CHAPTER

Best Practices in Knowledge Transfer

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INTRODUCTION

The United States operates as an innovation system — a loosely coupled interaction among universities, industry and government that generates new knowledge and technologies through basic research, primarily in universities, and educates young men and women to take such knowledge and technologies and move them into the marketplace as new products, processes or services. The core of this system derives from the report, *Science, the Endless Frontier*, issued at the end of World War II (Bush, 1945). The Bush Model made public and private research universities the primary research infrastructure of the nation. By funding university research projects, selected on the basis of merit review, the government's money does double duty: it procures new knowledge and it educates the next generation of researchers, engineers, doctors and business leaders.

MIT, as we know it today, epitomizes this approach and shows that over time, it can be very effective. In 1997, a report by the economics department of BankBoston, *MIT: The Impact of Innovation* (MIT, 1997) determined that there were over 4,000 extant companies founded or co-founded by MIT graduates or faculty, employing 1.1 million people worldwide, and receiving annual sales of $232 billion. MIT has also contributed to education beyond its own campus in two primary ways. First, educational knowledge and information have been transferred through the work of men and women who earned their doctoral degrees at MIT and then joined universities around the world as faculty members, taking with them MIT course notes, pedagogical approaches and the integration of research and teaching, all of which they modified, adopted and expanded to fit their own teaching contexts and objectives. Second, educational knowledge and pedagogy were promulgated through numerous textbooks.

But today the world expects a much faster pace, more goal-oriented research and education, better understood pathways to economic advancement, and recognition of the globalization of just about everything. Things are not only faster, they are more complex as boundaries between traditional disciplines must be penetrated or eliminated, and as the distinction between basic and applied research is frequently fuzzy or non-existent.

Establishing policies and mechanisms to meet these changing objectives is complicated because the stakeholders have varied objectives. Simply put, young people are usually attracted to science and engineering through curiosity, awe of nature, and excitement about fundamental unknowns; researchers advance their fields through fire in the belly and obsessive concentration on challenging puzzles; legislators believe that tax dollars for universities should produce jobs; and companies want faster and faster innovation that directly drives profits.

All of these considerations suggest that at minimum we must experiment with new models of knowledge transfer (and production). Yet we must do so with care, because the fact remains that the model derived from the Bush report has had astounding success, driving more than 50% of U.S. economic growth during the past 60 years.

The following sections are brief outlines of three large experiments in new modes of knowledge transfer involving MIT. The first, Knowledge Integration Communities developed by the Cambridge-MIT Institute, is intended to positively influence the competitiveness of an entire nation. The second, the DuPont-MIT Alliance, is intended to both advance science and technology and to create strong synergy between MIT and individual science-driven corporations. The third, MIT OpenCourseWare, is an initiative to promulgate educational materials and knowledge rapidly, freely and openly using the power of the internet and World Wide Web.

THE CAMBRIDGE-MIT INSTITUTE AND KNOWLEDGE INTEGRATION COMMUNITIES

The Cambridge-MIT Institute (CMI), an alliance of Cambridge University and MIT, is a bold and unique initiative funded by the U.K. government, initially for six years. The mission of CMI is to enhance the competitiveness, productivity, and entrepreneurship of the U.K. It is to do so by improving the effectiveness of knowledge exchange between universities and industry; educating leaders; creating new ideas; developing programmes for change in universities, industry and government; and building networks of participants beyond the two universities.

I note parenthetically that CMI has preferred the term knowledge *exchange* to knowledge *transfer*, because the latter connotes a one-directional handoff rather than a two-way exchange.

One explicit goal of CMI is to study the innovation process in a broad national context. Indeed, as part of CMI's work, Crawley and Greenwald (2004) have recently proposed a framework for national science, technology and innovation, based upon CMI experience, and especially on disciplined interviews of leaders in government, industry and universities on both sides of the Atlantic. Their national knowledge system consists of pathways through four stages: Discovery, Development, Deployment and Delivery.

To understand the motivation for forming Knowledge Integration Communities for CMI research projects, it is useful to draw on one of Crawley and Greenwald's observations: as products or services move from the deployment to the delivery stage, traditional economic market forces are in play and bring strong feedback and efficiency to the process. On the other hand, the movement of ideas from Discovery to Development usually has no market forces to bring either feedback or efficiency to the process. Presumably this process will always be inefficient; however, in the spirit of *Pasteur's Quadrant*, useful feedback can be had, and some efficiency improvement can be gained. The formation of Knowledge Integration Communities (KICs) for CMI research projects is an attempt to enhance feedback and efficiency — and to do so in a manner that elicits enthusiasm among the academic researchers who do the creative work. In other words, CMI research is intended to generate fundamental new ideas which can be developed with a consideration of use and an eye toward needs of industry.

Enhancing the effectiveness of knowledge exchange is the primary driving force in the CMI model. Knowledge exchange should link Research, Education and Industry, and CMI is positioned as a common platform for this exchange. The exchange occurs through Knowledge Integration in *Research*, through *Education* for innovation and leadership, and through engagement of *Industry*. As spelled out in detail by Acworth and Ghose (2004), KICs are the primary mechanism for knowledge exchange among stakeholders during the conception and execution of CMI research projects.

The stakeholders who comprise a KIC typically include academic researchers, industry participants from large and small companies, government policymakers, special interest groups such as regional development authorities, and educators from a variety of institutions who come together to pursue a common science, technology and social end goal. Although this broad involvement runs counter to many academic instincts, it appears to be working rather well because considerable thought and effort have been put into the process and because the concept itself arose out of careful discussion and iterative planning among the stakeholders.

CMI research projects are intended to discover knowledge and create technologies that have a potential for developing or advancing important, science- and technology-based industries. It is instructive to note that the current CMI KICs are Silent Aircraft (strategies and technologies to dramatically reduce noise beyond airports); Next Generation Drug Discovery (eliminating bottlenecks in drug discovery); Pervasive Computing (human-centred computing and the U.K. role in developing this emerging technology); Communications Innovation (developing roadmaps for U.K. global communications industries in collaboration with B.T.); Competitiveness and Education (a centre for executive education, benchmarking and assessment); and Quantum Computing (developing future computing and encryption technologies). These are "hot", exciting topics that provide excellent platforms for serious academic research.

A typical set of KIC participants are those in the Silent Aircraft Initiative in which representatives of Rolls Royce, British Airways, the British Airports Authority and regional airport operators join university researchers. The research component of a typical KIC is comprised of 4 to 6 individual research projects. The governing philosophy is to fund a modest number of large, interrelated projects, rather than a large number of small, unconnected ones. Actual research proposals are solicited from faculty of Cambridge and MIT by publishing broad themes suggested by the KIC. Specific ideas to be pursued are therefore developed by the researchers and are peer reviewed. Each KIC has a designated manager who maintains the multiple relationships and communication. The work of each KIC is formally reviewed every six months.

CMI's Knowledge Integration Communities are works in progress. More years of experience will be required to rigorously evaluate their effectiveness. Indeed, the hope and intent are that KICs develop into long-term, self-sustaining activities.

Louis Pasteur famously observed: "Chance favours the prepared mind." I consider that the goal of Knowledge Integration Communities is to support excellent fundamental research, but also to create a collective prepared mind of multiple stakeholders.

THE DUPONT-MIT ALLIANCE

The DuPont-MIT Alliance (DMA) similarly creates a collective prepared mind, but it is a more focused relationship and mechanism for knowledge transfer/exchange between MIT and a single corporation. It builds on strengths of both organizations and has established a strong synergy associated with fundamental strategic goals of DuPont and MIT at this point in time.

DuPont is a 200-year-old company with world-class R & D capabilities in areas such as polymer chemistry and engineering. It has had three distinct periods over its long history. In its first century, DuPont was focused on explosives. In its second century, it became a global company based on chemicals, energy and materials. As it has entered its third century, its strategy is to become a dynamic, science-based company that, as noted in the DuPont Vision Statement (2005), creates "sustainable solutions essential to a safer, healthier life for people everywhere".

DuPont has a specific interest in developing bio-based materials that can be produced with small environmental footprints. This interest is at the core of the first five years of DMA. MIT wants to do world-class interdisciplinary research in this area that has strong scientific and technological content, to advance both research and education, and to encourage industry development of our technologies, and value informed industrial input and feedback to much of our research. DMA is an experiment for both partners, and, to date, both partners regard it as a success. Of course, it has evolved and improved over time, and will continue to do so. What follows are some of the details that those involved think has made this a successful partnership and mechanism for knowledge transfer/exchange.

DMA supports research and education that is proposed *bottom up* by MIT faculty within broad thematic boundaries set by the sponsor. DuPont is engaged in both the evaluation of proposals and informs the conduct of the research through continuous, professional dialogue. In addition to funding research projects, DMA includes a Fellows Program and supports a variety of courses, workshops and tutorials at both DuPont and MIT.

During its first five years, DMA has supported 33 research projects, of which 19 are currently active. These have engaged 58 MIT faculty across 15 academic departments and centres. Projects have been fundamental, long-range and pre-competitive, but of clear interest to DuPont. White papers, 3 to 5 pages long, including skeletal budgets were solicited from the entire MIT faculty. Approximately 25% of the projects described in these white papers have been selected, based on quality and relevance to the DMA mission, and their authors were encouraged to submit full proposals. Approximately 85% of these proposals were funded after a rigorous review by faculty colleagues and, independently, by leading DuPont researchers. Large, multi-investigator, highly structured projects have flourished, along with smaller, more speculative, single-investigator seed grants. At the current time there are 58 graduate students and post-doctoral researchers. Agreements regarding intellectual property are favourable from DuPont's perspective, but are well within the bounds of MIT's normal policies.

A sense of the intellectual breadth and depth of DMA can be gained by considering some typical projects:

- Next-generation advances in metabolic engineering, including genome-wide analysis and modelling for the production of chemicals and intermediates from renewable bio-feedstocks;

- Early-stage research to develop a novel biopolymer-based nervous system implant that could replace non-functional brain tissue following traumatic brain injury;
- Development of a device for tissue-like culturing of liver cells, designed to provide early assessment of the toxicity of new pharmaceuticals; and
- Creation of a material inspired by the naturally water-repellent surface of the lotus leaf, with potential applications like self-cleaning fabrics and bacteria-resistant plumbing.

DMA also has a strong educational mission; indeed, a major sum is invested annually in education programmes in bio-based materials. These range from a one-day short course on biotechnology for senior DuPont executives, including the CEO, to a number of two-day short courses for engineers and managers, a lecture series, and several 2- to 3-hour tutorials on specialized topics.

DMA supports fellowships for first-year MIT graduate students. To date there have been 112 DMA Fellows. In addition to engagement with DMA projects and faculty, there is an annual Fellows visit to key DuPont research facilities. Needless to say, the Fellows programme is highly valued by MIT students and faculty, and creates a wealth of contact with DuPont.

Over time, increasing trust has been built, and through the ongoing work of the research teams and their interaction with their DuPont liaisons, DMA has become more tightly aligned with DuPont's business strategies and interests. But this has occurred in a transparent and academically acceptable manner. DMA will move forward with somewhat more clearly defined goals.

There are many characteristics of this alliance that have led to its general success as an innovative mechanism for knowledge transfer. DMA has critical mass, a good balance of academic goals and intellectual flexibility with business interests, and a continual flow of information and professional interaction. Education is recognized and supported. Perhaps the most important glue for this effort, however, is the trust developed by serious and continual engagement of first-rate engineers and scientists from the sponsor with the faculty and students.

MIT OPENCOURSEWARE

My final example of knowledge transfer, drawn from Vest (2005), concerns sharing educational materials through MIT's OpenCourseWare initiative. In 2002, with generous financial support from the Mellon and Hewlett Foundations, MIT pledged to make available on the web, free of charge to teachers and learners everywhere, the substantially complete teaching materials from virtually all of the approximately 2,000 subjects taught on the

MIT campus. For most subjects, these materials include a syllabus, course calendar, well-formatted and detailed lecture notes, exams, problem sets and solutions, lab and project plans, and, in a few cases, video lectures. The materials have been cleared for third-party intellectual property and are available to users under a creative commons license so that they can be used, distributed and modified for non-commercial purposes. This is a new, open form of publication and knowledge transfer. It is neither teaching nor the offering of courses or degrees. It is an exercise in openness, a catalyst for change and an adventure.

It is an adventure because it is a free-flowing, empowering and potentially democratizing force, so we do not know in advance the uses to which it will be put. Currently, materials for 1,100 courses are mounted. The OCW site — which typically has 20,000 unique visits per day — has 43% of its traffic from North America, 20% from East Asia, 16% from Western Europe, and the remaining 20% of the users are distributed across Latin America, Eastern Europe, the Middle East, the Pacific Region, and Sub-Saharan Africa. International usage is growing rapidly. Roughly 15% of OCW users are educators, and almost half of their usage is directly for course and curriculum development. One third are students complementing a subject they are taking at another college or university, or simply expanding their personal knowledge. Almost half are self-learners.

An Arizona high school teacher motivates and supervises group study of MIT OCW computer science materials within his after-school artificial intelligence club. A group of then-unemployed programmers in Silicon Valley used MIT OCW materials to master advanced computer languages, upgrading their skills when the job market became very tight. An educator at Al-Mansour University College in Baghdad is utilizing MIT OCW Aeronautics and Astronautics course material in his air traffic control research. The computer science department of a university in Legon, Ghana, is updating its entire curriculum and is using MIT OCW materials to help benchmark and revise their courses. An underground university based largely on MIT OCW educates young men and women who, because of their religion, are forbidden to attend one country's universities. Heavy use is made of OCW by almost 70% of the students on our own MIT campus to review courses they have taken in the past, to reinforce the classes they are currently taking and to explore other areas of study.

OpenCourseWare seems counter-intuitive in a market-driven world, but it represents the intellectual generosity that faculties of great American universities have demonstrated in many ways over the years. In an innovative way, it expresses a belief that education can be advanced around the world by constantly widening access to information and pedagogical organization and by inspiring others to participate.

MIT OCW is starting to catalyse other participants in a movement to deploy and use well organized open course materials. Universia, a network of 840 universities in Spain, Portugal and Latin America has translated into Spanish the materials from almost 100 MIT OCW courses and made them available on their website. The People's Republic of China has established CORE (China Open Resources for Education), a network of 100 universities with more than 10 million users. CORE's goal is to enhance the quality of higher education in China by translating MIT OCW and other course materials into Chinese, and also by sharing Chinese courses globally. Rai University in India has established a very substantial activity called Rai Courseware. Japan and France have OCW efforts underway.

In the U.S., the University of Michigan, Utah State University, the Johns Hopkins University School of Public Health and Tufts University's Health Sciences and Fletcher School of Diplomacy all have established OCW efforts. Here I use the term OCW to denote substantial, comprehensive, carefully managed, easily accessed, searchable, web-based collections of teaching materials for entire courses presented in a common format.

In this emerging open course ware movement, it is not only the teaching materials that are shared. We have also implemented and actively encouraged the sharing with other institutions of software, "know how" and other tools developed by MIT OCW.

Day-to-day communication and data transfer among scholars and researchers are now totally dominated by internet communications. Large, accessible scholarly archives like JSTOR and ARTSTOR are growing and heavily subscribed. There is an enormous potential impact of Google's new programme to provide free access to the content of several of the most important university libraries in the U.S. and the U.K. The use of OpenCourseWare is developing in the U.S., Asia and Europe. I believe that openness and sharing of intellectual resources and teaching materials — not closely controlled point-to-point distance education — are the most important emerging ethos of global higher education.

In my view, a global *Meta University* is arising that will accurately characterize higher education globally a decade or two hence. Like the computer operating system Linux, knowledge creation and teaching at each university will be elevated by the efforts of a multitude of individuals and groups all over the world. It will rapidly adapt to the changing learning styles of students who have grown up in a computationally rich environment. The biggest potential winners are in developing nations.

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