Report for the Educational Effectiveness Review

January 5, 2010

California Institute of Technology

Prepared for the Western Association of Schools and Colleges
by the California Institute of Technology

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ACRONYM LIST

ACM – Applied and Computational Mathematics

APh – Applied Physics

ARC – Academics and Research Committee

AO – Announcement of Opportunity (SURF)

Ay – Astrophysics

Bi – Biology

BE – Bioengineering

BIO – Division of Biology

BMB – Biochemistry and Molecular Biology

BoC – Board of Control

BUSAC – Biology Undergraduate Student Advisory Committee

CC – Curriculum Committee

CCE – Division of Chemistry and Chemical Engineering

CCSC – Core Curriculum Steering Committee

CCTF – Core Curriculum Task Force

CFR – Criteria for Review

Ch – Chemistry

ChE – Chemical Engineering

CIRP – Cooperative Institutional Research Program

CNS – Computational and Neural Systems

CPET – Caltech Project for Effective Teaching

CPR – Capacity and Preparatory Review

CS – Computer Science

CUE – Council on Undergraduate Education

EAS – Division of Engineering and Applied Science, and the undergraduate option in engineering in applied science

EE – Electrical Engineering

EER – Educational and Effectiveness Review

ESE – Environmental Science and Engineering

FERPA – Family Educational Rights and Privacy Act

FSRI – Freshmen Summer Research Institute

GPS – Division of Geological and Planetary Sciences

HSS – Division of the Humanities and Social Sciences

IST – Information Science and Technology

JPL – Jet Propulsion Laboratory

Ma – Mathematics

ME – Mechanical Engineering

NuSTAR – Nuclear Spectroscopic Telescope Array

Ph – Physics

PMA – Division of Physics, Mathematics, and Astronomy

RA – Resident Associate

SFC – Student-Faculty Conference

SURF – Summer Undergraduate Research Fellowship

TA – Teaching Assistant

TQFR – Teaching Quality Feedback Report

WASC – Western Association of Schools and Colleges

YESS – Young Engineering and Sciences Scholars

Report for the Educational Effectiveness Review

CALIFORNIA INSTITUTE OF TECHNOLOGY

ESSAY 1. INTRODUCTION AND OVERVIEW OF THE EDUCATIONAL EFFECTIVENESS REVIEW

The California Institute of Technology (Caltech) is an independent, privately supported university focused on research and education in science, engineering, and technology. As one of the world's major research centers, Caltech has world-class facilities on campus and several major off-site facilities. Caltech is also a center of education and learning with an undergraduate student body of approximately 950, a graduate student population of 1200, and a professorial faculty of 290.

Caltech has maintained accreditation through the Western Association of Schools and Colleges (WASC) since 1949 with the last accreditation review occurring in 1998. Caltech's proposal to WASC for reaccreditation was accepted in September 2006. The proposal was followed by the report for the Capacity and Preparatory Review (CPR) submitted in August 2008 and a team visit in November 2008. Following the visit, Caltech received the team report in January 2009 and the action letter from Dr. Ralph Wolff, WASC director, to Caltech President Jean-Lou Chameau in March 2009.

This report for the Educational Effectiveness Review (EER) is comprised of eight essays that focus on Caltech's approach to education, educational achievements of our students and alumni, and our efforts to assess, maintain, and improve educational quality. Some essays also include topics for further consideration identified in either the team report or the action letter. Essay 2 highlights activities that have occurred since the 2008 CPR visit, including strategic planning, budgeting, and support for students. In Essay 3, we summarize our educational assessment and planning processes. Essay 4 provides examples of changes within academic programs that have occurred since the last accreditation cycle.

In preparation for the CPR and EER studies, Caltech chose three areas of focus for review and assessment: 1) the undergraduate core curriculum, 2) the Honor Code, and 3) the programs supporting undergraduate research. The core curriculum consists of course work in mathematics and the sciences, as well as courses in the humanities, social sciences, scientific writing and oral communication, and physical education; it comprises over half of the curriculum for all Caltech undergraduate students. The WASC action letter indicated that the ongoing review of the core curriculum should continue, with a focus on "communicating its

rationale for both students and faculty." Essay 5 describes the on-going review, assessment, and implementation of changes within the core curriculum.

The Honor Code has been an essential part of Caltech culture for over a hundred years and guides conduct within the academic areas of Caltech. The Honor Code Handbook and other documents state that the Honor Code also applies to non-academic aspects of the student life at Caltech. The application to the non-academic arena can be challenging. As noted in the action letter, Caltech should "continue to give focused attention to the role of the Honor Code, clarifying its applicability in non-academic issues, while also emphasizing its educative functions and seeking higher levels of consistency in its application." Essay 6 outlines the efforts that have taken place with regard to the Honor Code since the CPR visit.

The third area of focus involves undergraduate research, which is an integral part of the Caltech education, especially in the summer via sponsorship of the Summer Undergraduate Research Fellowship (SURF) program. Research at the undergraduate level provides students with opportunities to interact with professors, graduate students, and postdoctoral scholars on basic and applied problems in science, engineering, social science, and the humanities. However, students often find it difficult to do research work during the academic year because of their demanding course schedules. The visiting team noted, "Continue with productive discussions regarding the critical role of undergraduate research in the curriculum of all students, with due consideration of the students' heavy workload, and with continuing clarification of the intended learning outcomes and assessment methods linked with undergraduate research." Progress towards these goals is discussed in Essay 7.

The processes to prepare for this review have generated considerable discussions about the three focus areas, and other areas such as the development of communication skills, programs to support graduate education, leadership development, and academic year research. In Essay 8, we summarize the findings of this educational effectiveness review, the common themes and recommendations that have emerged, and discuss some areas that could be possible directions for future reviews.

This report for the EER was prepared by the WASC Steering Committee with support and input from the Council on Undergraduate Education (CUE), several ad hoc committees that were formed around the three themes, and Caltech's Faculty Board. The broader Caltech community provided input to the process through the committees or through the accreditation website. The report also contains references to the WASC Criteria for Review (CFR) that are used within WASC's educational effectiveness framework.

ESSAY 2. AN UPDATE ON INSTITUTE ACTIVITIES SINCE THE CPR VISIT

(CFRs: 1.1-1.3, 1.5, 2.1, 2.8-2.10, 2.12, 2.13, 3.5, 3.6, 3.8, 4.1, 4.3, 4.6)

2.1 Brief overview of Caltech

As stated on page one of the Caltech catalog, "The mission of the California Institute of Technology is to expand human knowledge and benefit society through research integrated with education. We investigate the most challenging, fundamental problems in science and technology in a singularly collegial, interdisciplinary atmosphere, while educating outstanding students to become creative members of society."

Academics and research programs are carried out in each of Caltech's six divisions: Biology (BIO); Chemistry and Chemical Engineering (CCE); Engineering and Applied Science (EAS); Geological and Planetary Sciences (GPS); The Humanities and Social Sciences (HSS); and Physics, Mathematics, and Astronomy (PMA). Table 1 shows the distribution of students, professorial faculty, and other faculty (including visiting professors, full-time instructors, and part-time lecturers) across the six divisions for fall 2009. Although not apparent from the table, approximately 10% of the faculty members have appointments in more than one division; several of the graduate programs (Computation and Neural Systems, CNS; Biochemistry and Molecular Biology, BMB; and Environmental Science and Engineering, ESE) span two or more divisions. Approximately 15% of our undergraduates double major; of these double majors, students most often complete a degree program in the sciences or engineering and a degree program in the HSS division.

Table 1

Division	Undergraduate Students	Graduate Students**	Professorial Faculty	Other Faculty
BIO	52	142	32	1
CCE	125	245	37	6
EAS	340	493	76	21
GPS	16	73	32	1
HSS	9	29	46	21
PMA	149	197	67	17
Undeclared/ Unaffiliated*	259			17
Total	**950**	**1179**	**290**	**84**

*The undeclared undergraduates include new freshmen, returning freshmen, and a student in the Independent Studies Program; the unaffiliated faculty includes the university librarian, the director of athletics, the athletic coaches, and the coordinator and the lecturers for the performing and visual arts.

**The BMB graduate program is counted in BIO; CNS is counted in EAS; ESE is counted in EAS.

For fall 2009, 98% percent of Caltech's incoming freshmen were in the top 10% of their high school class. The composite SAT/ACT scores for the 25th to 75th percentile is 2170-2300, typically near or at the top of the schools reported in the *U.S. News and World Reports: America's Best Colleges*. Approximately half of incoming students have done some form of scientific research during high school. In the admissions process, prospective students are asked about their math and science activities including research projects and about how they express their interest, curiosity, or excitement about math, science or engineering. The admit rate for the class of 2009 was 15%.

The details of Caltech's governance, administration, and organizational structure, including the Board of Trustees and the Faculty Board can be found in Essay 2 of the CPR report. Since the CPR visit, there have been several changes within the administration; these changes are reflected in the updated organizational chart.

2.2 Aims and Needs Committee

In the spring of 2008, Caltech's President Chameau and Provost Stolper appointed an ad hoc "Aims and Needs Committee" to formulate institutional recommendations that would be of importance in the next five to ten years and that cross divisional boundaries. The charge to the committee was broad, encompassing the challenges of maintaining Caltech's excellence in research and education. The committee included faculty members from each of the six divisions.

In December 2008, the Aims and Needs Committee presented its recommendations to the Caltech Faculty Board, to the faculty, and to the Board of Trustees. Before presenting their recommendations, they indicated that they were guided by four principles, which they felt embodied Caltech's success:

- Caltech achieves visible impact out of proportion to its size by amplifying the efforts of individual faculty and making careful choices that both reflect the needs of society and require the type of fundamental research at which Caltech excels.
- Caltech attracts the best faculty, hiring selectively and ensuring that faculty members have the resources they need to succeed.
- Caltech enrolls the best students.
- Caltech takes a unique approach, focusing on areas that call for fundamental advances and that will be the starting point for new fields and disciplines.

Their recommendation encompassed six broad areas (in no specific order): the formation of an institute of sustainability; the launch of a cross-divisional, cross-disciplinary initiative in the life sciences; the possible formation of a seventh division within Caltech encompassing information science and technology; increased support for graduate and postdoctoral fellows at the divisional levels; support for pre-college education within the Pasadena area; and an increased focus on undergraduate education.

In the area of undergraduate education, the committee noted the challenges of maintaining an innovative and inspiring approach to undergraduate education. To continue to attract the best students and meet the needs of a changing student population, the Aims and Needs committee recommended several additional measures:

- Consistently promote high quality undergraduate teaching;
- Create opportunities for undergraduate research at the earliest levels;
- Support and encourage face-to-face meetings between student and faculty advisor;
- Increase support for innovation in undergraduate teaching;
- Encourage and promote breadth in course offerings, perhaps through partnerships with other institutions;
- Examine new ways of teaching the core curriculum.

In fall of 2009, Provost Stolper presented to the Institute Administrative Council and to the Board of Trustees an overview of Caltech's activities within the past year that relate to the suggestions of the Aims and Needs Committee. He also indicated that these suggestions will become part of the framework for Caltech's strategic plan. With regard to support for graduate students and postdoctoral scholars, he noted that new money continues to be raised for fellowships with the help of a new matching fund from a long-time Caltech supporter. With regard to undergraduate education, he described the revisions to the undergraduate advising program (see 2.5 below), the new Innovation in Education Fund (see 2.6), the review of the core curriculum (see Essay 5), and the on-going review processes associated with this accreditation report.

2.3 Impact of the economic downturn and communication with the community

With the economic downturn, Caltech's leadership, in consultation with the Board of Trustees, determined that it was necessary to reduce the FY2010 budget by approximately 5% of the total campus operating budget (excluding JPL). Because these discussions began in the fall of 2008 just after the October start of the FY2009 budget, it was possible by acting rapidly to introduce much of the required reduction early in FY2009. The budget reductions were made with the intent of preserving the Institute's core missions of education and research. These reductions required a reorganization of some units, the elimination of approximately 130 positions, and the postponement of non-critical activities and projects.

The impact of the financial changes was shared with the campus through memos to the community, and through separate town hall meetings with staff, and with graduate students and postdoctoral scholars. President Chameau and Provost Stolper also met with the faculty in each of the six divisions; President Chameau and Vice President for Business and Finance Currie updated the faculty through reports to the Faculty Board. In the spring of 2009, President Chameau and Vice President of Student Affairs Sargent met with residents of each of the eight undergraduate Houses to answer their questions and concerns about the budget reductions. The parents of Caltech's undergraduates also received a letter, which provided parents with an overview of some of the budgeting decisions as they affect students and financial aid.

At the October 2009 Faculty Board meeting, Vice President Currie presented an overview of the economic situation for FY2010. The governing principles in setting the budget involve the preservation of the core academic and research programs; the protection of need-based undergraduate financial aid and graduate stipends and salaries; and placing the endowment payout rate at a level that balances the need to preserve the principal with the need to provide appropriate levels of funding to support programs and infrastructure. For FY2010, Caltech does not plan any targeted layoffs; however, there was no annual salary increase for faculty and staff. Faculty hiring will continue but at a slower pace; staff hiring will be limited primarily to replacements. Most units received resources comparable to FY2009.

2.4 President's Diversity Council

The President's Diversity Council was created in 2008 to serve as the primary body for gender and diversity issues on campus with power to initiate, monitor, and assess programs as directed by the President. The WASC visiting team met with the Diversity Council during their visit; they noted in their report, "Gender diversity, equity, and inclusion have improved substantially, and must continue to do so. Efforts to expand the numbers of underrepresented minorities in all facets of Caltech must be further strengthened. The establishment of a position for a full-time specialist to recruit minority students is a good step forward."

Since the visit, Caltech has hired a full-time recruiter, who will focus on increasing the diversity of the Caltech undergraduate student body. Since her arrival in July 2009, she has been working with the admissions office and other campus offices to develop a strategy to enhance our success at recruiting, enrolling, and graduating a diverse undergraduate student body. For fall 2009, the freshman class includes 33 students from underrepresented minority groups, which represents 13% of the entering class. Although this percentage is lower than at peer research universities, it is significantly higher than prior years at Caltech. As described in the CPR report, the Young Engineers and Science Scholars (YESS) program, a summer residential 3-week science program for high school students, has helped to increase the number of minority students applying for admissions to Caltech. Last year, Caltech began participating in QuestBridge – a non-profit program that links bright and motivated low-income students with educational and scholarship opportunities at selective colleges and universities.

In addition to issues associated with undergraduate admissions, the Diversity Council recently examined graduation rates of our female and underrepresented minority students. Over the past five years, the 6-year graduation rates (the 6-year graduation rate for this period corresponds to students who entered between 1999 and 2003) for women (89%) have matched the graduation rates for men (89%); the graduation rates for underrepresented minority students have been consistently lower (73%). However, an analysis of recent trends shows a more favorable comparison. For students who entered in 2004, the five-year graduation rate for women is 95%; for men 89%; and for underrepresented minorities 86%. For students who entered in 2005, the four-year graduation rates for women (74%), underrepresented minorities (75%), and men (78%) are approximately equivalent. All of the underrepresented minority students (12 students) who entered in 2006 are currently enrolled; for 2007, 88% are enrolled (17 students entered); and 2008, all are enrolled (15 students entered).

The Diversity Council was interested in understanding the change in graduation rates for our minority students depending on whether they matriculated before or after 2004. Although there may be a combination of factors, the undergraduate admissions office underwent a change in leadership around 2004. At that time the admissions office became more proactive in recruitment of highly-talented minority undergraduates who would succeed at Caltech.

The Freshmen Summer Research Institute (FSRI) has also undergone changes in recent years and has been effective at retaining students. The FSRI is a 5-week program for incoming Caltech freshman who are underrepresented, underserved, and/or minority matriculants. It is designed to provide students with an opportunity to experience the research-based culture of Caltech prior to the start of classes and to prepare students for the first-year mathematics courses. After the start of freshman year, FSRI students are also invited to participate regularly in programs sponsored by the Caltech Center for Diversity. Students are invited to participate in FSRI after they are admitted to Caltech. Of the fifty FSRI participants over the past 5 years, only two have withdrawn from Caltech.

The faculty on the Diversity Council, along with several outside experts, also helped to support a review of the diversity programs sponsored by the Moore Foundation. In addition to the FSRI program, a grant from the Moore Foundation also supports YESS; the MURF summer research program for underrepresented college students (non-Caltech); and the GradPreview program for prospective graduate students. The Foundation also supports graduate and postdoctoral scholar fellowships. The purpose of the review was to assess the effectiveness of the funded programs and to initiate a process to plan for future support.

2.5 Undergraduate advising

At the time of the CPR visit, the Council on Undergraduate Education (CUE) had been discussing undergraduate advising. These discussions had been motivated by feedback from exit surveys that showed low student satisfaction with advising, especially with freshman advising. The Aims and Needs Committee and feedback from the Board of Trustees' Student Experience Committee also encouraged a review of the advising process. In addition, the undergraduate Deans, the Registrar, and the Vice Provost held an advising lunch meeting

with undergraduate option representatives (faculty members who oversee and coordinate academic issues within an option) to solicit their feedback on advising within the options; this group also supported changes to the advising system.

For incoming freshmen, faculty advisors traditionally have been assigned based on the intended major of the incoming student. However, each division had a different process for assigning the advisors. In addition, the advising load was significantly heavier in divisions with large student enrollments, such as engineering. Students also noted that the quality of advising was uneven across the Institute.

The CUE proposed a series of changes to the Faculty Board in April 2009. These changes are designed to improve the quality and amount of interaction between the faculty advisor and the undergraduate advisee.

For freshman advising in fall 2009, there are 36 advising groups consisting of one faculty member (in two groups there are two faculty members) plus seven freshmen. In addition, the faculty member may also include an upper class student as part of the advising group. The faculty advisors are tenured faculty members who have a reputation for being friendly, engaging, and approachable to students. These advising groups meet regularly throughout the year over an informal lunch, coffee, a hike or other activity. The advisor also meets individually with students to discuss registration, courses for the following term, or other issues that arise. The group advising helps to decrease the reluctance that students sometimes have in talking with a faculty member; students also see that many of their challenges or questions are also encountered by their peers.

Unlike prior years, all freshman advisors were invited to a lunch training with undergraduate Deans Hall and Green, Registrar Morley, Health and Counseling Center Director Austin, and Vice Provost Hunt to discuss the new advising program. The aim of the program was to provide information on the topics of likely interest to their advisees – responsibilities of an advisor; the core curriculum; the transition from high school to college; the registration process; the Honor Code; emotional and physical well-being; non-academic life; and freshman camp. In addition, the Freshman Advising Handbook was updated to reflect the changes in the advising system. Of the thirty-eight faculty members involved in the freshman advising program, thirty-seven were able to participate in one of the two scheduled lunches.

With the new system of freshman advising, students are assigned to their advisor without regard to their stated academic interests. Students can learn about potential majors from a variety of avenues during their first two to three quarters in residence. For the 2009-10 academic year, there are nine “frontier” courses that are designed primarily to introduce first-year students to the academic and research programs associated with different fields; three of these courses are new for 2009-10. The fields that are covered in these frontier courses are applied and computational mathematics (new); biology; chemistry; chemical engineering; computer science (new); engineering and applied science; electrical engineering (new); geological and planetary sciences; and physics. These courses are often held at noontime with lunch served. For many students, these courses are the first introduction to faculty within their potential majors; students also find that these courses provide an opportunity to learn

about research opportunities. In addition to the frontier courses, students have the opportunity to hear about specific options during orientation week. Some options may also offer an "open-house" during winter term in which students can find out more information about the major.

After declaring a major, students are reassigned an advisor within that field; most students stay with this faculty advisor for the duration of their undergraduate program. Although feedback on advising within a major received more positive feedback in exit surveys as compared to freshman advising, CUE also recommended changes to upper-class advising to strengthen the program. Because Caltech uses an electronic system for registration, some students and faculty members had replaced face-to-face meetings with electronic communication through the registration system. Beginning in 2009-10, all students are required to meet face-to-face with their advisor at least once per year to discuss their academic program. Students can provide feedback about their advisors and request a change in advisors if the situation is not working. The Dean's office is developing a new handbook, Information for Advisors of Upper-Class Students.

2.6 Innovation in Education Fund

In the fall of 2007, President Chameau announced the formation of an Innovation in Education Fund based on a recommendation from a 2007 report by an ad hoc committee looking at issues associated with the student experience and Student Affairs. The purpose of the fund is to encourage the faculty to be creative about the development of new courses, upgrade classroom and laboratory facilities to promote innovation, provide support for new educational experiences, and other educational activities.

Since its announcement, the fund has supported two key courses within the core curriculum: an introductory chemistry laboratory course (Ch 3x) and an introductory biology course (Bi 1x). Both of these courses are described in Essay 5 on the core curriculum. The fund has partially supported a recent effort by the faculty in mechanical engineering to modernize an undergraduate facility used for courses involving engineering design and construction. In 2008-09, faculty members in aeronautics and physics jointly sponsored a project-based course built around a planned mission for a space telescope, the Nuclear Spectroscopic Telescope Array (NuSTAR), which is being developed jointly by Caltech and the Jet Propulsion Laboratory. The course is designed to educate students about the science and engineering of space missions and to offer them an opportunity to observe and participate in the NuSTAR development from mission concept through launch.

In addition to the courses described above, the fund has also supported smaller projects. For fall 2009, the provost's office received thirteen proposals ranging from support for a new physics problem-solving competition to support for new visualization techniques for a core mathematics course. As this program develops, the provost's office is also planning a process to evaluate the supported programs.

2.7 Revisions to the Teaching Quality Feedback Reports and training for teaching assistants

In spring 2009, the CUE recommended changes to the Teaching Quality Feedback Report (TQFR), an electronic feedback system on teaching quality that is used across the six Caltech divisions. As a result, the questions have been modified to focus more on teaching effectiveness and student learning. In addition, the electronic system has been integrated with the Registrar's database to make the processing of the data more efficient. The numeric results of the surveys are available to the campus community; the comments are available to the instructor or teaching assistant, the division chair, and the division chair's designees as appropriate. The instructors and teaching assistants are notified after the results have been posted.

Professor Zhen-Gang Wang (center), recipient of the 2008 Feynman Prize for Excellence in Teaching. The Feynman Prize is awarded annually to honor a professor who demonstrates, in the broadest sense, unusual ability, creativity, and innovation in undergraduate and graduate classroom or laboratory teaching.

Caltech requires that every student complete Teaching Assistant (TA) training prior to serving as a TA. The training is offered as part of the orientation programming for incoming students. Additional training sessions are offered each term for students who are unable to attend in the fall, and for those students who are assigned TA duties after the start of the academic year. Last fall, we had 100 percent compliance with this requirement.

TA training has two central goals including: 1) distributing Institute policies and Institute expectations for compliance with these policies; and 2) training students on teaching and educational effectiveness. To support the first goal, speakers at TA training include members of the faculty, the FERPA officer, the Title IX coordinator, the Graduate Dean's Office and the Office of General Counsel. To support the second goal, the Caltech Project for Effective Teaching (CPET) provides professional development opportunities for teaching assistants. CPET also offers students certification in programs such as pedagogy and instruction. Some of these programs are staffed by outside specialists who provide expertise to support our teaching assistants' understanding of teaching and learning including classroom management, getting appropriate feedback, holding effective office hours, and supporting student needs. The feedback on these programs has been positive.

After much consideration, the Office of Graduate Studies is expanding TA training to include an online program in early 2010. The new training program will offer a number of interactive modules that students can access throughout their graduate school career and during their TA assignment. In addition to providing information on effective teaching, the online program will support TA work by offering information on how to deliver information, assess whether students have learned (and retained) that information, and to develop a course.

2.8 The Caltech Safety Net and the Mental Health Task Force

Caltech has a number of programs in place to address the emotional and physical well-being of members of the Caltech community. Since the CPR visit, we have continued to strengthen these programs.

In May 2009, the Faculty Board was updated by the director of Caltech's Health and Counseling Services on mental health services provided at Caltech, including education and awareness efforts. The director outlined the trainings that had been initiated for resident associates (RAs) living in the undergraduate and graduate housing, undergraduate health advocates, upper class counselors, staff within Student Affairs, faculty option representatives, option secretaries who interact regularly with graduate students, division chairs, and much of the faculty.

The director also outlined the Caltech Safety Net program, which is designed to strengthen the formal and informal systems that help identify individuals in distress and assist them in receiving support. The entire campus community was sent an email from President Chameau with a link to an online slideshow entitled, Caltech's Safety Net Approach: Preventing Suicides and Violence. This presentation reminds the community of the available resources, recommends that individuals be mindful of changes in behavior of those around them, and provides advice on how to intervene if someone is having emotional problems.

Student Affairs organizes a "Students of Concern" committee, which is comprised of faculty and staff. This committee meets biweekly to share concerns about individual students and to ensure that a support system is in place to assist such students. The personal information shared about students in these meetings is considered confidential and is only discussed outside the group on a need-to-know basis. Members of the group often find that students are utilizing services from several offices; hence, the group has a more complete picture of the student's situation. If it appears that a student is not getting sufficient support, one member of the group is designated to follow up with the student to offer assistance. In addition, Caltech has a Crisis Assessment and Response team, which meets to discuss situations involving faculty, staff, and students who pose a risk to safety or when their emotional well-being is severely compromised. The focus of this committee is to develop a plan to address the current situation and mitigate any risk.

Beginning in the summer of 2009, the campus embarked on further assessment of the processes and resources associated with supporting student mental health and well-being. These additional efforts included an evaluation of the campus resources from a representative of the Jed Foundation, a non-profit organization that works to reduce the rate of suicides and the prevalence of emotional distress among college students. In addition, President Chameau recently appointed a Mental Health Task Force with the following charge:

- Review policies, procedures, and strategies around student mental health crises, including interactions with campus units, parents, and other stakeholders;

- Evaluate the capacity and ability of the Health and Counseling Centers to meet the needs of the students;
- Review and assure that Caltech's policies, such as health insurance, leaves of absences and returns, are adequate to meet mental health care needs;
- Examine academic and personal stresses that affect the diversity of Caltech students, and, when possible, develop strategies to reduce these stresses;
- Provide students with education and training to deal with conflict, overcome disappointment, and to develop healthy relationships;
- Evaluate methods, including practices at other universities, to communicate and educate the community on mental health and well-being;
- Evaluate and reduce access to lethal means of suicide.

This committee has been meeting through the fall term and will continue meeting through this academic year and summer with a report expected in September 2010.

ESSAY 3. ASSESSMENT TOOLS AND PLANNING PROCESSES

(CFRs: 2.5, 2.7, 4.3-4.6)

Caltech uses a combination of mechanisms to evaluate its academic and research programs. These review processes include Caltech's visiting committees; the biennial Student-Faculty Conferences; student feedback through course evaluations such as the TQFR, enrollment statistics, exit and alumni surveys, and course-specific ombudspersons; and external accreditation processes such as ABET, Inc. These processes provide Caltech's faculty and trustees with feedback and assessment of our educational programs, as summarized in the following sections. In Essay 4, we show how these processes have been used to improve the educational programs at the option or division level; in Essay 5, we describe the use of these review processes within the core curriculum. To demonstrate how these processes have impacted the educational programs and courses, we have created a matrix that includes examples of these processes at both the option and course level.

3.1 Visiting committees

Visiting committees have been a part of the Caltech's assessment process for several decades via reviews of each of the six academic divisions. The function of the visiting committee is "to assess the Institute's research and teaching programs to affirm their strengths and to identify weaknesses and opportunities."

Over the last three years under leadership of President Chameau, Caltech has also initiated a set of Chair's Councils, which provide counsel and fund-raising support. Each division has at least one Chair's Council (there are four within the EAS division). These Councils meet once or twice a year. To allow for the formation of the Chairs' Councils, the visiting committee process has slowed from a regular three-year cycle to a five-year cycle. The most recent visiting committee was in the fall of 2007 for the EAS division. The next visiting committee

is scheduled for late spring 2010 for the GPS division, which was last reviewed in 2005. HSS will follow GPS in the fall of 2010.

The visiting committees are appointed by the president and are generally composed of approximately twelve members, half of whom are members of Caltech's Board of Trustees, and half of whom are distinguished faculty members from universities around the country or industrial experts in the field. During their two-to-three-day campus visits, the visiting committees meet with Caltech's administration, the division chair and faculty, and privately with groups of undergraduates, graduate students, postdoctoral scholars, and junior faculty. In preparation, the division submits a background briefing book that contains a review of the division's current activities and programs for research and teaching, the division's strategic plan, actions taken in response to previous visiting committee reports, and other issues to be addressed by the visiting committee. The briefing books typically include an analysis of the distribution of the division faculty, plans for future hiring, information on the student populations, a summary of courses taught, and some financial data. The faculty members within the divisions are engaged in the report's preparation. The written reports prepared by the visiting committees are distributed to the division faculty and a summary is provided to the Board of Trustees.

The visiting committees for each of the academic divisions provide feedback on our educational programs. A recent analysis of the visiting committee reports showed variations across the divisions in the questions asked of the visiting committee and the data collected regarding educational assessment. To further strengthen the visiting committee process, future visiting committees for each of the divisions will include several common questions regarding the quality and effectiveness of the academic programs, recognizing that these questions may evolve over time. The divisions will also be asked to provide a common set of data, such as graduation and retention statistics for undergraduate and graduate students; time to degree; placement summaries for graduating students; and statistics on the gender and ethnic composition of the students, postdoctoral scholars, and faculty within the division. The visiting committees will be asked to review the assessment process and to provide their own feedback on the quality of the educational programs.

3.2 Student-Faculty Conferences

Beginning in 1980, Caltech began to host Student-Faculty Conferences to provide a forum for students and faculty to discuss academic and student life issues. When these conferences were started, they were two-day events; the faculty was asked to cancel their classes to promote participation of both students and faculty. Through the 1980s the conferences were held every two years; however, they lost some momentum in the 1990s. After a five-year hiatus, the tradition was revived in 2002 for a one-day event. Since then, student-faculty conferences were held in 2003, 2005, 2007, and most recently in April 2009. In 2008, a half-day conference that focused on issues related to the student experience had strong student and faculty participation.

The conferences are organized by the undergraduate Academics and Research Committee (ARC) with support from faculty, Student Affairs, the CUE, and the Provost's Office. In the 2009 conference, there were campus-wide sessions involving the core curriculum; the humanities and social sciences; undergraduate research; and the student-experience trip (a trip taken by a dozen undergraduates in the fall of 2008 to several universities and colleges to learn about activities that could be incorporated into Caltech's academic and student life programs). A summary of the campus-wide sessions is available.

The 2008 Student-Faculty Conference, which focused on the undergraduate student experience.

In addition, there were smaller sessions that focused on specific undergraduate options: applied and computational mathematics (ACM); biology (Bi); chemistry (Ch); chemical engineering (ChE); computer science (CS); electrical engineering (EE); geological and planetary sciences (GPS); mathematics (Ma); mechanical engineering (ME); and physics (Ph), applied physics (APh), and astrophysics (Ay).

Each of these sessions was organized by a committee of undergraduates (typically 3-5) and faculty members (2-5). These committees began meeting as early as six months prior to the conference to develop specific discussion topics. These topics arose through meetings of the committees, surveys of students, and pre-conference open forums. In several of the sessions, a possible resolution of the issues was discussed prior to the conference. For each of the sessions, the organizing committee was urged to prepare a final summary of the discussion and the current status of any recommendations proposed by the committee.

As an example, the CS students and faculty chose five areas to focus their discussion: specific advanced CS courses, introductory CS courses, teaching quality, the relevance of the CS program for students interested in industrial positions, and the relevance of the program for students interested in pursuing research opportunities within CS. For each of these five topics, the CS students and faculty members developed both short- and long-term recommendations. Some of the recommendations regarding course changes have been implemented for fall 2010, including a new frontier course for incoming students interested in CS.

3.3 Student and alumni surveys and the ombuds system

To gather information on student goals, satisfaction, and future plans, Caltech surveys incoming freshman, and exiting undergraduate and graduate students. The data from these surveys is annually distributed to the division chairs and is part of the information that we plan to provide to visiting committees (see Appendix 2). The survey results have been used in preparation for this accreditation review, in discussions through the CUE, and other faculty committees and internal evaluation processes. The data regarding post-graduation plans of Caltech alumni are shared each year with Caltech's trustees.

In spring 2009, Caltech also participated in an alumni survey in conjunction with a group of highly selective post-secondary institutions. Undergraduate alumni from 1970 to 2008 were asked for information on their current careers, their post-Caltech education, their satisfaction with their undergraduate education, the educational preparation they received, and their current level of connection and support of Caltech. In preparation for this accreditation review, additional questions were also added to get alumni feedback on the core curriculum, undergraduate research, and the Honor Code. These results are discussed in the later sections of this report. A total of 2,286 alumni responded electronically to the survey for a response rate of 43.3%.

As noted in 2.7, Caltech has a course evaluation process through the TQFR. Although this electronic process is available for all divisions, some divisions supplement this feedback process with paper forms distributed in class. The numeric feedback from these reports is made available to the campus community; some divisions choose to make additional information available.

In many classes, there is a student ombudsperson who provides immediate feedback to the instructor on issues that may arise in homework, lectures, or with the teaching assistants. Each division manages the system of ombudspersons differently. For example, the faculty member may ask for a volunteer to serve as the ombudsperson. In the freshman physics course, there is a student ombudsperson from each of the eight undergraduate student Houses, and the faculty member teaching this course meets with the ombudspersons at scheduled meetings. In the biology division, the Biology Undergraduate Student Advisory Committee (BUSAC) organizes the system of ombudspersons.

Within the core curriculum, the ARC appoints one committee member to gather information on each of the core courses. Just after midterm exams each quarter, this group of ARC students meets with the Dean, the Associate Dean, the Chair of the Core Curriculum Steering Committee, and the Vice Provost to discuss the feedback from the courses. If the feedback indicates that there is a problem with one of the courses (such as excessive homework), the group develops a plan on how to give the feedback or suggestions to the faculty member.

3.4 Diagnostic exams for incoming students

As described in the CPR report, Caltech uses diagnostic exams in writing, physics, mathematics, and chemistry to place students with weaker high school backgrounds into the appropriate section or course. These exams are administered in the summer before the freshman year. Below is a brief summary of how these exams are used.

From the results of the physics and mathematics exams, students are placed in different recitation sections of the first quarter of the mathematics and physics courses. Students with weaker preparation in mathematics may also be required to take an additional quarter of mathematics. Entering students with advanced coursework in mathematics and physics have the option of taking an additional placement exam that could allow the student to begin the mathematics or physics sequence at an advanced level. For entering students with a strong background in chemistry, the student may elect to take the chemistry exam. Students who do

well on the chemistry placement exam may choose between two more advanced chemistry courses to fulfill the Institute's chemistry requirement.

For the writing diagnostic, students submit an essay that is used to determine whether the student is prepared for the freshman humanities courses. Students who have not developed sufficient writing skills may be required to take either a course in English as a Second Language or take an introductory composition course in addition to the core humanities requirements.

3.5 Engineering accreditation through ABET, Inc.

Caltech has accredited programs through ABET, Inc. in electrical engineering, mechanical engineering, and chemical engineering. The ABET process requires a regular review that includes an internal evaluation and self-study followed by a visit from an external evaluation team. There are nine criteria used in ABET accreditation: an evaluation of student performance; statements of educational objectives and processes for the evaluations of these objectives; a process that demonstrates that students attain a list of specific engineering outcomes; a process for continuous improvement; a curriculum appropriate to engineering; appropriate faculty; adequate facilities; institutional support and resources; and other criteria specific to the field of study. Hence, the ABET review process for these three engineering programs overlaps with the focus of the EER for these fields.

Caltech's ABET accreditation extends until September 2012; the next self study report is due in July 2011.

ESSAY 4. ACADEMIC PROGRAMS

(CFRs: 1.2, 1.7, 2.1-2.7, 2.10, 4.5)

4.1 Summary of placement of recent graduates

Each of Caltech's undergraduate academic programs provides an educational foundation that allows its graduates to pursue advanced education and/or careers in research and professional practice in many areas, especially in industry, academia, national laboratories, or business. For example, the description of the chemistry program from the Caltech catalog states: "Study in the chemistry option leads, especially when followed by graduate work, to careers in teaching and research at colleges and universities, in research for government and industry, in the operation and control of manufacturing processes, and in management and development positions in the chemical industry."

For the last two years, approximately 50% of our undergraduates have gone directly to graduate school. In the recent alumni survey, 70% of the respondents graduating in the last five years had enrolled in a graduate or professional degree program. For alumni six-to-ten years post- graduation, the number increases to 80%. For alumni ten-years post graduation, 38% indicated that they had received a PhD or were currently enrolled in a PhD program at the time of the survey. This percentage is consistent with data published in 2008 from the

National Science Foundation which indicated that Caltech was the top baccalaureate-origin institution of doctorate recipients across the United States. For every 100 Caltech baccalaureate recipients, an average of 35.2 recipients continued on to earn a PhD across all science and engineering fields between 1997 and 2006. Of our bachelor's recipients who have gone on to graduate school, 86% report that Caltech has prepared them "very well" or "more than adequately" for graduate or professional school.

Caltech alumni are most likely to report that they are working in private for-profit organizations (46%), in higher education (25%), or are self-employed (9%). The most frequently reported occupations are engineer (21%); programmer, computer scientist, or analyst (16%); college or university faculty member (13%); physical scientist (11%); management consultant, business manager, or administrator (6%); life scientist (5%); physician (4%); and financial manager or analyst (4%). Seventy-two percent of Caltech's alumni reported working in a field that is related to their undergraduate major; this percentage appears to be approximately the same for recent alumni and for alumni who graduated 30 years prior. Overall, 76% of graduates reported that Caltech prepared them "more than adequately" or "very well" for their current career.

June 2009 Graduates

*215 Bachelor of Science**
117 Master of Science
2 Engineer Degree
193 Doctor of Philosophy

**130 graduated with honor*

4.2 Examples of assessment and improvement within the undergraduate academic options

For fall 2009, Caltech has 26 undergraduate options (majors) and an independent studies program leading to the degree of Bachelor of Science. As shown in Table 2 below, the largest options are physics, mechanical engineering, computer science, chemical engineering, electrical engineering, chemistry, biology, and mathematics; these eight options constitute more than three-quarters of the undergraduate population. Some options, such as astrophysics, geology, and planetary science, have less than a dozen students.

Few students select an option in HSS as their major; however, students may select an HSS option (economics, English, or history, for example) as a double major. Currently, there are 40 seniors (out of 206) who intend to major in a second option; the most popular second major is business economics and management. First-year students do not declare a major until the middle of their third quarter in residence.

Table 2

Fall 2009 enrollment of sophomores, juniors and seniors in the largest options.

Option	Enrollment
Physics	87
Mechanical engineering	84
Computer science	67
Chemical engineering	66
Electrical engineering	65
Chemistry	59
Biology	52
Mathematics	51
Subtotal	531
Total of all sophomores, juniors, and seniors	692

Since the last accreditation visit, all of Caltech's academic programs have undergone review through the visiting committee process, the Student-Faculty Conferences, and through feedback from students, alumni, and occasionally employers. Several programs also have been accredited through ABET, Inc. Based on responses from the exit surveys, the options are sent a summary of the career or educational plans of their graduates along with data on student satisfaction (see Appendix 2, Exit Survey Summaries).

This essay presents major changes that have occurred in several of the largest undergraduate academic programs within three different divisions. The essay also highlights the use of our assessment processes that helped to shape these changes. To summarize the changes and the associated review processes, we have developed an assessment matrix.

4.2.1 EVOLUTION OF THE ENGINEERING AND APPLIED SCIENCE OPTION AND THE START OF THE MECHANICAL ENGINEERING AND COMPUTER SCIENCE OPTIONS

At the time of the last review in 1998, Caltech had four undergraduate degree programs within the EAS division: applied mathematics, applied physics, electrical engineering, and engineering and applied science. The EAS option was the largest undergraduate program at Caltech with approximately one-quarter of all students. As stated in the 1998-99 catalog, "The engineering and applied science option offers an unusually broad curriculum that permits students to tailor a course of study to their individual needs as well as pursue one of the more traditional engineering curricula." Within the EAS degree, there were suggested academic programs for students interested in aeronautics, applied mechanics, civil engineering, computer science, environmental engineering science, material science, and mechanical engineering. These programs were only suggestions; students had wide latitude in choosing their academic programs within the EAS division. However, if a student interested in mechanical engineering or aeronautics completed all of the recommended coursework for these programs, the student would receive a degree in engineering and applied science with a

"concentration" in one of these two areas; these were the only two programs with a concentration within the EAS degree.

In a presentation to the EAS visiting committee in 2000, the chair of the division (Professor Richard Murray) described some of the challenges of the undergraduate EAS degree program. He noted that the degree acts as a "catch-all" option because the curriculum requirements were broad and it was hard to ensure depth within the option; he also noted that because of the breadth of the degree program, the faculty within EAS did not take ownership of the program in the way that the EE faculty oversaw the EE degree program. In 2002, the EAS division had another visiting committee meeting, at which an update was given on the EAS degree. At that time, the faculty recommended a restructuring of the EAS degree to offer a new curriculum that balanced flexibility with specific requirements.

In connection with the discussions on the EAS degree program, the ME faculty proposed a new undergraduate degree program in ME. This program was approved through the curriculum committee and the Faculty Board in the spring of 2002. This change was designed to better prepare students for work and/or advanced study within the field. The faculty also observed that there were EAS students focused on mechanical engineering who were graduating with weak academic programs. By establishing a specific B.S. degree in ME, the faculty felt that they could develop a nationally-ranked program that would be attractive to Caltech undergraduates.

Around the same time, the faculty in computer science were also proposing a new degree program. The goals of the new CS program were to introduce students to the mathematical and engineering foundations of the discipline and to integrate research into the academic curriculum. The proposed program allowed flexibility within the upper division coursework and required a multi-quarter project or senior thesis. This program was approved by the Faculty Board in June 2003.

When the EAS visiting committee met in March 2004, they wrote, "The Division addressed two long-standing challenges with the creation of the undergraduate degree programs in computer science and mechanical engineering. The simplicity and appropriateness of the curricula belie the effort and thought that went into this endeavor." Since that time, the CS and ME programs have grown to be among Caltech's largest undergraduate programs.

With the establishment of the CS and ME degrees, the faculty within the EAS division began to consider the remaining components of the EAS bachelor's degree program. The faculty conducted a study that examined the transcripts of approximately 100 recent EAS graduates to determine what coursework students took to complete their degrees. From this study, it was apparent that although all graduates had met the formal requirements of the major, many had completed only a portion of a coherent suggested program within EAS. In the spring of 2003, the faculty within the division was surveyed regarding their views of the EAS degree. A majority of faculty members indicated that they preferred to see a revision of the EAS degree that provided more structure. The future of the EAS undergraduate program was also a topic of the 2003 Student-Faculty Conference.

In the spring of 2004, a new EAS degree program was presented to the EAS visiting committee. When the proposed new program was introduced, there were six possible areas of concentration: aeronautics; control and dynamical systems; computation and neural systems; environmental science and engineering; materials; and structural mechanics. Each of these proposed concentrations specified a level of coursework consistent with other degree programs at Caltech. In addition to the new concentrations, the EAS degree also provided an option for students to propose their own self-designed program within engineering; the program would have to be approved by the EAS oversight committee and contain sufficient coursework in computer science, laboratory science, oral communication, and advanced engineering mathematics. The proposed new EAS program was approved by the Faculty Board in June 2004.

Currently there are only three remaining concentrations within the EAS degree: computation and neural systems; environmental science and engineering; and material science. Beginning in 2005, the control and dynamical systems concentration within EAS was removed; instead, a minor in this field was started. By adding the minor program, students are able to specialize in control and dynamical systems in addition to a major field such as physics or mechanical engineering. Similar decisions were made regarding concentrations in aeronautics and structural mechanics; in 2007, minors in these fields were introduced. In 2009, there were six graduates within the EAS undergraduate option, and three students took a minor in control and dynamical systems. There were no minors in aeronautics or structural mechanics.

In summary, the EAS faculty recognized the shortcomings of an academic program that offered the students wide latitude in choice, but did not contain sufficient structure or oversight. With encouragement from the division chair and the visiting committee, the faculty developed three academic programs (the revised EAS, ME, and CS options) and three minors (control and dynamical systems; aerospace; and structural mechanics). The new ME and CS options are popular with the undergraduates and provide both depth and flexibility within these fields.

4.2.2 RESTRUCTURING OF THE CHEMICAL ENGINEERING OPTION

During the 2002 visiting committee meeting for the CCE division, the committee noted the drop in undergraduate enrollment of students within the ChE option. (In 2002, there were 10 B.S. graduates in chemical engineering; in 2003, there were 5; in 2004, the number dropped to 3). At the time of the visiting committee meeting, the ChE faculty had already begun discussions on designing a new curriculum that would be more relevant and appealing to Caltech undergraduates.

In the winter of 2003, a proposed new ChE curriculum was presented to the curriculum committee and approved by the Faculty Board. The new curriculum was designed to recognize the diversity of employment options for ChE graduates and Caltech's focus on translating fundamental science to engineering applications. The faculty also designed the program to place more emphasis on atomic and molecular level phenomena. To implement these changes, the faculty proposed specific course changes and the addition of four "tracks" that would allow specialization within the option's degree program (the four tracks are

biomolecular, materials, environmental, and process systems). Each of the tracks involved specific course work at the junior and senior levels. The 2006 CCE visiting committee wrote, "Chemical Engineering appears to have made real progress in addressing the curriculum challenges and the quality of teaching reported to the visiting committee in 2002. As evidenced by the increased number of majors and an overall higher level of satisfaction with teaching, the chemical engineers' proactive effort seems to have had a positive impact on the students' educational experience."

By modernizing the curriculum and introducing the track system, the faculty redefined the ChE program to be attractive to students and to provide the necessary background so that graduates would be successful in their future careers. At the 2007 and 2009 Student-Faculty Conferences, the ChE faculty and students discussed the revised curriculum and the degree requirements of the ChE option. As noted in the report for the 2009 SFC, "The track system has been a welcome addition to the chemical engineering curriculum." In 2009, there were 20 graduates in ChE, significantly more than five years earlier. Seventy percent of these students plan to go to graduate school immediately after graduation; of the students going to graduate school, two-thirds indicated in their exit survey that they would be attending their first-choice graduate program. The chemical engineering program also maintains accreditation through ABET, Inc.

4.2.3 RESTRUCTURING THE BIOLOGY OPTION

In 2003, the BIO division visiting committee wrote, "The committee believes that curricular change is required in order to increase the satisfaction of those already in biology and to attract more undergraduates to the major. This is the time when biology should be one of the most alluring subjects for Caltech undergraduates, and the Caltech curriculum in general should be producing undergraduates who are uniquely qualified to make significant contributions to the field." The committee also wrote, "We suggest that the Division institute creative new approaches to the core curriculum…"

When the visiting committee returned in May 2006, it raised some of the same issues that were discussed in 2003. In response to the 2006 visiting committee report, the division held a series of meetings with the entire biology faculty, the Biology Undergraduate Student Advisory Committee (BUSAC), and the biology representatives for the Student-Faculty Conference. Through these discussions, the division developed a framework for a revision to its introductory curriculum and a new approach to the upper division curriculum. These proposed changes were outlined in a letter from the chair of the BIO division (Professor Elliot Meyerowitz) to the visiting committee in December 2006.

The introductory curriculum included a revision of the required biology course within the core curriculum (this introductory course is The Biology and Biophysics of Viruses, Bi 1; more discussion about this course can be found in Essay 5). The division also proposed introducing changes that allowed well-prepared incoming students to replace the introductory requirements for the biology majors with more advanced course work. In addition, the proposed new biology major included a series of "tracks" (such as biochemistry, genetics,

neurobiology). Students would have a choice in their advanced coursework; however, they would have to include coursework from at least two of the tracks.

The curriculum changes were discussed at length at the April 2007 Student-Faculty Conference. The students on the biology SFC committee wrote, "The SFC hopes that the new biology option requirements will encourage students to pursue more advanced coursework in their fields of interest…. We applaud the faculty on the quality of the undergraduate curriculum." The changes were approved through the Faculty Board in June 2007, and adopted into the curriculum in the 2007-08 academic year.

With input from students and the visiting committee, the BIO division reinvigorated the undergraduate program. The positive response to these changes is evidenced by the feedback from the 2009 exit survey in which 89% of the biology seniors responded that they were "very satisfied" or "generally satisfied" with coursework within the biology option; whereas, in prior years the satisfaction level was between 50 and 60 percent.

4.2.4 THE NEW BIOENGINEERING OPTION

In the report of the 2003 BIO visiting committee, the committee wrote, "We suggest that the Divisional leadership continue to explore offering undergraduate courses in bioengineering, most of these would be interdisciplinary and interdivisional." A similar sentiment was voiced by the 2007 EAS visiting committee.

A graduate-level bioengineering (BE) program was introduced in 2001. Since that time, undergraduate students have been able to take courses within the graduate program, but they could not initially choose bioengineering as an option. However, the chemical engineering option has a bioengineering track, and the electrical engineering option has a recommended list of elective courses for students interested in bioengineering. In addition, several students used the flexibility of the revised EAS degree to craft their own program in bioengineering, subject to approval by the faculty. These approaches, however, did not meet the broad demand and interest of the undergraduate student body for a new major in bioengineering. Although there was no bioengineering undergraduate option, the level of student interest was significant enough that the 2007 Student-Faculty Conference had a bioengineering session dedicated to present a rationale for a future academic program in bioengineering.

After approximately two years of planning, the faculty associated with the graduate BE option proposed to the Faculty Board a new undergraduate option in March 2009. As found in the catalog description, "The undergraduate bioengineering option provides a foundation for graduate studies in the application of engineering principles to the design, analysis, construction, and manipulation of biological systems, and in the discovery and application of new engineering principles inspired by the properties of biological systems." This option combines coursework in biology, chemistry, mathematics, and computation with core bioengineering courses. In addition, students in the new program specialize within the field by selecting one of four tracks: synthetic biology, mechanics, devices, and a self-guided track that requires faculty approval. Each track culminates in a design lab that features the design and construction of a novel experimental system appropriate to the track.

With the start of the degree program in fall 2009, 33 students have already indicated that they intend to major in bioengineering, and approximately half of these students are interested in the synthetic biology track. Faculty from three different divisions (BIO, CCE, and EAS) and the Caltech administration have invested time, energy, and resources into this new undergraduate option, which will provide a unique opportunity for Caltech students to study at the intersection of biology and engineering.

New Rosen Bioengineering Center Funded

Seeing a burgeoning new research field at the interface of biology and engineering, the Benjamin M. Rosen Family Foundation of New York has donated $18 million to the California Institute of Technology to establish the Donna and Benjamin M. Rosen Bioengineering Center…. According to Ed Stolper, Caltech's provost, "Our current challenge is to provide an intellectual and programmatic focus on our growing teaching and research programs in bioengineering, spanning synthetic, systems, and computational biology; biomechanics and bio-inspired design; and development of novel biotechnologies. The Rosen Center will provide such a focus and critical support for these activities, which span many of the Institute's existing programs"

Caltech Press Release, 04/01/08

ESSAY 5. CORE CURRICULUM

(CFRs: 1.2, 2.3, 2.4-2.6, 4.3)

5.1 The purpose of the core curriculum

The educational philosophy of Caltech's undergraduate program was formulated by the modern founders of Caltech: Arthur Noyes, Robert Millikan, and George Ellery Hale. The founders envisioned that the undergraduate program would "include an unusually thorough training in the basic sciences of physics, chemistry, and mathematics, and a large proportion of cultural studies… It is hoped in this way to make the undergraduate courses of the Institute a combination of the fundamental scientific training with a broad cultural outlook." As described in the Caltech Faculty Handbook, their statement was adopted by the Board of Trustees in 1921, and is largely responsible for the present character of the Institute.

Since the 1920's, the core curriculum has undergone changes through a series of formal reviews (in addition to the current review, there were reviews in 1978-80; 1985-86; 1994-1996). As described below, there are additional mechanisms that provide regular feedback and evaluation of the core curriculum. Despite any revisions or modifications, the educational

purpose continues to embody the original vision of modern founders. As stated in the 2009-10 Caltech catalog:

> *A Caltech education requires not just the depth of an option, but also considerable breadth in basic science, humanities, and social science. Caltech's core curriculum prepares students for the interdisciplinary nature of contemporary research in science and technology. This encourages a culture of problem solving, collaboration, and communication while providing valuable experience in all fields of science. Significant study in the humanities and social sciences is an important component of Caltech's core curriculum, giving alumni the ability to navigate the societal, political, and economic factors that influence, and are influenced by, their work.*

A description of the breadth and extent of the core curriculum has recently been incorporated into the Freshman Advising Handbook and presented at the freshman advisor's lunch to provide guidance to faculty serving as advisors. A description of the core is included at the orientation for new undergraduate students. A survey of the 2009 incoming freshmen showed that 45% of the incoming students "strongly agreed" that they had an understanding of the content of the core curriculum before arriving on campus. After the orientation session at camp, the percentage increased to 75% of students strongly agreeing that they now understood the breadth and extent of the core; 24% indicated that they agreed somewhat.

The philosophy of the core is also restated in three of the educational outcomes associated with the Caltech undergraduate program, which are found below:

- Bachelor of Science graduates can identify, analyze, and solve challenging problems within and across science and engineering disciplines.
- Bachelor of Science graduates can apply their analytic skills to other areas of knowledge and understand issues important in our society.
- Caltech graduates can analyze, synthesize, and communicate ideas.

The following sections demonstrate how Caltech educates students in support of these goals and our processes to assess and evaluate these outcomes.

5.2 The core courses

As envisioned at the founding of modern Caltech in 1921, the core curriculum includes mathematics, physics, chemistry, and the humanities, but it has expanded since then to include coursework in biology, the social sciences, written scientific communication, physical education, and a science course chosen from a specific menu. Table 3 below lists the basic core requirements, the associated course number, and the number of units (a typical one-quarter course is 9 units).

Table 3		
Basic Core Requirements	**Course Number**	**Units**
Freshman Mathematics	Ma 1 abc*	27
Sophomore Mathematics	Ma 2 ab	18
Freshman Physics	Ph 1 abc	27
Sophomore Physics	Ph 2 ab	18
Freshman Chemistry	Ch 1 ab	15
Freshman Biology	Bi 1 or equivalent	9
Science Menu Class	Ay 1, Ch/APh 2, ESE 1, Ge 1, or IST 4	9
Freshman Chemistry Laboratory	Ch 3a or equivalent	6
Additional Introductory Laboratory	list of choices	6
Science Writing	list of choices	3
Humanities	2 introductory plus 2 advanced courses	36
Social Science	2 introductory plus 2 advanced courses	36
Additional Humanities or Social Sciences	4 courses	36
Physical Education	3 courses	9
Total		255 units
*The "abc" designation indicates that the course is conducted over the fall, winter, and spring quarter.		

Although not formally a part of the core, it is an Institute requirement that all undergraduate options require that students take a class in oral communication for 3 additional units. The total of 258 units (255 units for the core plus the 3 units for oral communication) comprises more than half of the 486 units required by most Caltech undergraduate options.

5.3 Assessing students' learning within the core

The assessment of student learning within the core is done through several mechanisms. As part of the preparation for the WASC review, some of the faculty members teaching within

the core were interviewed to determine their views of the educational goals for their class, the mechanisms used by the faculty members to evaluate how students reach the goals, and the feedback mechanisms they use to improve their course. The summaries of these interviews, the course syllabi, and samples of student work are available in Appendix 1 attached to this report.

Many faculty members monitor student performance on problems in homework sets or on exams. In some classes, teaching assistants grade the homework; however, many faculty members have methods to obtain feedback from the teaching assistants about homework that is difficult or problematic for students. As noted in Essay 3, many options and many of the core classes have a system using student ombudspersons who provide timely feedback to the faculty member(s) teaching the class. For example in Ch 1a, the professor takes a small group of students to lunch each week to hear directly from them about their understanding and learning within the course. Personal response systems (or "clickers") are used in Bi 1, Ch 1, and Ge 1 to spot-check student understanding and to allow the professor to refocus in real time on topics not fully understood by the students. In Ma 1 and Ph 1, there are small sections with approximately 20 students per section. In Ph 1, sections meet either two or three hours per week and many of the sections are led by a member of the professorial faculty. Thus for this course, faculty members have a direct knowledge of the level of understanding of students within the course. In the freshman humanities courses, classes are limited to 15-18 students; all students are required to participate in class discussion and to write several papers. In these courses, faculty members also meet students individually to assist in editing and organizing their papers.

As revealed in the interviews, faculty members teaching within the core use a variety of mechanisms to monitor student learning and make improvements within their classes. The information from these interviews will also be used by CUE to develop a methodology to share best practices for assessing student learning. With the on-going process to review the core curriculum (see 5.6), this information will be useful in promoting teaching effectiveness.

5.4 Evolution of the core curriculum

In the 1996 core curriculum report, the committee envisioned an evolutionary process in which further changes and monitoring of the core could take place on a regular basis. To this end, one of the recommendations of the review was to establish the Core Curriculum Steering Committee (CCSC), which was later formalized as a standing committee of the Faculty Board. As stated in the committee charge, "The CCSC coordinates and supervises content and teaching of the core curriculum. The committee also monitors the performance of the core curriculum courses and devises improvements in the core." In addition to the CCSC, the Curriculum Committee (CC) is another committee of the Faculty Board, which is charged to "exercise general supervision of the undergraduate curriculum." This committee reviews all proposed changes in the undergraduate program including courses. Hence, any changes to the core curriculum are brought to the CCSC and the CC for discussion. Depending on the issue, one committee may take the lead in discussing the proposed changes. Both committees must vote to approve of the proposed changes prior to submission to the Faculty Board for final approval.

In recent years, there have been a number of changes to the core curriculum. Below are some examples. These changes resulted from faculty and committee discussions, which in some cases were initiated through direct student feedback, feedback from the Student-Faculty Conferences, course surveys, faculty observations about the level of student performance, or a combination of these assessment tools. The changes described in this essay were approved by votes of the CCSC, the CC, and the Faculty Board.

5.4.1 BIOLOGY

The 1996 core review committee recommended that biology be included as a requirement within the core and not as one of the science menu courses (see section 5.4.4). The committee noted, "Among the sciences not currently in the core, biology has the largest impact in the scientific and non-scientific world… In all of science, it has arguably the strongest claim to being the 'science of the future.' Many believe that it contains the most exciting challenges in all of science."

Since that time, the course Bi 1 has been a part of the required core for non-majors (students who intend to choose biology as their major take Bi 8 and Bi 9 in the first year). The course began as Fundamentals of Modern Biology, a one-quarter course for 9 units designed to give students an introduction to modern biological techniques and to expose students to the logic of biological experiments and the multiple scales over which biological issues must be analyzed. The course was designed so that students were asked to "solve" a major topical issue. As indicated in the original course description, "By presenting the basic material as a means to understanding an engaging and topical issue, the course should help give the students a context in which to organize and employ the principles of modern biology." Over the first five years, the course focused on AIDS. In later years, the title changed to Drugs and the Brain, with a focus on understanding the mechanisms of drug addiction, the causes of major neurological diseases, and an introduction to medical therapies for these diseases. The most recent version is entitled The Biology and Biophysics of Viruses, which looks at recent advances in understanding how HIV and other viruses infect and cause damage in their hosts.

Students entering Caltech have a range of backgrounds based on their exposure to biology in high school. Some entering students have two years of biology, including an AP class; some have taken one year of regular biology; every year a few students have had no high school exposure to biology. With this range of backgrounds, the faculty members teaching Bi 1 have recognized the challenge of teaching a one-quarter topical biology class to non-majors. Based on feedback from the students through TQFR, the ombuds system, and the Student-Faculty Conferences, the biology faculty decided to create a new "experimental" course that could be substituted for Bi 1. This course would be "experimental" in content and in approach. The idea was to pilot a biology laboratory course for first-year students, which would energize students about modern biological questions and techniques.

The course, The Great Ideas of Biology (Bi 1x), was launched in spring term 2009 for 16 students who won the "Bi 1x lottery" sponsored by the Registrar's Office. The course is designed to combine molecular biology techniques and advanced microscopy around some of the "great ideas of biology" – including cell theory, the genetic code, and gene regulation. In

addition to laboratory experiments, the course includes a "journal club" in which the professor, students, and teaching assistants discuss recent research articles on related topics. The students also develop a portfolio of their work over the quarter (including microscopy images, graphs, pictures, etc.) and deliver a final presentation on a biology topic of their choice.

The feedback from the students in Bi 1x has been strongly positive. This course will be offered again in the spring of 2010 and has been supported through the Innovation in Education Fund and the BIO division.

In addition to offering Bi 1x, the biology faculty elected to allow students to take either Bi 1, Bi 1x, Introduction to Molecular Biology (Bi 8), or Cell Biology (Bi 9) to fulfill the Institute's biology requirement. In prior years, students with a major outside of biology could substitute both Bi 8 and Bi 9 to replace Bi 1. In addition, students who earned a 5 on the AP Biology exam may also petition to take a higher-level biology course to fulfill the biology requirement.

Out of the Classroom

[Grayson] Chadwick is anything but average. As a freshman in Bi 1, he proposed a novel treatment for HIV/AIDS that has captured the attention of experts in the field. This year, that idea has earned him a provisional one-year patent and the George W. and Bernice E. Green Memorial Prize for research. His idea is also being reviewed for funding by the Bill and Melinda Gates Foundation.

Chadwick's Bi 1 proposal involved the use of 'decoys' for HIV. HIV usually infects cells of the immune system, like T cells and macrophages. It then replicates by inserting its genetic sequence into its host's genome. Chadwick proposed that, by tricking HIV into infecting some decoy particle that didn't allow HIV to replicate, the HIV reproductive cycle could be stopped.

The California Tech*, April 26, 2009*

5.4.2 ANALYTIC AND PRACTICAL TRACKS OF PHYSICS 1bc

In the mid-1990s the physics faculty observed several changes in the character of Caltech undergraduates taking introductory physics, including a wider range of student backgrounds and interests in physics; the challenge associated with keeping the best students engaged while making the material accessible for the rest of the class; and a decline in the performance of students on the final exam. In response to these observations, the physics faculty introduced two tracks of the introductory physics course, Classical Mechanics and Electromagnetism (Ph 1abc). This course is a three-quarter sequence on mechanics,

electricity and magnetism, and special relativity. In the winter and spring terms, the courses Ph 1b and 1c are divided into the two tracks – "analytic" and "practical." Students choose their track based upon their own interests and preferences. The practical track emphasizes physical insight through examples and applications and includes a one-hour lecture per week involving demonstrations to illustrate the phenomena and basic concepts. In addition, there are three section hours per week designed for problem solving. The analytic track emphasizes physical intuition in problem solving and uses vector calculus techniques. The analytic track involves two 1-hour lectures per week plus two hours of section.

In prior years, the practical track of Ph 1bc also involved take-home labs. Each student was given a kit that included a soldering iron, resistors and transistors, a set of safety glasses, screwdrivers, and other materials, plus a lab manual and a set of experimental exercises. During the 2007 Student-Faculty Conference, students presented survey data suggesting that Ph 1bc-practical was "under-unitted," meaning that the course required more than nine hours of work per week. In particular, the take-home lab required a significant amount of time. Students had also complained about the time requirements through the physics ombuds meetings and through the TQFR. As a result, the enrollment of Ph 1bc-practical was slowly decreasing while Ph 1bc-analytic was increasing.

After some discussion among the physics faculty, the faculty decided that the best option was to leave the material in Ph 1bc-practical essentially unchanged, except to remove the take-home lab and turn it into a separate course (after some minor modifications). This change was implemented at the beginning of the 2008-09 academic year. The new course, Experiments in Electromagnetism Ph 8bc, can be used to satisfy the additional freshman lab requirement in the core. The response to the change has been quite positive. Enrollment in Ph 1bc-practical has increased and the enrollment in Ph 8 is reasonable. The physics faculty are pleased that Ph 8 is now available to any interested undergraduate.

5.4.3 CHEMISTRY LABORATORY

All Caltech undergraduates are required to take a one-quarter chemistry laboratory (Fundamental Techniques of Experimental Chemistry, Ch 3a) that introduces students to the basic principles and techniques of chemical synthesis and analysis. In addition, the course introduces students to basic laboratory techniques: formulating a hypothesis, making deductions, keeping a lab notebook, safety, and statistical analysis of data. The course Ch 3a is 6 units, and had involved five hours of laboratory plus one hour of pre-laboratory preparation. Feedback from the students through the TQFR and the 2007 Student-Faculty Conference indicated that students were dissatisfied with the course. Specifically, the students preferred to have lectures that accompany the labs so that

Donatela Bellone, a junior in chemistry, is a teaching assistant for Ch 1a.

they could more fully understand the experiments and to have the laboratory and the content of the course updated; students also considered the course to be under-unitted.

Although the course was designed for freshmen, the faculty in chemistry had observed that many students delayed taking the course until their junior or senior year. The reason given by many students was that it was difficult to fit a 5-hour laboratory course into the tight academic schedule. In 2006 the chair of the CCSC made a report to the Faculty Board discussing issues related to Ch 3a. He reported that only 57% of freshmen actually take the course during their first year of residence; as a result, they were unprepared for more advanced laboratory courses.

Through the Registrar's office, research was conducted on which students had not completed Ch 3a. Students were emailed and asked to enroll as soon as possible; some students were given advanced priority to register in the class. In 2007 through feedback from the CCSC and the CC, the Registrar's Office changed the procedure on how incoming freshman were enrolled in their courses for their first term. Students who scored well on the Chemistry AP examination and who indicated an interest in majoring in Ch or ChE were placed into Ch 3a, and their first-quarter class schedule was built around the timing of Ch 3a. Subsequently an increasing number of freshmen were completing the course within their first year.

In 2008, the faculty in chemistry recommended a choice in chemistry laboratory by proposing a new "experimental" section of Ch 3a called Ch 3x. The new course consists of one lecture hour plus four laboratory hours per week. The theme of the course is solar energy conversion. Students complete several multi-week experiments that are conceptually linked. By the end of the course, students can design and build their own "Graetzel" solar cell. These cells have electrodes comprised of thin films of TiO_2 quantum dots that are sensitized with dyes to convert optical radiation to electrical work. Each multi-week lab involves a pre-lab, write-up and data analysis, and data interpretation. More emphasis was placed on developing general experimental skills, including scientific method, statistical analysis, and numerical programming. In the final laboratory, the students build on the knowledge and skills gained from the prior experiments to "compete" in constructing the most efficient Graetzel cell.

In 2008-09, Ch3x was offered in the winter and spring terms with enrollment limited to 15 and 20 students, respectively. The chemistry faculty is expanding enrollment to forty to fifty students in three sections per term in 2009-10 and have reduced lab hours to three hours per week; they ultimately hope to make this course to be available to approximately two-thirds of the undergraduate student body. This course has been supported by the Innovation in Education Fund and the CCE division.

For the current academic year, the chemistry faculty also reorganized the Ch 3a laboratory. The course remains a laboratory that introduces students to the synthesis and characterization of molecules; however, the lab experiments have been streamlined, and some have been replaced with more up-to-date experiments using modern techniques and equipment. A lecture component has been added to the course so that students can connect the concepts taught in the lecture course (for example, bonding, polarity, and spectroscopy) with experimental measurements and analysis. The time required in the laboratory has been

decreased to three hours per week to make the total workload commensurate with the 6-unit listing.

In summary, the faculty has recently addressed the concerns about the required chemistry laboratory by including an accompanying lecture component and reducing the length of time in the laboratory and the workload of the course. Both courses have introduced student feedback surveys and employed undergraduate TAs to assess the impact of the new material and teaching strategies. By introducing the new Ch 3x and modernizing the Ch 3a laboratory, students now have a choice between two stimulating laboratories in which to develop and build their skills in experimental science.

Ch 3a Sees a Makeover

In response to student feedback, chemistry professors Mitchio Okumura and Doug Rees worked with graduate student Yoshie Narui over the summer to redesign the core freshman chemistry lab course Ch 3a.
"...the changes made to the course do a better job of teaching the student what's going on and instructing lab procedures."
"Overall I think it is a big improvement."

The California Tech, *October 26, 2009*

5.4.4 THE MENU COURSES

The menu courses expose students to aspects of science that are not covered in the standard core curriculum and thereby broaden their perspective on science and technology. The menu courses were first introduced following the 1996 review. Starting at that time, these courses have been offered in the spring term to take advantage of the course work covered in the first two quarters of physics, mathematics, and chemistry.

When introduced, students chose between The Evolving Universe (Ay 1) or Earth and the Environment (Ge 1). The goal of Ay 1 is to provide an appreciation of how our understanding and perception of the universe has evolved in response to new observational discoveries. Students learn about basic astronomical concepts and techniques, as well as recent research discoveries and new methodologies. Through measurements using astronomical data, students also learn the process of going from data acquisition to scientific interpretation. The focus of Ge 1 is to understand the planet on which we live and how its processes are discovered, quantified, and modeled using both concepts and techniques unique to the earth and planetary sciences and applications of modern chemistry, physics, and

biology. Such understanding is critical for all scientists and engineers as our society faces critical problems of climate change and other aspects of environmental science.

Ge 1 students examine the intrusion and metamorphism shown in the granite and the Precambrian Vishnu schist of the Grand Canyon.

Both Ay 1 and Ge 1 have undergone changes since they were first introduced. These courses have been offered every year and are viewed by student and faculty as successful menu courses. At the 2007 Student Faculty Conference, students advocated for additional menu courses and suggested that students be required to take not one, but two menu courses from a longer list of possible choices.

In recent years, the CCSC has encouraged a regular set of menu courses sponsored through the academic divisions. For spring 2009 (and anticipated for 2010), there were three menu courses in addition to Ay 1 and Ge 1: Introduction to Environmental Science and Engineering (ESE 1), Information and Logic (IST 4), and Introduction to Energy Sciences (Ch/APh 2). In these courses, students apply concepts from mathematics, physics, chemistry, or biology to problems in the environmental sciences, information sciences, or energy sciences. In addition, students are exposed to historical or current aspects of technology and society. In ESE 1, students develop a scientific framework to understand and evaluate environmental problems on local, regional, and global scales, and understand the dynamic interplay among the atmosphere, biosphere, geosphere, and hydrosphere. In IST 4, students develop an appreciation and a historical perspective of how digital information systems, such as their cell phones and computers, process and communicate information, and the changes that have occurred as a result of this technology. The students understand how to translate ideas to abstract formal systems (like Boolean algebra) and to physical substrates (like silicon) that compute. In Ch/APh 2, students learn the science and technology to generate energy and electricity through fossil fuels, nuclear power, renewables, and biological energy flows. In addition, all students in the class participate in a mock debate of the treaty for the United Nations Framework Convention on Climate Change in Copenhagen. Each student group represents a delegation from a different country (including Bangladesh, Iran, Russia, Germany, Japan, and the United States); each group writes a position paper and presents their country's policy towards the treaty based on an understanding of the country's energy resources, energy needs, and environmental and economic consequences of current world energy practices.

Besides giving students exposure to aspects of science about which they would otherwise not learn, each of the five menu courses includes scientific communication, involving a written report and/or an oral presentation. In Ay 1, students complete a written project in which they apply deductive reasoning to a complex problem in astronomy, such as evaluating the effects of a nearby supernova explosion on Earth. In Ge 1, students write an essay on the geological significance on one of the places visited during the class field trip to the Grand Canyon. In ESE 1, students discuss current environmental topics and complete a written project on the

role of the popular press in these issues. In IST 4, students participate in "hat" questions (students are awarded a baseball hat upon completion), which they present to the class; in addition, there is an extra credit essay and presentation.

5.4.5 SCIENCE WRITING AND ORAL COMMUNICATION COURSES

The 1996 core revision called for a course in oral communication. At that time, several options or divisions (EAS, Ge, and Ch) already required coursework in technical presentations. Although the committee wanted to ensure that all students graduating from Caltech learned skills in oral technical presentations, they also recognized that different options and divisions might have variations in style and emphasis within their courses. As a result, they left the implementation up to the options and the divisions.

The 1996 committee also advocated that all students should be required to take a course in science writing. "The purpose of the science communication written requirement is to introduce students to the particular challenges of clear and logical writing about science, both for other scientists and (to a lesser extent) for non-scientists." At the time of the 1996 report, the committee did not specify the details of how to implement the requirement. By 1999, all students were required to take a new course, Scientific Writing: Core 1 ab. This course was a 3-unit, two-quarter sequence (1 unit in the first quarter and 2 units in the second). In this course, students wrote a 3000-word paper about a technical subject; however, the papers were written for a non-technical audience. Each student worked with a faculty member and a professional editor. At the end of the quarter, the papers were published in the on-line student journal.

The purpose of the core writing course was debated by the faculty over several years with much of the discussion happening within the CCSC and CUE; it was also a discussion topic at the 2003 Student-Faculty Conference. Some faculty members preferred to see students writing technical papers within a science or engineering field rather than writing for a lay audience. In addition, there was a considerable cost associated with having a group of editors to run the course. At the May 2004 Faculty Board meeting, the CCSC recommended that the science writing requirements be implemented and taught within the divisions and not at the Institute level. Similar to the oral communication requirement, the options and divisions could make their own choices on an appropriate focus and audience for the writing assignment.

Currently there are five 3-unit science writing courses (Ay 11; Ch/ChE 91; E 11; Ge 13; and Ma 11) and five 3-unit oral presentation courses (Ay 30; E 10; Ch 90; Ge 109; Ma 10). In addition, several options have a 6-unit course that covers both written and oral scientific communication (Bi 24; BEM/Ec/SS 20; Ph 70). In chemical engineering, the oral communication course is part of a required laboratory course (ChE 126). These courses are taught by either professorial faculty members within the field or by professional staff members. The Hixon Writing Center, which was established with an endowment in 2001 to support writing across the curriculum, has also supported some of the science writing courses within the divisions. Students may also elect to take Writing Science (En 84), a 9-unit course taught within the HSS division to replace the division-specific science writing course.

Since the Institute introduced the science writing requirement ten years ago, the focus has changed from writing for a lay audience to writing specifically to an option or division. As described in section 5.5 below, there is mixed feedback on student writing. Hence, as discussed in section 5.7, the Caltech faculty is again rethinking the requirements in writing.

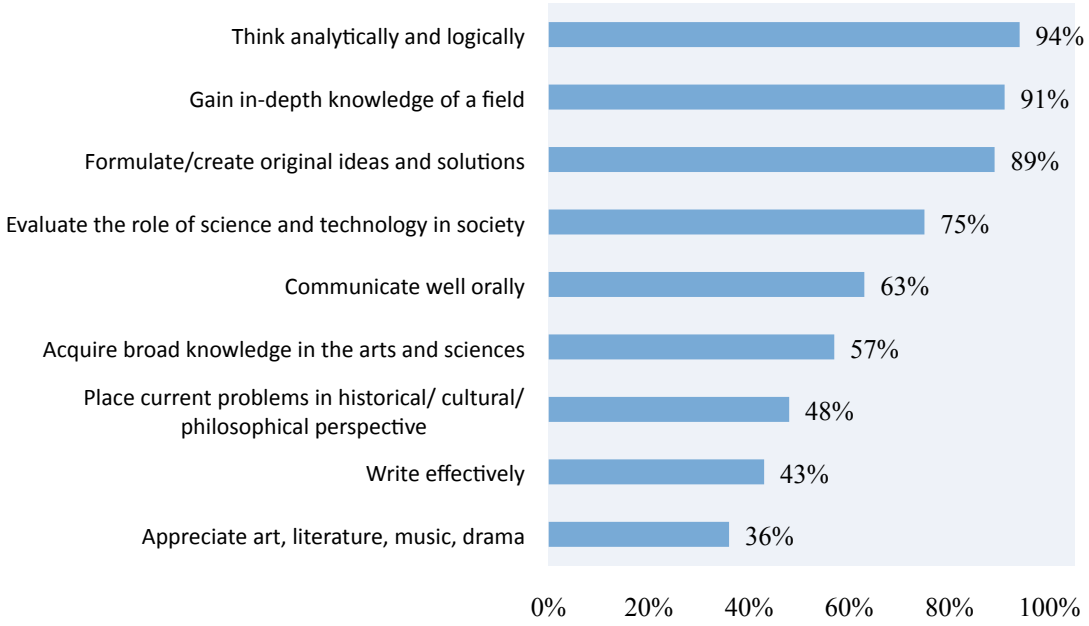
> ***From the Caltech Admission's website:***
>
> *Humanities courses are essential to the development of scientists who can communicate across academic disciplines and understand the cultural and political conditions that affect their work. Students explore concepts from the philosophy of science to the behaviors of individuals within economic and political institutions. Techers refine the communication and analytical skills that will compliment the knowledge they gain within the scientific curriculum.*
>
> *http://www.admissions.caltech.edu/learning/humanities*

5.5 Recent entrance, exit, and alumni surveys

Based on the freshman survey from the Cooperative Institutional Research Program (CIRP), a high fraction of students entering Caltech in fall 2009 rate their academic ability (98%), mathematical ability (94%), drive to achieve (94%), intellectual self-confidence (78%), and computer skills (53%) as "above average" or the "highest 10%" as compared with students their age. These indicators are similar to data from students entering Caltech in prior years and compare favorably with students entering peer institutions. However, their self ratings of creativity (58%), writing ability (61%), leadership ability (55%), public speaking ability (42%) and social self-confidence (43%) are lower than incoming students at peer institutions based on data from CIRP.

Figure 1 below shows data from the 2008 and 2009 senior exit survey; the response rate was nearly 80% with approximately 330 respondents. At graduation, the majority of graduates report growth in their ability to think analytically and logically; to gain an in-depth knowledge of a field; to formulate and create original ideas and solutions; and to communicate well orally. However, less than half of the graduates report growth in placing current problems in historical or cultural perspective; writing effectively; or appreciating art, literature, music, and drama.

Figure 1. Senior Exit Survey for 2008 and 2009
Percent of students who self-rate their abilities as "stronger" or "much stronger" as compared to when first entering Caltech

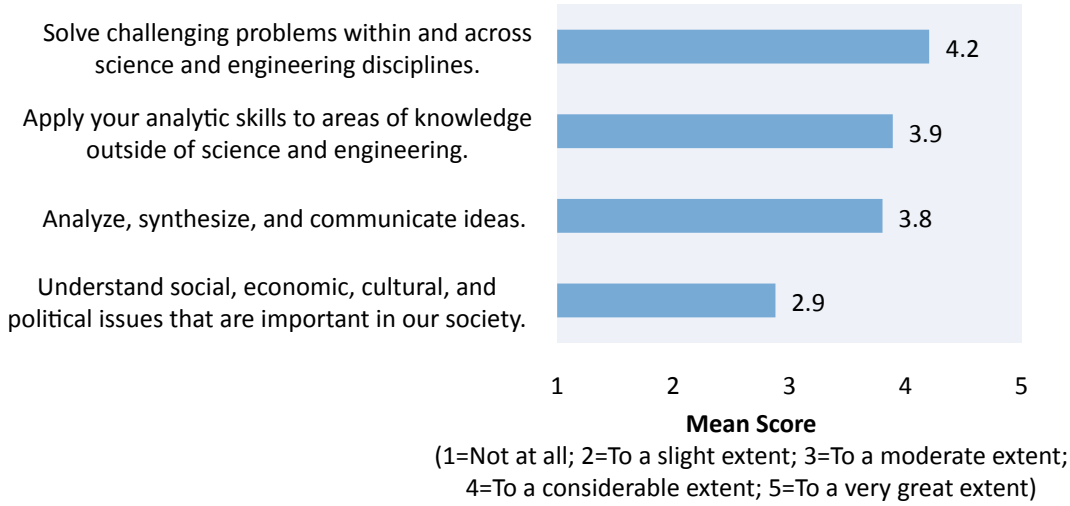


(Source: Responses from 2008 and 2009 senior exit surveys with approximately 330 respondents)

The recent alumni survey (see description in 3.3) was conducted with a consortium of highly selective post-secondary institutions, which enabled Caltech to obtain comparative data. Caltech alumni are distinctive relative to the science and engineering graduates of most other elite universities in their perception of their preparation to acquire new skills and knowledge on their own; to think analytically and logically; to use quantitative tools; to formulate creative ideas and solutions; to gain an in-depth knowledge of a field; and to understand the role of science and technology in society. On the other hand, compared with science and engineering alumni at comprehensive research universities, our alumni's perception of the preparation that they received at Caltech is lower with regard to writing effectively; communicating well orally; understanding social problems; being an effective leader; understanding the significance of the arts; and in reading or speaking a foreign language. Several of these topics, such as effective oral and written communication and an understanding of social problems, are aligned with Caltech's educational objectives. In addition, Caltech also envisions that our alumni are prepared to become leaders in their field. Because these survey results have only recently become available, Caltech's faculty and administration are just beginning the process of trying to understand their significance and how the Institute might improve both its programs and the perceptions of our alumni of those aspects of our programs in which they feel they were not uniformly well served.

With the recent alumni survey, Caltech also included some specific questions related to learning within the core curriculum. Fully 83% of all alumni respondents (from 1970 to 2008) agreed that the intellectual breadth of the core curriculum was valuable. As shown in figure 2 below, Caltech's alumni also indicated that the core prepared them to solve challenging problems within and across science and engineering disciplines, and to apply their analytic skills to areas of knowledge outside of science and engineering.

Figure 2. Caltech Alumni Survey (1970-2008)
To what extent did the core curriculum prepare you to:



Slightly fewer alumni who responded to the survey indicated that the core prepared them to analyze, synthesize, and communicate ideas. They perceive the weakest area to be the effectiveness of the curriculum in helping them to develop an understanding of social, economic, cultural, and political issues important in our society. Although not shown in the figure above, the survey also indicated that the majority of alumni (70%) agreed that core classes helped to promote collaboration between students. When asked if the core courses were more difficult than courses within their majors, the responses were mixed: recent alumni were more apt to indicate that the core curriculum was more difficult than coursework in their majors (41% agreeing that the core was more difficult; 31% disagreeing; and 28% neither agreeing nor disagreeing); alumni who graduated more than 10 years prior indicated the opposite (approximately 25% agreeing that the core was more difficult and 36% disagreeing). Across all graduation years, only a small percentage (typically 5%) suggested that the number of core courses should be increased.

5.6 The 2008-09 Core Curriculum Task Force

In the fall of 2007, the Caltech Faculty Board voted to review the core curriculum. This review was then incorporated into one of the three themes for the WASC CPR and EER. In 2008, the chair of the Faculty Board formally appointed a Core Curriculum Task Force (CCTF) composed of thirteen faculty members from the six divisions and four undergraduate students. The charge to the task force involves evaluating the content and learning outcomes of the core curriculum and teaching within the core. The task force was also asked about research opportunities available within the curriculum, advising, and about the possibility of shifting the academic calendar from quarters to semesters.

The CCTF surveyed the Caltech faculty members to get input and feedback on the core curriculum as it now stands and how it might be modified. Approximately 53% of the Caltech professorial faculty responded to the survey. Of those responding, 85% of the faculty indicated that Caltech should have a core curriculum; 4% responded that Caltech should not have a core curriculum, and 11% were unsure.

Faculty members were also asked to indicate whether specific topics within the sciences, engineering, humanities, and social sciences should be an "in-depth" aspect of the core, an "exposed" look at the topic, part of a "menu" course, "not in the core," or "no opinion." The topics in which the most popular faculty response was "in depth" included many topics currently found in the core, such as single variable calculus, linear algebra, multivariable calculus, ordinary differential equations, and probability (topics currently covered in Ma 1 and 2). Classical mechanics, electricity and magnetism, waves, thermodynamics, and quantum mechanics were also part of the "in depth" group, and are integral to the current Ph 1 and 2. Within the chemistry curriculum, the faculty indicated that chemical structure and bonding, atoms and the periodic table, properties of matter, and a chemistry laboratory should be an in-depth part of the core; these topics are included in Ch 1 and Ch 3a. Additionally, the survey shows that the faculty view cell biology, computer programming, and a physics laboratory important aspects of the core curriculum. The faculty also indicated that students should receive an in-depth exposure to writing, science writing, and English/literature.

During fall 2009, the CCTF made presentations to the Faculty Board, the Caltech faculty, and the undergraduate students at a recent open forum. The CCTF wrote and distributed a preliminary report in which they indicated their intent "to promote vigorous campus-wide discussion," which has been the case for each of these meetings. In the report, the CCTF stresses six major philosophical concepts in how the core should be approached:

- Multiple paths through required courses to recognize the range of backgrounds of entering students;
- Early exposure to faculty in non-lecture settings, such as a freshman seminar;
- Renormalization of the number of required courses in biology, chemistry, physics, and mathematics;
- An intensive emphasis on critical writing skills;
- An exposure to the fundamental ideas and applications of algorithms and computational science; and

- A commitment to laboratories that involve data collection and analysis, and the design and creation of a working prototype.

Through the preliminary report, the CCTF also proposed an academic program that reduces the physics curriculum to 3 quarters rather than the current 5 quarters; retains the 2 quarters of chemistry lecture; increases the biology curriculum to 2 quarters from the current 1 quarter; reduces the mathematics requirements to 4 quarters from 5; increases the number of laboratory courses from 2 to 3; and introduces a freshman seminar course and a course in algorithm development. The CCTF recommended a reduction in the total number of HSS courses from 12 to 10, but also suggested that there be four writing-intense courses on grades (two at the freshman level and two advanced humanities courses). In addition, the CCTF proposed that the pass-fail grading system be used only in the first quarter of the freshman year and not the second quarter, as is currently the policy.

As of the writing of this EER report, the discussions on the core curriculum are on-going. The WASC visiting team will be updated on these discussions during their visit.

5.7 On-going discussions concerning writing within the core

As described in 5.1, Caltech requires all undergraduates to complete four humanities courses (two at the freshman level and two advanced humanities courses); almost all of these courses have limited enrollments of 15 to 25 students to increase interactions between faculty and the students. They also have a significant emphasis on writing. The documentation in Appendix 1 shows examples of course syllabi, writing assignments, and supplementary writing materials that are provided in some humanities courses. All students are also required to complete a science writing course (see 5.4).

Despite the fact that students are required to take these writing courses, they perceive that Caltech has not prepared them to write effectively (see the data from graduating students and alumni presented in 5.5). To understand better why students did not feel that their writing had improved during their time at Caltech, a study was conducted to understand the writing coursework taken by students. As shown in Figure 1 for the 2008 and 2009 exit surveys, approximately 42% of graduating students indicated that their writing had improved; of the remaining students, 30% indicated that their writing skills had remained unchanged while at Caltech, and 28% indicated their writing skills had become weaker while at Caltech. An initial analysis of just the 2009 graduates showed that our international students are significantly more likely to report that their writing skills are stronger (83%) since coming to Caltech than are U.S. students (46%); other variables, such as grade point average, gender, race and/or ethnicity, major, and second majors (including a second major within HSS), were not statistically significant predictors of students' self-perceptions on writing.

For the 2009 graduates, 60 transcripts were examined for domestic students: 20 transcripts from students who reported that their writing skills had improved; 20 from students who reported that their skills had remained unchanged; and 20 from students who reported that their writing skills had become weaker. The analysis of the 60 transcripts showed little difference between the three groups of students, including grade point average for the

humanities courses, choices among humanities courses, and average number of SURFs (a SURF requires several written technical reports). The three groups of students had comparable scores on their SAT exams and scores for their writing assessment tests when they entered Caltech. Almost all of the 60 students took their science writing course in their last or second-to-last quarter in residence. In addition, approximately half of the students (equally among the three groups) took one or both of their advanced writing-intensive courses on a pass-fail basis or elected to take an advanced foreign language course to replace a writing-intensive course.

Based on this information, the faculty in the humanities recently discussed and debated issues associated with writing within the humanities courses. Because of the pass-fail grading system used in the first two quarters of the freshman year, most students take their writing-intensive freshman humanities courses on a pass-fail basis. The humanities faculty has observed that the pass-fail system allows students to hover just above the threshold for passing and not develop skills in writing, editing, and re-writing papers. As a result of their discussion, the humanities faculty voted to require that students take their introductory and advanced humanities courses on grades. Because these courses are a part of the core curriculum, the CC, the CCSC, and the Faculty Board will need to vote to approve these changes.

ESSAY 6. HONOR CODE

(CFRs: 1.2, 2.3, 2.4, 2.11, 4.3)

The Caltech Honor Code states: "No member of the Caltech community shall take unfair advantage of any other member of the Caltech community." This statement is found in the catalog, the Faculty Handbook, and the Honor Code Handbook. It is an integral part of Caltech and the foundation of Caltech's trust-based community. One of Caltech's educational outcomes captures the essence of the Honor Code; as found in the catalog, "Caltech graduates demonstrate integrity, personal and professional responsibility, and respect for others."

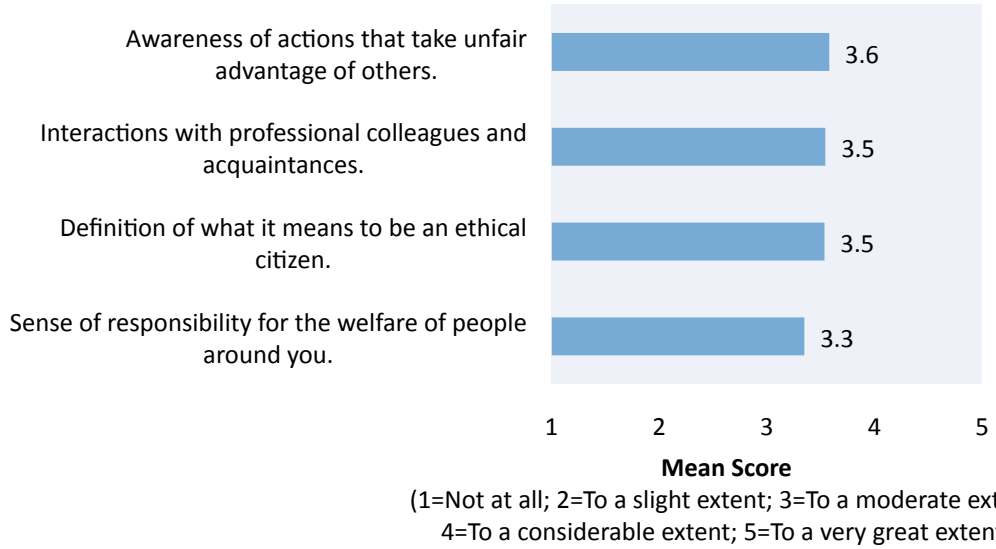
As noted by the WASC visiting team in November 2008, "Sustaining the Honor Code system requires dedication and care." Since that visit, Caltech has continued to promote campus engagement on the topic of the Honor Code, especially as it applies to life outside of academics. The academic application of the Code remains strong and we are working to enhance the understanding of the Honor Code throughout the campus community. Surveys of the alumni and the freshman class, presentations to faculty and students, training for resident associates and teaching assistants, and the formation of two different task forces have all been part of this important effort designed to move us toward sustaining a strong honor system at Caltech.

6.1 Alumni survey

Caltech has not previously conducted a survey of alumni regarding their perceptions of the Honor Code. Overall, the responses from the recent alumni survey (see 3.3 for a description of the survey) provide evidence that the code has a positive and lasting influence on our students. As shown in Figure 3 below, graduates from 1970 through 2008 indicated that the Honor Code moderately or considerably influenced their awareness of actions that take unfair advantage of others; their interactions with professional colleagues and acquaintances; their definition of what it means to be an ethical citizen; and their sense of responsibility for people around them. Although not shown in the figure, fully 83% of the alumni respondents "strongly agree" or "agree somewhat" that the Honor Code promotes the idea of individual responsibility for collective well-being and 84% agreed that it supports respectful, tolerant relationships between students. The statement, "Lessons from living on a campus with an Honor Code are easily extrapolated to real life," was endorsed as well but less strongly (65% agreed). As one recent alumnus wrote, "Regarding the Honor Code, I believe it is a truly unique aspect of Caltech, and it has left one of the most lasting impressions. It fosters an atmosphere of cooperation, teaches self-discipline, and most importantly, gives us the opportunity to face a difficult decision and always choose that which is right, not necessarily easiest."

Figure 3. Caltech Alumni Survey (1970-2008)

To what extent has the Honor Code influenced your:



6.2 The 2008-09 Honor Code Task Force

In December of 2008, the undergraduate chair of the Board of Control (the BoC, which is the student-run committee that investigates and makes recommendations on academic violations

of the Honor Code) appointed an Ad Hoc Honor Code Task Force of four students and four faculty members to review certain aspects of the Honor Code and to prepare a report to be presented at the Student-Faculty Conference in April 2009. The key issues to be addressed by the task force included: the workload of the student members of the BoC; the timeliness in handling complaints that are brought to the BoC; the turnover in the BoC membership and its effects on the consistency in decision making; ensuring transparency and fairness of the process; the education of students and faculty; and community confidence in the process.

At the 2009 Student-Faculty Conference, the task force proposed a series of changes to improve the effectiveness of the BoC. The BoC often faces difficulty in finding enough representatives to investigate an Honor Code violation, which may result in a delay in the process. As a result, the task force recommended a significant increase in the number of BoC representatives (from the previous 11 representatives to 20); this change would also have the positive effect of reducing the work load of individual representatives. The task force proposed a required training session for all BoC members, which would be open to the community; the training session would educate new representatives, encourage discussion about the BoC among its members, develop a consistent approach to decision making, and provide BoC representatives an opportunity to discuss past decisions. In addition, the task force proposed that two "advocate" representatives be assigned to each case to represent the interests of the community and the interests of the student accused of the Honor Code violation. The task force also advocated for greater transparency and suggested that the BoC publish case summaries that would provide general descriptions of the process without compromising student confidentiality.

In the fall of 2009, undergraduates voted to approve: an increase in the number of representatives to the BoC, a required training program, clarifications to the review and appeals processes, and several changes designed to support a student facing the BoC investigative process. Some of these changes have already been enacted; the changes in membership will be implemented when new BoC representatives are chosen in the winter of 2010.

6.3 Education within the community

The CPR report outlined the processes used to educate students and faculty about the Honor Code. Since that report, several additional mechanisms have been introduced to increase awareness and understanding of the Honor Code and its supporting processes. At the time of the CPR visit, we reported that we were following through with a recommendation from the Faculty Board that each option or small division have a faculty member serve as an Honor Code representative. After some discussion with the CUE, the undergraduate Deans Hall and Green, and Vice Provost Hunt invited the undergraduate option representatives to serve in this capacity; the option representatives were then invited to a lunch-time training session on the Honor Code. The presentation included an overview of the BoC and the Conduct Review Committee that investigates non-academic Honor Code and policy violations, and a discussion of ways that faculty could support the Honor Code. Of the twenty-six option representatives, thirteen were able to attend and all option representatives were sent the supporting materials. The training session will be repeated in 2010.

Incoming students are introduced to the Honor Code during the fall orientation week. This year, the student presenters emphasized the application of the Honor Code to non-academic as well as to academic matters. In an anonymous survey given a few days after the presentation on the Honor Code, almost 100% of the new students said they understand how the Honor Code applies to both academic situations and non-academic situations.

The Honor Code was also included in the training luncheon for freshman advisors and in the revised Freshman Advising Handbook (see 2.5). In the presentation and documentation, faculty members are reminded that, as advisors, their role is to provide advice and counsel to the student.

This year, training for the RAs living in student housing also included a session on the Honor Code. The student leaders and the undergraduate Deans leading the training reminded the graduate student RAs about the Honor Code and their role in supporting and advising students who are going through hearings for violations.

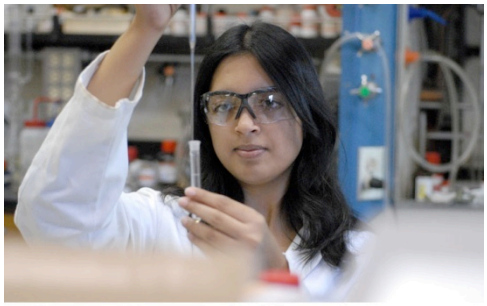
6.4 Honor Code committee focused on non-academic violations

Dean Green and Professor Ingersoll are chairing a new committee to develop ways to increase awareness among the student body of the application of the Honor Code to non-academic situations. The committee is composed of three faculty members and three students and is currently interviewing resident associates, current undergraduate leaders, and other community members to explore additional ways to support non-academic applications of the Honor Code. The committee has been meeting biweekly since October and will continue into winter term. These efforts will be reported to the WASC team during their visit.

ESSAY 7. UNDERGRADUATE RESEARCH

(CFRs: 1.2, 2.4, 2.11, 3.5, 4.3)

Research is a central aspect of Caltech's undergraduate program. As described in the CPR report, there are three main avenues for undergraduate research: research during the academic year for credit through a senior thesis or for research organized with an individual faculty member; work for pay during the summer or academic year; or through Caltech's Summer Undergraduate Research Fellowship (SURF) program. Approximately 75% of the undergraduate student body participate in SURF; approximately 80% participate in some form of research.



Under the mentorship of Dr. Jack Roberts, chemical engineering sophomore Misha Imtiaz works on her SURF project "Conformational Analysis of 3-Guanidino-propionic Acid."

The following section highlights some of the feedback from the alumni survey on undergraduate research. This essay also addresses some of the issues raised by the WASC visiting team during the CPR visit, along with the team's recommendations. These recommendations have framed much of the faculty and student discussions and actions over the past year.

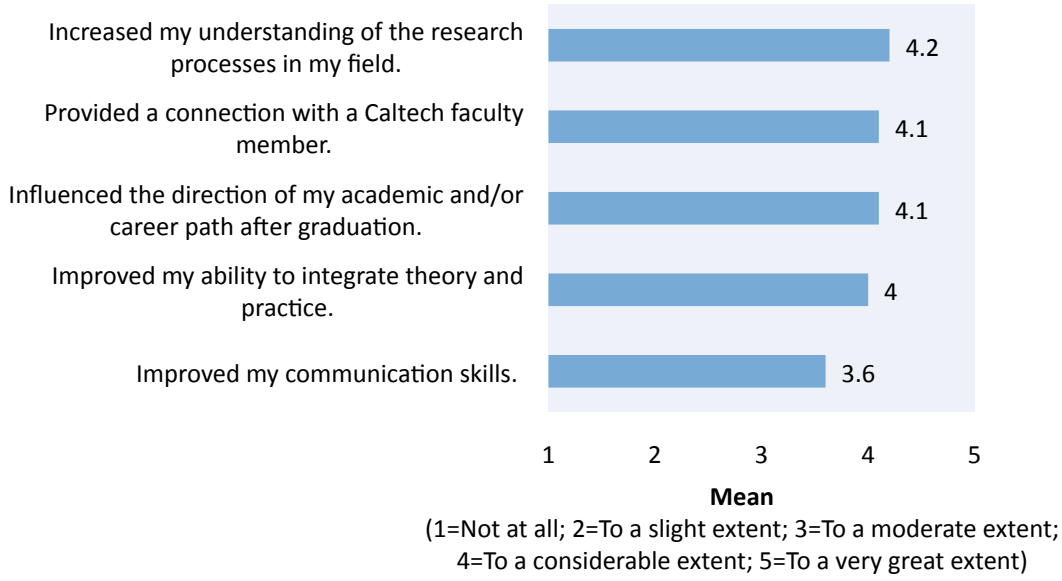
7.1 Alumni survey

The alumni survey included several questions on undergraduate research. As shown in Figure 4, alumni who participated in undergraduate research indicated that to a "considerable extent" or to a "very great extent" their undergraduate research experience increased their understanding of the research process in their field; provided a connection with a Caltech faculty member; influenced the direction of their academic and/or career path after graduation; and improved their ability to integrate theory and practice. To a lesser extent, they indicated that research helped to improve their communication skills.

For alumni who graduated between 2004 and 2008, 70% agreed that research was an "integral part of my undergraduate education" with 19% disagreeing and 11% neither agreeing nor disagreeing. This percentage is significantly larger than for alumni who graduated 30 years prior (less than half of the alumni from the 1970s or 1980s agreed that research was integral to their education).

Figure 4. Caltech Alumni Survey (1970-2008)

To what extent do you agree or disagree with the following statements regarding your research experiences:



(1=Not at all; 2=To a slight extent; 3=To a moderate extent; 4=To a considerable extent; 5=To a very great extent)

7.2 Commitment to undergraduate research

The visiting team wrote, "Caltech has exceptional undergraduate research programs and opportunities, and the SURF endowment has been increased to make them more widely available. This effort should be sustained." In the 2009 SURF Annual Report, President Chameau addressed the nation's economic downturn and the ways in which Caltech's administration and faculty addressed concerns of its potential impact on undergraduate research. Although the value of the SURF endowment and the Institute payout from the endowment decreased, there was a strong commitment to maintaining summer research opportunities at the same level as in previous years. President Chameau wrote, "Last fall, as we began to evaluate how our income would be affected by these economic changes, the campus leadership worked hard to ensure that the core of our academic and research endeavors would remain strong. As a key component of undergraduate education, SURF was certainly a priority. In December 2008, when the SURF application period opened, we took a series of measures to quickly respond to potential funding problems. 1) The SURF director provided weekly updates to the provost regarding the number of available research opportunities. 2) The division chairs and the provost urged faculty not to shy away from making summer commitments to undergraduates. 3) With the support of JPL Director Charles Elachi, additional research opportunities were made available at JPL. 4) Guided by our Business and Finance team, we did our best to protect programs that provided undergraduate aid and support."

The result of these efforts was that nearly 50 more Caltech students than the year before participated in undergraduate research through SURF. More students than in prior years applied and were admitted into the program and faculty financial contributions to the program increased substantially. Although Caltech's comprehensive fundraising campaign closed, there are continued efforts to increase SURF support. In 2009, five newly sponsored SURF endowments were established. Several offices within Caltech's development office have highlighted SURF in their print or on-line materials to keep SURF in the mind of potential donors.

The visiting team recommended that the research programs would benefit from a "uniform faculty commitment to, and an understanding of, the programs and educational objectives of students' research experiences." For over thirty years, Caltech faculty has demonstrated a strong support of undergraduate research. Of the current professorial faculty, 86% have mentored an undergraduate student through SURF during their tenure at Caltech, and 77% have participated as a mentor in the past five years. Additionally, Caltech maintains a course-free summer term to allow students the opportunity to engage fully in research. In addition, Caltech faculty members provide a significant financial investment to support undergraduate research, indicating a high level of commitment to the undergraduate research enterprise.

On-going efforts help introduce new faculty to undergraduate research at the Institute. Each fall, the Director of Student-Faculty Programs meets with new faculty to introduce them to SURF and other summer undergraduate research programs. New faculty are informed that through campus fundraising, financial support is offered to junior faculty for several years so

that they can sponsor SURF students while they are applying and waiting for grant support. These features are also mentioned during the orientation lunches for new faculty.

7.3 Student learning associated with research experiences

In 2008 Caltech faculty identified and established a set of student learning outcomes related to participation in undergraduate research. These learning outcomes include developing a research question, applying basic principles and knowledge to the question, and collecting and interpreting data. While there was campus-wide discussion about these outcomes, more work needs to be done in helping faculty and students understand the outcomes and how to support and measure successful progress. Starting within the SURF program, the following strategies are either now in place or will be implemented during the 2010 summer application process:

- Incorporate learning outcomes in the Freshman Advising Handbook;
- Outline the learning outcomes in the faculty call for announcements of opportunity (AO). Each fall, faculty are invited to post AOs that inform students of summer research opportunities available in their groups. The new call for AOs reinforces the student learning outcomes associated with undergraduate research;
- Include the learning outcomes in student pre-application and acceptance materials. The SURF website serves as a hub of information where students learn about the program. This addition will provide students with a better understanding of the outcomes of the program before they even apply. Additionally, all students must sign an acceptance form when offered a SURF placement. This acceptance form outlines both what is expected from the students and what the students can expect from the program;
- Send a letter to all faculty mentors and co-mentors highlighting the learning outcomes and offering ways in which they can support students' development in these areas;
- Include the learning outcomes in training for co-mentors (graduate students, postdoctoral scholars, and research scientists who work with SURF students);
- Incorporate the learning outcomes in student information sessions.

Caltech faculty play an integral role in assessing the quality, rigor, and outcomes associated with undergraduate research efforts. In the SURF program, assessment efforts are embedded throughout the experience. Students work with potential faculty mentors to write a research proposal. Faculty mentors assess a student's application and proposal package based on established criteria and potential outcomes. After submission, each application and proposal package is reviewed by an independent faculty member and recommendations for funding are made. During the 10-week summer period, the SURF students work with mentors or co-mentors to write two progress reports, an abstract, and a final technical report. At the conclusion, students give a final oral or poster presentation. Each interaction provides a chance for feedback, review, assessment, and, if needed, course correction.

Over the past year, we have focused on strengthening and/or developing a set of rubrics that faculty can use during these critical assessment junctures. These rubrics have been

incorporated into the proposal review process, the mentor recommendation process, the judging guidelines for both the final oral and poster presentations, and the final paper review.

7.4 Communication skills

As SURF mentor Dr. Terry Cole once said, "Science not communicated is essentially science not done." This adage has been at the core of the SURF communications program. Although not shown in Figure 4, the percentage of alumni who agree that their research experience has improved their communication skills has increased over the years. In fact, recent graduates with research experience are almost twice as likely as are those with no research experience to report that Caltech prepared them to communicate well orally. Furthermore, 25% of the 2008 graduating class single- or co-authored a manuscript in a peer-reviewed journal, and 28% presented a talk or a poster at a professional conference. SURF provides several opportunities for students to practice, enhance, and be recognized for effective communication skills.

As indicated earlier, SURF students are required to write two progress reports, an abstract and a final technical paper, and give a final oral presentation. Collectively, these requirements help students develop their communication skills over the period of their project. Students are given strong guidelines to successfully complete each requirement; faculty mentor feedback and ultimate approval is required.

Through SURF, there are several prizes that provide incentives and recognition for students who effectively communicate their science. The Perpall Speaking Competition was created in 1993 as an incentive for Caltech students to give excellent oral presentations. Students who present their research at SURF Seminar Day are automatically eligible for the competition. Students are made well aware of the judging criteria used to evaluate the presentations. Each year, thirty to forty students advance to a semi-final round of the competition; six to eight students advance to a final round of talks. The Gee Family Poster Prize was introduced in 2009 as an incentive to encourage and support excellence in effective scientific communication. The judging is focused on the excellence of the poster presentation, and not on the significance of the research results. Students are strongly encouraged to learn how to present highly technical information to a general, yet educated, audience. Posters are judged on content, visual organization, and verbal presentation. The third prize, the Gordon McClure Memorial Prize for Communication Skills, is also new this year and was established to recognize one rising sophomore, junior, and senior who have demonstrated strong written and/or oral communication skills, starting with their summer research and progressing over the course of the year.

This past summer, one of the science writing courses (E 11) was offered to students participating in SURF. This summer course option was popular with students and helped to improve their writing skills as they performed their research.

7.5 Academic year research

In Spring 2009, the Academic Policies Committee, led by Professor Paul Bellan, looked into the number of students completing a senior thesis. Almost all of the seniors completing a thesis for their primary option were in EE, ChE, APh, GPS, Ch, Ph, ME, and Ma. All students with a double major in philosophy completed a thesis and 60% of students with a double major in English completed a senior thesis.

During the 2009 Student-Faculty Conference, the ARC also provided suggestions on how to better encourage students to do a senior thesis. These suggestions include the presentation of an award at graduation for the best senior theses, recognition on the diploma of anyone who completed a senior thesis, emphasizing the advantages of senior theses in the Caltech catalog, and having senior theses fulfill the scientific writing requirement. Although there has not been any action on these recommendations yet, the CUE will be following up on the recommendations over this academic year.

This year the SURF Administrative Committee discussed ways to better support students who wish to engage in research activities during the academic year. In November 2009, the Administrative Committee also met with members of the CCTF to discuss ways to incorporate undergraduate research into the core curriculum.

In summary, undergraduate research provides students with a unique learning environment that engages them in state-of-the-art research questions and provides them opportunities to interact with Caltech faculty, graduate students, postdoctoral scholars, and scientists. The Caltech faculty recognizes the value of the research experience; however, the challenge remains in providing opportunities during the academic year.

ESSAY 8. CALTECH'S FUTURE DIRECTIONS IN EDUCATIONAL EFFECTIVENESS

Caltech's educational mission is to provide students an outstanding education in a research environment that prepares them for leadership positions, especially in science, engineering, technology, medicine, business, and academia. To this end, Caltech maintains review processes that help to ensure the quality and effectiveness of our educational programs. This essay provides a summary of these efforts in the context of the WASC standards and presents an overview of ongoing and future directions.

8.1 The WASC standards

The WASC EER process requires that Caltech, as well as other universities in the western region, provide evidence of the educational achievement of our students, evidence and actions taken to improve student performance, and the results of our review processes. Using

the four WASC standards, we provide a short summary of these measures as presented in the first seven essays of this report.

Standard 1: Defining institutional purpose and ensuring educational objectives. Essay 2 presents an overview of Caltech and the actions taken since the CPR visit, including the establishment of a new undergraduate advising program; support for teaching and learning through the Innovation in Education Fund, TA training, and student feedback systems; support for student mental health and well being; and efforts to ensure the admission and retention of women and underrepresented students. The three themes for this review, the core curriculum, the Honor Code, and undergraduate research programs, are aligned with the mission of Caltech.

Standard 2: Achieving educational objectives through core functions. In Essay 3, we outline the assessment processes used at the institutional, program, and course level, including the visiting committees, the Student-Faculty Conferences, student and alumni feedback, evaluation and placement of incoming students, and accreditation through ABET, Inc. In Essay 4, we present specific examples of the review processes and subsequent changes for several academic programs (ME, CS, Bi, and ChE); in addition, we describe the process to initiate a new cross-disciplinary program in BE. In Essay 5.3-4, we describe the evaluation and evolution of several courses within the core curriculum including the introductory biology course, the tracks within the physics curriculum, the required chemistry laboratory, the menu courses, and the science writing and communication courses. In Essay 6 we describe the on-going review of the Honor Code. Essay 7.3 and 7.4 presents our efforts in reviewing the processes associated with undergraduate research.

Standard 3: Developing and applying resources and organizational structure to assure sustainability. Caltech is committed to its educational program and support for students, even in the current economic climate as described in Essay 2.3 and Essay 7.2. Caltech engages its faculty and other stakeholders in decision-making processes through its organizational structure and systems for input and feedback.

Standard 4: Creating an organization committed to learning and improvement. Caltech uses the committees of the Faculty Board including the Core Curriculum Task Force (Essay 5.6), administrative committees such as the CUE, and ad hoc committees like the Aims and Needs Committee (Essay 2.2) to review, plan, and assess our research and educational programs. The work of these committees is supported by data from surveys, student feedback, and faculty assessment of student learning. Essays 5.7, 6.4, and 7.3 also describe the continuing processes of evaluation associated with the core curriculum, the Honor Code, and undergraduate research.

8.2 On-going and future directions for review

The preparation for the CPR and the EER reviews has been informative and our efforts have resulted in positive changes and improvements within Caltech's educational programs. Through this process we articulated the institution-level learning outcomes for our students. These outcomes are consistent with Caltech's educational mission and capture our emphasis

on skills associated with analysis, problem solving, synthesis, and the investigation and communication of ideas. These skills are developed through the core curriculum, through coursework within the options, and through research experiences. With Caltech's long history of an Honor Code, we also hope to develop graduates who demonstrate integrity, personal and professional responsibility, and respect for others.

Through this process, we also recognize that there remain areas for improvement. The exit and alumni surveys show that our alumni do not feel that they sufficiently developed their skills in writing and oral communication. As described in Essay 5.7, the humanities faculty have been discussing the writing-intensive courses required within the core. Through the core curriculum discussion and through CUE, there will be ongoing discussions on the importance of effective communication and methods by which we communicate this importance to our students.

As described in Essay 5, the process of reviewing the core will be ongoing, and any changes will probably take several years to implement. However, the faculty is committed to improving the quality of student education and the experience within the core curriculum; the faculty are also interested in including opportunities for research within the academic year.

Caltech strives to educate students to become leaders. Leadership requires a combination of skills, including communication, teamwork, integrity, and respect for others. Relative to science and engineering graduates at peer institutions, a smaller fraction of our graduates responded that Caltech prepared them for becoming an effective leader. In addition, 70% of our alumni indicated that Caltech should increase its emphasis on "teaching leadership skills." Because leadership development combines several of the areas of current emphasis (writing, oral communication, and non-academic aspects of the Honor Code), leadership development might be a fruitful area for investigation in the future.

Much of the CPR and EER reviews focused on our undergraduate students. Graduate education was one of the areas of review in the 1998 WASC review. With more graduate students than undergraduates, Caltech may also want to explore issues (including communication skills and the Honor Code) that are of importance across the graduate program.

This review process has included student and alumni data collected from surveys and from other sources, such as student enrollment numbers and graduation statistics. The CUE has a broad charge and provides a forum for analyzing and discussing undergraduate issues, oversight on teaching, and improving the quality of the educational programs for undergraduates. Although not currently part of CUE's charge, this committee will also be responsible for coordinating, reviewing, and disseminating data associated with student and alumni surveys on the quality and effectiveness of Caltech's undergraduate programs.

In conclusion, this review process has allowed us to examine our educational and co-curricular programs, our objectives for student learning, and our ability to reach these objectives. As we move forward, we will use this review to sustain and enhance Caltech's

excellence in educating and preparing outstanding students for the range of complex and interdisciplinary challenges that they may meet in their future careers.

Caltech Commencement Address
Secretary of Energy, Dr. Steven Chu
June 12, 2009

To the Class of 2009, let me congratulate you on your achievement. You should be proud of the fact that you survived many shocks and are here today. The first shock might have been the discovery your freshman year that you are not alone: child prodigies are everywhere…

You should also be proud that you now have one of the finest liberal arts educations possible. "How does my Caltech training qualify as a liberal arts education?" you may well ask. The goal of a liberal arts education is to teach you how to think rigorously and critically, and to give you the tools to teach yourself. Your quantitative and intellectually demanding training will allow you to venture wherever your curiosity will take you.

Finally, you should be proud to be graduating from an institution where nerds are welcomed. … You might think, "If a person is athletic, socially graceful, and has broad interests, then they are not nerds." Perhaps so, but I want to celebrate people of intelligence, focus, and technical achievement. The ability to understand details does not mean that you are incapable of forming deep insights. In your future life, it is important that you develop broad interests to help you see the forest as well as the trees. It is also important that you cherish your skill to understand something deeply. …

Graduates of the class of 2009, you have an extraordinary role to play in our future. As you enter the next phase in your life, you will no doubt follow your intellectual passions. … I hope you will develop the passion and the voice to help the world in ways both large and small. Nothing will give you greater satisfaction.

Please accept my warmest congratulations. May you live long and prosper. May the Force be with you. May you help save our planet for your children and for all the future children of the world.

APPENDIX 1: CORE CURRICULUM DATA PORTFOLIO

(files available online at http://accreditation.caltech.edu/wasceer)

Bi 1: The Biology and Biophysics of Viruses

- Bi 1 Syllabus
- Bi 1 Course assessment
- Bi 1 2009 Ombuds meeting notes
- Examples of coursework:
  - Bi 1 Finals
  - Bi 1 Midterms
  - Bi 1 Problem set #1
  - Bi 1 Problem set #2
  - Bi 1 Problem set #3
  - Bi 1 Problem set #4
  - Bi 1 Problem set #5
  - Bi 1 Problem set #6
  - Bi 1 Problem set #7
  - Bi 1 Problem set #8

Bi 1x: The Great Ideas of Biology

- Bi 1x Syllabus
- Bi 1x Course assessment
- Bi 1x Grading rubric
- *The Tech* article: A New Spin on Bi 1
- Examples of coursework:
  - Bi 1x Final portfolio #1
  - Bi 1x Final portfolio #2
  - Bi 1x Problem set #1
  - Bi 1x Problem set #2

Ch 1a: General Chemistry

- Ch 1a Syllabus
- Ch 1a Course assessment

Ch 3a: Fundamental Techniques of Experimental Chemistry

- Ch 3a Syllabus
- Ch 3a Fall 2009 midterm survey
- Ch 3a *The Tech* article: Ch 3a Sees a Makeover

Ch 3x: Fundamental Techniques of Experimental Chemistry

- Ch 3x Syllabus
- Ch 3x Course assessment
- Ch 3x Survey results
- Ch 3x The Tech article: New Introductory Chem Lab an Alternative to Ch 3a Requirement
- Example of coursework:
  - Ch 3x Lab notes

Humanities

- Humanities assessment
- Writing Assessment for Freshmen and Transfer Students (WAFT):
    - Writing assignment and source commentary
    - Scoring guide for writing assessment
    - Writing sample (low score)
    - Writing sample (average)
    - Writing sample (high score)

Hum 2: American Society and Politics

- Hum 2 Syllabus

Hum 3b: Early Modern Europe

- Hum 3b Syllabus
- Example of the writing revision process:
    - Writing topic
    - Rough draft
    - Peer review worksheet
    - Revision analysis
    - Final draft

Hum/Pl 9: Knowledge and Reality

- Writing guidelines
- Argument clinic
- Plagiarism statement
- Abbreviations for proofreading
- Peer review worksheet
- Writing topics
- Examples of coursework

Ma 1abc: Calculus of One and Several Variables and Linear Algebra

- Ma 1 abc Course assessment
- Ma 1a Section 1: Freshman Mathematics
- Ma 1a Calculus of One and Several Variables
- Ma 1bc Analytic and practical tracks information for students
- Ma 1bc Analytic
- Ma 1bc Practical

Ph 1abc: Classical Mechanics and Electromagnetism

- Ph 1abc Course assessment
- Ph 1bc Analytical and practical tracks information for students
- Information about physics placement exam
- Ph 1 Faculty Board minutes (Nov. 9, 1992)
- Ph 1 Memo (July 9, 1992)
- Ph 1c Quiz
- Ph 1c Quiz solutions

Science Writing

Bi 24: Technical Communication for Biologists

- Bi 24 Syllabus
- Bi 24 Course assessment

E11: Written Technical Communication in Engineering and Applied Science

- E 11 Syllabus
- E 11 Course assessment

En 84: Writing Science

- En 84 Syllabus
- En 84 Course assessment

Ge 13: Scientific Writing in Geology

- Ge 13 Syllabus
- Ge 13 Course assessment:

Menu Courses:

Ay 1: The Evolving Universe

- Ay 1 Syllabus
- Ay 1 Course assessment
- Examples of coursework:
  - Ay 1 Paper #1
  - Ay 1 Paper #2

Ch/APh 2: Introduction to Energy Sciences

- Ch/APh 2 Syllabus
- Ch/APh 2 Course assessment
- Examples of coursework:
  - Ch/APh 2 United Nations Mock Debate
  - Ch/APh 2 Problem set #3

ESE 1: Introduction to Environmental Science and Engineering

- ESE 1 Syllabus
- ESE 1 Course assessment
- ESE 1 Grading policy
- Examples of coursework:
  - ESE 1 Homework #1
  - ESE 1 Homework #2

Ge 1: Earth and Environment

- Ge 1 Syllabus
- Ge 1 Course assessment
- Examples of coursework:
  - Ge 1 Field report #1
  - Ge 1 Field report #2
  - Ge 1 Homework #1
  - Ge 1 Homework #2

IST 4: Information and Logic

IST 4 Course assessment

Examples of coursework:

- IST 4 Problem set #2
- IST 4 Problem set #4
- IST 4 Problem set #5
- IST 4 Problem set #6

APPENDIX 2: INSTITUTE/OPTION DATA PORTFOLIO

(files available online at http://accreditation.caltech.edu/wasceer)

ASSESSMENT STUDIES

Assessment at the Course and Option Level – Matrix Table

2009 Senior Exit Survey Summaries

Applied and computational mathematics, Computer science
Applied physics, Computation and neural systems, Environmental science and engineering
Biology
Chemical engineering
Chemistry
Computer science
Electrical engineering
Geological and planetary sciences
Humanities and Social Sciences primary major
Humanities and Social Sciences secondary major
Mathematics
Mechanical engineering, Aerospace
Physics, Astrophysics

2009 Student-Faculty Conference

Final reports or presentation:

Applied and computational mathematics
Biology
Chemical engineering
Chemistry
Computer science
Electrical engineering
Geological and planetary sciences
Humanities
Mathematics
Mechanical engineering
Physics
Social Sciences
Undergraduate research

Visiting Committee Reports and Briefing Books*

Excerpts from Visiting Committee reports

BIO	May 16-18, 2006
EAS	October 30 – November 1, 2007
CCE	January 25-27, 2006
PMA	January 31 – February 2, 2007
GPS	March 30 – April 1, 2005
HSS	October 6-8, 2005

*Available to WASC team during the March 2010 visit.

APPENDIX 3: REQUIRED DATA TABLES

(files available online at http://accreditation.caltech.edu/wasceer)

Appendix 3: Required Data Tables

Summary Data

Table 7.1: Inventory of Educational Effectiveness

Table 8.1: Summary of Concurrent Accreditation

8.1.1 Bachelor of Science Placement Data

8.1.2 ABET Reaccreditation Letter 2008

8.1.3 ABET Accreditation Report