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Technology Management Educational Initiatives in Asia: A Case Study From the National University of Singapore

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In 2005 the Faculty of Engineering at the National University of Singapore relaunched a master's of science program in the management of technology (MSc/MOT) after it was moved from the School of Business where, as the first of its kind in Asia, it was started in 1992. The opportunity to relaunch the program in the faculty of engineering provided a new opportunity to refresh the program and introduce management of technology (MOT) courses that were not feasible when the program resided in the School of Business. We discuss how this move allowed the program designers to account for the unique needs of innovation management in a small and newly developed Asian country by introducing courses into the curriculum that could only have been offered in a faculty of engineering. The unique courses include Intellectual Property Management, Management of Industrial Research and Development, Systems Architecture, and Systems Engineering. From a pedagogical perspective, we also examine the advantages of offering the program on a part-time basis to accommodate working engineers and managers. We reflect on how Singapore's experiences in designing appropriate curricula, overcoming resource constraints, and leveraging resources for management of technology programs might be useful to other developing nations. Finally, we discuss a potential approach for integrating MOT programs into the core engineering curriculum as a way to enhance the value of traditional professional degrees.

BACKGROUND

The education and related academic research programs in the interdisciplinary field of the management of technology (MOT) have been well developed in the U.S. and Europe since the early eighties. Such master's-level MOT programs were designed as alternatives to the traditional masters of business administration (MBA) program (Badawy, 1998). Although there are currently over 200 MOT programs being offered worldwide (Alvear, Rueda, Hernandez, & Kocaoglu, 2006), there continue to be very few in emerging economies, particularly those of Southeast Asia. The pace of MOT program development in Asia, including technology-oriented economies like Japan and South Korea, has been slower than in the United States (Minden & Wong, 1996). It was only in 2002 that an initiative of Japan's Ministry of Economics, Trade and Industry (METI) provided significant government funding to universities to develop such programs (METI, 2005; Okutsu, Ikawa, & Kameoka, 2004). Their target was to train 10,000 MOT specialists a year for at least 5 years in order to rapidly make up lost time and create the necessary human capital pool to enhance Japanese capabilities in the management of technology. The corresponding effort in South Korea is also quite recent, while the need for such

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programs in the emerging economies of China and India is only now being felt with the steep development trajectory of their high-tech industries.

We elaborate on the experience of Singapore, namely, the experience of the National University of Singapore, in establishing a master's of science in the management of technology (MSc/MOT) program. Its history of being originally hosted in the School of Business, terminated, and then reintroduced in the faculty of engineering highlights potentially useful lessons to educators and curriculum designers on success factors. The revival of the MSc/MOT program created an opportunity to redesign the program to account for the needs of a newly developed economy in a globalized world. The challenges in designing appropriate curricula, finding suitable lecturers, and supplementing teaching materials with Asian cases are discussed with the hope that the lessons learned could be useful to developing nations and, perhaps, to continual program development in developed nations.

The paper is structured as follows. In the first section we explain the industrial context in Singapore in order to underline the importance of the MOT program to the nation's economy. In the second, we describe the origin and evolution of the MOT program at the National University of Singapore. Next, we provide details of the course curriculum design. Then we outline the experience gained and the lessons learned from establishing this program so that they might serve as a guidepost to others embarking on a similar journey. We end with final remarks on the important role of a champion/leader and the need to adapt the curriculum to the needs of the country.

THE INDUSTRIAL CONTEXT FOR MOT IN SINGAPORE

To continue creating jobs for a country with no natural resources, including potable water, the Singapore government focused on the development of a knowledge-based economy to build its national advantage.[1] For example, it has promoted the practice of knowledge-intensive manufacturing with concurrent design and research and development (R&D) activities. This is also evident from Singapore's R&D investment (Hang, 2007; Wong & Singh, 2008). The R&D investment in the 1980s accounted for less than 0.5% of the GDP, while the investment had increased significantly to 2.39% of the GDP in 2006.[2] Singapore has continued to attract and root high-end, high value-added manufacturing investments from multinational companies (MNCs). Increasingly, the MNCs (such as HP/Compaq, GE, Philips, Siemens, Matsushita/Panasonic, Microsoft, Toshiba, Seagate, etc.) have also established design, research and development (DR&D) centers in Singapore as a part of their globalized organizational structures. Correspondingly, the number of research scientists and engineers (RSE) in the nation increased from 8.5 RSEs per 10,000 labor force in the 1980s to 90 RSEs per 10,000 labor force in 2006.[3]

To facilitate the training of high valued-added human resources in anticipation of the continual demands of such firms, the Singapore government increased funding and other resources to enhance university research and establish various mission-oriented research institutes (Hang, 2007). These were used to attract and retain foreign intellectual talent, to nurture the engineering and management skills of local workers, and to demonstrate Singapore's capacity for advanced DR&D.[4] Multinational companies would be able to quickly hire trained engineers from the universities and research institutes to establish new DR&D centers or to increase the capacity of existing ones in Singapore. The research institutes transferred the necessary technologies to support the local industry which, at the time, consisted of small- and medium-size enterprises (SMEs) that could not muster the manpower or financial resources to support the DR&D teams needed to meet the rapidly changing demands of their MNC clients.[5]

Although there was a huge shift in Singapore's R&D investment, in the initial days, many of the MNCs' Singapore R&D centers concentrated solely on R&D project execution (Hang, 2007). Strategic level decisions on the management of technology, such as those related to technology policy, early stage R&D investments, and new product development were centralized at the headquarters of the MNCs in Europe, the U.K., the U.S., or Japan. As capability in MOT is known to help managers address critical issues such as planning, development, and implementing technological capabilities to shape and accomplish the strategic and operational objectives of the organization (as de-

[1] http://www.edb.gov.sg/edb/sg/en_uk/index/about_us.html

[2] http://www.a-star.edu.sg/a_star/90-Annual-R-D-Survey

[3] http://www.a-star.edu.sg/astar/front/media/content_uploads/R&D_Survey_Booklets_2006.pdf

[4] http://www.nytimes.com/2006/08/17/business/worldbusiness/17stem.html?ex=1313467200&en=a3268595bc581cd7&ei=5088&partner=rssnyt&emc=rss

[5] http://www.a-star.edu.sg/a_star/25-Exploit-Technologies

fined by the U.S. National Science Foundation[6]), there was little need for engineers and managers in Singapore to be trained in MOT to the master's degree level. However, as the economies of Southeast Asia started growing at a rapid rate, the need for managers who knew MOT at the strategic level became more acute. The high costs of engineering and scientific talent in the West combined with the growing domestic markets of East Asia and China pushed many MNCs to accelerate their DR&D facilities in the region. The shift in Singapore to high value-added activities occurred in two waves.

In the first wave, some MNCs, such as HP/Compaq, moved some of their product charters to Singapore, which meant the transfer to Singapore of key decision-making functions related to product design, marketing, and the supply chain.[7] To manage the transfer of such activities, experienced technology managers were sent from the companies' overseas headquarters to Singapore. Correspondingly, senior local engineers and technologists were sent to the company's overseas headquarters for training in MOT. In response, the Singapore government began to emphasize the need for the local university system to train technologically savvy managers. The second wave saw the employment of locally trained MOT managers who could assume responsibility as product and technology champions with regional and global roles in the MNCs. As the MNCs experienced success with these locally trained but globally positioned MOT managers, they were able to shift a greater number of product charters to Singapore. These managers increasingly took on more than just product charter roles, becoming responsible for market development, new product development, intellectual property (IP) management, and even basic technological innovation processes.

Concurrent with the increase in high value-added MNC activities in the region, the advent of open-innovation practices (Chesbrough, 2003) also created opportunities for small- and medium-sized technology enterprises to expand their operations in service to their MNC clients. Other technology SMEs were able to capitalize on the development of local MOT talent by hiring the more entrepreneurial managers from MNCs to staff their rapidly expanding regional operations. Hence, a secondary impact of the MOT curricula, originally designed to produce technology savvy managers for MNCs, was the enhancement of SMEs' capacity for technology management, which fueled their globalization efforts. This enabled entrepreneurs to build enterprises using new approaches, such as disruptive innovation and the bottom-of-pyramid strategy (Hang, 2007). These approaches, which exploited the smallness and resource-poor characteristics of start-ups, led to the development of ancillary value-added products and services such as solid-state hard drives, USB drives, and the like, which eventually became large businesses in their own right.[8]

GENESIS AND EVOLUTION OF THE MSC/MOT PROGRAM

When the need for a graduate level program in MOT was identified by the Singapore government in 1992, it fell to the National University of Singapore (NUS) to design and deliver it. As a comprehensive university with medical and engineering schools, it was felt by the government that NUS would be the logical choice for the first MSc/MOT program in Asia (Minden & Wong, 1996). It was hosted by the School of Business in close collaboration with the Faculty of Engineering. From 1992 to 2000, more than 500 students graduated with their MSc/MOT, and many now work in R&D and technology-intensive industries in the public and private sectors in Singapore and other parts of Asia. A reflection of the significant role of the electronics manufacturing industry and information and communications technology (ICT) services in the local and regional economies, half of the MOT graduates were first trained as electronic engineers and information and communications technology (ICT) professionals.

The program was designed as a 2-year part-time degree with classes conducted in the evening to accommodate participants with full-time jobs. A full-time program was later introduced to meet the needs of international students and domestic students who desired a quicker, 1-year program of study. A subsequent program assessment using feedback from graduates suggested that the part-time program was more effective, as it allowed the participants to directly apply to their workplace what they had learned in class through project assignments that encouraged such work-related applications (Minden & Wong, 1996).

Even though the program was popular with employers and students, the School of Business de-

[6] http://www.nsf.gov/

[7] One author of the paper served as deputy chairman of Singapore's National Science and Technology board (http://www.a-star.edu.sg/) from 1991–1999 and then as executive deputy chairman of the Agency of Science, Technology and Research (http://www.a-star.edu.sg/) from 2001–2003. The statements of this paragraph and subsequent ones are based on his first-hand experience.

[8] http://www.trek2000.com.sg/

cided to cancel it in 2000. Administrators decided to focus their resources on the full-time MBA program, which they believed was necessary for the school to be internationally ranked. The school also experienced difficulty recruiting tenure-track faculty with sufficient technical training and work experience to teach the program and also publish in the leading peer-reviewed business-related journals. The final factor in the decision was the bursting of the Internet bubble in 2001, which the administrators believed signaled the end of the market for such programs.

As a result of a call by the government to continue educating engineer-managers, the Faculty of Engineering at NUS decided to revive the MSc/MOT in 2004. This time the program was hosted by the Faculty of Engineering in collaboration with the School of Business. Enrollment in 2005 was 38 students, rising to 56 students in 2006, and then to the current enrollment of 69 students in 2007. Because of the popularity of the MSc/MOT program, a master's of science in intellectual property management (MSc/IPM)) was established in collaboration with the Faculty of Law in 2006.[9] In the MSc/IPM program, students must first complete an Intellectual Property Law certificate program, with a workload equivalent to half of an MSc, in the Faculty of Law. This gives students an academic foundation to understand the various aspects of intellectual property law and practices, sufficient for those who intend to become patent agents. The students then fulfill their degree requirements with five MSc/MOT courses that focus on innovation management. The program attracted an enrollment of 15 enthusiastic students in 2006 and rose to 17 students in 2007. Hence, the MSc/IPM program regularly feeds students into the relevant MSc/MOT classes.

At the undergraduate level, the demand for a basic MOT education was met in 2005 with a minor concentration offered jointly by the School of Business and Faculty of Engineering.[10] This program experienced a steady increase in enrollment with student registrations of 10, 12, and 38 in 2005, 2006, and 2007, respectively. Starting in 2007, having experienced success with the relaunch, the School of Business, in collaboration with the Faculty of Engineering, introduced a double major in engineering and management (technology) with an initial enrollment of 40 engineering students.[11]

Finally, the organizational support for the MSc/MOT program and its hybrids was put in place in July 2007. To support education and research in the management of technology and innovation, NUS chartered a new Division of Engineering and Technology Management (D-ETM) in the Faculty of Engineering. The division proceeded to introduce, within only one year, a new set of core undergraduate courses and a PhD program in technology and innovation management. This concluded the first phase of the national MOT initiative. It was built on the foundation of Singapore's long tradition of science and technology education (Kong, 2004). In the following, we examine the effort and results of this first phase, concluding with a discussion of the the program's future.

CURRICULUM DESIGN

The purpose of the new MSc/MOT program is to better educate engineers and scientists to manage the activities associated with bringing high-technology products to the marketplace. Participants are taught to manage the processes in technology commercialization and new product development and to lead the upstream activities related to R&D project planning and execution. When the program was being contemplated in 2004, discussions with industry leaders and potential students established that a sufficient demand for a full-time program did not yet exist in Singapore and other Asian countries. However, there was a strong indication of a healthy demand for a part-time graduate level program for working engineers and scientists, and that it would grow rapidly as countries in the region moved up the value curve in their industrial production capacity. The basic technical education and experience of the students meant that such a MOT program could focus on the managerial aspects of technology management supported by technology briefings to update the students' technical knowledge.

The MSc/MOT curriculum hosted by D-ETM includes core and elective classes. In total, students must complete at least 40 credit hours to obtain the MSc degree. As shown in Table 1, students complete at least four of the five core modules and fulfill the balance of the ten modules from a list of approved electives. Each module is equivalent to 4 credit hours in content with the exception of a research project module which has a workload equivalent to 8 credit hours. From the years of experience in educating engineering students through part-time evening programs at the Faculty of Engineering, the curriculum designers felt that most students would be able to complete the MSc in 2 years of part-time work.

The five core modules comprising 20 credit hours

[9] http://www.eng.nus.edu.sg/etm/Program/msc-ipm.htm

[10] http://www.eng.nus.edu.sg/etm/Program/minor-mot.htm

[11] http://bschool.nus.edu.sg/NUSBBA/tabid/658/Default.aspx

TABLE 1
MSc/MOT Modules

	Modules	Teaching Departments
Core	Management of Technological Innovation	Business/ETM
	Cost Analysis and Engineering Economy (or Finance for Engineering & Technology Management)	ISE/ETM
	Systems Approach to Project Management	ISE
	IP Management	ETM
	Management of Industrial R&D	ETM
Electives (Strategic Aspects)	Decision Analysis	ISE
	Knowledge Management	ETM
	Creativity & Innovation	ETM
	Strategic & New Product Development	ETM
	Technology Intelligence & IP Strategy	ETM
Electives (Organizational & Systems Aspects)	Management and Organization	Business
	Systems Engineering	ETM
	Systems Architecture	ETM
Electives (Entrepreneurship Aspects)	Corporate Entrepreneurship	Business/ETM
	Technopreneurship	Business
	Analyzing Hi-Tech Opportunities	ETM
	User-Centered Engineering & Product Development	ETM
Electives (Operational Aspects)	Managing Operations	Business
	Quality Planning and Management	ISE
	Industrial Logistics	ISE
Electives (Others)	Research Project	ETM
	IP Law for Engineers and Scientists	Law

ISE = Industrial & Systems Engineering; ETM = Engineering & Technology Management.

provide a balanced introduction to management and a technology-oriented foundation for taking the elective modules that are more specialized (see Table 1). The module Management of Technological Innovation provides an overview of technology management and helps students develop a good conceptual foundation for managing technological innovation. It is assumed that students who are working in industry have a basic knowledge of marketing and business/corporate strategy, either from their undergraduate engineering education or from previous on-the-job training. The modules Cost Analysis and Engineering Economy (or Finance for Engineering and Technology Management) and Systems Approach to Project Management are designed to enhance financial analysis and systems thinking/planning skills.

The program offers two distinct core modules: IP Management and Management of Industrial R&D (see Appendix A). The module IP Management strengthens the students' basic knowledge of the management of IP assets to facilitate strategy formulation for maximizing IP values and R&D planning. The module Management of Industrial R&D focuses on the development of the current third-generation and emerging fourth-generation R&D management practices in industry resulting from the increased importance of discontinuous innovation approaches. It integrates R&D planning with technology and business strategy formulation. These two core modules were included because of a national agenda to bolster higher levels of innovation and value creation among Singaporean firms and MNCs in Singapore. This trend toward the higher end of the value curve is also evident in the technology policies of other emerging Asian economies such as Malaysia, Thailand, Hong Kong, and Taiwan. Discussions with public and private stakeholders of the program, such as government officials and companies, confirm this observation.

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The electives shown in Table 1 are organized into four areas: Strategic Aspects, Organizational & Systems Aspects, Entrepreneurial Aspects, and Operational Aspects. The breadth of these areas is comparable to other well-known programs, such as those shown in Table 2. Owing to its foundation in the School of Engineering, the NUS program

TABLE 2
Comparision of MSc Programs

University	NUS	Stanford	Waterloo	TU- Eindhoven
Title of MSc Programs	Management of Technology (MOT)	Management Science & Engineering (MS&E)	Management Science (with a focus on MOT)	Innovation Management
Modules	**Core** ■ Management of Technological Innovation ■ Cost Analysis and Engineering Economy/or Finance for Engineering & Technology Management ■ Systems Approach to Project Management ■ IP Management ■ Management of Industrial R&D **Electives** ■ Decision Analysis ■ Knowledge Management ■ Creativity & Innovation ■ Strategic & New Product Development ■ Technology Intelligence & IP Strategy ■ Management & Organization ■ Systems Engineering ■ Systems Architecture ■ Corporate Entrepreneurship ■ Technopreneurship ■ Analyzing Hi-Tech Opportunities ■ User-Centered Engineering & Product Development ■ Managing Operations ■ IP Law for Engineers & Scientists ■ Research Project	**Core** ■ Strategy in Technology-based Companies ■ Industrial Accounting ■ Economic Analysis ■ Organizational Behaviour and Management ■ Dynamic Systems ■ Global Entrepreneurial Marketing ■ Decision Analysis I (to choose 5) **Electives** ■ Manufacturing Strategy ■ Innovations in Manufacturing ■ Management and Organization of R&D ■ Creativity and Innovation ■ Engineering Risk Analysis ■ Decision Analysis I ■ Quality Engineering ■ Management of New Product Development ■ Building Entrepreneurial Organizations ■ Strategy Modelling	**Core** ■ Foundations of Senior Management ■ Research Methods in Management Science ■ Principles of Management of Technology ■ Principles of Operations Research ■ Organizational Theory and Behavior ■ Economics Concepts for Management ■ Management of Technological Innovation ■ Final Research/Design Paper **Electives** ■ Knowledge Management ■ Management of Quality ■ Logistics and Supply Chain Management ■ Entrepreneurship and Intrapreneurship ■ Statistical Quality Control ■ Communications Management	**Core** ■ Philosophy of Management Science ■ Innovation Networks and Alliance Management ■ Marketing and Innovation ■ New Product Development ■ Management Accounting ■ Quality in Short Cycle Product Development Processes ■ Research Design, Data Collection and Analysis ■ **Master's Thesis** **Electives** ■ Technology and Growth ■ Project and Process Management ■ Human Aspects of PD and Quality ■ Quality and Reliability by Design ■ Entrepreneurship ■ Knowledge Processes and Management ■ Strategic Sourcing and Supply Management ■ Strategy & Technology Management

could offer 5 additional unique elective modules: Systems Engineering, Systems Architecture, Analyzing High-Tech Opportunities, User-Centered Engineering & Product Development, and Technology Intelligence & IP Strategy (module contents are outlined in Appendix B). The inclusion of such modules reflects the intention of the curriculum design to enhance the connection between technology creation and management. The cultivation of systemic or systems thinking would enable students to develop a richer understanding of the complexity they will face in a globalized and fast-changing world (Atwater, Kannan, & Stephens, 2008). In addition, the elective modules grouped under the strategic and entrepreneurship aspects provide an opportunity for students to gain substantial entrepreneurship education beyond business plan development (Honig, 2004; DeTienne & Chandler, 2004).

To augment the MSc/MOT program, D-ETM created three undergraduate MOT modules that are offered in the Faculty of Engineering and the School of Business: Systems Thinking & Engineering, Technology Management Strategy, and Engineering Product Development. These modules form the core requirements for the minor in MOT certificate and one of the majors in the newly introduced double major in the Engineering & Management (technology) program. The double major is hosted by the School of Business in collaboration with the Faculty of Engineering. Well-performing double major students are encouraged to take two advanced modules, Creativity & Innovation and IP Law for Engineers and Scientists, from the graduate MSc/MOT program. One effect of this is a boost in course enrollment, which eases the staffing overhead. The undergraduate curriculum for the second major in management (technology) is shown in Table 3.

The teaching method adopted at D-ETM is a combination of lecture and case discussion. The lecturing method, which is prevalent in engineering schools, is effective in quickly conveying large amounts of new information to students. However, it is less stimulating, especially for more mature students with many years of work experience. Instead of the conventional professor-centric one-way communication style of lecturing, more and more "problem-based learning" sessions have been introduced in engineering modules to stimulate students to interact with the professor who serves the role of a facilitator. The case discussion approach, which is more prevalent in business schools, is more demanding of the students as they are expected to do substantial homework to read, study, and analyze the cases and come to the class prepared to contribute to the class discussion. Peer learning through in-class discussions and group projects is also expected to enhance students' communication capabilities and self-confidence. While the modules taught by other engineering departments and the business schools will naturally follow the conventional style of that discipline, the new modules introduced by D-ETM are mostly taught using the case discussion approach or a mix of lecture and case discussion. In some modules, such as Creativity and Innovation, the lecture part is largely replaced by the problem-based learning approach.[12]

TABLE 3
Second Major in Management (Technology)

Students are required to complete 48 modular credits as follows:

Completion of the minor in MOT by reading the following 6 modules (4 credits per module):
- Financial Accounting
- Principles of Marketing
- Systems Thinking and Engineering
- Technological Innovation
- Engineering Product Development
- Technology Management Strategy

Completion of another 6 modules relating to general and engineering management including:
- Operations Management
- Project Management or Project Risk Management

Completion of 4 electives from the School of Business or the Faculty of Engineering such as:
- Entrepreneurial Marketing
- Financial Risk Management
- Leadership in Organization
- Organizational Effectiveness
- Product and Brand Management
- Creativity and Innovation or
- IP Law for Engineers & Scientists

EXPERIENCE GAINED AND LESSONS LEARNED

Establishing the MOT Discipline

In contrast to other MOT programs in the United States and Europe, most Asian universities do not offer a master's-level MOT program or, if they do, it is hosted in their school of business or management. At NUS, the MOT program was first hosted in the business school but later moved to engineering. The experience at NUS suggests that this model may be worth considering for universities that are starting such programs, as the engineering faculty can cover the technology component of the program more readily or are at least sympathetic to the notion of technology management. Recent updates in engineering education certification, led by the United States, now require a large component of the courses

[12] http://www.chemeng.mcmaster.ca/pbl/pbl.htm

to be business-related. Hence, the marriage between technology and management is more quickly consummated in engineering, whereas in schools of business, technology is not a required component of the standard business curriculum.

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The transition of the program host from business to engineering was expected to be a major challenge. As the faculty of engineering willingly embraced the program, regarding it as a flagship program for educating global engineering leaders, it committed resources to the cause, especially the appointment of a strong leader. With strong academic credentials, senior administration capability/experience, and keen interest to create an impactful program, the dynamic leader managed to overcome various difficulties in establishing the MOT discipline. First, the university's approval was obtained to create a home for multidisciplinary academics who want to develop tenure-tracked careers in the domain of technology management. Next, a successful effort was expended to attract adjunct faculty who were retired senior technology managers from industry, such as CTOs, with deep experience in the practical aspects of MOT and who wanted to pass on their knowledge in the classroom. Finally, a natural synergy between MOT and other related engineering programs, such as industrial and systems engineering, was cultivated and strengthened. As a confident and willing host, the close collaboration with the School of Business has also worked out well, thanks to NUS's culture as a comprehensive university.

It turned out that MOT programs were better received when administered in collaboration with other schools from across the campus. In part, this ensured a healthy enrollment for the programs. More important, the resulting classes reflected a broader set of experiences, competencies, and interests, which led to a more dynamic learning environment for both the students and faculty. Finally, since students received multiple certifications when they completed the degree, hybrid programs like the MSc/IPM were viewed as time efficient. This last factor was important for small economies that are dependent on human capital as their main source of value creation since certification was a way to indicate high-value human capital.

Identity of the Discipline

Because MOT is a new discipline established in the Faculty of Engineering in close collaboration with the business school, its initial positioning in the market is critical. During discussions with employers and potential students, the program administrator realized that in Singapore, as well as in most parts of Asia, there was not yet a strong demand for MSc/MOT graduates to be recruited directly from the open market. However, there has been an increasing need for educational programs to enhance the knowledge and skills of engineers and engineering managers toward technology management. The part-time MSc/MOT education program has thus been designed to meet this emerging demand. A smaller number of full-time students, especially those from other Asian countries, could easily be accommodated by allowing the students to take double the study load of the part-time students.

Because the students are already working, the problem of career development and job search is significantly mitigated. Given that companies still recruit to fill functional roles, as opposed to product champions or multidisciplinary roles, placing graduates from MOT programs has been an issue for administrators around the world. At NUS, the MSc/MOT program is simply a basis for future promotions or expanded job roles in companies that are already looking for such competencies from their employees. In addition, because the Singapore government subsidizes the staffing and resource requirements of the program, students do not pay very much tuition to enroll and, therefore, find it an easy decision to make.

The identity of the MOT discipline could be further strengthened by a strong and active alumni in the near future, and the NUS Business school has done very well in building up a strong MBA alumni network. Hence, the MOT program administrator is now learning from the business school on how to establish a similar alumni network which will provide strong linkages with the faculty of engineering as well as facilitate social networking, which is good for both the professional and career advancement of alumni.

In the context of the Singapore national innovation system, the MSc/MOT is hailed as a pioneering program in human capital development. Hence, the experiences of the program's design and implementation are now being used to build or inform other programs in universities and research institutes. The program is potentially part of a future effort to formally introduce graduate technology entrepreneurship education in collaboration with the School of Business, together with new investments by the government to expand venture capital funding for technology start-ups, and for the creation of a national Innovation Policy Centre.[13]

Curriculum Development

The major challenges one would face in curriculum design and development for MOT are how one could strike a balance between theory and practice, and how one could balance between the coverage of business management fundamentals and the more focused technology/innovation management topics, especially when the total time duration is limited to 40 modular credits (10 modules of 4 credits/module) in an MSc program.

At NUS, the design and development of the MSc/MOT curriculum was facilitated by an extensive analysis of curricular models from American and European universities (Badawy, 1998; Mallick & Chaudhury, 2000; Alvear et al., 2006). The views of experienced technology managers from industry were sought for their practical perspectives. After all of this research, analysis, and consultation, a short list of 5 modules was chosen as the program's core, from which students would need to complete at least 4. A much longer list of electives, as discussed earlier and shown in Table 1, was also created to give students a broad choice for further specialization within the MOT discipline. This flexible curriculum structure was well received by the employers and the students during marketing sessions and by the subsequent choices students made. In April 2008 a survey was conducted with 163 recent graduates and current students of the program.[14] Based on an analysis of 67 valid responses, the program appears to have achieved its primary objective of enhancing the academic and practical preparation of graduates in technology and innovation management. Based on their popularity, some core modules, such as Management of Technological Innovation and Management of Industrial R&D will be offered twice a year, rather than only once, starting in 2009.

Instructors in the program have also reported that some students, especially those from the region outside of Singapore, lacked suitable academic preparation in marketing and strategy. Even domestic students who may have taken the relevant business modules during their engineering studies did not always recall what they had learned, especially if they entered their first jobs as hard-core engineers. The original assumption in the design of the program was that students would be familiar with basic strategy and marketing concepts. Hence, in the next revision of the curriculum, slated for August 2009, the program designers will introduce short review courses during orientation to familiarize students with the basic concepts. This way, even if the students have to self-study, they will have a platform to accelerate their learning.

Teaching

The establishment of a brand new MSc/MOT program would incur tremendous time and effort in building up the teaching resources. The program designers have significantly reduced the scale of this challenge by tapping the teaching resources of their partners, namely, the Department of Industrial & Systems Engineering in the Faculty of Engineering and the Business School. Having leveraged the teaching resources of these partner academic units by cross-listing the available modules into the MSc/MOT curriculum, D-ETM only has to provide resources for teaching half of the core and half of the elective modules, thereby achieving a tremendous savings.

The most difficult *implementation* task was the recruitment of scholar-teachers as academic staff to teach specific MOT modules. As NUS is a research-intensive university, excellent teaching and research are essential components of an academic staff member's career development and assessment metrics. Without an active research program comprising both academic staff and PhD students, it would be difficult to attract new scholar-teachers to join the D-ETM. An active research program is also needed to create new localized cases for classroom use. Hence, a PhD program[15] has been launched in parallel with the continuing development of the MSc program. As a result, three new tenure-track faculty with formal academic

[13] http://www.nrf.gov.sg/nrf/otherProgrammes.aspx?id=1206

[14] More on the survey can be found at http://www.eng.nus.edu.sg/etm/Documents/Survey Results-2008-07-29 (2).pdf

[15] http://www.eng.nus.edu.sg/etm/Publication/publication.htm

training in MOT have been hired into the D-ETM to form the core group of scholar-teachers in addition to four engineering academic staff who have joint appointments with D-ETM.

The program designers have also noted that some of the MOT modules offered, such as IP Management, are more challenging to staff than the others because they require the faculty member to have extensive industrial experience before he or she can effectively convey the practical fundamentals. At the same time, the faculty member must be conversant with interactive pedagogies (i.e., have teaching competency) to effectively employ the case studies. To meet such teaching challenges, four visiting professors with relevant expertise are invited to spend at least one semester each year in the D-ETM to teach modules and conduct joint research with other faculty in the division. Two of these visiting professors are scholar-teachers from well-known universities in Europe and Asia who also have extensive industrial consulting experience with multinational companies, while the other two are retired technology managers from European and U.S. multinational companies. The visiting professors are much appreciated by the students as they are also able to provide a more global perspective of MOT. The teaching team is further complemented by five adjunct faculty members who currently work as senior technology managers in industry. Overall, the mix of teachers from academic and industry backgrounds is about even, which has resulted in favorable feedback from the students in the program.

Overall, the mix of teachers from academic and industry backgrounds is about even, which has resulted in favorable feedback from the students in the program.

Another challenge in MOT teaching is to find a good balance between lecture and case discussion methods. From the survey of students conducted in April 2008, it was confirmed that students were satisfied with the mixed pedagogy of lecture and case discussion with ratios from 60:40 to 50:50. This is comparable to instructional methods used by many MOT graduate programs elsewhere (Mallick & Chaudhury, 2000). While the students have learned a great deal from the MOT modules, the instructors have reported that the best learning is through project work, especially the research project module, which has 8 modular credits. About 10% of the students have chosen the research project as an elective. Some proposed company problems and then applied the new MOT knowledge they had acquired to complete a small-scale research project that created an opportunity for them to learn more deeply while solving a real problem. Others participated as team members in the professor's applied research project and completed their individual project reports while benefiting greatly from peer learning among the research team members.

Faculty members have also observed that when Asian cases are used their class discussions appear to be more animated. Using Asian cases across the curriculum is challenging, as the majority of the published cases are written in a Western context and of Western firms. For modules taught by D-ETM, local experts from industry (including those from foreign companies operating in Singapore and Asia) are frequently invited to share their experiences with the class. At the same time, cases are being written from materials produced by the project module and by the students in the newly introduced PhD program.

Strategy for Growth

Having established the two basic MOT educational programs (MSc and double major undergraduate), the Division of Engineering & Technology will embark on evolutionary developments based on the experience it has gained. Three new objectives have been envisaged. The first is to take advantage of its close association with other engineering departments, since D-ETM is hosted by the Faculty of Engineering. In education, for instance, new modules such as the Management of Engineering Systems Development, in contrast with the more traditional Management of Product Development, could be developed. Another educational opportunity will be the addition of MOT modules into existing engineering MSc programs to broaden their scope. MOT research in emerging engineering sectors such as interactive digital media, clean energy, water resources, silver-hair technologies, and so forth could also be explored, as MOT professors and research students could collaborate quite readily with other engineering colleagues and students.

The second objective is to offer the MOT educational opportunity to all engineering PhD students. Most of these students are expected to become innovation leaders in the future knowledge economy, and it is important to equip them with basic MOT knowledge and skills so that they can, in turn, be "change agents" in the organizations they serve, particularly in the small- or medium-sized companies and brand new start-ups. A graduate certificate program (where students would complete only 4 modules instead of

the 10 modules in the full MSc program) has accordingly been planned to be introduced in the 2009 new academic year.

The third objective is to introduce an executive MOT program where senior managers from industry could study and learn from one another, using their rich industrial experiences. Similar to executive MBA programs, students in the executive MOT program would be able to maintain substantial parts of their full-time work while creating opportunities for high-level business networking and studying over a 1 to 2-year period. An executive graduate certificate program in MOT may be launched soon after a regional market survey of its demand is established. The executive education program schedule of periodic concentrated study periods with residential arrangements would also enable D-ETM to offer educational opportunities to practicing managers from other parts of Asia.

FINAL REMARKS

The journey traveled by NUS in establishing an academic program in the management of technology was very challenging, as most new interdisciplinary programs tend to be. It is clear from the elaborations above that the institution's support in appointing a champion/leader was critical to the successful launching of the MOT educational programs in the Faculty of Engineering. Such a candidate should have the respect of the academic community and have senior administration experience. The champion/leader in this case has wisely collaborated with other related departments, especially the Industrial & Systems Engineering Department within the Faculty of Engineering and the Business School. This would be an approach highly recommended to all others whenever it is applicable. Good execution of the management plan for obtaining vital resources, convincing colleagues to join the program, curriculum design, marketing to industry, academic staff recruitment, and so forth were all essential—this cannot not be overemphasized for a new initiative, as mature students from industry are very vocal and engaging.

While the new MOT curriculum designed at NUS can serve as a useful and general reference, some parts of the curriculum will have to be adapted in other countries, including other Asian countries, as the industry context varies from one country to another. We recommend that industry be consulted as early as possible, for both the curriculum content as well as the decision of whether to offer a part-time program. Such an approach will ensure that the program will be relevant to the needs of the country and enable the program to tap experienced industry managers who may even serve as adjunct academic staff.

APPENDIX A

IP Management

This module focuses on the management of IP assets, which have become more valuable than conventional physical assets in a knowledge economy. It will present the different needs and strategies of IP owners and those who own the complementary assets, such as manufacturing, marketing, and distribution. Both the commercialization strategies for maximization of IP values and the feedback to management to improve decision making at the R&D and corporate strategy levels will be addressed.

Management of Industrial R&D

The first part of this module will introduce the 3rd generation R&D practice, which is used currently by successful industrial organizations. The strategic role of R&D in innovation, organization issues in R&D, and the evaluation of returns and risks will be presented. The second part of this module will introduce the emerging 4th generation R&D practice, which will augment the current practice in addressing new issues due to discontinuous innovation, increasing importance of tacit knowledge, and the need to embrace knowledge management in R&D.

APPENDIX B

Systems Engineering

Systems engineering is an interdisciplinary approach to realizing the successful creation of systems that meet customer and stakeholder requirements with due consideration of the system's performance and impact over the entire life cycle. The module covers the fundamental methods and concepts of this approach, including those to surface system requirements; architect options and alternatives; model systems; evaluate performance; and analyze tradeoffs.

Systems Architecture

Systems architecture deals with principles of implementation and evaluation of complex systems. Developing architecture is the most abstract function in system/product development. The course examines various notions of systems architecting (including aspects of organizational and information architecture) and offers principles and tools for its development. A wide variety of real-world case studies (including examples of transportation, utility, electronic, mechanical, enterprise, etc.) will be drawn upon. The course addresses issues such as dealing with legacy and change, enterprise-wide interoperability as well as support for knowledge management.

Analyzing High-Tech Opportunities

The aim of this module is to help students identify and analyze entrepreneurial opportunities in high-technology industries through the use of multidisciplinary problem solving in com-

plex systems. After introducing key concepts for doing this in the first five classes, the professor will use these key concepts to describe the history of the five industry sectors/systems. For each sector, students both individually and in teams will use this information and the key concepts to choose and analyze a specific entrepreneurial opportunity. The professor will also provide the students with a list of possible entrepreneurial opportunities that the students are recommended to review before the classes on the specific sector have begun.

User-Centered Engineering & Product Development

The first part covers fundamentals of user-centered engineering, various techniques and tools for obtaining voice of customers, data analyses, utilization of multisource data, and application of these to create decision support tools for product design and implementation of product development roadmaps. The second part covers case studies in different product domains with relevant small projects to familiarize students with the various usability-engineering processes and to reinforce classroom learning. The course aims to provide students with knowledge of user-centered engineering principles and tools and equip them to manage and better leverage user-centered engineering resources in product development.

Technology Intelligence & IP Strategy

The goals of this module are set for learning the fundamentals of strategy in business, technology and IP, as well as the skill training of information/intelligence analysis. This module assigns projects to participants and evaluates their learning outcomes both in knowledge and skill, which include the following: (a) Theory and practice of strategic analysis: strategic planning and business policy, game theory, and co-opetition; (b) Technology competition models: technology life cycle and innovative patterns, innovation models; (c) In-house IP management and strategy: research strategy and patent portfolio, economic analysis of IP disputes, corporate management of IP; and (d) Information search and intelligence analysis: web-based analysis of competitive intelligence and patinformatics.

REFERENCES

Alvear, A., Rueda, G. R., Hernandez, I. P., & Kocaoglu, D. F. 2006. Analysis of the engineering and technology management (ETM) educational programs. ***PICMET 2006: Technology Management for the Global Future,*** 3: 1325–1331.

Atwater, B., Kannan, V. R., & Stephens, A. A. 2008. Cultivating systemic thinking in the next generation of business leaders. ***Academy of Management Learning & Education,*** 7(1): 34–52.

Badawy, M. K. 1998. Technology management education: Alternative models. ***California Management Review,*** 40(4); 94–116.

Chesbrough, H. W. 2003. ***Open innovation.*** Cambridge, MA: Harvard Business School Press.

DeTienne, D. R., & Chandler, G. N. 2004. Opportunity identification and its role in the entrepreneurial classroom: A pedagogical approach and empirical test. ***Academy of Management Learning & Education,*** 3: 242–257.

Hang, C. C. 2007. R&D in science & engineering for Singapore's economic development: Strategies and key results. ***Internal Report No. 1/07, Div. of Eng. & Tech Mgmt,*** National University of Singapore.

Honig, B. 2004. Entrepreneurship education: Toward a model of contingency-based business planning. ***Academy of Management Learning & Education,*** 3(3): 258–273.

Kong, L. 2004. ***Science and education in an Asian tiger.*** Available at www.brightminds.uq.edu.an/TRC/downloads/ScienceEducationAT.pdf.

Mallick, D. N., & Chaudhury, A. 2000. Technology management education in MBA programs: A competitive study of knowledge and skill requirements. ***Journal of Engineering and Technology Management,*** 17(2): 153–173.

METI, 2005. ***A guide to MOT in Japan.*** Japan: Academia-Industry Cooperation Promotion Division, Ministry of Economy, Trade and Industry.

Minden, K., & Wong, P. K. (Eds.). 1996. ***Developing technology managers in the Pacific Rim: Comparative strategies.*** New York: M E Sharpe.

Okutsu, S., Ikawa, Y., & Kameoka, A. 2004. Analysis of Japanese MOT education requirements by a needs-seeds matrix. ***Proc. of IEEE International Engineering Management Conference:*** 248–252.

Wong, P. K., & Singh, A. 2008. From technology adopter to innovator: The dynamics of change in the National System of Innovation in Singapore. In C. Edquist & L. Hommen (Eds.), ***Small economy innovation systems: Comparing globalization, change and policy in Asia and Europe:*** 71–112. Elgar.

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