**TPI** Technology Policy International, LLC

# CROSS-DISCIPLINARY EDUCATION IN U.S. COLLEGES AND UNIVERSITIES, PART I: UNDERGRADUATE STUDENTS

A Report to JST

David W. Cheney

Christopher T. Hill

Patrick H. Windham

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## PREFACE

The study underlying this report was commissioned by the Washington, D.C., office of the Japan Science and Technology Agency (JST) and was conducted by Technology Policy International, LLC.

The opinions expressed in this report do not necessarily reflect the views of JST or of other institutions with which the TPI partners are affiliated.

David W. Cheney
Managing Partner
Los Osos, California
david.cheney@technopoli.net

George R. Heaton, Jr.
Partner
Boston, Massachusetts
george.heaton@technopoli.net

Christopher T. Hill
Partner
Knoxville, Tennessee
christopher.hill@technopoli.net

Patrick H. Windham
Consultant
Palo Alto, California
patrick.windham@technopoli.net

## ABOUT TPI'S PARTNERS AND CONSULTANT

*David W. Cheney* is a consultant and the former Director of the Center for Science, Technology and Economic Development at SRI International, where his work focused on planning and evaluating science, technology, and innovation programs and institutions, primarily in the US and Middle East. He has also been a consultant to the World Bank and an adjunct professor at George Mason University. Before joining SRI in 1998, he was a senior executive in the US Department of Energy, serving as director of the Secretary of Energy Advisory Board and advisor to the Deputy Secretary on industrial partnerships and national laboratories. He previously was a senior associate with the Council on Competitiveness, and an analyst with the Congressional Research Service. He has also held positions with the Internet Policy Institute, the Optoelectronics Industry Development Association, the Competitiveness Policy Council, and the Institute for Policy Science at Saitama University in Japan. He has a PhD in public policy from George Mason University, a MS in Technology and Policy from MIT and a BS in Geology & Biology from Brown University.

*George R. Heaton, Jr.* is a member of the faculty at the Worcester Polytechnic Institute in Massachusetts and an independent consultant in science and technology policy, environmental policy and law. Trained as a lawyer, Mr. Heaton has been on the faculty of the Massachusetts Institute of Technology and has worked widely for public and private technical and policy institutions in the US and abroad. Maintaining extensive professional and personal relations in Japan, Mr. Heaton was a Visiting Professor at Saitama University in 1986-87 and the First Foreign Scholar of the Ministry of Health and Welfare in 1989-90.

*Christopher T. Hill* is Professor Emeritus of Public Policy and former Vice Provost for Research at George Mason University in Fairfax, Virginia. He was a Senior Fellow at SRI International from 2011 until early 2016. After earning three degrees in chemical engineering and practicing in that field at Uniroyal Corporation and Washington University in St. Louis, he has devoted more than four decades to practice, research and teaching in science, technology and innovation policy, including service at MIT, the Office of Technology Assessment, the Congressional Research Service, the National Academy of Engineering/National Academy of Sciences and the RAND Critical Technologies Institute.

*Patrick H. Windham* is a consultant to TPI and a university lecturer on science and technology policy. He teaches in the Public Policy Program at Stanford University and in the past also has taught at the University of California's Washington, DC, center and the University of Maryland. From 1984 until 1997 he served as a Senior Professional Staff Member for the Subcommittee on Science, Technology, and Space of the US Senate's Committee on Commerce, Science, and Transportation. He helped Senators oversee and draft legislation for several major civilian science and technology agencies and focused particularly on issues of science, technology, and US industrial competitiveness. Mr. Windham received an B.A. from Stanford University and a Master of Public Policy degree from the University of California at Berkeley.

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# CROSS-DISCIPLINARY EDUCATION IN U.S. COLLEGES AND UNIVERSITIES, PART I: UNDERGRADUATE STUDENTS

## INTRODUCTION AND OVERVIEW

For several decades U.S. higher education has grown increasingly cross-disciplinary both substantively and organizationally. This trend has replaced an earlier embrace of the academic disciplines as the foundation of a proper higher education.

This report examines the history, development, and character of cross-disciplinary higher education in the United States, with an emphasis on undergraduate education. It is conceived as the first of two reports; the second will examine cross-disciplinary developments in graduate education and research.

To understand the dynamics of the promotion and acceptance of cross-disciplinary education, it is useful to review how U.S. higher education institutions emerged over time, where "institutions" refers not only to individual colleges and universities but also to the many organizations, practices, and even ideologies that grew up around the higher education enterprise.

Looking even more deeply, it is useful to reflect on the evolving role of higher education in American society—on the expectations that society has for colleges and universities, for their graduates, and for their place in the world.

Organizational structures, norms, rules, and incentives both evolve in response to changing societal expectations and help shape those expectations. Developments such as the shift over time from disciplinary education to cross-disciplinary education are both enabled and constrained by institutions. In this report we show how the trend toward cross-disciplinarity has been shaped by pre-existing organizational characteristics.

Thus, this report seeks to show not only what happened, but how it happened, what factors have influenced the spread and success of cross-disciplinarity, and the compromises that are often struck by those who would promote cross-disciplinary approaches.

# THE EVOLVING ROLES OF U.S. HIGHER EDUCATION

## ESSENTIAL TENSIONS IN HIGHER EDUCATION

The U.S. higher education enterprise is huge, growing, and diverse along many dimensions. It includes some four thousand accredited, degree-granting colleges, universities, academies, institutes, and other organizations. The enterprise includes prominent and generally large institutions known around the world, such as Stanford, MIT, Harvard, the University of Chicago, the University of California System, and Pennsylvania State University, as well as smaller, local institutions known only to those who live and learn in the same region.

But, within this huge and diverse enterprise one can observe four essential tensions between polar opposite educational philosophies and purpose. These tensions are:

1. Knowledge specialization vs. knowledge integration
2. Knowledge depth vs. breadth
3. Fundamental principles vs. applications
4. Learning problem-solving skills vs. leadership.

How these tensions get resolved, or at least reach workable accommodations with each other, tends to define the character of each university. Their resolution may also differ among different disciplines in the same institution. It may even differ among scholars working in the same disciplines in the same institution.

Let us briefly explore these essential tensions.

### Cross-Disciplinary Defined

We think of "disciplines" as bodies of knowledge that incorporate unique contents and employ unique methodologies for apprehending and explaining the contents of their unique world. Canonical disciplines include, for example, chemistry, history, mathematics, physics, classics, philosophy, and economics, to name a few. Disciplines can also be thought of as the well-defined groups of scholars and teachers who are experts in the substance and methodologies of the disciplines they espouse.

Cross-disciplinary endeavors, including education, then, are those that make active use of two or more disciplines at the same time. Some observers go to great lengths to differentiate among cross-disciplinary, multi-disciplinary, interdisciplinary, and transdisciplinary activities. Unless there is reason not to, we use cross-disciplinary to refer to all these variants.

## KNOWLEDGE SPECIALIZATION VS INTEGRATION

The tension here is between two approaches. One focuses undergraduate education on learning one or more disciplines as understood by experts in those discipline. The other frames undergraduate education around examining societal problems from the perspectives of multiple disciplines. Following the second approach, students learn what is needed from each discipline that they need to know to make progress on the problem they are studying.

Philosophically, the discipline-by-discipline approach is based on the notion that students arrive at higher education having little or no real understanding of the core disciplines and that their interests are best served by requiring them to take separate courses from experts in each field. For students who are motivated to study each discipline, this approach can work well. However, other students who do not understand how and why various disciplines might be of value to them sometimes view taking course outside their chosen discipline as distractions or bureaucratic requirements to be fulfilled rather than as subjects worth learning.

By contrast, the integrated approach focuses heavily on motivating student engagement with diverse disciplines by exposing them to the value of those disciplines as they grapple with understanding "real-world" problems and issues. Students participating in integrated learning, it is hoped, will come to understand and appreciate the contributions of several disciplines to resolving issues. This approach can work well in broadening the horizons of students but has been criticized because it tends to under-emphasize a systematic approach to understanding each discipline on its own terms.

## KNOWLEDGE DEPTH VS BREADTH

This tension is similar to but not the same as the "specialization vs integration" tension. At one end of the tension, knowledge depth is like knowledge specialization in that teaching and learning are focused on learning a single discipline in detail. However, at the other end of this tension, breadth emphasizes learning several disciplines, but learning each one separately and not in an integrated manner. Thus, even when breadth of learning is the objective, each topic is approached as it is taught by specialists in each field.

A practical illustration of the "breadth" approach is an undergraduate curriculum that expects students to select one major field of study, say history or chemistry, and to select one or perhaps two minor fields of study at the same time. So, a person majoring in history might also minor in economics and in Elizabethan literature.

Another illustration of the breadth approach is a curriculum that requires students to select a major and to add to it survey courses in several other fields. In the liberal arts and humanities, the selection of survey courses is sometimes referred to as a "distribution" requirement. Similarly, accredited undergraduate engineering programs in the United States must require their students to take a minimum of a semester's worth of courses in the "humanities and social sciences," broadly defined.

## FUNDAMENTAL PRINCIPLES VS APPLICATIONS

This tension has been especially prominent in devising curricula for undergraduate engineering programs. The fundamental principles approach argues that students are best prepared for a lifetime career as practicing engineers by learning the fundamental principles of the various subdisciplines that inform their work. From this perspective, what is important to learn are the "engineering sciences" that can be deployed to analyze problems and to devise and analyze alternative solutions to them. Put another way, from this point of view, solutions to problems can be arrived at by deduction from fundamental principles in the context of well-posed problems.

On the other hand, the applications approach recognizes that many real-world engineering problems are highly complex and/or depend on many variables whose values and behavior are uncertain or even unknowable in advance. Well-educated engineers, in this view, should be deeply informed about heuristics, short cuts, rules of thumb, empirical models, and simplified analyses that are often sufficient to solve a given problem or that are the only real basis in prior experience for solving new problems in a reasonable time.

Engineering as a field of practice and study in the United States underwent something of a revolution in the post-world-war-II era as previous curricula based heavily on study of applications were replaced by curricula heavily based on studies of engineering sciences and fundamentals. In more recent decades, however, a kind of balance has been sought in which both fundamentals and experiences in applications are included in modern curricula.

Something of the same evolution has happened in the field of business. Just as engineering education went through a period of intense embrace of learning the engineering sciences, business school curricula came to be heavily dependent on studies in economics, finance, statistics, psychology, and operations research. More recently, applications-based fields like manufacturing operations, logistics, strategy, and general management have returned to the center of the curriculum, even as some of the fundamentals of economics, psychology, and operations research have remained as well.

## LEARNING PROBLEM-SOLVING SKILLS VS LEADERSHIP

One of the key tensions in higher education, especially in engineering and other technical fields, arises from the contrast between the engineer as a solver of problems and the engineer as a leader of technical work or as an entrepreneur in creating new organizations or companies based on a technical idea.

Some engineering schools take great pride in graduating engineers who are well prepared to diagnose and analyze problems and to invent or design solutions to those problems. Engineers or other technical professionals who are well-trained in these skills are highly valued in consulting work and in large technical organizations in industrial and government settings.

By contrast, engineers who have been taught by example, by illustration, and by extra-classroom experiences to lead organizations or to recognize opportunities to build new organizations or new companies to meet emerging societal needs have become more highly valued over time as industry has shifted from a mass production model to an entrepreneurial, start-up, new ventures model.

Similarly tensions exist within the field of business education as well as in some of the more applied science fields such as geology and earth sciences, environmental sciences, and medical technology.

## A PERSPECTIVE ON THE FOUR TENSIONS

The four tensions are not entirely independent. For example, “specialization” typically emphasizes “depth” of knowledge of a particular field over knowledge of several fields. “Mastery of fundamental principles” is often at the core of both “specialization” and “depth.” “Problem solving” is relatively closer to “depth” than to breadth, although it benefits from both.

Similarly, “integration” of knowledge is built on foundations of a “breadth” of knowledge and is key to both “applications” and “leadership and entrepreneurship.”

# HOW RESOLUTION OF THE FOUR TENSIONS AFFECTS HIGHER EDUCATION

## DIVERSITY OF GOALS ACROSS INSTITUTIONS

The four tensions reflect differences among institutions in what they consider their goals for their students to fulfill. Put another way, where an institution lies along the continuum of goals has a lot to do with what the institution considers an “educated” person to be. Looking again at the four tensions, does an institution (a college or university or a department within one of these) seek to educate graduates who will be specialists in one field or another, or does it seek to educate students broadly? Similarly, does a college of business or engineering envision that its graduates will be able to function well as problem solvers within large companies or other organizations, or does it envision its graduates moving quickly into management and leadership positions, or, perhaps, working with a small team to build a start-up company?

Over time, different institutions have become known for being at one point or another along the lines representing the four tensions. These perspectives tend to be reflected in how institutions describe themselves on their web sites or in their student recruitment brochures.

Institutions that have adopted vision and mission statements often specify where they aspire to be on the various lines of tension.

## STUDENT EXPECTATIONS AND EXPERIENCES

When students apply for entrance to specific colleges or universities, they have little or no understanding of the decisions that the various colleges or universities have made, explicitly or implicitly, about where they stand on the four tensions.  At the same time, students may have little or no understanding about their own goals as they might be reflected in something like the four tensions.

Under the best of conditions, for students, attending college or university is not so much a mechanism for reaffirming the outlooks on life that they brought with them from family, schools, and communities as it is a process of discovery—of learning about concepts, ideas, communities, and perspectives that they knew little or nothing about when they arrived.

Thus, for example, most new college or university students don't know whether they'd like to learn one subject in depth or develop a general understanding of several disciplines and subjects.  They don't know whether they'd be good at solving problems or working on new theories or leading teams and organizations.

For these kinds of reasons, most colleges and universities in the United States offer first-year students an opportunity to try several approaches to learning and to life skills.  Even so, technical fields like engineering, allied health, and applied sciences require a greater degree of focus and of specialization by students from the outset than do the liberal arts, humanities, and basic natural sciences.

## FACULTY INCENTIVES, PERFORMANCE AND ACCOUNTABILITY

How an institution has decided to focus its efforts across the four tensions will influence the nature of the faculty they attract and recruit as well as how they assess the performance of those faculty.

Few if any colleges or universities are "pure types;" that is, few if any seek to hire only faculty who are especially good at, say, in-depth education in a single discipline .  Similarly, few colleges and universities hire only faculty members who are especially good at helping students appreciate and understand the contributions of multiple disciplines.

Furthermore, faculty respond not only to the needs of their students and the demands of their employing university.  They also are guided by their own discipline's understanding of what is important to teach and learn as reflected in curriculum guidelines, the core themes of journals in the field, and the judgments made by faculty members from other universities about the quality of their work when faculty members are being assessed for hiring, promotion, or tenure.

## UNIVERSITY ACADEMIC ORGANIZATION AND STRUCTURE

The great majority of U.S. colleges and universities have adopted the discipline- or field-based department as their basic structural unit. In most departments, most faculty members have their highest degrees in the discipline of the department. Departments consider themselves not only the stewards and teachers of their disciplines but also a conduit for exchange of ideas, curricula, students, and notions of what constitutes a proper basis for awarding a degree in their field.

In the United States, as compared with institutions in many European and Asian countries, departments are relatively democratic and egalitarian units. Regardless of whether the chair or head of the department is elected by his or colleagues or is appointed by a higher-ranking official such as a dean or provost, he or she makes decisions based on extensive consultation with colleagues in the department and on votes of the members of the department. Departments are also often the foundational organizational element that has and controls its own budget.

By their nature, departments are more likely to resist cross-disciplinary educational efforts than to support them. Cross disciplinarity may be perceived by departments as undermining the conceptual foundations of the university. Faculty engagement in cross disciplinarity may be seen as exploiting valuable human resources that would better be applied to meeting the needs of the discipline. And cross-disciplinary efforts may be seen as diverting scarce financial resources away from the departments.

# THE STRUCTURE OF U.S. UNDERGRADUATE EDUCATION

## DISCIPLINARY STRUCTURES

For many decades, U.S. undergraduate education has been organized around disciplinary departments along familiar lines—departments of English, history, mathematics, chemistry, etc. The faculties of these departments have defined the subject matter that constitutes the foundations of degrees in their fields of study. The senior managing faculty member of a department is usually called a “chair” or sometimes a “department head.”

Departments that are somewhat similar are typically clustered into larger units commonly called “schools” or sometimes called “divisions” or “colleges.[1]” So, a school of humanities and social sciences might include such departments as history, philosophy, English, foreign languages, sociology, etc. A college of engineering might include aeronautical, chemical, civil, electrical, mechanical, and other engineering departments. The senior managing faculty member of a school or college is usually called a “dean.” Above the deans would be the senior institutional academic officer, typically called a provost or a vice president for academic affairs.

The terminology used to designate academic units at various levels is not consistent across higher education institutions. For example, some large universities may include departments, divisions, schools, and colleges all at the same time.

The notion or concept of an academic “discipline” is not fixed in time or place. For example, over time, the discipline of philosophy has fractured into an array of fields including psychology, religious studies, ethics, and mathematics. In other cases, new disciplines have formed from the combination of all or parts of pre-existing disciplines. Examples of such combination would be the formation of computer science from an amalgamation of elements of mathematics and electric engineering, and then the formation of bioinformatics from an amalgamation of elements of computer science and molecular biology. More generally, new disciplines constantly form from both subdivision and recombination of bodies of knowledge.

Undergraduate students typically choose a discipline or field of study in which to “major,” and they may also choose to “minor” in one or more additional fields. To earn a degree in a major requires taking a certain minimum array of, and number of, courses offered by faculty from the department of the major discipline or field. To earn a minor requires fewer courses than a major.

Faculty members associated with a department are expected to teach courses in their discipline for the benefit of students who are majoring in that field. In addition, such faculty generally teach courses in their disciplines for the benefit of other students who require instruction in that field. For example, nearly all students take courses in mathematics and English, regardless of their majors, so the teaching duties of faculty members in those departments are predominantly made up of teaching students who are not majoring in their disciplines.

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[1] The word “college” is sometimes used in the United States to refer to an entire higher education institution and at other times to a subdivision of a higher education institution. These designations arose historically without any particular rationale and, even today, the only way to know which way the word is being used in a particular case is to take into account its context.

A key contributor to the resilience of the academic disciplines in universities and colleges is the process of voluntary accreditation. Under this process, both universities and some of their departments are subjected to periodic review by outside peers from other institutions who examine the nature and quality of the curriculum and other aspects of educational programs to ensure that they meet voluntary standards established by the institutions collectively. Accreditation is organized by disciplinary, regional, and national non-profit organizations set up for this purpose. Accreditation organizations are, in turn, lightly supervised by the federal government, by professional bodies, or both. One important effect of accreditation is to reinforce the privileged position within the university of the discipline-based departments and fields, especially those that are accredited separately from the university as a whole.

## CROSS-DISCIPLINARY STRUCTURES

### DISTRIBUTION REQUIREMENTS

Each major field of study usually specifies the number of courses and/or the types of courses, that students must take "outside their major." All engineering students, for example, are usually required to take at least one semester's worth of courses in the "humanities and social sciences." All liberal arts and humanities students may be required to take a two-course sequence in, for example, a field of science, mathematics, and/or performing or fine arts. Distribution requirements are designed to compel students to be exposed to disciplines other than their major interests in hopes that such exposure will enable them to become more rounded graduates, citizens, and leaders.

### MINORS, CERTIFICATES, OPTIONS AND OTHER AREAS OF INTEREST

Most colleges and universities offer individual students a variety of ways to pursue interests in two or more fields during a regular undergraduate course of study.

As noted above, many students choose not only a major field but also one or more minor fields. Typically, a minor is complementary to the major—for example, a chemical engineering major might choose a chemistry minor—but some students choose to take less directly related minors—for example, a civil engineering major might minor in political science or economics. Some even take completely unrelated minors, such as a physics major taking a minor in violin performance.

Some secondary fields of study emphasize practical skills training in the context of a college education, such as a science major choosing to learn a great deal about software coding. The skills training may be recognized by the college award of a certificate in the skills area.

Over the years, some disciplines fracture into sub-disciplines, each of which deserves formal recognition. An example is the discipline of electrical engineering which has long recognized major differences between a focus on electronics and a focus on power production and management. Thus, a student may choose a major that leads to a degree in electrical engineering with an option in microelectronics or an option in electric power engineering.

Finally, ambitious students may choose to "double major," which means that they organize their course work so that upon graduation they qualify for two degrees simultaneously. Many double majors are in relatively closely related fields, such as physics and math or mechanical engineering and materials science. Others might reflect a student's breadth of interest in highly divergent fields such as an engineering specialty as major number one, and a completely different field such as a foreign language or biology as major number two.

## CROSS-CUTTING PROGRAMS

On occasion, it becomes apparent that many students are choosing to combine education in two or more fields in similar ways. Some faculty members may recognize that there are job opportunities for graduates who have exposure to and skills in a new cluster of fields. Thus begins the transition of cross-disciplinary study from actions and choices made by individual students toward programmatic design and implementation for cohorts of students with similar combined interests.

From a developmental point of view, such cross-cutting programs typically begin as optional courses offered as electives for a few students with special interests. For example, faculty members from different fields who have worked together on a research project that requires collaboration between their fields may decide to offer a course featuring that collaborative interest. The contemporary field of bioinformatics had this sort of origins as biologists began to call upon computer scientists for help in managing the torrents of data that contemporary instrumentation was beginning to yield, especially as DNA sequencing began to take its place as a central tool in life sciences research and practice. Early on, a few students majoring in biology chose to study computer science to learn how to manage their data. Computer science students began to perceive opportunities to apply their skills professionally to the management and exploitation of biological data but they also realized that they needed to know something about molecular biology to be able to contribute substantially. From these sorts of experiences on many campuses, the cross-cutting field of bioinformatics began to take shape. Over the ensuring couple of decades, bioinformatics has matured to the point that it is now a recognized field unto itself.

A similar story could be told about the field of materials science and engineering, which grew out of the recognition that such diverse fields as chemical and mechanical engineering, metallurgy, ceramics engineering, polymer science, and solid-state physics had common interests in understanding the structures and properties of diverse materials used in many different applications. In this case, a concerted effort was made in the early 1960s in the United States to establish cross-disciplinary centers or programs in materials science and engineering to take advantage of synergies arising from combining knowledge of each of the relevant disciplines.

A more recent example of cross-cutting programs is the development of programs of study in entrepreneurship and technology management. Responding to market needs for engineers with the ability to manage large scale projects profitably and for business majors who understood how technology is developed and commercialized, many colleges and universities have built formal programs or have taken other approaches to entrepreneurship and technology management. Some offer formal degrees in entrepreneurship and/or technology management. Others offer minors or certificates in these activities. Still others treat entrepreneurship as a "meta-educational" process in which students learn by creating new firms, some real and some simulated, by working in teams with faculty mentors, as well as with successful entrepreneurs who have actually built and operated start-ups and other kinds of entrepreneurial ventures.

## OTHER APPROACHES TO CROSS-DISCIPLINARY STUDY

U.S. colleges and universities feature an almost endless array of creative approaches to enabling and encouraging cross-disciplinary studies by undergraduates.

Many universities encourage their students to participate in community-level projects, typically working to help solve issues and problems in the community that address the needs of low-income, disabled, or other disadvantaged people; that address environmental quality issues; that engage around community planning and civic engagement; or otherwise work hand-in-hand with community members to address real needs. In common with most real-world problems, addressing such needs effectively nearly always requires contributions from multiple disciplines, from psychology, to sociology, to political science, to waste water treatment, to organizational design and management, to environmental monitoring, to information and communications design, and so on. The learning theory of such engagement is that students learn the importance of both many disciplines and of involvement of affected publics in studying and assessing solutions proposed by experts in various disciplines who may have more narrow perspectives.

Such community engagement can also be formalized through internships, under which students typically spend uncompensated time working in or contributing to an ongoing organization, under the oversight of both a faculty observer and a mentor from the host organization. While not all internships are effective, good ones get students deeply engaged in the real work of the organization, be it a firm, a government agency, a non-profit organization, or a community group. As with community engagement more generally, internships teach the kinds of tacit skills needed to succeed in organizations, the importance of multiple disciplines, and the roles of diverse individuals and skills in organizational success.

Closer to the core mission of the college or university, universities often offer “special topics” courses that are focused on issues of the day, such as climate change or controlling artificial intelligence, rather than on the enduring wisdom embodied in more formal and long-lasting core courses. Once again, since such courses tend to be organized around real problems, they necessarily involve engagement with the perspectives of multiple disciplines.

Finally, while research engagement is the focus of the anticipated second report in this series, we should remark on how undergraduate involvement in doing research projects almost always leads to a recognition that multiple disciplines are essential to addressing almost any complex research question. Universities often formalize the “undergraduate research experience.” Some such experiences entail student participation in large research projects being conducted by graduate students, post-docs, and faculty. But others require the undergraduate student, working under the guidance of a faculty member or graduate student, to conceive of and execute his or her own research project.

## STUDENT EXPERIENCES WITH CROSS-DISCIPLINARY EDUCATION

In many of today’s colleges and universities, cross disciplinary study in one form or another is more the norm than the exception. University presidents down to the least experienced member of the faculty often tell students that cross-disciplinary, interdisciplinary, multidisciplinary, and transdisciplinary studies and research are the way of the future. Integration across disciplines is not only tolerated; it is celebrated.

At the same time, students are faced with an institutional bureaucracy and even physical structures that are based on the old models of separate and individual disciplinary fiefdoms—strong disciplines with powerful department heads housed in their own buildings, curricula that presume single-discipline majors, and alumni who extol the virtues of this or that department, college, or school. Students are not infrequently told that, to succeed, they must master a skill, a craft, a body of knowledge, a discipline. And, because faculty members have divergent views of the value of cross disciplinary studies, students can expect to encounter professors, mentors, advisors, and others who advise against “dilettantish interdisciplinary studies” and who call into question the professional commitments of faculty members who dare to explore outside their own fields.

The net result of this foment and disagreement is that students are often left to fend for themselves; to sort out their own pathways toward solid learning and preparation for life, or at least for graduate school or first jobs. But, this foment also nurtures flexibility, so that students who are equipped to make use of all the resources of the college or university can find ways to cross disciplines productively and effectively.

Fully engaged faculty mentors are extremely important to the success of students who opt for cross disciplinary experiences. Rather than advocate for one form or another of educational experience, mentors do best when they first listen and understand what students are looking for. Students, differ, of course, with some looking for firm and assured guidance from mentors, whereas others are looking to mentors for open discussion of the pros and cons of the diverse paths open to them. All of this has strengthened the need for campus resources to help students find their way, to figure out what interests them most and to find out how to get it. As a result, colleges and universities devote much greater resources than they once did to student advising.

## STUDENT ADMISSIONS

In the U.S., potential students who contemplate going to college or university must apply to the institutions they might like to attend. The student admissions process functions much like a giant marketplace, with students facing a bewildering array of possible institutions to attend, and institutions facing a bewildering array of potential students to admit.

Many kinds of people help students think about where they might want to go and what they might want to study, including parents and other family, high school teachers and advisory staff, peers, and, in some cases professional admissions consultants. Students' perceived options also are shaped by institutional reputation, the visibility of athletic teams, geographic location, the costs of attendance, availability of financial assistance, and many other factors. Students are relatively good at self-sorting. For example, only academically gifted students would reasonably expect to be successful in applying to highly visibly, academically strong institutions like, say, Stanford, Harvard, MIT or the University of Virginia.

In deciding whom to admit, colleges and universities look at a variety of characteristics of applicants. Some are obvious, such as high school academic performance, scores on national standardized tests, and teacher recommendations. Institutions also look at the "whole student," including such factors as enthusiasm, maturity, and engagement in diverse and interesting non-academic pursuits such as sports, music, creative arts, community leadership, and civic mindedness. Money also plays a role on the part of both students and institutions.

Where does student interest in cross-disciplinary study enter the admissions process? What role does it play? In most institutions, students are admitted to the college or university "at large." That is, they are not admitted to study a certain topic or discipline. Rather, students are encouraged to "find their way" to a discipline or other career path after they have been admitted, and sometimes only after a semester or even a full year of diverse study. It is common under these conditions for students to arrive at opening day of their first year at university having firm opinions regarding their choice of major or discipline, only to discover during their first semester or first year that other disciplines interest them much more than they anticipated.

Other institutions do expect applicants to select their preferred major before they begin their higher education studies. This is especially true of students who are interested in majors in which the structure of knowledge is strongly hierarchical and cumulative, such as engineering, earth sciences, or chemistry. Even in this situation, however, students can decide to change their majors after some period of study.

Thus, the student's choice of a major and/or minor fields of study is generally viewed as changeable, at least for the first two years of a four-year program of study. Of course, the further along a student is in his or her program, the more difficult a change of major becomes. After changing their majors, some students require more than four years to complete their undergraduate programs because they need to take extra courses to complete the new majors' course requirements.

If a student has accumulated most or all the course requirements for a particular major but has also decided to take another major for graduation, he or she may easily arrange to graduate with two majors, or what is commonly called a "double major."

## PREPARATION FOR GRADUATE AND PROFESSIONAL EDUCATION

Increasing proportions of undergraduates intend at some future point to continue their formal education by pursuing graduate degrees in their undergraduate field, by changing to an entirely different field for graduate education, or by using their undergraduate degree as a springboard to enrollment in professional fields such as medicine, law, or dentistry which do not offer preparatory undergraduate degrees.

Undergraduates who intend to go on to graduate school in the same field in which they earned their undergraduate degrees usually follow fairly straightforward pathways. They usually seek to focus their undergraduate experience on the core courses in their field of study that will make them as competitive as possible for admission to leading graduate programs that can offer financial assistance.

Undergraduates do sometimes decide to attend graduate school in radically different fields from their undergraduate degree field. If such students realize that they are interested in changing fields, they may decide to take as diversified program of undergraduate study as they can to strengthen their preparation for a planned change of field.

Undergraduate students who are interested in continuing for a professional degree are often advised to take certain courses outside the field of their undergraduate major to strengthen their case for admissions to professional courses of study. For example, engineering students interested in law may be advised to take undergraduate courses in history or political science to prepare for law school, while liberal arts undergraduates interested in law school may be advised to take extra undergraduate courses in mathematics, philosophy, or logic to help them prepare for the rigors of legal education. Similarly, both natural sciences and engineering can be strong preparation for medical school, but undergraduates majoring in sciences or engineering may be advised to take undergraduate courses in biology, molecular biology, or even psychology to help them prepare to succeed in medical school. Thus, the process of preparing for graduate professional education can be a pathway to students experiencing cross-disciplinary course work as undergraduates.

## INTERACTIONS OF CROSS-DISCIPLINARY EDUCATION AND INSTITUTIONAL ADMINISTRATION

As discussed previously, academic administration is organized around disciplines through departments and around clusters of disciplines through schools and colleges. These discipline-based academic administrative structures can act as impediments to exploring and carrying out cross disciplinary teaching at the undergraduate level.

Universities and colleges are also served by a substantial number of non-academic administrative entities concerned with such areas as finances and accounting; admissions; enrollment management; student services, financial aid; personnel management/human relations; fund raising; facilities construction and operation; purchasing; research administration; legal affairs; auditing; marketing and promotion; hospitality (dormitories, food services, medical services); community relations; political relations; compliance with local, state and federal regulations; alumni relations; and so on and on.

As with academic administration, some key non-academic administrative functions can also influence the success of cross-disciplinary undergraduate studies.

For example, financial management systems may be organized around disciplinary academic structures (departments, schools, and colleges) as the core elements for budgeting, financing, accounting, and auditing. The institution's budget may be built around meeting the needs of the departments, schools, and colleges as determined principally by the size and compensation of their faculties and by the number of students who are enrolled in the classes they teach. Likewise, university facilities (buildings, offices, classrooms, laboratories) may be allocated to departments, schools, and colleges on similar grounds. Promotional activities such as brochures, web sites, visitations by potential students, and even admissions may be organized around the needs and staff of departments, schools, and colleges.

The main theme here is that cross-disciplinary activities of whatever kind may not be reflected or adequately represented and reflected when decisions are made about the availability and use of institutional resources. Typically, cross-disciplinary activities find themselves struggling for office space, financing, representation, and so on. Leaders of cross-disciplinary activities may find themselves engaged in endless struggles for resources, recognition, and representation at all levels. In this sense, such activities may be perceived by themselves and by others as tangential; as something separate and apart from the "core" activities of the institution. This lack of full regard may also be reflected in a general sense at the university that cross-disciplinary study is somehow of "lesser" stature than the activities of the traditional departments and schools. Some university and community leaders may even view cross-disciplinary activities as a threat to the core strategic direction of the university.

Offsetting this rather negative assessment of how universities and colleges manage cross-disciplinary activities, it is interesting to note that in recent years there has been something of a "boom" in interest in cross-disciplinarity in all its forms. A casual perusal of posted advertisements by universities and colleges that are seeking new presidents or provosts will reveal that a commitment to cross-disciplinarity is a key requirement of people who would apply to be considered for such positions.

Put another way, cross-disciplinarity is currently enjoying something of a "boom."

## EXAMPLES OF INSTITUTIONAL ENGAGEMENTS IN CROSS-DISCIPLINARY UNDERGRADUATE EDUCATION

Most U.S. universities and colleges are engaged in one or more ways with cross-disciplinary undergraduate activities. Here are a few brief illustrations.

### BROWN UNIVERSITY

Established in 1764, Brown is one of America's oldest and most distinguished universities. Brown is a private university and is a member of the highly exclusive Ivy League group of universities.

Brown was an early and comprehensive adopter of an undergraduate curriculum that sets aside the standard disciplinary structure. As stated in Wikipedia:

> *In 1969, Brown adopted its "Open Curriculum" after a period of student lobbying. The new curriculum eliminated mandatory "general education" distribution requirements, made students "the architects of their own syllabus" and allowed them to take any course for a grade of satisfactory (Pass) or no-credit (Fail) which is unrecorded on external transcripts.*[2]

This simple quotation does not do justice to the full scope of Brown's "Open Curriculum" reform.[3] Indeed, the reform was based on student "lobbying." However, that lobbying involved dozens of students and many faculty over a period of more than a year and resulted in a 400-page report of a serious in-depth study of curricula at Brown and elsewhere and that engaged the faculty and administration in creating a new approach to undergraduate education.[4]

Today, after half a century, Brown remains committed to the curriculum adopted in 1969. The option to take courses pass/fail was established to encourage students to take courses outside of their comfort zone – so that they can take challenging courses and explore different fields without fear of poor grades. Students at Brown must declare a major and take a required number of course hours in that major field. The remainder of the courses required to complete a degree are decided by the student and do not need to fall into any particular distribution requirement, minor, certificate or other structured mechanism. Students at Brown can create their own interdisciplinary major if one of the 80 existing majors does not meet their need. This requires creating and obtaining approval for a coherent course of study.

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[2] Wikipeida, Brown University, accessed March 15, 2023

[3] Wikipedia, Open Curriculum (Brown University), accessed March 15, 2023.

[4] The Magaziner-Maxwell report, on the web at: https://library.brown.edu/libweb/papers/BrownCurriculum.pdf

## GEORGE MASON UNIVERSITY

George Mason University ("Mason") is radically different from Brown. Mason was established in the 1960s as a two-year branch campus of the venerable and distinguished University of Virginia. Mason was created to serve the needs of the very rapidly growing northern Virginia region, which had no other significant public higher education institution. Mason's enrollment grew with the region and by 1975 it was reorganized as a separate public university of the State of Virginia.

Out of both practical and political necessity, Mason found it convenient to organize many of its programs along multidisciplinary lines. For example, in its early years Mason had just two units concerned with the social sciences. One of these was a department of Economics, which was set up on traditional lines except that the core intellectual foundation of that department was in the fields of Austrian and experimental economics rather than in the field of neo-classical economics which then dominated economics instruction nationwide. The other social science department was a department of Public and International Affairs. Its faculty included professors with terminal degrees in a number of fields including political science, public administration, international relations, sociology, anthropology, communications, and civil engineering. Undergraduates earned cross-disciplinary bachelor's degrees in Public and International Affairs rather than in any of the constituent disciplines. Somewhat similar although less radical organizations constituted Mason's School of Information Technology and Engineering and its College of Arts and Sciences.[5]

Today Mason is the largest of the seven major public universities in the State of Virginia with some 40,000 students enrolled. As it has grown, it has lost some of its commitment to cross disciplinarity and now has most of the standard discipline-based departments found in most large public institutions. Mason has not been able to withstand the pressures from both internal and external constituencies to recognize the core disciplines.

At the same time, Mason has retained its commitment to formalizing interdisciplinary undergraduate education. This commitment is reflected in the large numbers of minors and graduate certificates that are available.[6]

## MASSACHUSETTS INSTITUTE OF TECHNOLOGY

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[5] Even more radical approaches were taken to structuring graduate programs at Mason. These will be discussed in the follow-on report on cross disciplinary approaches to graduate education.

[6] https://catalog.gmu.edu/programs/#filter=.filter_22

Massachusetts Institute of Technology (MIT) is a medium-sized private university that has long been seen as offering the epitome of education and research in engineering and applied and fundamental sciences in the United States. From its founding in Boston in 1861, MIT has usually put unusually heavy emphasis on education that prepares graduates to address the needs of society in a practical manner.

For an educational institution, MIT excels at making fruitful connections with the broader world that involve students and faculty in addressing key issues of the day. Collaborations of MIT faculty and students with established companies are legion, and MIT has also been the platform from which many students and faculty members have launched start-up companies, some of which have become, or were major employers and contributors to the private sector and/or governments.[7]

MIT has hosted very large numbers of cross-disciplinary laboratories and other academic research and education initiatives, nearly all of which attract substantial participation by undergraduate students in many fields to work together on both practical and long-term problems. MIT has been a leader in such cross-disciplinary efforts as public policy, energy, biological engineering, advanced materials, environmental management, software engineering, and artificial intelligence.

## STANFORD UNIVERSITY

Stanford is today widely recognized as one of the leading comprehensive universities in the world. In engineering Stanford competes favorably with MIT, in the sciences with Harvard and the University of California, and in the social sciences and humanities with Harvard, Columbia and the University of Chicago. Stanford's traditional departments are generally very strong. It also has a major commitment to cross-disciplinary work and has many such programs and centers. However, Stanford, like other universities, makes a clear distinction between departments and interdisciplinary "programs." As at many other universities, interdisciplinary programs often struggle to get stable funding, building space, and faculty positions.

At Stanford, the largest numbers of undergraduate majors are in the School of Humanities and Sciences and in the School of Engineering. Humanities and Sciences has 23 regular departmental majors and twenty-five interdisciplinary programs.[8] All are open to

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[7] See, for example, Wikipedia, Massachusetts Institute of Technology, accessed March 15, 2023.

[8] For a list see: https://drive.google.com/file/d/1kFAsIi4NDS64UMhuZsR5tUOVQOdZzPvf/view

undergraduates. The School of Engineering also has six interdepartmental major programs and an option for an "individually designed major in engineering."[9]

Within Humanities and Sciences, two of the oldest interdisciplinary programs are Human Biology and Science, Technology, and Society. They illustrate how Stanford's interdisciplinary programs were created and how they operate today. Senior faculty members created both programs in the 1970s. Both offer their own courses and encourage students to take other courses in regular departments.

Human Biology began as a combination of biology, ecology, and psychology. It very quickly proved popular with undergraduates who planned to apply to medical schools.

The faculty who started what is now called the Science, Technology, and Society Program wanted to provide students with training in how to think about the ethical, social, and public policy questions associated with advanced technologies such as nuclear power – and today, one would say, also technologies such as artificial intelligence and genome editing. STS students typically combine courses in computer science and other technical fields with the Program's own courses. STS has proved popular with several groups of students, including students interested in working in information technology companies.

While many interdisciplinary programs in Stanford's School of Humanities and Sciences are popular with students, these programs often struggle for funding, building space, and faculty budgets. For example, most programs in the School of Humanities and Sciences do not have their own tenured faculty. Instead, they must rely on faculty from departments who volunteer to teach program courses and on part-time, non-tenured "adjunct" instructors. Programs such as STS have to fight for office space and budgets to pay instructors.

The situation in the School of Engineering is different. Students enrolled in the interdepartmental majors study with tenure track faculty in engineering, science, and mathematics departments.

Stanford recently created an entire interdisciplinary "school:" the Doerr School of Sustainability. The new school is an expanded version of Stanford's earlier School of Earth, Energy, and Environmental Sciences. Here is a description from a Stanford website:

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[9] For a list see: Source: https://engineering.stanford.edu/students-academics/academics/undergraduate-degree-programs

> The Stanford Doerr School of Sustainability draws on a deep understanding of Earth, climate and society to create solutions at a global scale, in collaboration with partners worldwide. The school strives to create a future where humans and nature thrive in concert and in perpetuity. The school includes a novel three-part structure with departments and programs to generate scholarship, institutes that innovate across disciplines, and an accelerator to drive policy and technology solutions to sustainability challenges. With more than 100 faculty, and nearly 1,000 students in six departments, one social sciences division and three interdisciplinary programs, the school brings together all areas of scholarship that, together, are crucial for advancing the long-term prosperity of the planet.[10]

Stanford's interdisciplinary and interdepartmental programs illustrate several key features about this university.

First, Stanford's administrators and faculty are flexible; if senior professors are willing to create a new interdisciplinary program and can show that the new major will be academically rigorous, then the president of the university and the Faculty Senate (the organization of senior professors) will support the creation of the program.

Second, many students like these interdisciplinary programs, either because they believe that the programs will help them in the job market or because they care about major issues such as climate change and sustainability.

Third, most Stanford undergraduates do not choose to pursue PhD programs in traditional disciplines and thus do not need to have undergraduate degrees in those disciplines. Most Stanford undergraduates who pursue advanced degrees either seek a master's degree (often at Stanford) or go to medical, business, or law schools, which do not necessarily require an undergraduate degree in a traditional academic discipline for admission.

Fourth, while Stanford is flexible about establishing interdisciplinary programs, the university's organization and budget are still built around traditional academic departments and their faculty members.

## CONCLUDING OBSERVATIONS

Higher education institutions in the United States are, for the most part, deeply engaged in cross disciplinary activities, not only in research and graduate studies, but also in

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[10] "Stanford's Schools and Programs," https://facts.stanford.edu/academics/.

undergraduate studies. This report has outlined some of these kinds of activities, has discussed their origins and successes as well as some of the institutional factors that enable or Inhibit cross-disciplinary study, or that manage to do both at once.

The prevalence of cross disciplinary activities at the undergraduate level is not the result of any grand national scheme to supplant or replace disciplinary and departmental-level efforts with cross disciplinary activities that are somehow less rigorous or less well-vetted than those conducted under the rubric of the “core” disciplines. Instead they have grown up on many campuses and in many contexts in recognition that universities have unique and valuable resources, especially educated people, who can make stronger contributions to society and to education by working across disciplinary lines than can be offered by working within the bounds of a single discipline.

As enrollment growth has slowed in many universities, the competition among universities for students has intensified. One way universities are competing is to offer a wider array of programs and options for students to earn degrees. Cross-disciplinary programs are an important contributor to this competition.

In addition, higher education curricula are only lightly regulated by the U.S. federal government, which has left greater room for curricular experimentation than exists in other countries where government agencies oversee university curricula.

Finally, the strong emphasis on cross-disciplinary graduate education and research in U.S. colleges and universities has created opportunities for undergraduates for cross disciplinary studies.