process of effective integration and utilization of innovation, strategic, operational, and commercial mission of an enterprise for gaining competitive advantage (Badawy 2009). 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 (Boland et al. 2007; Damanpour and Wischnevsky 2006). The concept of technology management is quite broad since it covers not only R&D, but also the management of product, process, service, and information technologies. 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 (Chang and Harrington 2007). A more detailed analysis of the nature, orientation, and conceptual design of MOT as a field of study is provided in Section 6 of this chapter.

For our purposes in this chapter, *technical professionals* are defined as scientists, engineers, computer systems analysts, information technology specialists, and other types of technical professionals working at different functional specialties in technology-based organizations. These functions include R&D; design engineering; manufacturing technology; quality assurance; technical services; artificial intelligence; expert systems; product, process, and information technology; total quality management; and other related technical functions.

Current university degree programs provide technical professionals with two major possibilities, or avenues, for management education: the MBA and the MEM. Before undertaking a research-based diagnostic assessment of the broad characteristics of university management educational programs, we should first understand the nature, issues, and unique problems of managing technology. It is this uniqueness that mandates different kinds of educational programs for developing managerial skills in technical professionals. This would enable them to meet the global challenges of managing technology in the twenty-first century.

The notion that a good manager can manage anything regardless of its technological base is simplistic, misleading, and must be abandoned (Maerki 2008; Mintzberg 2005). Corporate practices in the United States 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 here is: How can managers manage something they do not understand?

The point is not that CEOs and top executive staff must become technology specialists (Armstrong 2005; Schwandt 2005). 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. It is noteworthy here to mention that even though not technically educated, top executives need an emotional and cultural attachment to technology. The bottom line is that many executives, although not technically educated, have that passion and emotional attachment to technology because of what it can do for the organization.

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 marketplace. For more and more firms, effective performance in developing, adopting, and using technological innovation is becoming vital to success in the marketplace. 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 (Dertouzos et al. 1989).

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

Effective managers of technology invariably attribute their success largely to their ability to create a vision. 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. 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. In short, their vision is based on knowledge of where technology has been and where it is going.

Executive action, however, often reflects cluttered vision, a lack of focus, and inadequate strategic thinking (Badawy 1993, 1996; Dertouzos 1989; Fink and Holden 2005). Instead of a company concentrating on what it can do best, it 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 such training has been, for the most part, 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 (Hesselbein et al. 2002; Ling et al. 2008; McDonald et al. 2008; Nadkarni 2003). Technology direction usually emanates from senior management (with help from technology professionals who know the technologies and where they are heading), 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 (Gales 2008). They consequently lack an understanding of linking business and technical priorities, managing technological strategy, and planning technology. Compared with Europe and Japan, more U.S. managers come up through nonproduction 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 for the last 35 years in technology-based global markets. Instead of fostering technological innovation for competitive advantage, top management decisions were largely based on creating value through corporate financial manipulations, stock market maneuvers, and financial accounting schemes and gimmicks.

The current massive problems faced by General Motors, Kodak, Xerox, and Motorola—among others—are an excellent case in point. Because of the varied and complicated strategic situations faced by these firms, it is quite possible that a host of other factors have complicated the context within which those companies are operating. 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 characteristics. While these features are difficult to quantify, they nevertheless present a corporate profile that is distinctively different from traditional nontechnology-based organizations (Augsdorfer 2008; Clark and Konrad 2008). These features include:

- Technology-based organizations typically employ a large number of engineers, scientists, and other technical professionals.
- 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 a competitive advantage.
- Inventions and innovations by the technical staff are usually protected by patents and other means of protecting intellectual property rights.
- Product, process, service, 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. 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, processes, and services 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.

This analysis clearly suggests that technical professionals are the most important asset in the technology management function. In organizations whose most valued product is essentially ideas, the importance of effectively managing and using intellectual capital cannot 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. In short, the primary problems of managing technology are not technical—they are human!

The scholarly and professional literatures draw a profile of the technical professional stereotype. Michael Badawy's work and research studies for the last three decades, however, clearly show that there are enormous variations both among and between different professional groups (for example, scientists versus engineers) in regard to complexity configurations, technological competences, leadership quotients, behavioral prototypes, creative orientations, risk aversion, and attitudinal inclinations (Badawy 1995; Elsbach and Hargadon 2006; Siemsen, 2008).

While the well-documented evidence presented by Badawy and others is quite compelling (Badawy 1992; Green and Aiman-Smith 2004), the features of the technical professional stereotypes continue to dominate the literature. They 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 for learning and acquiring knowledge for its own sake.
- They have strong personalities and individualized value systems and ways of thinking.
- They have a high propensity for risk-taking, experimentation, and trying new approaches to known phenomena.

Furthermore, there are well-documented studies showing that scientists, engineers, and other technical professionals tend to be different from other segments of the labor force (Allen 1984; Badawy 1995). There are also well-documented differences between engineers and scientists as two separate groups. As such, these differences set engineers and scientists apart from those working in other traditional individual activities such as marketing, purchasing, and personnel.

Appropriate organizational designs depend to a large degree on the characteristics of the task to be performed. From this perspective, there are significant differences

Table 1.1: 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	Social and interpersonal skills; divergent ways of thinking	Administrative (structural aspects of the organization)
4. Key managerial priorities	The R&D director is the chief technologist of the business	Marketing, production, and finance are key functions with top priorities
5. Managerial leadership style	Participative	Directive

between R&D activities and other traditional corporate functions such as Marketing and Finance (Hidalgo and Albors 2008; Phaal et al. 2006.) To give an example, 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. Table 1.1 provides the broad differences between R&D and other corporate functions.

As a result of these differences in task characteristics, R&D scientists tend to be different from other corporate 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.
- They tend to identify more with their professional peers than with their company (Casper and Murray 2005; Collins and Hitt 2006).

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 (Badawy 1992, 2008). The evidence on the need for a technology management education, however, remains compelling. There are five major forces that contribute to this:

1. The necessity of understanding the complex problems of managing technology
2. The critical need for a broad vision of technology as an integral link in corporate strategy
3. Managing technological innovation as a top-management responsibility
4. The context and core competence of technology-based organizations
5. The unique characteristics of technical professionals

It should be noted here that I fully realize that Table 1.1 is simply a snapshot, since there are major variations among corporate functions. For example, in item 3, while administrative, interpersonal, and technical skills are important in all managerial functions, the importance of social and interpersonal skills is more dominant in an R&D management environment as a major component of leadership, cross-disciplinary teams, creativity, and innovation in general. It follows that the differences presented in Tables 1.1 and 1.2 are not necessarily dichotomies or opposing statements at the opposite ends of the continuum, but rather an illustrative stereotype of the degrees of variations among the issues discussed.

A DIAGNOSTIC ASSESSMENT OF ACADEMIC MANAGEMENT EDUCATION: A PROPOSED PARADIGM SHIFT

In the first edition of my book, *Developing Managerial Skills in Engineers and Scientists* (1982) I issued a warning to the academic and business professional communities concerning problems with existing models of management education, and suggested a prescription for remedies. Some took notice of the issues raised and accordingly made changes in undergraduate and MBA curricula. The rest thought such warning is not warranted and just continued to do business as usual; now, roughly three decades later, the problems have gotten a lot worse!

The accumulated evidence suggests that management education is in trouble. Our current approaches to education and career development are obsolete. They are incapable of preparing and developing the managerial know-how, skills, and attitudes required to manage and effectively cope with the accelerating rate of social and technological change in society and its institutions. Both the universities and the business communities have allowed themselves to become so absorbed in their own particular concerns that they have tended to overlook their essential need for interdependence.

I subsequently organized and chaired an All-Academy Showcase Session for The Academy of Management on "How Can Business Schools Do Well by Doing Good? An Action Agenda for Re-Focusing Management Education." The major theme of the presentation focused on the notion that management education is too theoretical and too academic and does not, in fact, provide graduates with

Table 1.2: A Diagnostic Assessment of Academic Management Education: A Paradigm Shift

Variables and Features	Current Traditional Practices	Proposed Innovative Paradigms
I. Domain and Philosophical Theme		
• Concept and major thrust	• Similar to other university units	• Applied professional school
• Disciplinary orientation	• Management as a discipline	• Managing as a practice • Disciplinary training only for potential scholars
• Major focus	• Knowledge • No skill orientation	• Knowledge and practice
• Usual outcomes	• Solutions looking for problems to solve (Want-Driven)	• Problems looking for solutions (Need-Driven)
II. Curriculum Content and Orientation		
• Dominant feature	• Normative (what should be)	• Positive (what is)
• Core Driver	• Discipline and product driven (Technology push) • New product is not tailored to fit customer needs—input centric	• Market or customer driven (Market pull)—output centric
• Mode of operation of schools of management	• They teach about management	• A person can learn *how* to manage—but not necessarily be *taught* to manage
• Theory versus Practice	• Growing divergence	• Maintaining balance
III. A Diagnostic Assessment		
• Value orientation	• Excessively rational	• Organizations in action
• Widening gap between management science and management technology	• Overemphasis on analytical tools • No other discipline in which practice seems so unaffected by its own principles • No other intellectual field in which practitioners contribute less to management theory	• Theory and practice must be intertwined • For a professional discipline to mature and grow, both communities must contribute
• Transitioning from folklore to science	• One of the few academic areas that does not have an internal foundation • There is no common internal base, and we build on the foundations constructed in other disciplines	• Like medicine or chemistry, the management discipline needs to develop a common internal base, strong internal foundations, and well-recognized boundaries
• Management education has little management in it	• The heart of the manager's job receives very little attention • Organizational Behavior (OB) has become synonymous with the practice of management • A social-science-based curriculum	• Student should not be shortchanged • Behavioral contributions to the study of management should not have become the principles of management • A clinically relevant curriculum is needed
• Providing students with the wrong skills	• Overdevelops analytical skills—but not administrative or interpersonal • Academic management teaching is like teaching swimming without water • Student's diagnostic skills remain highly underdeveloped because data and problems were given to them—not found • Superficial top management skill orientation	• Students should be taught how to use these tools in practice in the first place • Design tool courses that are problems-oriented, not techniques-oriented • Problem-finding skills are far more important than problem-solving skills • A realistic profile is needed

Table 1.2: (*Continued*)

Variables and Features	Current Traditional Practices	Proposed Innovative Paradigms
• Faulty learning process	• The assumption that experience is the best teacher is highly questionable • Learning by modeling • Instruction is faculty-oriented as the student plays a very passive role in the learning process	• The value of these experience-centered educational techniques is highly limited • Learning by discovery (through both deduction and induction) • As the recipient of knowledge, the student must have a choice about what to learn, how, when, and where
• Faulty preparation of faculty	• Many management professors are teaching in a field for which they were not trained • Trained in management—not managing • Sink-or-swim teaching methods • No first-hand experience in management practice • Academics and practitioners are members of two different breeds	• Issues need to be candidly addressed and corrected
• Inadequate university reward systems	• Preoccupation with publishing esoteric and irrelevant research findings • Uselessness (out of touch) • Academic reward systems reward the wrong behavior—hopelessly irrelevant research to the training needs of the business community • Professors are hired as teachers, but evaluated as scholars or researchers • The cookie-cutter MBA theory of management is the prevailing norm • Outmoded faculty hiring practices	• The normal relationship between a professional school and its clients needs to be restored • Usefulness and relevance • By rewarding mediocrity, we discourage excellence • Dysfunctional and counterproductive • Consider adopting the medical model: two professional ladders—discipline-based versus clinical faculty

the proper training and skills they are going to need to function effectively as managers. Academic management programs clearly reflect the growing divergence between management education and management practice.

I suggested the following seven-item agenda for reforming management education:

1. Explore the strategic roles of The Association to Advance Collegiate Schools of Business (AACSB)
2. Become more output-centric (market-driven)
3. Shift to a more clinically relevant curriculum
4. Establish two professional faculty ladders
5. Teaching and research should focus on usefulness and relevance (instead of uselessness)
6. Consider offering a new doctorate degree in management education
7. Foster strong linkages, bonds, and alliances between academia and business and industry

Table 1.2 provides an important portrait and compelling evidence on the dysfunctional value of the MBA degree for technical professionals. These patterns are so lively when the current traditional practices in academic management education are contrasted with the proposed innovative paradigms. As discussed earlier, readers should not look at the diagnostic assessments provided in the table as opposing statements at the opposite ends of the continuum. Rather, they represent relative (not absolute) variations between the current and innovative paradigms presented.

As shown in Table 1.2, the typical MBA curriculum is too theoretical and academic to provide professionals with the proper training and skills they are going to need to function effectively as managers. There is also mounting evidence about the dissatisfaction of the corporate community with the quality of MBAs and the general performance of business schools. This negative sentiment was made clear in a recent executive survey.

Industry people repeatedly expressed concerns about academia teaching all the wrong things. They explained that academe is the industry's only supplier with quality so bad that 100 percent 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 interrelationship of those two things—managing technology.

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 (Ghoshal 2005). Since 1996, the number of corporate universities has grown from around 1,000 to over 1,800. Although these universities were 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 expressed concerns about another field of which MBA program architects should take serious notice (Ackoff 1987, 1994). 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 operations research and management science (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." 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" (Mintzberg 2005).

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 (Connolly 2003; Pfeffer 2005; Pfeffer and Fong 2003; Van de Ven and Johnson 2006). As noted earlier, MBA programs have generally taught the flawed 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 flawed and shallow concept of the professional manager, a pseudoprofessional who has no special expertise in any particular industry or technology but, nevertheless, can step in to a 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, and quarterly earnings, while 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 (Loyd et al. 2005; Maerki 2008; Tushman et al. 2007).

The preceding analysis clearly suggests that what is required of educational institutions in the twenty-first century is a different set of managerial concepts, competencies, and skills for the effective management of technology. These weaknesses and shortcomings of typical MBA programs can be addressed through specific areas or fields that can be covered in an MOT educational program. As outlined in the National Research Council reports, eight primary needs in technology management have been identified (National Research Council 1987, 1991).

1. How to integrate technology into the overall strategic objectives of the firm
2. How to get into and out of technologies faster and more efficiently
3. How to assess and evaluate technology more efficiently
4. How to accomplish technology transfers
5. How to reduce new product development time
6. How to manage large, complex, and interdisciplinary or inter-organizational projects and systems
7. How to manage the organization's internal use of technology
8. How to leverage the effectiveness of technical professionals

Few of these topical areas, however, are covered in current MBA curricula. Furthermore, a clinically based curriculum would be needed for a meaningful skill-development program in management or MOT. Many of the elements and foundations of this clinical training have already been identified in Table 1.2 under the column heading "Proposed Innovative Paradigms." The salient characteristics of this advanced education would include: initiating faculty positions as "Professor of the Practice," knowledge and skill development, learning by doing, meaningful internship as part of educational programs, practical applications, problem-finding skills (as opposed to problem-solving), learning how to ask the right questions, and so forth. In short, the core premise would be "You do it, you learn it."

ALTERNATIVE DELIVERY SYSTEMS FOR MANAGEMENT OF TECHNOLOGY (MOT) EDUCATION

In addition to the MBA degree program, other avenues for academic management educational delivery for technical professionals would include both the EM and MOT Master's degree programs. As a serious student of MOT, I find it exceedingly tempting here to delve into a detailed discussion of the varied, extensive maze, and blueprints of EM and MOT template programs offered around the world.

I've decided, however, not to take this road for several reasons. As an emerging discipline, there is no widely shared model or a blueprint for an MOT curriculum available yet. This means that, at the end of the day, the appropriate curriculum must depend on the judgment of the faculty, university administrators, and the corporate community. It follows that it is quite conceivable that the MOT curriculum will vary among colleges as a function of the program objectives, educational philosophy, market needs, distinctive competence of the school and its geographical location, and other community-based considerations.

I've written extensively over the years about these important issues elsewhere (Badawy 1992, 1995, 1996, 2008). To further enhance my contribution to the development of MOT, I provide, in the balance of this chapter, a road map reflecting a proposed analytical research-based architecture for technology and innovation management education that we can test and build on. Note that because of the evolving nature of the field of MOT, speculation is rather risky and should be avoided since there are no well-established models.

THE STRATEGIC POSITIONING OF MOT IN THE MANAGEMENT EDUCATION ARENA

A Conceptual Design of MOT as a Field of Study

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" (National Research Council). It appears that another disciplinary perspective is that MOT can be viewed and conceptualized as comprising three distinct activities:

1. *Management of the Development of Technology:* This is the product and service development process. It is especially important in today's environment, which features short product life cycles, multinational venturing, large-scale product management, multidisciplinary components, application of scientific principles over engineering know-how, and extensive use of design aids and tools.
2. *Managing the Technology Itself:* This involves the management of highly complex automated production processes and systems having a low labor content, such as a chemical plant or an automated factory.
3. *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.

As noted earlier, because of the evolving nature of the field of MOT, there are no established models. Tables 1.3 and 1.4 present useful information for the conceptualization of MOT and identification of its scope and boundaries. An MOT degree for professionals is an appropriate means for gaining an effective understanding of the management of technology. While nontechnical MBA managers may understand the technologies being employed by their firms, they don't have enough background to develop an intuition for which possible technologies now on the horizon are apt to become important and which are 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 (Hambrick 2005). As noted earlier, foreign managers would have this advantage because, in addition to their managerial backgrounds, they also have technical backgrounds as business engineers, which their U.S. counterparts generally lack.

Based on the preceding, 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 six basic components:
  - R&D management
  - product technology management
  - process technology management
  - service technology management
  - information technology management

Table 1.3: Conceptualization of MOT: A Proposed Model

Phases/Spectrum	Process	Output
Technology planning and development	Basic research Applied research Development Innovation/entrepreneurship	New Knowledge Invention Innovation Entrepreneurship
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

Table 1.4: Scope and Boundaries of MOT

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

  - innovation and entrepreneurship (Badawy and Badawy 1993)
- MOT is an interdisciplinary field of study with a dual orientation: It is cross-disciplinary and problem driven.
- 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.
- The MOT field has a largely diffused and fragmented research base. This is a natural phase in the development of an evolving discipline (Pilkington and Teichert 2006).

- Managing technology has a strong strategic orientation relating to the role of technology in corporate strategy.
- 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 (that is, 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, service technology management, process technology management, and information technology management.

My research studies provide further evidence lending strong support to this position and make an appealing case for a degree program in MOT (Badawy 1993, 2008). This can be articulated as follows.

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 a 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 by way of 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 engineering.

THE NEW GLOBAL CORPORATE REALITIES AND THEIR IMPLICATIONS FOR TECHNOLOGY AND INNOVATION MANAGEMENT EDUCATIONAL CURRICULA

The New Realities

During the last two decades, significant changes have taken place in corporate R&D and technology management practices. Global changes in information technology and social, cultural, demographic, economic, competitive, and worldwide political developments have had a massive impact on corporate management strategies, practices, functions, and managerial styles. Nowhere have these impacts been more profound than in the effective use of technical professionals as the corporate core intellectual capital.

This section identifies some of the new realities, forces, and mandates that are shaping the corporate R&D and technology management environment in the twenty-first century. On the other hand, the next section titled "A Paradigm Shift: Architecture and Disciplinary Foundations for Designing Technology and Innovation Management Educational Curricula" proposes action strategies for guiding corporate technology leaders in implementing practical mechanisms for leading the intellectual capital for technological innovation. It is precisely these strategies that must serve as guideposts for faculty, curriculum planners, corporate executives, and university administrators in their serious efforts for designing and implementing meaningful MOT educational curricula. In short, these action strategies will define the scope, boundaries, and parameters of MOT as a unique field of study and a discipline distinctively different from general management MBA curricula. The future direction of MOT as a discipline and a practice will largely depend on how it is viewed, developed, and structured using these powerful disciplinary lenses (Bamberger 2008).

Now, we visit the new realities. The last 20 years have witnessed shifts from traditional thinking and technology management practices to contemporary trends and organizational patterns reflecting the new realities of corporate internal and external environments. The following is a representative listing of some of these forces. Note that the differences between these shifts may vary among cases and variables and could be viewed more or less in absolute or relative terms. For presentation purposes, I have organized the new realities into a two-module framework.

Strategic Shifts in Managing Technology (Nine Forces)

1. From the competitive advantage fundamentally rooted in efficiency and cost savings in traditional resources (for example, labor, land, and capital), to a competitive advantage that is technology- and strategy-driven
2. From traditional labor-intensive strategies to technology-driven global competitive strategies, as technology has become the great equalizer among companies and countries
3. From a strong product, process, and manufacturing orientation to a predominantly service sector where information technology is the currency of the day
4. From R&D management as a stand-alone component to technology management as an encompassing total system
5. From closed to open innovation systems
6. From a Not Invented Here (NIH) attitude to corporate technological collaboration and alliances
7. From largely home-grown growth technology strategies to "growth from without" in the form of technological acquisition, joint ventures, and partnerships
8. From mega centers and R&D laboratories to technological entrepreneurship where organizational size does not matter
9. From large companies as the major source of technological innovation to smaller companies—where small is beautiful

Shifts in Corporate Structures, Leadership Styles, and Managerial Skills (Eight Forces)

1. From the traditional static view of management as a practice and a profession to a more contemporary model viewing management as a new form of social technology or an architecture of an organization encompassing an integrated system of interactions and interrelationships between the primary organizational resources: technological, informational, human, physical, and financial (Badawy 1996, 2008; Van Der Vegt et al. 2006)
2. From traditional bureaucratic and hierarchical structures to a more fluid, flexible, and adaptable organizational architecture where the corporate capacity for survival depends on its capacity to change, adapt, and avail itself of new opportunities
3. From product management to process management represented by the project, matrix, and hybrid forms of organization with the goal of maintaining flexibility to maximize profitability, market share, and competitiveness
4. From the economies of scale to the economies of scope (or variety) of the flexible production or service delivery system
5. From traditional corporate-centered approaches to time-based management focusing on the customer while coping with time-to-market pressures
6. From the traditional managerial authority, control, and power focused on the skill sets necessary for doing things right, to innovative leadership styles requiring vision, inspiration, competencies, and capabilities for doing the right thing
7. From the traditional belief that managers are necessary to the new recognition that leaders are essential
8. From a traditional managerial authority to a newer form of shared authority where there are many chiefs with collaborative authority shared among: Chief Knowledge Officer (CKO); Chief Information Officer (CIO); Chief Technology Officer (CTO); Chief Learning Officer (CLO); and Chief Ethics Officer (CEO)—with many gray areas and overlapping accountability boundaries

A Paradigm Shift: Architecture and Disciplinary Foundations for Designing Technology and Innovation Management Educational Curricula

The preceding 17 trends and forces have profound implications for corporate technology management leaders charged with the responsibility of designing and implementing practical mechanisms for leading technical professionals toward enhancing technological innovation. Clearly, the comparative analysis between traditional and newly emerging strategies provided in Table 1.5 actually represents some implications of the 17 forces discussed in the previous section. Therefore, these strategies, in fact, follow from those trends and forces. It should also be noted here that the transition from traditional strategies to newly emerging strategies represents a continuum. Successful companies do not necessarily go from A to B and, therefore, they may not lie at either end of this continuum.

Readers should also note that the classification in Table 1.5 is not intended as old versus new. Instead, the

Table 1.5: An Architecture and Foundation for Designing MOT Educational Curricula

Variables	Traditional Strategies and Practices	Newly Emerging Strategies and Practices
I. Strategic Drivers		
1. Concept	Invention—newness in concept	Innovation—newness in use or application
2. Dominant thrust	Discipline- or product-driven	Market- or customer-driven
3. Core driver	Technology push (depending on industry)	Demand pull (depending on industry)
4. Strategic orientation	"Want-driven"—solutions looking for problems to solve	"Need-driven"—problems looking for solutions
5. Purpose or goal	Creating knowledge	Commercialization of knowledge
6. Distinctive capabilities	Strong engineering orientation	Strong service orientation
7. Dominant player	R&D/technology	Marketing and strategic integration
8. Strong focus	On technological discoveries	On technological entrepreneurship for exploiting scientific findings
9. Future target	Next-generation science and technology	Creative destruction or disruptive innovation (or technological discontinuities)
10. Organizational architecture	Disciplined organizational designs with strong emphasis on efficiency and coordination	Fluid organizational designs with strong emphasis on management of technological innovation

Table 1.5: (*Continued*)

Variables	Traditional Strategies and Practices	Newly Emerging Strategies and Practices
II. Intellectual Capital and Technological Innovation		
1. Corporate target mission	Achieving efficiency	Achieving effectiveness
2. Management technologies and methods	Largely labor-oriented	Largely knowledge-oriented
3. Major form of capital	Physical resources	Knowledge
4. Primary focus	Traditional corporate functions	Knowledge management
5. Source of competitive advantage	R&D	Intellectual capital
6. Technical populations	Highly homogeneous	Highly diverse and heterogeneous
7. Technology operations	Coherent strategies for effective utilization	Outsourcing and offshoring
8. Corporate culture	Relatively strong	Multifaceted, fragmented with a weaker sense of employee loyalty
9. Tenure and organizational careers	Long tenure with stable careers	Much shorter, portable careers, with no binding ties
10. Major players	Individual technologies	Technology project team: cross-functional, cross-disciplinary, cross-national, and cross-cultural
11. Impact of IT and communications technology	Specific time and space-based R&D projects	Highly dispersed and virtual distance-based technology teams
12. Modes of R&D, knowledge exchange, and communication	Professional conferences and library-based projects	Internet, search engines, and Web-based databases
13. Changing job market	Position advertising and recruitment	Internet-based, and an electronic job marketplace
14. Creativity type	Pure intellectual creativity	Applied creativity
15. Mode of operation	Individuals create—lone wolf approach	Teams or groups innovate—enlightened trial and error
16. Heavy investment	In technological infrastructure and labor-intensive projects—individuals doing cutting-edge R&D	In applied R&D, people with different skill sets to play multiple roles
17. Philosophical themes	"If it ain't broke, don't fix it"	"If it ain't broke, break it"
18. Attitude toward failure	Mistakes are discouraged at all costs	Failure is the discipline through which we advance Fail often to succeed sooner.

table highlights the change in focus. A case in point, for example, is that there is now a stronger focus on knowledge commercialization and open innovation than before. In this sense, the table can be looked at as a continuum, with relative rather than absolute differences between the two columns provided.

It follows that the intent is to raise substantive questions that need to be addressed. Thus, Table 1.5 provides a useful typology for presenting and addressing complex phenomena.

Most important, it is precisely these practices that are at the heart of well-designed technology and innovation management educational programs. This is essentially what technical professionals go back to school for: to learn, practice, and develop their sound managerial skills and potential.

ISSUES, CHALLENGES, AND FUTURE DIRECTIONS: A 10-ITEM ACTION AGENDA

The term *technocologists* was coined to refer to technology management scholars (Badawy 1993). We have a major responsibility as technocologists, indeed an obligation, for the development and growth of our field. As such, I've identified a sample of issues and challenges that require the serious attention of MOT scholars and management educators. For clarity, most of these are posed in the form of questions to be addressed, as a proposed research agenda.

1. What would it take to translate the proposed paradigms presented earlier into meaningful action items for implementation?
2. How can we go about developing a unified body of knowledge for MOT education with a common language, shared vocabulary, a solid research base, and a profound meaningful disciplinary domain and intellectual conceptual boundaries?
3. How can we streamline our efforts for moving MOT to a mature disciplinary status as an intellectually applied professional field—just like the fields of medicine, law, and engineering? How can we go about establishing or building a meaningful MOT think tank, since MOT does not currently really have a stable home?
4. Considering that the MOT field will not develop, grow, flourish, and mature without a solid research base, what is the MOT scholars' responsibility for publishing and supporting the MOT specialty journals as scholarly and professional quality research outlets?
5. How can we go about fostering close linkages among MOT educators, scholars, and the professional MOT community for meaningful, relevant, and useful MOT research?
6. Without a clear understanding of the field's intellectual boundaries, it will be difficult for MOT to gain recognition. Note that disciplinary and program accreditation can not be achieved without a solid consensus on the field's substantive domain, research base, and intellectual boundaries. What lessons can we learn from well-established accreditation agencies such as the AACSB (Romero 2008)? It is critically important for us as technocologists and for our discipline to do it right the first time!
7. In addition to rewarding basic research efforts, how can university reward systems be transformed to also reward relevant, applied, and useful research done in applied professional disciplines?
8. How can management and business school faculty and university administrators go about making the paradigm shift for achieving a balance in emphasis between:
   i. Knowledge versus skills
   ii. Knowing versus doing
   iii. Dicipline-based versus clinically-based training
   iv. Research rigor versus relevance
9. How can we go about transforming management education from a solely product-focused teaching and research to a dual product and service focus? (Ford and Bowen 2008).
10. How can schools of management and business achieve cultural transformation by adopting two professional faculty ladders (with the same parity) for hiring and tenure consideration: discipline-based faculty and clinical faculty operating together as cross-functional and cross-disciplinary teams (for example, the medical model)?

I firmly believe that we are at a crossroads at this stage of the MOT field disciplinary development. Can we really afford to let our field continue to flounder, remain out of focus, and fragmented, or should we re-examine our souls, practice what we preach as teachers and scholars of innovation and reform, and streamline our efforts for establishing MOT as a meaningful serious academic discipline and a practice?

Clearly, I am opting for the latter choice—and I would invite all of you to join me in spearheading this effort. Wouldn't it be a wonderful thing if technocologists, business, and engineering schools got the notion that the best way to do well is by doing good?

GLOSSARY

Research Architecture: Defined as the "character or style of building; the action or process of building; construction; the result or product of architectural work; a fundamental underlying design of computer hardware, software, or both"—Random House Webster's College Dictionary (New York: Random House 2007). This term is used in this chapter to refer to a standalone piece targeted toward providing the building blocks based on what is available in the literature, and proposing an action agenda for future research.

Technical Professionals: Defined as scientists, engineers, computer systems analysts, information technology specialists, and other types of technical professionals working at different functional specialties in technology-based organizations. These functions include R&D; design engineering; manufacturing technology; quality assurance; technical services, artificial intelligence; expert systems; product, process, and information technology; total quality management, and other related technical functions.

Technocologists: A term coined by Michael K. Badawy (*Management as a New Technology,* New York: McGraw-Hill 1993) to refer to technology management scholars: academics, researchers, and students involved in doing research and scholarship for advancing knowledge through developing conceptual and theoretical contributions to the field of technology and innovation management.

Management of Technology (MOT): 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. MOT is an integrative interdisciplinary field of study characterized as having six basic components: R&D management; product technology management; process technology management; service technology management; information technology management; and innovation and entrepreneurship. MOT has a distinctive scope and is much broader than production and operations management, industrial engineering, engineering management, and entrepreneurship.

Technology-Based Organizations: Defined as those institutions that 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. These organizations typically employ a large number of technical professionals and 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 in the form of product, process, and service inventions and innovations.

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