Technology Management: Adapting to A Rapidly Changing World

James N. McKirahan, Jr.
Indiana State University
James.McKirahan@indstate.edu

Austin Cheney
Eastern Illinois University
acheney@eiu.edu

Abstract

Technology management, or the strategic management of technology to provide an economic, political, and technological edge over peers or competitors, has been a concern of the United States since at least the end of World War II. Now, several emerging megatrends are recognized, including the increased urbanization of the world's population, interconnectedness among economies and economic power shifts, and climate change, impacting the need for more efficient and effective technology diffusion and technology transfer. Several key areas ranging from mobile internet and pervasive social media to advanced robotics, artificial intelligence, next-generation genomics, and biotechnology, are influencing the occurrence of these trends. As a result, the capabilities of individual humans, and humanity in general, are changing rapidly and profoundly.

Technology diffusion has seldom aligned with the speed at which innovation occurs. With the exponential rate at which technological change is happening now, the issue of technology diffusion and transfer is exacerbated. Currently in the United States, there are at least four dozen undergraduate or graduate academic programs with the moniker of Management of Technology or Technology Management. But do the current perspective of what is meant by technology management and the identified competencies in technology management academic programs align with the megatrends and the need for technology diffusion and technology transfer vital to the US and other countries?

The objectives of this paper are several fold. First, for background purposes, technology management, technology diffusion, and technology transfer are defined. Second, the recently emerging broad technological trends are described, and the current perspective and competencies aligned to academic programs in technology management in the United States are identified. Third, we describe approaches to technology management programs in Europe and Asia. Finally, insights are shared regarding whether academic technology management programs align to emerging world trends, and direction for further study is identified. This paper will be of interest to the academy, nations, societies, industry, and businesses throughout the world.

Introduction

The concept of technology management (TM) has been around at least since World War II. Its significance has been linked to the economic, social, and political well-being and livelihood of not only individuals, but of nations too. Emphasis on TM increased after World War II, and with the escalation of tensions during the Cold War [1]. The United States viewed the management of technology not only as a political, economic, and industrial imperative for the U.S., but for its allies including Japan, Canada, and Great Britain, in response to the military build-up of the USSR. It was difficult afterward not to note how the increasing use of technology impacted social institutions, the organization of work, the development of human-built environments, and world-wide economics [2]. Notable contributors to the development of TM as a concept, and then the academic discipline and industrial pursuits of it, include Frederick Winslow Taylor, Henri Fayol, Walther Ratheneau, Henry Ford, and James Burnham, as well as others.

Academic TM programs worldwide now have acknowledged that effective management of technology impacts nations' research and development capabilities, technology transfer, development of technological skills, capabilities, and knowledge. Within this paper, technology, technology management, and concepts critical to technology management are discussed. A discussion of the critical importance of technology management because of the exponentially increasing rate of technological change and aforementioned megatrends follows. The direction and aspects of TM programs in the US, Asia, and Europe are investigated to help determine how effectively they address these emerging trends.

Technology

Noori [3] suggests technology contains three major components. The *hardware* component of technology includes the physical or logical plant (machines, equipment, and their contrivance together) for carrying out tasks to achieve goals and objectives. It includes *software* or sets of rules, guidelines, and algorithms for using the hardware to achieve goals and objectives. Further, technology includes *brainware*. The brainware component implies a purpose to the objectives, goals, and application of the hardware, and the software of technology including the know-how and knowing-why portion of technology use. Orlikowski [4] states technology is defined according to *scope* and by the *role* of its usage. In using *scope* to define technology according to the aspects comprising technology, the word *role* implies the interactions resulting from technology usage. Technology educator R. Thomas Wright [5] described technology as being products, processes or organizations to define technology in the following manner:

"Technology is humans using objects (tools, machines, systems, and materials) to change the natural and human-made (built) environment. Technology is conscious, purposeful actions by people designed to extend human ability or potential to do work. Technology increases human capabilities, is dynamic and constantly changing (evolving). It is not always good and it is different from science; it's applied science."

Regarding the impact of technology on the future, The World Economic Forum [6] recently stated, *"Technology is understood as a broad concept covering not only products such as machinery, equipment, and material, but also processes and organization methods, all linked by the common factor of enhancing efficiency in production. In addition, technology adoption contributes to a conducive innovation ecosystem."*

In noting how technology is changing the world of work, Levin [7] cites three trends impacting work. The ability to carry around sophisticated computational devices known as cellphones to communicate virtually immediately anywhere in the world with virtually anyone using the technology is one impact. Increased connectivity to the world-wide web is another trend. A third trend is the increasing development of cloud-delivered enterprise applications accessible over the web, and not requiring virtual private network (VPN) access to use it. These three trends are influencing the emergence of work into *knowledge-work.* This transition to knowledge-work promotes a worldwide, mobile-knowledge workforce. Levin notes that the *change management* of technology, or simply technology management, is vital to humanity's future. With this consideration, the authors of this article suggest using a more contemporary definition for technology relative to technology management and its impactful-ness on humanity:

"Technology is the amalgamation of infinite ideas manifesting into the physical objects and structures, including organizations, policies, laws, norms, and the devices, humans use to maintain their existence or to further their wants, needs, or desires. It includes any human-made single purposes tools, multiple purpose devices, or complex systems and accompanying techniques for lessening human toil. Technology magnifies human abilities to exceed physical, biological, or cognitive limitations. It causes stratification in humanity through the specialization of tasks and processes, while lessening or creating disparity where none before existed."

Technology Management

Technology Management (TM) or Management of Technology (MoT) links engineering, science and management disciplines to plan, develop, and implement technological capabilities to shape and accomplish the strategic and operational goals of the organization [8]. Thamhain [9] stated that Management of Technology is the art and science of creating value by using technology with other resources of the organization.

Gaynor [10] viewed technology management as linking the disciples of engineering, science, and management to plan, develop and implement technological capabilities for shaping and accomplishing an organization's strategic and operational objectives. The International Technology and Engineering Educators Association (ITEEA) defines a technology manager as one possessing a minimum level of technical knowledge, with skills in one or more contextual areas and applied abilities in system design, application, products, or processes [11]. Thamhain [12] also defined management of technology as being both an art and a science for creating value using technology together with other resources in an organization.

Literature review suggests several concepts important to effective TM. These concepts include but are not limited to technology diffusion, technology transfer, absorptive capacity, desorptive capacity, and the social spheres of influence upon technology use.

Concepts of Technology Management

Technology artifact

Borgo et al. [13] suggest technology is more than being simply tools, technique, actions, and systems. They provide the terminology *technical artifact* to describe technology as the intentional acts, agents, and attributions of human activity, using tools and developing them into processes, and suggesting a philosophical nature to technology use. It is a term applicable to virtually any human endeavor and to the resulting effects of technology use.

Technology diffusion

Aspects and characteristics of diffusion of innovation provide for the concept known as *technology diffusion*. As diffusion of innovation is key to *technology transfer*, Rogers [14] states an innovation is an idea, practice or an object that is new to an individual or a unit of adoption, and its transfer is dependent on being *communicated, over time, through certain channels, and among members of a social system*. This techno-socio connection is important to the context in which a technology is ultimately used. Relative to communication channels, over time, through certain channels and social systems, cost is a primary motivator regarding innovation and technology diffusion [15]. Underdeveloped countries are at a disadvantage regarding the adoption of outside advanced technologies. A certain threshold of technological development must be met in order to be able to accept outside technologies. A term that has been associated with this concept is *technology acceptance.* The wider the gap between a country's existing level of technical development and the technology available to be introduced from a more developed nation, the longer and more difficult technology adoption becomes. Diffusion of technology through technology transfer accounts for a large portion of income disparity across countries [16]. Several metrics have been pointed out as being useful for accessing the technological capabilities of nations useful toward technology management [17].

Technology excellence

Technology excellence is key to technology management. Technology excellence involves three phases: 1) *shaping,* which is the acquiring, developing, and enriching of technological knowledge resources, 2) *melding,* involves the blending of knowledge resources to create new processes, capabilities, expertise, and skills, and 3) *leveraging,* is the application of technological knowledge resources to exploit new opportunities and to reveal new knowledge resources to cycle back to the shaping phase. Japan was extremely successful utilizing these phases rebuilding after World War II [18].

Technology transfer

Technology transfer describes the process or actions through which tools, technological capability, technological know-how, and experience, move from outside sources to a single entity or multiple organizations. The first association of the term "technology transfer" is to economic development due to technological advancements. Noting Soundarajan, economic growth due to technological advancement based upon the transfer of technology from developed countries to lesser developed countries of the world provided basis for terminology as first world (developed), 2nd world (developing), and 3rd world (underdeveloped) countries in the world [19]. Technology transfer associated to innovation and economic principles often occurs directionally from developed countries to lesser developed countries. Technology policy and decision-making are guiding factors as to the extent at which technology transfer takes place [20]. Technology transfer is often multifaceted. It involves opportunity, desire or need, search for appropriateness, comparison, selection, acquisition, implementation, and term of use. The extent of technology transfer may be tacit, implied, non-specific, or specific. Technology transfer can occur as a single instantaneous event or as a multiple stage process of events. Critical points to understanding technology transfer are suggested as follows:

1) *Technology transfer is non-linear and it may have varied associations.* Aspects of technology transfer transactions do not always occur on a one-to-one basis. Often the aspects of the transfer occurs on a one-to-many or a many-to-one basis.
2) *Integration is key to technology transfer.* As technology itself is a multi-dimensional commodity the components of a technology transfer often occurs through a variety of sources or suppliers in order for a technology to become an end-use, turnkey, complex system.
3) *Technology transfer is dynamic.* As technology does not remain static over a period of time, the aspects of technology transfer also changes and evolves over time.
4) *Technology transfer implies technology diffusion.*
5) *Technology transfer requires industrial and community technology opinion leaders to leverage successful transfer.*
6) *Emerging technological developments, patterns and trajectories define for organizations which technology transfers to purse to remain competitive.*
7) *Awareness gaps exist* communicating available technology for transfer from country to country, region to region, or locality to locality.
8) *Technology transfer can minimize disparity and cause disparity.*
9) *User-producer interactions are often underestimated* during the process of innovation during technology transfer.
10) *Possession of a technological resource does not necessarily imply use or effective transfer and use of a technological resource.*
11) *Policy measures must be flexible* amongst potential technology users to address a wide variety of needs.
12) There is often a *strong cultural dynamic embedded within technologies*. Understanding the cultural dynamic is critical to *technological adoption* for successful technology transfer to occur. The impacts of technology transfer need be considered prior to the action to technology transfer occurring.

13) *Managerial capability is essential to technology transfer* between industry and countries accepting technology transfer [21].

In recent years, the complexity of the transfer process has been examined by a growing number of researchers whose findings are beginning to impact technology policy decision-making. Metrics similar to *Technology Achievement Index* are used as a verification of technological development due to and through technology transfer [22].

Absorptive capacity and desorptive capacity

Two measures important to technology transfer are absorptive capacity and desorptive capacity. The ability to acquire and utilize external knowledge by an organization is known as absorptive capacity. The ability of an organization to transfer technology outward from it to other entities is known as desorptive capacity [23].

Technology roadmapping

Technology roadmapping, a concept originating with Motorola in the 1970's, is a robust technology management tool. The goal of developing the tool was to align product development with investment to address future market needs [24]. Business and industry use technology roadmapping to effectively manage technology and innovation to maintain and gain competitive advantage [25]. Technology roadmapping is also utilized at an industry level through collectives of interested stakeholders in a given industry. These stakeholders span small and large, public and private organizations, including industry consultants and government officials. Industry roadmaps are developed to stimulate industrial collaborations and focus and accelerate the technology advancement in an industrial sector [26].

Evidence of Rapid Technology Change Regarding the Need for Technology Management

As suggested by technology contemporaries including James Burke, Kevin Kelly, Ray Kurzweil, and through application of Moore's Law, the management of technology is essential now due to the exponential rate of change occurring in the world today as a result of technology use [27-29, 30]. Technology is transitioning work from what were once primarily labor-intensive activities to primarily knowledge-intensive activities [31]. In the manufacturing sector alone it is reported that knowledge workers, or workers relying primarily on data and information to accomplished their work, currently represent about 40% of the manufacturing workforce [32]. Research suggests 47% of existing American jobs are at risk of elimination due to computerization and automation. It was found that computerization is especially likely to impact fields including transportation and logistics, production labor, and administrative support occupations. The losses will likely occur in stages. Services, sales and construction positions will likely be the first to be impacted. The rate of dislocation of management, science and engineering jobs is likely less pronounced since activities in these career fields are more difficult to automate, but this is dependent upon the rate at which artificial intelligence will develop [33]. Understanding the historical connections between innovation, urbanization, and transportation is important for technology management. These connections play a part in technology development, innovation, patenting, and diffusion of technology [34].

Workers with creativity and social skills in services, sales and construction areas will be less susceptible to computerization and automation displacement [35]. By 2020 it has been suggested that there will be an additional 5.9 million Americans without high school degreesand up to 1.5 million fewer college graduates to meet America's employment demands [36]. Forty percent of the executives whose companies intended to hire new workers in coming years have noted skills gaps in work applicants leading to positions being open for up to six months or longer. Healthcare, business services, leisure and hospitality, construction, manufacturing, and retailing will account for as much as 85 percent of all new future jobs. Twelve, emerging disruptive technologies have been identified as influencing life, business, and the global economy [37]. These emerging disruptive technologies include:

1) Mobile internet
2) Automation of knowledge work
3) Development of The Internet of Things (IoT)
4) Cloud technology
5) Advanced robotics
6) Autonomous and near-autonomous vehicles
7) Next-generation genomics
8) Energy storage
9) 3D printing
10) Advanced materials
11) Advances in oil and gas exploration and recovery
12) Advances in renewable energy

Berger and Frey [38] investigated work employment opportunities in new industries first appearing only between 2000 and 2010. They concluded that skilled workers are more readily capable of accepting technological change than workers lacking technical skills. Furthermore, they noted that the need for skilled work within existing, prior to year 2000 industries, has decreased. Workers in new industries were found to be young and better educated "due to skill-based technological change" than previous era workers. They found that individuals with STEM degrees were more likely to select new industries for work while professional degreed individuals were less likely to work in new industries. The new industries are more likely to occur in cities given a historical advantage through hosting land-grant colleges, with a better educated population and higher concentration of skilled workers. The implication is that "places that are plentiful in educated people benefit from the diffusion of technological knowledge across companies and industries." They noted a geographical correlation to new industry development. The highest fraction of new industry workers are particularly located in the northeast and western states in America, and particularly in the cities of, in order, San Jose, CA; Santa Fe, NM; Washington, D.C.; San Francisco, CA; and Provo, UT.

The Future of Jobs report published by the World Economic Forum poses that a fourth industrial revolution is occurring [39]. Disruptions driving this industrial revolution include climate concerns and natural resources constraints, the changing flexibility of work and work environments, the development of energy supplies technology, robotics and autonomous transportation, longevity and the aging of societies, and the rapid urbanization of populations.

Spheres of Influence upon Technology Management

Social, political, and economic spheres of society influence the management and use of technology [40]. Design and implementation of technology are patterned after a wide range of 'social' and 'economic' factors, and based upon 'technical' considerations [41]. Rogers stated how technology clusters impact human interactions [42] while many philosophers including Feenberg, Marcuse, Borgmann, Ihde, and Latour have provided abstract theorizations concerning technology's influence upon society, and impacts of human technology usage on humanity [43]. Orlikowski noted several important concepts toward understanding technology management. First, there are shared "interpretations of interventions" concerning technology use. Structural models describe technological and sociological interactions relative to how technology is a product and medium of human actions. This can be considered deterministic [44]. The *Forces of Change Model* is useful for recognizing the challenges and opportunities facing technology management education [45]. This model lists challenges and opportunities to technology management, including:

Environmental issues
National defense and homeland security
Health issues
Demographic trends
Cultural and economic division
Deregulation and instability of global financial industry

Other models are suggested for conceptualizing management of technology [46] [47]. Noting Figure 1, McKirahan and Cheney suggest using a *Social Spheres of Influence Upon Technology* model for conceptualizing strategies to ensure successful technology management abstraction.

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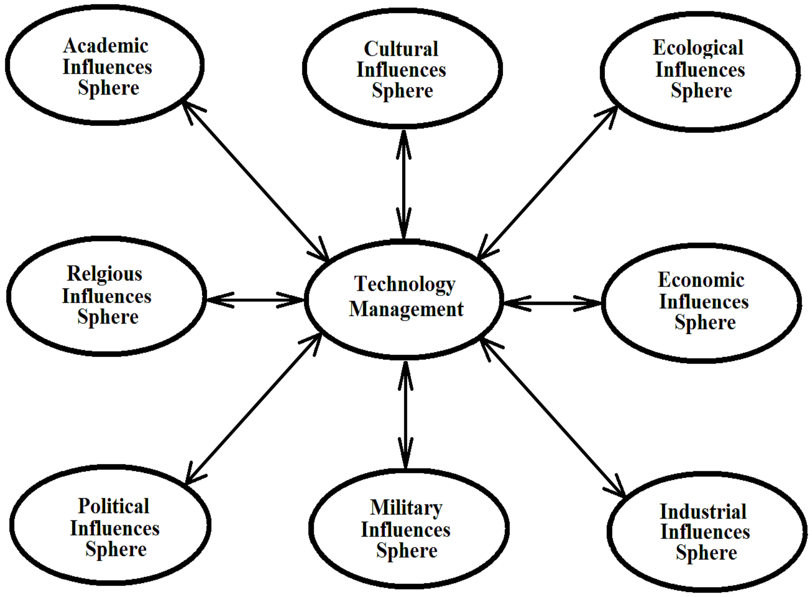

Figure 1: The Social Spheres of Influence Upon Technology

Aspects of Technology Management Important to Industry

As technology management (TM) initially came about as an academic discipline after World War II aimed at enhancing nation-state capabilities, it has been suggested that *value creation* is imperative for not only business and industry, but for academic technology management programs. In doing so, TM becomes an engine for progress and economic health regarding development of advanced economies throughout the world. Whereas traditional management is valuable for understanding, assimilating, integrating and directing technology and technology-facilitated innovation for the benefit of enterprise and customers, technology management enhances competencies for creating and improving products, processes, and services in the marketplace. But modern TM programs are quite diverse in nature. The academic fields of engineering and technology management evolved into academic disciples at opposite ends of a spectrum with the technology management programs constantly being added, remade, evolved, and retired. The varied focus of the many TM programs includes entrepreneurship, technology commercialization, operations and project management, information technology management, societal implications and awareness of technology, and technology strategy. The discipline of technology management, defined within a contextual setting of engineering and technology management (ETM), falls in between engineering at one end of a spectrum, with masters of business of business administration (MBA) and public policy at the other end of the spectrum. The academic discipline of technology management is noted as containing knowledge areas including *knowledge of technology, knowledge of technology-linked management topics, knowledge of general management topics, and knowledge of supporting disciplines* [48] [49] [50].

Aspects of Technology Management Programs in the U.S.

There have been varying perceptions regarding the competencies and skills of technologists and technology managers. Doggett, McGee & Scott [51] conducted two surveys to establish a technology management competency model. The following questions were asked to narrow the perception: 1) What is the core body of knowledge for an entry level technology manager? and 2) What are the core competencies for an entry level technology manager? Two contexts arise from the core competency model. The *applied context* defines technology management according to process, project, systems, and operations. Within the *management context* self-management, people management, quality management, and risk management are criteria defining the competencies. Concerning process and self-management, identified competencies included *responsibility, integrity, knowledge, self-monitoring, discipline, and values*. Concerning project and people management, the criteria *leading, listening, organizing, mentoring, planning, knowledge of group dynamics, respect, decision-making, empowerment, and staffing* emerged. Concerning systems and quality management standards, *improvement, quality frameworks, and costumer focused reliability. Concerning the operations and risk management: analysis of risk, risk tools and techniques, risk tolerance/appetite for risk, risk prioritization, and risk culture and context* were defining characteristics of technology management. This model, with three levels, defines a body of knowledge useful for the academic discipline of technology management in the U.S.

Technology Management Programs in the U.S.

Through a search of the internet and survey of the membership of the Association of Technology, Management, and Applied Engineering (ATMAE), academic programs using technology and management in their title were found. A list of these programs is provided below:

1) Bemidji State University –Technology Management (BAS)
2) Boston University - Operations & Technology Management (BS, PhD)
3) Bowling Green State University Construction Management, and Technology (BS)
4) Central Connecticut State University - Industrial Technology – Technology Management (MS)
5) Central Michigan University – Industrial Technology Management (BAA, BA, BS)
6) Columbia University – Technology Management (MS)
7) Davenport University – Technology Management (MS)
8) Eastern Illinois University – Technology Management (MS)
9) Eastern Michigan University – Technology Management (BS)
10) East Carolina University – Technology Management (PhD)
11) Georgetown University – Technology Management (MS)
12) George Mason University – Technology Management Leadership (MS)
13) Georgia Institute of Technology – Management of Technology, Information Technology Management (MBA-MOT and PhD)
14) Herzing University – Technology Management (BS)
15) Indiana State University – Technology Management (BS, MS, PhD)
16) Jackson State University Technology Management (BS, MS)

17) Marshall University – Technology Management (MS)
18) Massachusetts Institute of Technology – Technology, Management, and Policy Program (MS, PhD)
19) Millersville University of Pennsylvania – Applied Engineering & Technology Management (BS)
20) Neumont University – Technology Management (BS)
21) New York University – Polytechnic School of Engineering - Business and Technology Management (BS); Management of Technology (MS); Technology Management (PhD)
22) North Carolina Agriculture &Technology University – Technology Management (PhD)
23) Northern Illinois University – Industrial Management & Technology Emphasis (BS)
24) Ohio Northern University Manufacturing Technology with Management (BS)
25) Ohio University – Engineering Technology and Management (BS) and Technical Operations Management (BS)
26) Portland State University – Engineering and Technology Management (MS); Technology Management (PhD)
27) Southeast Missouri State University – Technology Management (BS, MS)
28) Stanford University – Technology Management Center - Science, Technology and Society (BS)
29) Stevenson University – Business and Technology Management (MS)
30) Texas A&M Commerce – Technology Management (MS)
31) Texas AM University – Technology Management (BS)
32) Texas A&M University Kingsville – Industrial Management and Technology (BS)
33) Texas State University – Technology Management (MS)
34) University of Bridgeport – Technology Management (MS, PhD)
35) University of California at Santa Barbara – Technology Management (MS)
36) University of Central Missouri – Technology Management (PhD)
37) University of Idaho – Technology Management (MS)
38) University of Illinois – Technology Management (MS)
39) University of Northern Iowa – Technology Management (BA)
40) University of Pennsylvania – Technology Management (MS)
41) University of Southern Maine – Technology Management (BS)
42) University of St. Thomas Minnesota – Technology Management (MS)
43) University of Wisconsin – Platteville – Manufacturing Technology Management (BS)
44) Utah Valley University – Technology Management (AAS, BS)
45) Washington State University – Engineering Technology Management (MS)
46) Western Kentucky University – Engineering Technology Management (MS)
47) Wichita State University – Engineering Technology Management (BS)

Aspects of Technology Management Programs in Asia

Japan after World War II is an example of effective and productive technology management and technological excellence. Japan has always been a country with very few natural resources. After being devastated during WWII, Japan set about to rebuild their country. Technology management was imperative in making Japan a leading economic power in the world. Core values include engendering a homogeneous culture, reinforcing productivity norms, receptive to absorptive technology development, human resources development, and intense focus on operations management to promote effective technology management. In being mindful of market and customer concerns, innovation and research and development were high national priorities after WWII. Identifying technology of generic significance, but with high potential growth was key. Leaders participated in technology forecasting and roadmapping, with commercialization of technological capabilities in mind. Ideation and diffusion of technology were paramount to their becoming a worldwide techno-industrial economic power after WWII. Because of Japan's close proximity to other Asian countries, including South Korea and Taiwan, technology transfer easily occurred [52].

Undergraduate management of technology (MoT) programs provided in Malaysia adhere to the 2003 established International Association of Technology Management (IAMOT) credo for providing technology management programs. Goals by industrial and education leaders for this country include shifting from a labor-intensive economy to a knowledge-intensive economy and for the country to become a *technology provider* rather than a *technology user* type country. Five knowledge groups define MoT in Malaysia according to the credo [53]. These knowledge groups include:

Management of Technology (MoT) Centered knowledge
Knowledge of Corporate Functions
Technology-Centered Knowledge
Special Requirements/Assignments
Knowledge of Supporting Disciplines

The five MoT programs in Malaysia according to this credo include:

Bachelor Degree in Management (Technology)
Bachelor in Technology Management (Production and Operation)
Bachelor in Industrial Technology Management
Bachelor in Technology Management (Innovation Technology)
Bachelor in Technology Management (High Technology Marketing)

Malaysia, in being a natural resource wealthy, yet developing, country in Asia, has identified sustainable technology management as vital toward development of its country [54]. As a hub, the capital Singapore when initially attracting multinational high technology, value added companies, recognized difficulty in bringing Western technologists and engineers to the country to manage their high technology companies. In response, research was conducted for establishing the MSc/MoT degree at National University of Singapore (NUS). They benchmarked NUS, Stanford University, University of Waterloo, and Eindhoven University, Masters MoT programs [55].

Aspects of Technology Management Programs in Europe

Leaders from higher education, the corporate sector, and the public sectors in Europe were interviewed to determine whether graduate and post graduate technology management (TM) programs in Europe were adequately addressing the emerging needs of business and academia in Europe. First, interviews were conducted of technology leaders there and covering a range of topics. Pedagogical approach and content provided in current technology management programs, whether the programs were delivered on-site or off-site, how the content was provided (i.e. either via in-house presentation, by consultants and business school faculty), the topical focus of the TM programs, and the expected outcomes of the TM programs, were addressed during the interviews. From these initial interviews it was determined TM education in Europe had evolved in different ways since the 1990's. Two emerging trends were determined. Demand for *specific skills* development was occurring. Second, an anticipation of outcomes toward *organizational renewal*, and *venture entrepreneurial-ship* was occurring. Based upon these findings, a typological view of specific skills versus generic skills development, and job efficiency and career focus versus company renewal and venture focus, was developed [56].

The following conclusions from the interviews and the topology were then reached. A first trend noted was the need for the development of *generic technology skills* for the retaining and recruitment of employees in the workforce in Europe. A second trend toward European companies was in providing *specialized, on-the job training* in companies, and provided by consultants. It was noted that universities and higher education institutes were not well suited for transferring the "specific skills" and "tacit knowledge" of companies to potential workers. It was further noted that *consultants were more adept at providing specific skills* with consideration of "different industry sectors and cultures" and that "boot camp-type" educational programs were preferred for attaining company-focused objectives. A clear trend was noted toward *"embedding generic skills into technology-specific programs"* to emphasize industry-specific needs in Europe. Gleaned from the article is that TM programs in Europe are contextually different from those in the US with the European programs having a strong business and entrepreneur component while the U.S. programs emphasis is technical competency [56]. A primary concern regarding technology management in the EU educational systems is toward respecting cultural values across countries, businesses, and industries there [57].

Conclusion

Since World War II, technology management has been of great concern, and is of exceptional relevance now. Technological megatrends are deterministically driving life, business, and the global economy. Twelve, emerging disruptive technologies noted in the paper are pushing various facets of modern life. These megatrends have major implications toward the concept of technology management and the providing of technology management-related education. Work is transitioning from what was once predominantly labor-intensive activities to knowledge-intensive activities. This phenomenon is causing worker displacement. Geographic areas already experiencing technological advantages hosting high technology business and industry will further their technological advantages. As various facets of society influence technology management, technology and society have reciprocal effects upon each other. As noted in the paper by Berger and Frey in the paper, STEM degreed graduates like those produced from technology management programs are in high demand, likely more easily transition to other emerging technology occupations than those graduates without STEM degrees. Providing basic technology skills seems more germane to undergraduate applied science and applied engineering programs. Concepts like technical artifact, technology transfer, technology roadmapping, etc. are important toward understanding technology management and providing technology management-related education. Academic technology management programs exist worldwide not only to provide technology skills, but to provide technology management skills.

Technology management not only has evolved in a variety of ways in the U.S., but in Asia and Europe as well, toward addressing emerging economic, political, and socio-technological needs. Companies, at least in Europe, have come to realize that academic TM programs can only provide basic technology skills and conceptual knowledge regarding technology management. Although European companies find the level of basic technical skills and TM concepts provided by higher education institutions acceptable, they utilize outside sources including specialists and consultants to address their specific technology and TM needs. It is essential that technology management programs provide business and industry, along with consideration of society in general, not only with the necessary skills and competencies, but the proper balance of various skills, in order to meet workforce needs. *What is the appropriate balance of theoretical and practical development necessary to produce graduates who make the most impact when entering the workforce?* Consideration of both the Asian and European technology management approaches discussed in the paper, in contrast to American technology management approaches for benchmarking purposes, may very well provide an answer to this question.

With the rapid pace of technological change and the influences of globalization occurring, industry-influenced instructional design very well may be used as a starting point toward filling gaps between what academia provides educationally, and what industry practitioners and society needs and requires. Finally, using an industry-influenced starting point can help determine when TM programs, regardless of geographic region where provided, undergo revision or continuous improvement efforts toward remaining current and appropriate. Additional investigation into the similarities and differences between technology management programs for benchmarking purposes, and technology management needs relative to industry and society, both in the US and abroad, provides avenues for additional research. These types of opportunities help ensure TM program currency and should be explored further.

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Biographies

JAMES MCKIRAHAN is currently an assistant professor in Applied Engineering and Technology Management in the College of Technology at Indiana State University. Dr. McKirahan earned an Associate of Applied science degree in Electronics Technology from Southern Illinois University-Carbondale, Bachelor's and Master's degrees in Industrial Technology and Technology, respectively, from Eastern Illinois University, and a Ph.D. in Technology Management, Manufacturing Systems from Indiana State University. He has several years of manufacturing management, consulting, and industrial manufacturing supervision experience as well as 17 years of collegiate teaching experience. He is a member of the Association of Technology, Management, and Applied Engineering (ATMAE), the Society of Plastics Engineers (SPE), and the Society of Manufacturing Engineers (SME). Dr. McKirahan may be reached at James.McKirahan@indstate.edu.

AUSTIN CHENEY is currently Chair and Professor of the School of Technology at Eastern Illinois University. He has over 25 years of experience as an engineer, manager, and educator. Dr. Cheney earned his B.M.E. and M.S. degrees in mechanical engineering from the University of Dayton, MBA from Eastern Illinois University, and an Interdisciplinary Ph.D. in Management of Technology from Vanderbilt University. He is an active member of the Society of Manufacturing Engineers and the Association for Technology, Management, and Applied Engineering, and serves as Faculty Board representative to the Electronic Components Industry Association Foundation. He is a registered Professional Engineer in Ohio and a Certified Manufacturing Engineer. Dr. Cheney may be reached at acheney@eiu.edu.