University Collaboration for Innovation

Lessons from the Cambridge-MIT Institute

David Good, Suzanne Greenwald, Roy Cox and Megan Goldman (Eds.)
GLOBAL PERSPECTIVES ON HIGHER EDUCATION

Volume 4

Higher education worldwide is in a period of transition, affected by globalization, the advent of mass access, changing relationships between the university and the state, and the new technologies, among others. Global Perspectives on Higher Education provides cogent analysis and comparative perspectives on these and other central issues affecting postsecondary education worldwide.

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University Collaboration for Innovation
Lessons from the Cambridge-MIT Institute

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About the Authors
This book describes and explores an experiment: an experiment rooted in two countries, the USA and the UK, and in two universities, Massachusetts Institute of Technology and Cambridge University, but whose reach is global. The lessons that can be learned from the experiment have value for all governments, all research bodies and all institutions of higher education world-wide.

The idea for the experiment sprang from the UK Chancellor of the Exchequer’s concern that UK industry did not appear to work as closely with universities as one would wish, and this, in turn, affected the level of success of UK competitiveness, entrepreneurship and productivity. As a result, the Cambridge-MIT Institute (CMI) was established in 2000: a partnership between one of the US’s leading institutions, famous for fostering entrepreneurial attitudes and links with industry over many years, and Cambridge, renowned for its teaching methods and research. Each might contribute new insights into how students become innovative thinkers and entrepreneurs, how knowledge might be integrated into research, and how industry and universities might most effectively engage with each other.

The work with students, which is explored in a number of chapters in the book, applies the most recent findings of educational research to illuminate our understanding of how best to ‘grow’ people who will perceive the world through an innovative and entrepreneurial lens throughout their adulthood. A key chapter explores the concept of self-efficacy. Charles Vest, the former President of MIT, speaking at a meeting of the Foundation for Science and Technology in July, 2005 summed it up succinctly:

We need to instil in our students a sense of self-efficacy, that is, students need to learn that they can make a difference. They need to believe that they can make things happen…They need to understand that they do not need to fit into a preconceived mould, and that they should be prepared to take risks.

Those who learn self-efficacy can think ‘out of the box,’ think internationally and globally, and maintain a sense of excitement in moving into new fields of endeavour. The exchanges of undergraduate students between the two institutions throughout the six years of CMI has brought new understandings of how the methods, processes and shape of the curricula affect those who move through them.

Another area where recent educational research findings have been applied in the Cambridge/MIT context is considered in the chapter on Threshold Concepts. A student can only move forward in his or her understanding of a subject when he or she has crossed the ‘threshold’ of a particular idea which opens up new perceptions. This makes fascinating reading: our understanding is enhanced of
how people learn, and how important is the grasping of ‘key intellectual concepts’ in studying virtually any discipline. The ability of teachers to recognize the key threshold concepts within their own discipline, and hence take special care in teaching them, is emphasized and illustrated.

The book also explores exactly how knowledge has been integrated successfully into research. This aspect of CMI alone can arguably be seen as validating the experiment. The value of networks can hardly be underestimated. CMI established ‘Knowledge Integration Communities’ (KICs) which bring together a range of stakeholders—regional development agencies, government policy makers, communications agencies, members drawn from large and small companies, and academic researchers and lecturers. These communities work together from the inception of a research project, through to its finalization, implementation and dissemination. Undergraduate students can be involved, and this has proved a stimulating insight for them into the world of research thinking. All the research programmes established by CMI make use of knowledge integration communities: the benefits for all parties are considerable.

This book, then, charts the outcomes of a strategic alliance of two major international universities, established by the UK Government in light of the need to enhance the entrepreneurship, competitiveness and productivity of the UK. Its findings are valuable, particularly in the insights it gives us into how a student can be encouraged to think in an innovative manner, and how industry and acade

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SECTION 1. THE POLICY AND PRACTICE OF INSTITUTIONAL CHANGE
INTRODUCTION

A happy confluence of factors led to Britain being the birthplace of the Industrial Revolution and the economic success story of the 18th and 19th centuries. These factors included, inter alia, advanced financial institutions, technological innovators, a liberal economic environment, significant natural supplies of coal and iron, and an advantageous geographical position as a maritime nation. Its success was exceptional when one considers the size of its landmass and population. Such early pre-eminence ensured, however, that comparative economic decline was inevitable. If you start at the top, the only way is down, and Britain’s economic performance compared to other industrialising nations has been the subject of concern for politicians and policy makers since at least the 1880’s (Kennedy 1987; Crafts 1997; Uglow 2002). In the period since, the reasons to be fearful unfortunately only increased, especially since 1945, as the UK has watched its growth rates and productivity gains lag behind those of most of its economic competitors for most of the time. These concerns were further accentuated in the closing decades of the Twentieth Century when the competitive pressure on companies and nations of the older industrialised economies was intensified by the rapid growth of the developing and transitional economies of Asia.

While the growth of the industrialised economies has been dependent on scientific discovery and innovation on a historically unprecedented scale, the paradox for Britain has been that throughout this long period in which its economy was initially matched and then superseded by others, its scientific achievements have continued on a scale which has been out of all proportion in comparison to the funding committed to research and the number of people involved. The importance of the connection between discovery and innovation on the one hand, and economic prosperity on the other has also been an enduring obsession in the UK.

Queen Victoria’s husband, Prince Albert, was President of the Royal Commission for the Great Exhibition of 1851 and had a keen interest in the relationship between Science, Art, and Commerce where the term “Art” was taken to naturally include the Arts of Manufacture. Subsequent to the exhibition, he supported the allocation of land in South Kensington and proceeds from the exhibition to support various Schools and Institutes whose purpose was to be the discovery of commercially valuable knowledge and practices (Weintraub, 1997). This area, often known as Albertopolis, includes amongst others the modern day Imperial College, the Royal College of Art, and the Victoria and Albert Museum who continue this mission to this day. Prince Albert also had a similar impact on the University of Cambridge.
after he became Chancellor in 1847, introducing many reforms which led ultimately to key developments in many scientific and mathematical subjects, and ultimately the introduction of research and education in engineering (Brooke, Leader et al., 1988; Leedham-Green, 1996).

These initiatives paralleled developments in many other industrialised countries at the time, and each development was a spur for the others in a way which is redolent of contemporary policy concerns over science innovation and economic growth. In the founding documents of the Massachusetts Institute of Technology (MIT), explicit reference was made by its founder, William Barton Rogers, to newly founded institutions elsewhere, making explicit reference to the developments in South Kensington (Rogers, 1861). He argued that what New England needed if it was to maintain its industrial success was an “Institute of Technology which would form itself into a department of investigation and publication intended to promote research in connection with industrial science” (ibid p6). The education it would offer would “become indispensable to fit us for competition with other nations in the race of industrial activity” (ibid., p. 21).

Despite these early recommendations and actions, we find Alfred Marshall bemoaning just after the First World War that German industry was far nimbler in exploiting British discoveries than British industry (Marshall 1919). The story remains the same throughout much of the twentieth century with many politicians seeing science and technology as the way to revive British economic fortunes, and looking approvingly at the impact of US Universities on the US economy. Winston Churchill, having witnessed the mobilisation of US science and industry during World War II, was particularly impressed with MIT and he hoped a UK version could be established. Churchill College, Cambridge which was founded in 1958 in honour of him reflects this in its statutes which specify that the great majority of the student body should study science and technology. This view was shared across the political spectrum with Harold Wilson, the leader of the 1964-70 Labour Government, proclaiming that he would reinvigorate the UK economy in a white-hot technological revolution in which UK industry would benefit from the successes of UK science.

The one exception to this trend was the Conservative Government which was in power from 1979-97. In the period 1980-95, it implemented a considerable cutback in science funding although the impact on overall R&D funding was lessened as UK scientists sought alternative sources of funding, and subsequently the new Government elected in 1997 reversed those cutbacks and doubled the budget of the UK Office of Science and Technology between 1997 and 2005 (King 2004). In common with Winston Churchill, the UK Chancellor of the Exchequer, Gordon Brown, was particularly impressed by the role of MIT. As a result of an initiative from him in the context of the 1998 Competitiveness White Paper, the Cambridge MIT Institute (CMI) came into being on July 1st 2000.

MIT has a widespread reputation in the USA for being a major research partner for numerous government projects and industrial conglomerates. From its foundation in 1861, it was dedicated to the discovery of useful knowledge. In World War II, the impact of its erstwhile Dean of Engineering and Vice President Vannevar, Bush on mobilising science in pursuit of the war effort and his subsequent articulation of what US Government science policy should be after the
war is legendary (Zachary 1999). In the 1980’s, this leadership role was extended at a time of extensive self-doubt in the US manufacturing sector by MIT’s conduct of a number of important industry studies (Dertouzos, Lester et al. 1989). The summary account of that overall effect is to be found in the 1997 Bank Boston Report entitled “MIT: The Impact of Innovation”. As that report notes at its outset, “if the companies founded by MIT graduates and faculty formed an independent nation, the revenues produced by the companies would make that nation the 24th largest economy in the world. The 4,000 MIT-related companies employ 1.1 million people and have annual world sales of $232 billion. That is roughly equal to a gross domestic product of $116 billion, which is a little less than the GDP of South Africa and more than the GDP of Thailand.” (p4) All of this is achieved by a steady population of just under a thousand faculty members, an undergraduate population of just over four thousand, and a graduate one of just over six thousand. One can see why these data would attract attention, and while Cambridge University has not been studied in the same way, it is clear that the City and the region have benefited enormously from businesses and innovations deriving from the University. (Segal Quince Wicksteed. 1985; Segal Quince Wicksteed. 2000)

As the proposal document on which it was founded stated: “The Cambridge-MIT Institute (CMI) is a new form of academic enterprise, bringing together two of the world’s great universities, that builds on the complementary strengths of each institution. CMI will undertake ambitious programmes which will cover education, research and outreach. The aims of the programmes are to effect cultural change in both institutions, to improve the effectiveness of university industry interactions, and to improve entrepreneurship, productivity and competitiveness in the UK economy.” In other words, it addressed the three strands of activity which are to be found in a university with the novelty lying in the fact that Cambridge and MIT were to do this intensively with just one another, even though there were over three thousand miles of ocean between them.

The idea of international university collaboration is not new, and there are a wide range of international university networks and collaborative fora. The difference in this case was that the two partners were expected to do it intensively on the basis of public funding with an expressed national economic goal in view. The proposal document further stated, emphasising the economic purpose behind the endeavour, that “the primary goal of CMI, agreed with the Chancellor of the Exchequer, is to undertake joint educational and research initiatives that will improve entrepreneurship, productivity and competitiveness in the UK.”

IMPLEMENTATION AND HYPOTHESIS TESTING

CMI was an important and innovative policy initiative by the UK Government. Its specific focus on this one partnership meant that it had a very different character to most if not all policy initiatives in this domain. The goals were comparatively clear, as was the mechanism by which they were to be addressed, but there was little by way of previous evidence as to how that mechanism should be operated, nor what its actual effects would be. It was, in many respects, a test of the
hypothesis that one could bring something of MIT’s effect on the US economy to the UK via a partnership between Cambridge and MIT. The process of implementing this policy would necessarily have more of the character of a research and development exercise than the roll-out of a preordained implementation plan.

The goals set for CMI in this R&D project were also challenging. This new form of academic enterprise not only had to effect cultural change in two successful institutions with a joint life span of over 900 years between them, but also had to improve university-industry relations, as well as entrepreneurship, productivity and competitiveness in the UK economy. It also should be noted that by 2000, the UK Higher Education system had had nearly twenty years of changes to its funding levels and structures, the introduction of various audit and assessment regimes which were themselves the subject of constant change, and a massive increase in student numbers at those higher education institutions established before 1992, and at numerous new ones which had been granted their own degree awarding powers in that year. As the OECD thematic review of tertiary education noted in 1997, “With the possible exception of New Zealand, in none of the countries taking part in this review have changes in higher education policy and structure been greater and the debate more intense than in the United Kingdom” (p6). It was a system in flux.

The budget available for this, £65.1m from public funds, was substantial when compared to normal university funding arrangements from public sources. However, when spread out over the six year period of the programme, it amounted to significantly under 1% of the joint income of CU and MIT per annum, and the funds were to cover four programmes: one on undergraduate education, one on professional practice, one on research, and one designed to network UK institutions with similar missions for their own locality. Consequently, the challenge to the CMI education programmes was to find a way of targeting the part of that funding available to them so as to make a contribution to all these diverse goals by building on the strengths of both Cambridge and MIT while leaving a secure and relevant research basis for any further initiatives or developments in the future.

At the outset, it seemed apparent that the way in which an institution’s educational programmes make an impact on the wider society and its economy is through the development of its students as human capital. The idea of human capital as a parallel to physical capital has many antecedents, but it owes its popularity in economics to Becker’s work (Becker, 1964), and related ideas in sociology owe much to Bourdieu (Bourdieu & Passeron. 1977). While there is much debate about what the concept should or should not include, and how its component parts can be measured, one might identify three components of an individual’s capacities on which a university education might plausibly be thought to have an impact. First, there is the knowledge the student acquires; second, the development of his/her capacity to lead and create; and third, the social networks each student becomes part of or can subsequently access and his/her capacity to operate as a trusting and trusted agent within them. The specific institution the student attends and the course of study taken may further enhance or diminish the value of these components.
While the development of the first of these may be investigated by examining the curriculum which has been offered, it was clear that this would not give much insight into the other two, nor would it give insight into how the culture and pedagogic practices of a University contribute to the other two. Consequently, it was important for CMI to initiate several lines of enquiry into these characteristics of the two Universities. The greater part of this book considers the substance of this work, and the lessons to be drawn for future interventions and investigations.

Choosing Interventions

Universities’ educational programmes are an open book. Apart from the usual constraints of libel and good taste, no one is restricted from reporting on their experiences, and the wealth of first hand accounts of them is testimony to this. They are also the subject of many works of fiction which vary greatly in their correspondence to reality. Given this context, it is surprising to discover that little of the extensive research on higher education pays much attention to the student’s experience and perspective. At the outset, CMI had as part of its intended activities a resource for investigating student views and related views from the faculty, which provided an important source of information to guide its interventions. This was the plan to have a student exchange programme between the two institutions.

Students moving between institutions for the purposes of study is hardly a novel idea, especially if one remembers the peripatetic lifestyle of the medieval student or scholar in Europe. However, both Cambridge and MIT were unusual when compared to most other universities in having very little provision for students to work away from their home institution. At Cambridge, this historic reluctance to set up such programmes reflected a firmly held view that the specific course content was only part of the education which either institution offered. In Cambridge, this is formalised in the requirement that students must keep a certain number of terms i.e. be in residence for a certain period of time before they are deemed to be qualified for a degree, and a similar view prevails at MIT. vii It was also based on factors which provided two important design constraints for the establishment of the Cambridge-MIT Exchange programme (CME) when combined with a third constraint which was a CMI requirement.

The first two constraints were that students should not be delayed in their time to graduation; and that the work they do when away from their home institution should leave them in a position to do at least as well on their return as they would have done if they had not gone away. viii The third constraint was that the student’s time spent working in the other university’s degree programme should be sandwiched in between time in their home institution. The reasoning behind this was that in the first year of the degree, students need to adjust to their new circumstances and develop their working practices, and in the final year, they are taking a key part of their education which is the capstone to the course as a whole and fundamental in delivering the distinctive part of the Cambridge or MIT experience. It was also recognised that a cohort of students who returned from a
year away would bring back with them new ideas and attitudes in relation to their
degree course, and this could be an important stimulus for change.

The result of these constraints produced a very specific kind of exchange
programme. In its ideal form it was a literal exchange of students, like for like,
between the two Universities. For example, if a third year mechanical engineering
student from Fitzwilliam College at Cambridge went to MIT for a year, then he or
she would be replaced in Fitzwilliam by a third year mechanical engineering
student from MIT. Short stay exchanges between the two were contemplated and
explored, but the conclusion was that unless a student had a full year in the new
environment, it was too hard to profit from his/her time away. They would invest
as much time and energy in acclimatising as students on a full year exchange, but
would then have very little time to profit from that investment. While at the other
institution, each student would take a set of courses which were agreed upon by
members of both the sending and receiving departments as sufficient for allowing
the student to make good academic progress on his or her return in the following
year. The faculty involved in this course specification process also played a role in
selecting the students to take part, and in monitoring and supporting their progress
during the year.

This process of course comparison and close student support enabled both the
Faculty involved and the CMI team to learn much about the instructor’s view of
the courses and pedagogies, and CMI continued to learn from them through
subsequent workshops where exchange coordinators from all subjects and both
universities met to discuss their work. This was very helpful in guiding our choice
of interventions, but another major resource for learning about the two systems
which the exchange programme offered was the students themselves. In having
two groups of intelligent, highly motivated students moving from one system to the
other, there was an opportunity to test the impact on them and garner their accounts
of their experiences. While CMI team members and Cambridge and MIT faculty
spent much time listening to and learning from the exchange students views, an
external group of evaluators was also appointed to conduct a more systematic and
independent investigation. This group provided many important insights, and
initiated many other investigations and initiatives.

Thus our work on those elements of human capital to do with personal qualities
and the use of specific areas of knowledge and expertise to achieve CMI’s goals
was developed. Choices as to which areas of research should be the focus of new
curricular development were guided by both the research investments CMI was
making, and by the views of industry stakeholders and academic partners. The
CMI research agenda was particularly important in this as it was strongly oriented
to what Stokes has called Pasteur’s Quadrant (Stokes 1997) and which is simply
illustrated in the table below.
UK HIGHER EDUCATION LANDSCAPE & THE CAMBRIDGE-MIT INITIATIVE

Table 1: Pasteur’s Quadrant

<table>
<thead>
<tr>
<th>Quest for fundamental understanding</th>
<th>No</th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consideration of use</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>Edison</td>
<td>Pasteur</td>
</tr>
<tr>
<td>No</td>
<td></td>
<td>Bohr</td>
</tr>
</tbody>
</table>

As Stokes argued, while some may be just interested in an effective solution to a problem e.g. Edison, and others may be interested in the quest for fundamental understanding e.g. Bohr, there has always been an important intersection of these two ambitions e.g. Pasteur. None of this is to say, of course, that effective solutions may not be important in advancing knowledge. Indeed many technical solutions may lead to important advances as the science catches up with the application. Equally, scientific developments and advances may be pursued for purely theoretical reasons and can appear to have no potential application, and yet prove to be extremely important later. However, as Stokes argued, there is a class of problem that has both theoretical and practical significance and university research has become skewed away from considerations of use with an elevation in the status of pure research over applied.

A constant theme which emerged in consultations about which subject areas to support was the importance of interdisciplinarity. Key new developments happen at the interface between longstanding and well-identified areas of work. In the context of any single subject, there is an unsurprising emphasis on ensuring that students acquire sufficient depth of understanding of the existing knowledge of the subject as well as its analytical techniques, mathematical models and methods of enquiry. Given the explosion of the research literature in many key technological subjects over the past two decades, even if it were possible, it is no longer a viable option to teach a subject by teaching all of it. It is even less likely, therefore, that one can teach an interdisciplinary area by teaching both sides of a disciplinary divide in the confines of a three or four year degree.

No matter what knowledge and expertise is acquired by a student in the course of a degree, much of it will be superseded during his or her working life. It therefore becomes imperative that the education provided to a student if he or she is to remain at the forefront of his or her area of work should enable life-long learning and further intellectual and personal development in the years and decades after graduation to take place. Thus both the subject matter and the pedagogies used must focus the student on achieving the conceptual depth and understanding...
which will enable further intellectual development. Achieving this is far from
simple (Barnett & Ceci, 2002).

The net result of these various enquiries and consultations was that CMI created
a programme of intervention and evaluation which is referred to as “Education for
Innovation”.

EDUCATION FOR INNOVATION

CMI’s educational goal was to develop programmes and practices that would
enhance the capacity of graduates to work more effectively than their predecessors
at the University-Industry interface. In essence, the goal was to enable them to
become the creative leaders and innovators in the economy. A central part of the
overall CMI strategy has been to focus on those points of intersection of interest
between Industry and Research, Industry and Education, Education and Research
and Industry, Research and Education.

In the UK context, funding to support research, education and outreach comes
from central government under three separate headings, and there is
encouragement to institutions to work across these divides. Making university
courses more attentive to the needs of the industries and institutions which employ
most students upon graduation might undermine historic academic values. This
view is not to be dismissed lightly. It is therefore of some significance that CMI’s
position is a reaffirmation of the importance of key traditional academic values.

Each project, under the heading of “Education for Innovation,” addresses three
separate sub-headings: conceptual depth, transferable skills and personal
development.

Conceptual Depth

What constitutes conceptual depth is always a difficult issue, and it is often easier
to define its absence than its presence. Benjamin Bloom made an early and
important attempt at defining depth (Bloom, 1956; Krathwohl & Bloom, 1964). In
recent years, this has been further refined and developed in the work of Anderson
and others (Anderson, Krathwohl et al., 2001). The following provides their
account of conceptual depth beginning with the simplest and most shallow.
Table 2: Levels of Conceptual Depth

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remembering</td>
<td>Recalling information, recognising, listing, describing, retrieving, naming, finding</td>
</tr>
<tr>
<td>Understanding</td>
<td>Explaining ideas or concepts, interpreting, summarising, paraphrasing, classifying, explaining</td>
</tr>
<tr>
<td>Applying</td>
<td>Using information in another familiar situation, implementing, carrying out, using, executing</td>
</tr>
<tr>
<td>Analysing</td>
<td>Breaking information into parts to explore understandings &amp; relationships. Comparing, organising, deconstructing, interrogating, finding.</td>
</tr>
<tr>
<td>Evaluating</td>
<td>Justifying a decision or course of action checking, hypothesising, critiquing, experimenting, judging</td>
</tr>
<tr>
<td>Creating</td>
<td>Generating new ideas, products, or ways of viewing things, designing, constructing, planning, producing, inventing.</td>
</tr>
</tbody>
</table>

None of the terms used in a taxonomy such as this are unproblematic. All have multiple uses in everyday language and there is great potential for disagreement over their meaning. However, there will probably be little disagreement over the endpoints. Indeed the deepest level is evocative of the demand placed on Ph.D. examiners by universities that a candidate’s dissertation should make a contribution to knowledge. It is also interesting to note from the point of view of the CMI work that Anderson and his colleagues propose a distinction between applying existing ideas and formulating new ones or new products. From the point of view of educating the innovator, this emphasises the importance of conceptual depth, and the distinction between the routine application of accepted scientific ideas, and the generation of novel and innovative solutions.

Transferable Skills

Modern-day innovations are rarely the result of the lone inventor. Interaction within a group is essential. Much innovative work takes place at the boundaries between conventional disciplines, and the exploitation of innovation requires a further level of boundary crossing between research and innovation on the one hand, and management and finance on the other. For this to be possible, individuals need not only an in-depth understanding of their subject, but the capacity to articulate it in a way which is intelligible to a colleague. Furthermore, they must be able to appreciate and understand the contributions of others which derive from areas of expertise foreign to themselves. These communicative skills are highly valuable and are difficult to acquire. They are developed through a wide variety of activities within the university, both formal and informal. Those activities which
challenge the individual with alternate points of view and give him or her extensive experience of crossing various boundaries are particularly valuable.

**Personal Development**

Individuals also require the attitudes and character which enable them to deliver innovations. This is the third key element which has evolved over the course of CMI’s educational work. At its heart is Albert Bandura’s concept of self-efficacy, (Bandura, 1997). If an individual has a high level of self-efficacy, he or she has a secure and positive understanding of his or her abilities, and the belief that they can be developed in whatever way necessary to achieve his or her goals. Such individuals respond to difficulty by trying harder, remaining persistent in the face of setbacks, and not making negative self attributions when failing to achieve some goal. While many self-efficacious individuals may have high self-esteem and self-confidence, these latter two characteristics are not the same. An individual may be quite self-efficacious yet paradoxically have low self-esteem and thus low self-confidence. A key component of Bandura’s work is the proposition that one’s sense of self-efficacy has its principle root in what he terms authentic mastery experiences. That is the direct experience of acting in some relevant way on one’s understanding and being successful in doing so. As a corollary the individual is able to recognise other self-efficacious individuals, and hence learn from them through a process of social learning.

**LOOKING AHEAD**

These three components of the CMI work have developed over the course of the past five years. The succeeding chapters examine processes of change in the student, the curriculum, and the institution as experienced in our work. What will become apparent is that both the formal and the informal elements in a student’s education, the pedagogic techniques as well as the content to which he or she is exposed, and the overall culture of an institution, all play a major role in developing the individual student through the course of his or her time at university.

**NOTES**

1 May be found at [http://libraries.mit.edu/archives/mithistory/founding.html](http://libraries.mit.edu/archives/mithistory/founding.html)
2 Renamed the Office of Science and Innovation on April 1 2006
3 Chief Finance Minister of the Government
4 See his report to President Truman entitled Science the Endless Frontier available at [http://www.nsf.gov/about/history/vbush1945.htm](http://www.nsf.gov/about/history/vbush1945.htm)