Journal of ENGINEERING AND TECHNOLOGY MANAGEMENT JET-M

J. Eng. Technol. Manage. 17 (2000) 153–173

www.elsevier.com/locate/jengtecman

Technology management education in MBA programs: a comparative study of knowledge and skill requirements

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Abstract

This study attempts to explore the content and process of technology management education in the context of masters of business administration (MBA) programs in the US. Based on two mail surveys, the research identifies the knowledge and skills that are necessary for effective management of technology. Except for a few specific knowledge and skill areas, general agreement was found to exist between academicians and practitioners as to what knowledge and skills are important for effective management of technology. Knowledge of business strategy and competition, the strategic role of technology in business, new product development and the understanding of issues related to implementation of new technology were found to be important for management of technology. Moreover, effective oral and written communication and the ability to achieve implementation are considered essential skills for managing technology. Implications and future research directions are discussed. © 2000 Elsevier Science B.V. All rights reserved.

Keywords: Technology management education; MBA programs; Curriculum design

1. Introduction

Technology is a fundamental source of competitive advantage. Throughout history, successful technological adoption has not only driven the survival and success of firms, but has also influenced the economic fate of nations and individuals (Noori, 1990, p. 70). In this century, technological innovations in areas such as materials, electronics,

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PII: S0923-4748(00)00019-5

aerospace, computers, telecommunication and biotechnology have helped to establish the US as a dominant force in the world economy. Yet, concerns about ‘‘our effectiveness in generating and exploiting technology’’ have continued to persist (Steele, 1989, p. xvii). For example, The MIT Commission on Industrial Productivity cites ‘‘weak technology management practice’’ as a major cause for the decline of competitiveness of many key US industries (Dertouzos et al., 1990). There is a general realization that the ‘‘genius of the future lies not in technology alone, but in the ability to manage it’’ (slogan of Bell Atlantic) (Kocaoglu, 1990).

The focus of this investigation is on technology management, vis-à-vis engineering management. While there are common issues shared between the two fields, ‘‘the universe of activities firms need to manage to develop and implement technology is much broader in scope than the engineering function alone’’ (Steele, 1989). Badawy (1995), for example, observes that ‘‘Engineering management concerns the process of managing the engineering function itself. Often it is concerned with managing the corporate engineering function as well as its interfaces with other corporate functions. Management of technology is a much broader concept than engineering management’’. Management of technology links engineering, science, and management disciplines to plan, develop, and implement technological capabilities to shape and accomplish the strategic and operational objectives of an organization (NRC, 1987).

Engineering management, in contrast to technology management, is a much older subject. A survey of over 3000 universities worldwide identified 159 programs in engineering management and related subjects in 1994. The engineering schools offered a majority of these programs. While engineering management is an established discipline with a considerable history, management of technology has yet to be recognized as a discipline (NRC, 1987). Even though there is a history of vigorous research in areas relating to management of technology, there are far fewer programs in the area of technology management. The number of programs bearing the title, ‘‘management of technology’’ had reached 20 by 1994, and there were 22 other programs that were similar in nature. Of these 42 programs, only 16 were offered by business schools alone, 11 were offered jointly by engineering and business schools, and the remaining 15 were offered by engineering schools (Kocaoglu, 1994).

In business schools currently, far fewer students are being educated in the area of technology management than in other established business disciplines such as finance, marketing, and operations (Sheridan, 1993). In a business environment dominated by technology, executives with little or no technical background are often required to make decisions relating to their firm’s technology. A survey of 236 large US companies revealed that almost 50% of technology-related decisions are made by executives with only a general management background (Maglitta, 1994). These decisions have a significant impact on customers, employees and other stakeholders, as well as on the bottom-line in perhaps unintended ways. As a result, there has been a growing recognition by both the business community and business schools of the role of technology in the success of business organizations (NRC, 1987; Solow, 1988; Porter, 1996). Accordingly, business schools in the US are being encouraged to introduce technology management courses and programs into their curriculum (AACSB, 1997; Badawy, 1995, 1998; Kocaoglu, 1994; Burgunder, 1995).

However, one of the major challenges confronting both academicians and practitioners is the need to know what knowledge and skills managers must possess in order to successfully manage technology. Likewise, there is also a need to identify the appropriate pedagogy for teaching technology management (NRC, 1987; Schillinger and Wiener, 1993). This study explores such issues relating to the content and process of technology management education in the context of MBA programs in the US.

This paper is organized into six sections. Section 2 presents the research objectives and discusses the relevant literature. Section 3 goes on to describe the questionnaire based, mail survey methodology used to collect the data. The survey was administered in two phases: the first focused on the academicians, while the second phase targeted to practitioners. Section 4 of this paper presents the results of both surveys. Finally, Section 5 summarizes the contributions of this study and discusses their implications. The limitations of this study and directions for future research are also discussed in this section.

2. Research objectives and relevant literature

The following four issues related to the content and process of technology management education, in the context of MBA programs, are addressed in the present study.

- Essential *knowledge* and *skill* areas are identified from the perspectives of academicians as well as the practitioners.
- The relative importance of each knowledge and skill area is assessed.
- Areas needing urgent improvement are identified.
- Instructional methods being used for technology management education are reviewed.

A questionnaire-based mailed survey research methodology was used to collect the necessary data. Similar approaches to identifying educational needs have been adopted in other fields related to management education. For instance, Nelson (1991) made use of a survey to determine the knowledge and skills requirement of the end-user of information technology. Similarly, the Committee for a Review of the OR/MS Master's Degree Curriculum used a survey to evaluate the knowledge and skills required for success (Dyer et al., 1993). More recently, a survey was used to determine the importance of required and elective courses in operations management programs (Taj et al., 1996). A detailed discussion of the issues addressed in this paper is provided in the following section.

First, any attempt to develop a technology management curriculum must begin with an understanding of the knowledge (Pears, 1966) and skills (Whetten and Cameron, 1995) that executives must possess in order to manage technology. However, unlike established business disciplines such as marketing, finance and operations, there is no consensus on the content of a technology management curriculum. The task force on management of technology identified eight major technology management areas that are important for gaining competitive advantage. However, it refrained from defining the field, since it considered technology management to be still an emerging area (NRC, 1987). Yet, agreement on content is not only essential for the development of curriculum, but also for the development of the field in general. In order to develop a technology management course, professors need to know what knowledge and skills are important for managing technology. In this paper, as a part of the first objective, the essential knowledge and skills required for technology management are identified[1].

Second, identification of knowledge and skills and their relative importance are necessary, but not sufficient, for the development of an efficient and effective technology management curriculum. This is so because business schools are not the only venue where students can acquire them. For example, many students enroll in MBA programs with prior exposure to theory and practice of technology management (Maglitta, 1995). They also learn many of the required fundamentals from other courses. Moreover, any course on technology management must successfully compete for time and others scarce resources. Business schools are experiencing strong pressure not only to reduce costs, but also the duration of their MBA programs as well (Svetcov, 1995). Thus, curriculum development should focus on improving those knowledge and skills that students are least likely to bring with them or to acquire them from other courses in the MBA program. This will require an efficient prioritization of curriculum content, which is the second objective of our paper.

Third, the effectiveness of any professional program should be measured by its relevance to practice (Mintzberg, 1987). In a recent report, William Ziegler of Anderson Consulting, whose technology practice unit recruited 450 MBAs in 1995–1996, notes: ‘‘The value of an MBA program is directly related to its basis in reality’’ (Maglitta, 1995). In general, universities have concentrated for some time on the issue of tailoring their professional education programs, such as MBA program, more closely to the requirements of the industry for the next century (AACSB, 1990; Boyatzis et al., 1995; Barr and Harris, 1997). However, significant differences remain between academicians and practitioners on what business schools should teach (Badawy, 1995, p. 183). The criticisms leveled against MBA graduates in recent years (Business Week, 1988; Fuchberg, 1990; Porter and McKibbin, 1988) are matters of concern. Thus, a curriculum on technology management should be able to strike a creative balance between the perceptions of professors and those of practicing managers. This paper, accordingly, explores the degree of congruence between what professors think should be taught and what the practitioners think is necessary. This may reveal a few areas that require urgent attention from academia. This is the third research objective of the paper.

Finally, any attempt to introduce a technology management curriculum into the MBA program must address the issue of the process required to deliver the content in a

[1] A survey of university courses in the UK identified six major categories of technology management education (Weimer, 1991). Management of technology has also been viewed as consisting of four (Badawy, 1995) or five major categories (Herink, 1989). See Badawy (1995) for an overview of these categories. Although significant overlap exists among these proposed classification schemes, fundamental disagreement remains as to how the field of study should be defined. In fact, a preliminary examination of the technology management courses offered in a few leading MBA programs failed to identify significant similarities (Mallick and Chaudhury, 1996).

classroom. This is because efficiency and effectiveness of teaching knowledge and skill content of a course is influenced by the process. Two methods of instruction that are popular in business schools are case study and the traditional lecture approach. The lecture method is generally considered the most efficient way to teach a large quantity of knowledge content within a limited time-frame, but it is not the most effective teaching method when measured against a benchmark of what students learn (Garvin, 1991). Alternatively, the case study method is very effective in the development of skills, approaches and philosophy of management; however, they are not efficient transmitters of knowledge (Shapiro, 1984). Moreover, neither of these two approaches can effectively describe or provide experience with various management techniques. Problem sets and exercises, for example, are more effective in this respect. In addition, other instructional methods, such as video presentations, projects, company visits and guest speakers from industry, are often used by professors to infuse reality into the class room. Thus, in this paper, as the fourth and final objective, instructional methodologies for a technology management curriculum are reviewed.

3. Research design and measures

3.1. Target population and method

Professors have the primary responsibility for curriculum development in business schools. The manner in which they design and conduct their courses has a significant impact on what students learn in MBA programs (Singley and Anderson, 1989). Previous research has identified a strong positive correlation between a professor's intent and student outcome in business schools (Boyatzis, 1991). Such studies point to the fact that professors in business schools teach what they consider to be important for students to learn and that students learn what professors intend to teach. Yet, as noted in the previous section, the voice of practitioners should be present as a guide to any professional program because they are in a better position to identify the needs that are relevant to the challenges they encounter in their everyday practice.

Accordingly, the present survey was conducted in two phases. The first phase targeted professors who teach technology management or related courses in MBA programs. The second phase focused on business executives who are responsible for managing technology in the industry. Such an approach is likely to highlight various perspectives and the differences in value systems and cultures between academia and business (Badawy, 1995, p. 183). It is also expected to provide a deeper understanding of the common challenges that confront academia and business. Similar approaches to assessing educational needs in other disciplines have been reported (Boyatzis, 1982; Campbell et al., 1970; Luthans et al., 1988; Spencer and Spencer, 1993; Mentkowski et al., 1982).

3.2. Survey instruments:

Two separate survey instruments were developed for the two target populations. The survey instrument targeted to professors teaching technology management courses in the

MBA programs will be described first. It was then modified to make it suitable for business executives.

The survey instrument was developed in several steps. A preliminary survey of technology management courses offered as part of MBA programs in the US was conducted. Also, leading topics in technology management literature were identified. The initial draft of the survey instrument was reviewed by two groups of business professors. Five such professors who are engaged with the field of technology management were asked to review the instrument. Their feedback was used to validate the content of the survey instrument. The second group consisted of five business professors teaching courses other than technology management. Feedback from this group was used to improve the structure of the survey instrument. Thus, through an iterative process, a survey instrument consisting of 74 items, organized into four parts, was developed.

The first part of the survey instrument focused on the demographic information related to the university, the school and the program of the respondent. This section also solicited background information on the respondent. The second part of the instrument focused on identifying instructional methods used for teaching technology management courses. This part also explored the characteristics of the technology management courses taught by respondents. The third and fourth components of the survey instrument focused on the content of technology management courses. The third part listed 23 knowledge areas for which respondents were asked to assign a rating to indicate the importance of each area. In the absence of a validated objective measure, the respondents were asked to use a five-point scale (5 = Very important, 1 = Not at all important). The respondents were also asked to indicate the level of coverage given to each knowledge area in their courses using a five-point scale (5 = Extensive coverage, 1 = No coverage at all). The fourth section asked similar questions with respect to skill contents. Here, the respondents were asked to rate the importance of each listed skill for effective management of technology using a five-point scale (5 = Very important, 1 = Not at all important). The respondents were also asked to rate the extent to which students have an opportunity to develop the specified skill in the courses they teach (5 = Sufficient opportunity, 1 = None at all).

A second survey instrument consisting 82 items, also organized into four parts, was developed to capture the views of executives responsible for managing technology. The first part focused on the demographic information related to the organization of the respondent. This part also obtained background information on the respondent. The second section focused on the technology management experience of the respondent. This part explored the characteristics of the technology project managed by the respondent. The third and fourth sections focused on various technology management knowledge and skills similar to the professor survey. The items in the first and the second sections were different so as to reflect the differences in the target population. In contrast, the items in the third and fourth sections were the same in order to allow for comparison of various perspectives. This instrument was also pretested for clarity and organization by five executives responsible for managing technology in their respective organizations, and their feedback was incorporated in the final instrument.

In both the third and fourth parts, respondents were given an opportunity to indicate additional knowledge and skills that were not included in the questionnaire, but which they felt were important to technology management. Respondents were also asked a final open-ended question where they could say anything that they felt was important to technology management but was not adequately addressed in the survey. However, less than 2% of the respondents choose to indicate any additional knowledge and skills that were not covered in the questionnaire. This suggests that the lists of knowledge and skills presented in the questionnaire were relatively comprehensive.

3.3. Data collection procedure

In order to reach the target population, an archival search of the published 1994–1995 course catalogues of all AACSB accredited MBA programs in the US was conducted. Schools offering technology-management-related courses in their MBA programs were identified. A database of the professors teaching technology-management-related courses in MBA programs was developed. The database was supplemented with professors who are members of the Decision Sciences Institute (DSI) and who had indicated an interest in technology management in a DSI membership survey. Professors who were members of the IEEE Engineering Management — Management of Technology (EM-MOT) discussion group were also included in the database. Duplicate and incomplete entries were purged to create a mailing list of professors in business schools interested in technology management. The survey instrument was mailed to each of these 307 addresses in the database in the fall of 1995. Sixty completed questionnaires were returned and nine were returned as undeliverable, resulting in approximately 20% response rate.

In order to reach the target population for the second survey, questionnaires were sent to the Automation Forum, a division of the National Electrical Manufacturers Association. In the spring of 1996 these questionnaires, along with a letter of sponsorship, was sent by the Automation Forum to 300 executives having project management or a higher level of responsibility. A reminder letter was mailed 3 weeks following the original solicitation. Forty-seven completed questionnaires were returned, resulting in approximately 16% response rate.

4. Results and discussion

4.1. Preliminary findings

The respondent profiles for the professors survey and the executive survey are summarized in Tables 1–3 and in Tables 4–6, respectively.

Table 1
Profile of the universities, schools, and graduate programs of the professors survey sample (student enrollment numbers)

	Sample Size	Mean	Minimum	Maximum	Mode	Median
University size	45	18,444	2700	60,000	12,000	17,000
School size	45	1917	150	6000	1000	1700
Graduate program size	46	764	26	4000	400	600

Table 2
Educational background of the responding professors

Education	Number	% of Sample
PhD/DBA	41	89
Business/Management	6	15
POM	9	22
OR/MS	6	15
IS	4	10
MOT	3	7
Organizational behavior	3	7
Engineering	3	7
Economics	3	7
Other	4	10
MBA	19	41
MS or equivalent	29	63
Science	13	28
Engineering	20	44

Table 1 presents student enrollment in the universities, schools and graduate programs of the responding professors. A majority of the respondents (96%) are affiliated with graduate business schools offering MBA programs. Approximately 62% are affiliated with schools offering doctoral programs in business. About 22% reported that their school offered specialized graduate programs, such as Executive and Evening MBAs. Thus, the survey represents professors from a wide range of universities and schools offering MBA programs.

The education and experience of the professors teaching technology management in business schools are presented in Tables 2 and 3, respectively. Almost 90% of the professors of technology management courses have earned doctoral degrees, more than 80% of which are in business/management or related areas. Other areas of concentration at the doctoral level include public policy, physiology, sociology and chemistry. More than half the professors have had formal education in engineering at the undergraduate or graduate levels. Other areas mentioned as undergraduate majors included economics, physics, chemistry and mathematics. Almost 70% of the respondents have master's degrees either in engineering or in a business-related discipline such as management science or economics. About 40% of the professors have an MBA degree.

Table 3
Experience of the responding professors

Full time working experience (years)	Academic		Industrial	
	Number	%	Number	%
0–5	6	13	22	48
6–10	9	20	16	35
> 10	31	67	8	17
Average (years)	16.70		7.34	

Table 4
Profile of the firms and division of the executive survey sample

	Sample size	Mean	Minimum	Maximum	Mode	Median
Firm sales (in millions)	40	$9373	$18	$70,000	$500	$950
Firm size (no. of employees)	42	34,913	30	250,000	5000	4250
Division sales (in millions)	26	$1941	$10	$14,500	$1000	$280
Division size (no. of employees)	37	3623	8	25,000	500	500

Thus, most of the respondents have formal education in business or in technical fields. Also, most have considerable academic experience, and a few have industrial experience as well.

Table 4 presents the profiles of organizations whose executives responded to the survey. The annual sales and the number of employees indicate that the sample included both large and small-sized firms.

Table 5 presents the educational level of the responding executives. The majority of the respondents (95%) have earned at least a bachelor's degree. Electrical engineering (36%) and mechanical engineering (18%) were mentioned most often as majors. Other engineering majors reported were industrial engineering, computer science and ocean engineering. About 18% of the respondents have an undergraduate major in a discipline other than engineering, such as physics, chemistry, biology, operations research, mathematics and economics. Only a few (6%) have undergraduate nontechnical majors, such as history, political science and business. More than half of the respondents have a graduate degree in management, engineering or both. Clearly, the MBA is a popular graduate program among the respondents. More than 75% of the respondents have some formal education in technology management. Thus, the survey represents the views of executives with a wide range of educational backgrounds and who are familiar with both technical and managerial issues

Table 6 presents the experience profile of the respondents. All the respondents have experience in managing either product or process technology. Most of them have experience in managing product development projects (82%), process improvement projects (80%) or both (60%). Process improvement projects often involved the use of

Table 5
Educational background of the executives in the sample

Education	Number	% of Sample
PhD/DBA	3	7
MBA	17	39
MS Engineering	14	32
BS Engineering	34	77
Major/concentration in MOT	12	27
Five or more courses in MOT	9	20
Four or less courses in MOT	14	32
No courses in MOT	9	20

Table 6
Experience of the executives in the sample

Full time working experience (years)	Academic		Industrial	
	Number	%	Number	%
None	34	77	0	0
1-5	5	11	3	7
6-10	3	7	6	14
> 10	2	5	35	79
Average (years)	2		21	

information technology. Frequently (66%), the respondents work with technologies that are new to their organization. A majority of the respondents have 10 or more years of working experience in the industry. Titles of these individuals frequently included president, general manager, director of research and development, vice president of operations, senior vice president and project manager. Thus, the survey was able to reach the target population and their response represents senior level executive opinion on technology management.

4.2. Essential knowledge and skill areas: professors vs. practitioners

Table 7 presents findings relating to knowledge areas relevant for technology management. It provides responses from both the academic and the executive groups. Letters in column 1 indicate the original ordering of the items in the questionnaire. For each one of the knowledge areas listed in column 2, respondents were asked to rate its importance in managing technology. The importance ratings, summarized in column 3, were computed using the average of the importance ratings for all respondents. Similarly, the importance ratings from the executive survey are summarized in column 6.

The professors were asked to rate the level of coverage provided in their courses for each one of the knowledge areas listed in column 2. The coverage level ratings, summarized in column 4, were computed using the simple average of the coverage level ratings by individual respondents. The differences between the importance and the coverage levels ratings were calculated to obtain a measure of the deficiency for each knowledge areas, which is presented in column 5.

Similarly, the executives were asked to rate their proficiency in each one of the listed knowledge areas in column 2. The average proficiency ratings are presented in column 7. The differences between the importance and the proficiency ratings were computed to obtain a measure of the deficiency for each of the knowledge areas, which is presented in column 8.

Table 8 presents a similar analysis for the skills necessary for the effective management of technology. For each one of the skill areas listed in column 2, the respondents were asked to rate its importance. The importance ratings by the professors and the executives are summarized in columns 3 and 6, respectively.

Table 7
Knowledge content of MOT as perceived by the professors and executives

1	2	3	4	5	6	7	8
Item	Knowledge	Professors			Executives		
		Importance	Coverage	Deficiency *	Importance	Proficiency	Deficiency
a	General business functions	3.82	2.33	1.49	4.11	3.66	0.45 *
b	General engineering functions	2.55	1.82	0.73	3.86	3.80	0.04
c	Business strategy and competition	3.89	3.18	0.71	4.16	3.48	0.68 *
d	Strategic role of technology in business	4.36	3.87	0.49	4.25	3.80	0.45 *
e	Selection of technological projects	3.80	3.11	0.69	3.93	3.36	0.57 *
f	Timing of technological choice	3.73	2.98	0.75	3.98	3.50	0.48 *
g	Technology acquisition	3.73	3.11	0.62	3.66	3.27	0.39 *
h	Transfer of technology between organizations	3.80	3.29	0.51	3.52	3.43	0.09
i	Transfer of technology within organization	3.98	3.42	0.56	4.11	3.55	0.56 *
j	Process of technological innovation	3.73	2.87	0.86	3.60	3.21	0.40 *
k	Management of research	3.20	2.51	0.69	3.48	3.14	0.39 *
l	New product development	3.93	3.24	0.69	4.20	3.75	0.45 *
m	Internal use of information technology	3.04	2.33	0.71	3.19	2.93	0.26
n	Internal use of manufacturing technology	3.60	2.91	0.69	3.80	3.55	0.25
o	Implementation of new technology	4.31	3.73	0.58	4.14	3.73	0.41 *
p	Evaluation of technical projects	3.47	2.51	0.96	3.60	3.35	0.25
q	Financing technical projects	2.84	1.93	0.91	3.52	3.26	0.26
r	Legal aspects	2.78	1.69	1.09	3.35	2.51	0.84 *
s	Social issues	2.91	2.24	0.67	3.09	3.00	0.09
t	Ethical issues	2.89	2.11	0.78	3.14	3.05	0.09
u	Environmental issues	3.02	2.07	0.95	3.09	3.05	0.04
v	Influence of government policy	2.98	2.07	0.91	2.74	2.53	0.21
	Average	3.47	2.70	0.77	3.66	3.31	0.35

* Statistically significant with $p < 0.05$.

The professors were asked to indicate the level of opportunity their courses provide to students for developing the skills listed in column 2. The opportunity level ratings for each of the skills in column 2 are summarized in column 4. The measure of deficiency,

Table 8
Required skill for MOT as perceived by the professors and executives

1	2	3	4	5	6	7	8
Item	Skill set	Professors			Executives		
		Importance	Opportunity	Deficiency *	Importance	Proficiency	Deficiency
a	Ability to apply analytical techniques	4.09	3.40	0.69	4.18	3.89	0.29 *
b	Ability to apply theoretical knowledge	3.95	3.74	0.21	3.66	3.63	0.03
c	Effective oral communication skills	4.24	3.51	0.73	4.50	4.30	0.20 *
d	Effective written communication skills	4.40	3.71	0.69	4.43	4.20	0.23
e	Solving problems on a timely basis	4.07	2.98	1.09	4.57	4.20	0.37 *
f	Management of risk and uncertainty	3.78	2.79	0.99	4.30	3.91	0.39 *
g	Managing complex and ambiguous situation	4.24	3.34	0.90	4.32	3.93	0.39 *
h	Handling data gaps and conflicts	3.34	2.53	0.81	4.00	3.68	0.32 *
i	Working across functional boundaries	4.47	3.70	0.77	4.34	4.11	0.23 *
j	Gaining users' support	4.05	3.02	1.03	4.27	3.89	0.38 *
k	Facility in humans relations	4.04	2.91	1.13	3.89	3.71	0.18
l	Achieving implementation	4.33	3.09	1.24	4.59	4.14	0.45 *
m	Producing clearly actionable results	3.72	2.76	0.96	4.36	3.98	0.38 *
n	Identification of new technological opportunity	4.29	3.11	1.18	3.95	3.36	0.59 *
o	Integration of technology and business strategy	4.56	3.68	0.88	4.25	3.48	0.77 *
p	Perform technological assessment/evaluation	3.44	2.42	1.02	3.77	3.05	0.72 *
q	Ability to manage technical professionals	3.82	2.70	1.12	4.36	3.75	0.61 *
	Average	4.05	3.14	0.91	4.22	3.84	0.38

* Statistically significant with $p < 0.05$.

which is the difference between the importance and opportunity ratings, is presented in column 5.

Similarly, the executives were asked to indicate their level of proficiency in each one of the skills listed in column 2. These proficiency ratings are presented in column 7. The

Table 9
Instructional methods used for teaching MOT by the responding professors

	Number	% of Sample	Average proportion of time
Lecture	42	93	33
Case analysis	35	78	33
Class discussion	35	78	25
Presentation	31	67	16
Other	12	27	15

deficiency in each one of the listed skills, as measured by the difference between the importance and proficiency ratings, is presented in column 8.

Table 9 presents findings concerning the instructional methods used by the professors. The majority taught a semester-long, three-credit-hour, elective course on technology management in MBA programs. Class size ranged from 8 to 250 with 44 students being the average. The mode and median of class sizes are 30 and 35, respectively. While 91% of the respondents used cases, only 47% used textbooks. Moreover, 80% indicated that they used articles from both academic and popular presses as supplementary reading materials.

4.3. Relative importance of knowledge and skill areas: professors vs. practitioners

Table 8 provides perspectives of the professors and executives with regard to the importance, coverage (proficiency) and deficiency related to the knowledge content of technology management. Based on analysis of variance (ANOVA), the null hypothesis that professors and executives consider all listed knowledge areas as equally important was rejected ($p < 0.001$). Similarly, the null hypothesis that existing management of technology courses provide equal coverage to all listed knowledge areas and that executives are equally proficient in all listed knowledge areas was rejected ($p < 0.001$). Also, the null hypothesis that existing management of technology courses have similar deficiencies and that executives have similar deficiencies in all listed knowledge areas was rejected ($p < 0.001$). Therefore, the listed knowledge content in Table 8 is ranked in Table 10. The rankings based on professors ratings on importance, coverage, and deficiency are presented in columns 3, 4 and 5, respectively. The rankings based on executives ratings of usefulness, proficiency, and deficiency are presented in columns 6, 7, and 8 respectively.

The rankings from the professors survey (column 3) reveal that the top five knowledge areas are the strategic role of technology in business, the implementation of new technology, the transfer of technology within organization, new product development, and business strategy and competition. The least important knowledge areas included the general engineering function, legal aspects, financing technical projects, ethical issues and social issues. Column 4 indicates that the top five areas in which course coverage is given are the strategic role of technology in business, the implementation of new technology, the transfer of technology within organization, the transfer of technology between organization, and new product development. Legal issues, the

Table 10
Knowledge content of MOT: comparison of professors and executive perspectives

1	2	3	4	5	6	7	8
Item	Knowledge	Professors			Executives		
		Rank	Rank	Rank	Rank	Rank	Rank
d	Strategic role of technology in business	1	1	22	1	1	6
o	Implementation of new technology	2	2	19	4	4	9
i	Transfer of technology within organization	3	3	20	6	6	4
l	New product development	4	5	13	2	3	7
c	Business strategy and competition	5	6	11	3	9	2
a	General business functions	6	14	1	5	5	8
e	Selection of technological projects	7	7	14	8	11	3
h	Transfer of technology between organizations	8	4	21	14	10	18
f	Timing of technological choice	9	9	9	7	8	5
g	Technology acquisition	10	8	18	11	13	11
j	Process of technological innovation	11	11	7	12	15	10
n	Internal use of manufacturing technology	12	10	15	10	7	15
p	Evaluation of technical projects	13	12	3	13	12	16
k	Management of research	14	13	16	16	16	12
m	Internal use of information technology	15	15	12	18	20	14
u	Environmental issues	16	18	4	21	18	22
v	Influence of government policy	17	19	5	22	21	17
s	Social issues	18	16	17	20	19	20
t	Ethical issues	19	17	8	19	17	19
q*	Financing technical projects	20	20	6	15	14	13
r*	Legal aspects	21	22	2	17	22	1
b*	General engineering functions	22	21	10	9	2	21

* Statistically significant ($p < 0.05$) difference in importance.

general engineering function, financing technical projects, the influence of government policies, and environmental issues are the areas where coverage levels are the lowest.

Thus, the professors are providing more coverage to those areas that they consider to be important. This concurs with the findings of other studies on the MBA curriculum (Boyatzis, 1991). We find statistically significant deficiencies in all knowledge areas ($p < 0.05$). The top five areas in which the courses are most deficient (column 5) are the general business functions, legal aspects, the evaluation of technical projects, environmental issues, and the influence of government policies. The areas in which courses are least deficient are the strategic role of technology in business, the transfer of technology within organization, the transfer of technology between organization, the implementation of new technology, and technology acquisition.

According to the executive survey (column 6), the top five knowledge areas are the strategic role of business, new product development, business strategy and competition, the implementation of new technology, and the general business functions. The least important knowledge areas are the influence of government policies, the internal use of manufacturing technology, and environmental, social and ethical issues related to technology management. Column 7 indicates that the top five areas in which executives consider themselves as being the most proficient are the strategic role of technology in business, the general engineering functions, new product development, implementation of new technology, and general business functions. Legal issues, the internal use of manufacturing technology, and environmental, social and ethical issues are the areas where respondents are least proficient.

Thus, the respondents are more proficient in areas that they consider important for the management of technology. However, it is not clear from this study if they have developed such proficiency in these areas through their schooling and/or their experience. We find statistically significant deficiencies exist in the legal aspects of managing technology, business strategy and competition, the selection of technological projects, the transfer of technology within organization, the timing of technological choice, the strategic role of technology in business, new product development, the implementation of new technology, the process of technological innovation, technology acquisition, and management of research ($p < 0.05$).

A comparison of the importance ratings (using *t*-test) by the professors and the executives (columns 3 and 6 in Table 7) identified only three statistically significant differences, which were in the following knowledge areas: the general engineering function, the financing of new technology, and the legal aspects of managing technology ($p < 0.05$). The executives consistently rated these areas as more important than the professors. The top four important areas identified by both the professors and the executives are the strategic role of technology in business, the implementation of new technology, new product development, and business strategy and competition. The transfer of technology within the organization was rated as one of the top five knowledge areas by the professors, but it was rated sixth by the executives. Knowledge of general business functions was rated as one of the top five by the executives, but it was rated sixth by the professors. The two knowledge areas identified as being least important by both the groups are social and ethical issues. This is surprising as the legal, social and ethical concerns related to new technology, such as information and biotechnology, are reported frequently in the literature (Spero, 1990; Magretta, 1997).

4.4. Areas needing significant improvement

Thus, even though there is general concurrence between the professors and the executives concerning the knowledge content of technology management, there are specific areas of disagreement that need to be addressed. A comparison of the coverage rankings (column 4 in Table 7) demonstrates that coverage of the existing courses are in general agreement with what is considered important (column 3) by the professors, as well as what is deemed to be important (column 5) by the executives. However, there are some knowledge areas where there are some disagreements. For example, the transfer of technology between organizations is receiving more coverage, even though it is not considered to be one of the top five knowledge categories by both the professors and the executives. In fact, this is one of the areas in which executives believe that they are least deficient. Perhaps the topic related to technology acquisition is also being given more coverage in the existing courses. Also, the legal aspects of managing technology is receiving the least amount of coverage in the existing courses, while this is the area where executives are considered to be most deficient. However, this is thought to be one of the least important topics by both the professors and the executives.

Table 8 provides the perspectives of the professors and executives on the importance, opportunity (proficiency) and deficiency related to the skill content of technology management. Based on ANOVA, the null hypothesis that professors and executives consider all skills as equally important is rejected ($p < 0.001$). Similarly, the null hypotheses that existing MOT courses are providing the opportunity to develop all listed skills equally and that executives are proficient in all the listed skills equally is rejected ($p < 0.001$). The hypotheses that existing MOT courses have similar deficiency in all listed skill areas and executives have similar deficiency in all listed areas are also rejected ($p < 0.001$). Therefore, the listed skill content in Table 8 is ranked in Table 11. The rankings based on professors ratings of importance, opportunity, and deficiency are presented in columns 3, 4, and 5 respectively. The rankings based on executives ratings on importance, proficiency and deficiency are presented in columns 6, 7, and 8 respectively.

From the rankings of the professors survey, column 3 reveals that the five most important skills for management of technology are the integration of technology strategy with business strategy, working across functional boundaries, effective written communication skills, achieving implementation, and the identification of new technological opportunities. The least important skills are handling data gaps and conflicts, performing technological assessment and evaluation, producing clearly actionable results, the man-

Table 11
Required skills for MOT: a comparison of professors and executive perspectives

1	2	3	4	5	6	7	8
	Skill Set	Professors			Executives		
		Rank	Rank	Rank	Rank	Rank	Rank
o	Integration of technology with business strategy	1	4	11	11	15	1
i	Working across functional boundaries	2	3	13	7	5	13
d	Effective written communication skills	3	2	15	4	3	14
l	Achieving implementation	4	9	1	1	4	5
n	Identification of new technological opportunity	5	8	2	14	16	4
c	Effective oral communication skills	6	5	14	3	1	15
g	Managing complex and ambiguous situation	7	7	10	8	7	6
a	Ability to apply analytical techniques	8	6	16	12	10	12
e*	Solving problems on a timely basis	9	11	5	2	2	10
j	Gaining users' support	10	10	6	10	9	9
k	Facility in human relations	11	12	3	15	12	16
b	Ability to apply theoretical knowledge	12	1	17	17	14	17
q*	Ability to manage technical professionals	13	15	4	6	11	3
f*	Management of risk and uncertainty	14	13	8	9	8	7
m*	Producing clearly actionable results	15	14	9	5	6	8
p	Perform technological assessment/evaluation	16	17	7	16	17	2
h*	Handling data gaps and conflicts	17	16	12	13	13	11

* Statistically significant ($p < 0.05$) difference in importance.

agement of risks and uncertainty, and the ability to manage technical professionals. Column 4 indicates that the top five areas in which respondents consider that their courses provide opportunity to develop are the ability to apply theoretical knowledge, effective written communication skills, working across functional boundaries, the integration of technology with business strategy, and effective oral communication skills. Skill areas that had least opportunity for learning are performing technological assessment/evaluation, handling data gaps and conflicts, the ability to manage technical professionals, producing clearly actionable results, and managing risks and uncertainty.

It is noteworthy that while the professors do not consider the ability to apply theoretical knowledge as being very important, the courses they teach provided the greatest opportunity to acquire theoretical knowledge. Other than that, the professors tend to provide opportunities to learn those skills that they deem as being important. Statistically significant deficiencies were found in all listed skill areas ($p < 0.05$). The skill areas that are the most deficient (column 5) are achieving implementation, the identification of new technological opportunities, facility in human relations, the ability to manage technical professionals, and solving problems on a timely basis. The skill areas where course coverage was the least deficient are the ability to apply theoretical knowledge, the ability to apply analytical skills, and effective oral communication.

According to the executive survey (column 6), the top five skills identified are achieving implementation, solving problems on a timely basis, effective oral and written communications, and producing clearly actionable results. The least important skills are the ability to apply theoretical knowledge, the ability to perform technology assessment/evaluation, facility in human relations, the identification of technological opportunity, and the ability to handle data gaps and conflicts. The top five areas in which the executives consider themselves as being most proficient (column 7) are effective oral communication skills, solving problems on a timely basis, effective written communication skills, achieving implementation, and working across functional boundaries. Areas where the respondents feel that they are least proficient are performing technological assessment/evaluation, the identification of new technological opportunities, the integration of technology with business strategy, the ability to apply theoretical knowledge, and handling data gaps and conflicts.

Thus, the respondents are more proficient in those areas they deem as being important. However, it is not clear if they have developed such proficiency in these areas through schooling and/or experience. Statistically significant deficiency exists in all but three areas ($p < 0.05$). The skills that are most deficient are the integration of technology with business strategy, perform technological assessment/evaluation, the ability to manage technical professionals, the identification of new technological opportunity, and achieving implementation. The skills where executives are the least deficient are ability to apply theoretical knowledge, facility in human relations, effective written and oral communications, and working across functional boundaries. Thus, the results reveal which skills are important, in which areas respondents are most proficient, and which areas needs more attention.

A comparison of the importance ratings (using *t*-test) by the professors and the executives (columns 3 and 5 in Table 8) identified only five statistically significant differences, which were in the following five skills: solving problems on a timely basis, management of risks and uncertainty, handling data gaps and conflicts, producing clearly actionable results, and the ability to manage technical professionals ($p < 0.05$). The executives consistently rated these five areas as more important than the professors. The two top important skills rated by both the professors and the executives are achieving implementation and effective written communication. The skills that are identified as the least important by both groups are handling data gaps and conflicts, and the ability to perform technology assessment/evaluation. Thus, even though there is some agreement on what skills are important for managing technology, the disagreement between the professors and the executives are wider in the area of skills than in the area of knowledge.

Tables 10 and 11 identify which knowledge and skill areas are important to technology management. They also provide a measure of importance for each of the knowledge and skill areas. This information will be useful to professors interested in developing new courses on technology management, as they attempt to define what should be taught in technology management. The measure of differences will be useful to those interested in improving their existing courses on technology management.

4.5. Instructional methods

Finally, the process through which professors deliver the content of technology management courses they teach was examined. Table 9 presents the findings for the instructional methods used by professors. The majority taught a semester long, three-credit-hour, elective course on technology management in MBA programs. Although, the lecture method was reported as being instructional method by 93% of the respondents, the average amount of class time devoted to lecture is only 33%. Case analysis is used by 78% of the responding professors, but the average time devoted to case analysis is also 33%. This is so because there were more respondents using only cases than those using solely lectures as the instructional method.

A large number of respondents also indicated the use of a discussion format and presentations by students, as well as guest speakers. Other instructional methods mentioned include projects, plant visits and videos. Instead of using any single instructional method, most respondents adopted a combination of instructional methods. While 91% of the respondents used cases, only 47% used textbooks, which suggests that many professors are not satisfied with the available textbooks on this subject. Moreover, 80% indicated that they used articles from both academic and popular press as supplementary reading. This underscores the need for textbooks supplemented by readings.

5. Implications and directions for future research

Government, industry and universities in the US are committed to preparing executives for meeting the challenges of the future. Attempts are being made to introduce technology management programs and courses into business school curriculum (Badawy, 1995; Burgunder, 1995; Kocaoglu, 1994; NRC, 1987). This research attempted to contribute to such efforts by investigating the perspectives of both academicians and practitioners alike. Using a two-phase mail survey methodology, the content and process of technology management education in the context of MBA programs offered by the graduate schools of business in the US was explored.

Except for a few specific knowledge and skill areas, there is general agreement between professors and executives as to what knowledge and skills are important for the effective management of technology. This is a crucial finding because the effectiveness of any professional program should be judged by its relevance to practice, and in recent times, MBA programs have been criticized for their lack of relevance.

The study also revealed that all knowledge and skills are not perceived as being equally important for effective management of technology. This investigation provided a measure for determining which knowledge and skills are more important than others. Thus, the findings will be useful for assigning priority to the content of technology management education under the existing condition of constrained resources in MBA programs.

The results also identified the knowledge and skills which are not adequately addressed by the existing technology management curriculum as well as the knowledge and skills where executives are most deficient. Thus, the findings will be helpful in improving the effectiveness of the technology management education in MBA programs by focusing improvement efforts in areas where they are most needed.

The results of the study also revealed that lecture and case analysis are the dominant methods of instruction used by the faculty teaching technology management which is similar to the instructional methods used by the other disciplines in the MBA programs. Therefore, the introduction of management of technology in MBA programs is not expected to place any extra pedagogical demand on the interested faculty and the school in general.

These findings will serve as a benchmark for developing new technology management curricula and for improving existing technology management courses and programs. However, the results should be placed in the proper perspective as the study has a number of limitations. First, while this study helped to identify importance, coverage (proficiency) and deficiency in knowledge and skill content of technology management education, it is not essential that all deficiencies in knowledge and skill content be addressed within a technology management course. These findings engender a set of important research questions: (1) which deficiencies should be addressed within an MOT course, (2) which deficiencies should be addressed elsewhere, but within an MBA program, and (3) which deficiencies should be addressed through training at the workplace? Further research will be necessary to respond to these questions in order to develop an effective and efficient MOT curriculum.

Next, management of technology is a rapidly growing field, and it would be instructive to examine if there are differences of opinion based on the education and experience of the professors and executives. It would also be useful to investigate if there are differences based on organizational size. For the present study, as a result of the small sample size, further analysis would have required partitioning the data into even smaller sets. Thus, further investigation will be necessary to address these important issues.

Finally, the low response rates of both surveys leads to issue of the generalizability and reliability of the findings. The existence of very few MOT programs in the business schools identified in recent studies (Kocaoglu, 1990, 1994) provide a partial explanation of the low response for the professors survey. About 62% of the sample in this survey represent faculty from business schools with doctoral programs. However, only 93 schools out of 324 offering AACSB accredited MBA programs offer doctoral programs in business (AACSB, 1998). Thus, the results presented in this study are dominated by the views of the faculty from these schools. Similarly, 55% of the sample in the executive survey were from the electrical, electronics and computer-related industries because the executive survey was distributed to the members of the Automation Forum, a division of the National Electrical Manufacturers' Association.

Management of technology will continue to be a challenging task. This exploratory study attempted to address a few important issues related to the content and process of technology management education in MBA programs. It is anticipated that scholars interested in technology management education and practice will find the results of this study to be important and suggestive of relevant future research directions.

Acknowledgements

We gratefully acknowledge the helpful and incisive comments of the anonymous reviewers, and the editor-in-chief, Professor Michael K. Badawy, on an earlier version of the paper.

We also acknowledge the support of the Automation Forum, a division of the National Electrical Manufacturers Association, for sponsoring a part of the study.

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