Center for Teaching, Learning, and Outreach

June 14, 2020
Detailed Report for Reaccreditation
California Institute of Technology

Table of Contents

CTLO

Part 1: Introduction

HISTORY AND STRUCTURE

Caltech includes in its mission statement the desire to "expand human knowledge and benefit society through research integrated with education." To further enhance the educational part of its mission, teaching quality was identified as an area for additional focus at Caltech during the 2010 reaccreditation cycle. Between 2010 and 2012, then-Vice-Provost Dr. Melany Hunt consulted broadly with faculty and invited leading directors of peer institutions' centers for teaching and learning to lead discussions and workshops at Caltech (e.g., with new faculty and graduate TAs). The CTLO began with the hiring of the founding director, Dr. Cassandra Volpe Horii, in August 2012. A 2011 grant from the S.D. Bechtel Jr. Foundation for the construction of the Bechtel Residence included funds for educational outreach, and after a needs assessment in 2012, Hunt and Horii decided to marry the two foci within the center. Today, the CTLO continues to bring together under a unified umbrella support for all forms of education and teaching: university teaching through work with faculty, instructors, TAs, and students who plan to teach in the future, and educational outreach through work with local, regional, and national K-12 schools and initiatives, which frequently involves Caltech faculty, staff, and students. The CTLO remains part of the Office of the Provost, reporting to the Vice Provost for Education, Dr. Cindy Weinstein. The center is located on the 3rd floor of the Center for Student Services, partially co-located with the Hixon Writing Center.

The CTLO has an informal faculty advisory committee, which has helped to create and refine the center's vision, mission, and values:

Caltech's vision is for the Institute's teaching and educational excellence to parallel our renowned research excellence. **The mission of the Center for Teaching, Learning, and Outreach** is to work toward this vision by:
- supporting instruction,
- enhancing learning, and
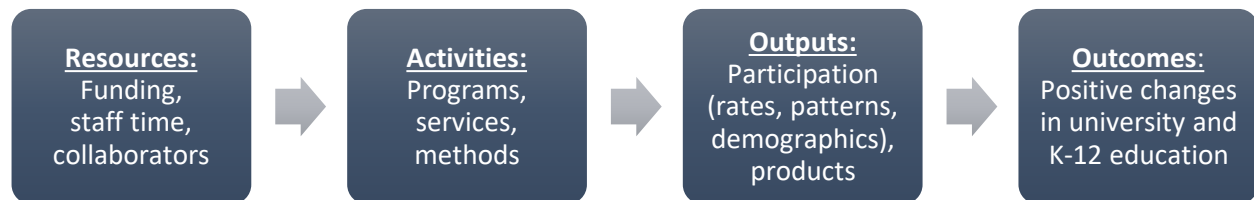- facilitating educational outreach.

The CTLO is committed to advancing evidence-based, inclusive practices through our programs and services, and to fostering innovation based on this foundation.

In 2016, the CTLO received the inaugural Caltech Team Impact Award, recognizing the center's significant contributions to the work and mission of the Institute.

In the context of 2020 reaccreditation, this report primarily focuses on university teaching efforts and impacts of the CTLO on the Caltech community, which contribute to the two Caltech-chosen areas of focus within the WSCUC Thematic Pathways approach: (1) the Core Curriculum and (2) Academic and co-curricular support structures. Following Caltech's 2020 reaccreditation process, the CTLO will update and revise these formal vision, mission, and values statements to better reflect progress, current goals, and new evidence.

RESOURCES, PROGRAMS, SERVICES, AND INTENDED OUTCOMES

CTLO programs and services are based on a logic model, articulating how our resources and activities are intended to lead to outputs (i.e., participation rates, products) and outcomes (short, middle, and long-term, demonstrable changes in teaching, learning, and outreach). Detailed logic models for university teaching and outreach are included as an appendix to this report.

Resources: Funding, staff time, collaborators	→	**Activities:** Programs, services, methods	→	**Outputs:** Participation (rates, patterns, demographics), products	→	**Outcomes:** Positive changes in university and K-12 education

The CTLO works diligently to ensure effective and efficient use of **resources,** including both funds and time. We recognize that both internal staff time and time invested by faculty, students, and others are valuable.

As of May 2020, CTLO staff include:
- A full-time director, responsible for CTLO oversight, budgeting, and delivery of a substantial amount of university teaching-related programming (Dr. Cassandra Horii).
- Two full-time associate directors, one focusing on university teaching (Dr. Jenn Weaver), the other on educational outreach (Mr. Mitch Aiken), each with planning and program delivery responsibilities.
- One full-time program manager for educational outreach (Dr. Kitty Cahalan).
- 2/3 of the time of an office administrator, whose remaining time is applied to the Hixon Writing Center (Ms. Leslie Rico).
- A half-time office assistant (currently vacant).
- A temporary, half-time assessment and evaluation specialist (this position was filled for a limited time to focus on educational outreach in 2018-19; we hope to rehire for this position after the COVID-19 crisis, pending capacity and funding).

The CTLO works with a graduate student affiliate at the level of approximately five hours per week; this graduate student leads the efforts of the Caltech Project for Effective Teaching, a grad/postdoc-focused set of programs on teaching professional development. While not employed or paid by CTLO, we have also worked with graduate "teaching fellows" in several departments; in these instances, CTLO trains and mentors the advanced graduate students to serve as mentors on teaching for other TAs, and faculty leaders also guide their work.

CTLO **activities** include a range of programs and services, briefly described in the following table, showing their topical foci and audiences.

Type or program or service	Topical Focus		Audience		
	University Teaching	Educational Outreach	Faculty, PIs	Students, Postdocs	Community
Individual consultations (one-to-one feedback, teaching observations, project/course/proposal development, teaching statements, etc.)	✓	✓	✓	✓	
Stand-alone workshops, demonstrations, and one-time events (e.g., teaching statement workshops, inclusive classrooms workshops, seminars, science nights)	✓	✓	✓	✓	✓
Cohort programs (e.g., multi-session short courses, credit-bearing courses, faculty learning communities, STEM camps, ongoing K-12 school partnership programs)	✓	✓	✓	✓	✓
Major campus events (e.g., teaching conference, "TeachWeek," open houses)	✓	✓	✓	✓	✓
Certificates (in-depth programs resulting in documentation of achievement via letter or transcript notation)	✓			✓	
Collaboration and service (e.g., institutional committees, consultations and projects with divisions/options, advising student leaders, groups, and other offices; supporting the Provost's Innovation in Education Fund)	✓	✓	✓	✓	
Instructional technology (e.g., primary point of contact for MOOCs on Coursera and edX, functional owner of the campus LMS, advice on use of instructional tech. for teaching in a variety of formats)	✓		✓	✓	

In subsequent sections, we will present **outputs** of CTLO's work and primarily discuss how CTLO programs and services have contributed to the following overarching **outcomes** for university-level teaching:

- Reduce course-related issues and concerns
- Improve student learning and educational experience
- Foster instructor learning and adoption of inclusive, evidence-based practices
- Foster a sustainable culture of excellence in teaching

In addition, the CTLO's educational outreach efforts are intended to promote positive impacts in STEM learning, attitudes, and future plans among K-12 students, while also engaging Caltech participants in meaningful work that contributes to their personal and professional development. This report will not delve into outcomes for K-12 teachers, students, and the community, but will address impacts for Caltech faculty and students who participate in outreach efforts.

The CTLO has intentionally integrated diversity, equity, and inclusion across programs and services, weaving evidence-based approaches demonstrated to lead to more equitable student achievement throughout programs on university teaching, and prioritizing educational outreach

that serves and creates partnerships with schools and communities with populations that have traditionally been marginalized in STEM studies and careers. In practice, this emphasis in our work manifests (a) in purposeful discussion of inclusive teaching in every TA orientation program, teaching conference, credit-bearing course, and short course on teaching; (b) in our advancement of dedicated attention to equity through prominent efforts like the AAU-funded Inclusive Caltech Core program; and (c) in advising faculty writing research grants with educational components to center inclusive practices and making equity a focus in other consultations, whether individually or with committees and campus leaders. In educational outreach, we prioritize work with the local public schools, while engaging with private schools on a more limited basis where collaboration has the potential to advance educational opportunities for all students. Our primary partner is the Pasadena Unified School District, in which 73.3% of students identify in racial and ethnic categories historically underrepresented in STEM (11.1% Black, 59.9% Hispanic,1.9% Filipino, 0.2% Native American/Alaskan, 0.2% Pacific Islander), and 67.8% of students are eligible for free and reduced-price meals (2019-20 PUSD Demographic Data). In revenue-generating programs, mainly tuition-based summer K-12 programs, we make scholarships available in collaboration with partner organizations and/or with donor support.

Part 2: Participation

Campus engagement and participation is one type of output that is a prerequisite to achieving many of the outcomes introduced above. The CTLO is a distinctive case of a new teaching center among peer institutions created within the past decade; there was essentially no model upon which to base our expectations for participation and growth. Below, we present data from our first year of operation (2012-13) through the last full year completed as of May 2020 (2018-19); the CTLO data year begins one week prior to the start of Caltech classes each fall.

The CTLO tracks participation in two main ways, consistent with other centers and across our own records over time. **Number of services** refers to a total of all instances of participation, and may include multiple services to the same person (i.e., Professor A. comes to a workshop, which counts as one service, and then a consultation, which counts as a second service). **Number of unique individuals** (e.g., unique faculty, unique graduate students) refers to a total of distinct, identifiable persons, and does not include any multiple counts of services to the same person (i.e., Professor A. counts as one unique individual, regardless of the number of consultations and workshops they attend). Whenever possible, the CTLO collects and tracks participation by **named individuals**, using electronic RSVPs and event check-ins. However, for large community events and certain campus programs where logistics prevent this approach, we record the number of people who attend and track engagement by **non-named participants.**

During the first seven years of CTLO operation, the center provided over **12,600 services to named individuals** (mostly about university teaching), representing over **4,000 unique individuals**, and provided nearly **80,000 services to non-named participants** (mostly as educational outreach). The CTLO worked with over 85% of faculty within the first five years of

operation, and after seven years, has engaged with nearly all faculty. The CTLO has worked with nearly all graduate students as well. We have found no direct points of comparison for these cumulative participation figures, but it has been suggested that exemplary centers should achieve a "critical mass" of participation among instructors by exceeding the roughly 15% of populations that are often considered innovators or early adopters (ACE/POD Network, 2018). Based on the CTLO's presentations and discussions with peer institutions and other centers, the above reach appears to be a stand-out accomplishment nationally and internationally.

CTLO services to named individuals include our work with faculty, graduate students, undergraduates, postdocs, staff, and external partners/participants. As shown on the next page, graduate students have represented a majority of services in any given year—they are a large population, include many who serve as TAs, and the CTLO provides a full day of required programming, the Caltech Teaching Conference, within graduate orientation week.

The growth in CTLO services over the first several years of operation is notable, peaking in year 5, and returning to a steadier, still substantial number in subsequent years. The peak in year 5 was driven by the overlap in several large initiatives: (1) TeachWeek in January 2017; this was the second time we offered this week of talks and open classes, with a larger-than-usual number of events and strong publicity by the Office of Strategic Communications, (2) high-profile guest speakers at other times, such as Dr. David Asai (HHMI) and Dr. Catherine Drennan (MIT) and (3) a large number of events and programs in partnership with divisions and options. Another contributing factor to the somewhat lower, but more sustainable and possibly more impactful participation rates in years 6 and 7, is likely the CTLO's steady move toward more cohort-based programs, which engage faculty and students across multiple sessions and weeks on in-depth, evidence-based, inclusive course design and teaching practices. Such a program appears as just one "service," even though it represents a much deeper form of engagement, as will be discussed later in this report.

CTLO Services to Named Individuals by Role and Year
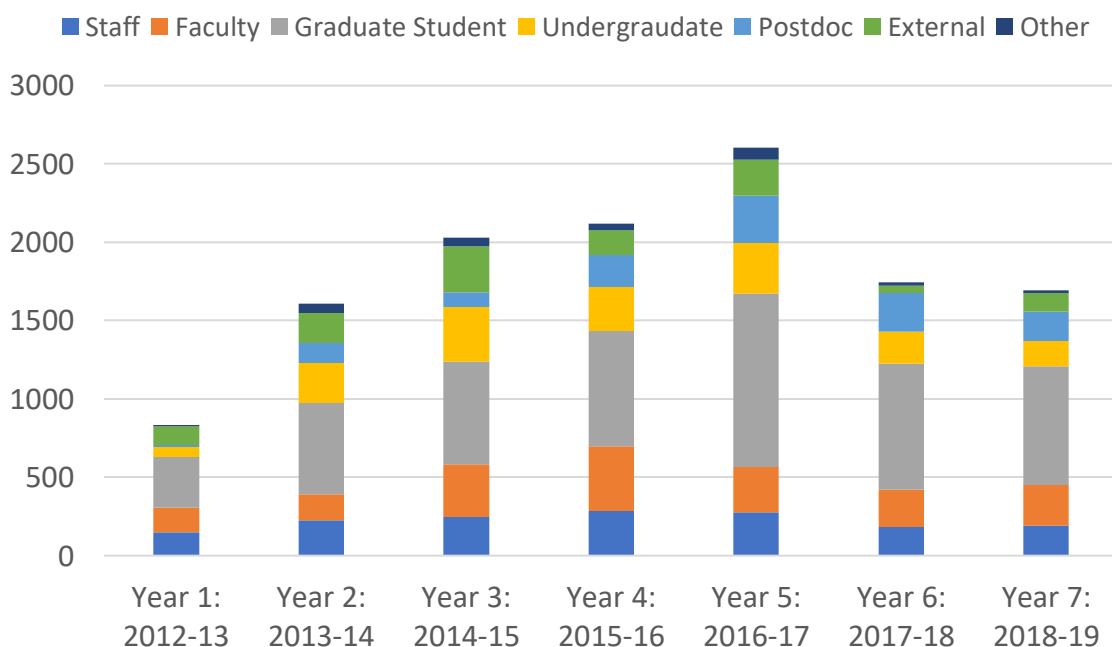
The CTLO has also made resources available on-demand at http://ctlo.caltech.edu; a new website went live in June 2019, for which we have website analytics through the end of April 2020. The website is accessed throughout the year, typically at a rate of 8,000-9,000 page views per month during the academic year, and 5,000-6,000 page view per month during the summer. The website welcomes approximately 2,000-3,000 active users per month during the academic year and 1,000-1,500 in summer. The majority of page views come from within the US (69%) and more specifically, within California (59%), largely from Pasadena, Los Angeles, and other nearby cities, likely representing a high proportion of Caltech community members. The CTLO's YouTube channel features videos of teaching-related talks and content created for the web, with individual video view counts ranging from near 1,000 to over 44,000.
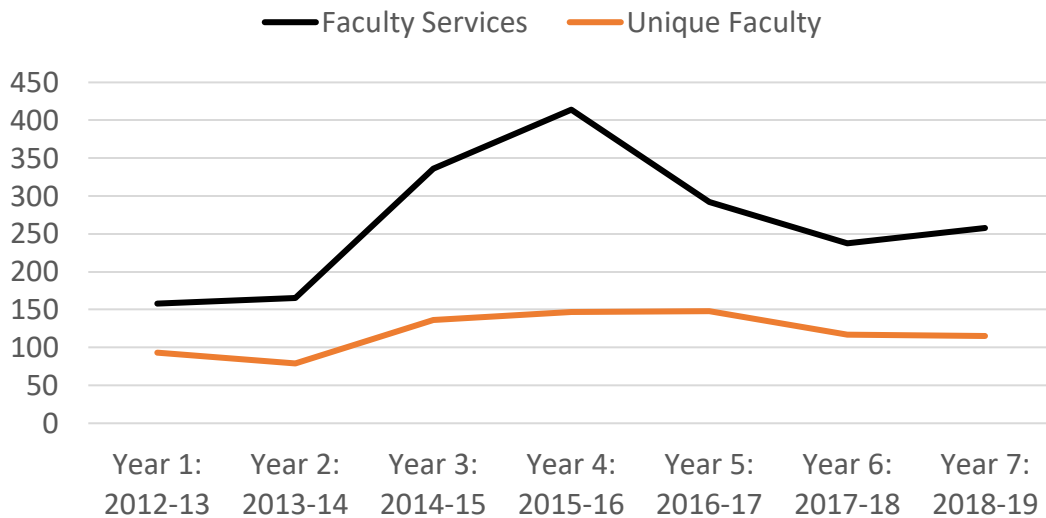
FACULTY PARTICIPATION

The CTLO has worked with 335 unique faculty members during our first seven years of operation. Caltech currently has approximately 320 full-time faculty, including professorial and full-time teaching faculty. The apparent reach is higher than the current full-time count because the CTLO has also worked with part-time, emeritus, and term-limited faculty (e.g., postdoctoral instructors, lecturers) no longer working at Caltech, who are not represented in the current, official Caltech faculty total. Of the unique faculty who worked with the CTLO, 96% did so on university teaching topics, 34% on educational outreach topics, and 29% on both.
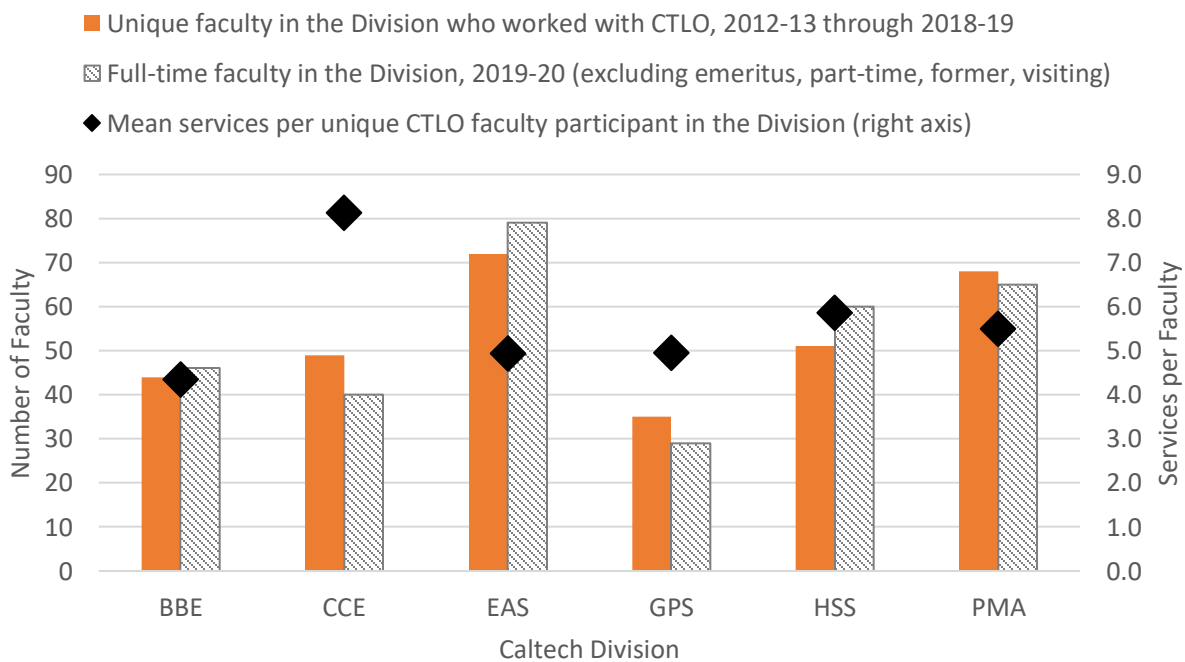
Different from overall services, CTLO peak services to faculty occurred in year 4, likely a product of the first TeachWeek featuring Dr. Eric Mazur (Harvard) and a large number of other events, and has leveled off since then. We have worked with approximately 100 to 150 unique faculty members each year since our third year of operation; this seems to be a steady, sustainable benchmark for our campus, representing around one third to one

Number of Services Per Unique Faculty Member, All 7 Years

half of active teaching faculty engaging with the CTLO each year. For comparison, in a national survey of well-established centers, directors estimated one semester's reach among faculty at 38%, on average (Bishop and Keehn, 2015); this figure is potentially subject to inflation without supporting data, which was not requested. Over all seven years, the CTLO has provided over 1860 services to faculty—an average of 5.6 services per unique faculty member. 55% of unique faculty participants have engaged with three or more CTLO programs and/or services. These levels of participation exceed most sociological estimates of critical mass or tipping point for new ideas and approaches in populations.
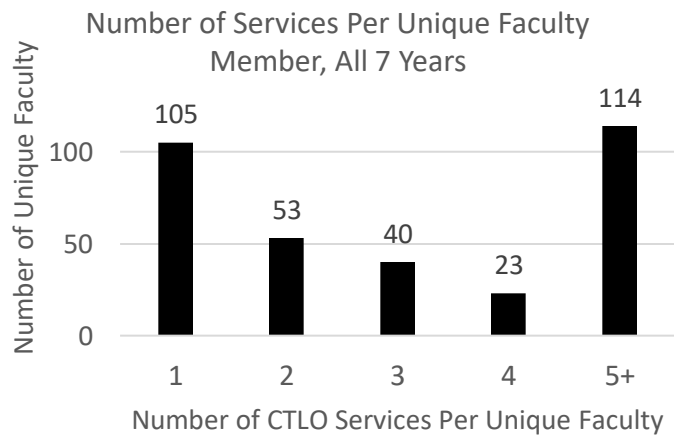
CTLO Faculty Services and Unique Faculty by Year

The CTLO has engaged faculty across all divisions,[1] ranks, and appointment types. Engagement by division, as shown below, has generally been proportional to division size, with higher numbers of unique faculty participants relative to division size in CCE, GPS, and PMA, and a high number of services per unique faculty member in CCE. These differences are modest and are likely influenced by a variety of factors, such as faculty interest, types of courses, number of new courses, and whether there are new lecturers or postdoctoral instructors regularly joining the division; we found no serious gaps and no divisions where faculty have been less engaged than expected.

■ Unique faculty in the Division who worked with CTLO, 2012-13 through 2018-19

▨ Full-time faculty in the Division, 2019-20 (excluding emeritus, part-time, former, visiting)

◆ Mean services per unique CTLO faculty participant in the Division (right axis)

[1] Caltech's six academic divisions are Biology and Biological Engineering (BBE), Chemistry and Chemical Engineering (CCE), Engineering and Applied Sciences (EAS), Geological and Planetary Sciences (GPS), Humanities and Social Sciences (HSS), and Physics, Mathematics, and Astronomy (PMA).

Counter to the stereotype that early career faculty might be more interested in teaching and/or outreach than later career faculty, CTLO staff have observed strong participation across faculty ranks, especially among full professors. 53% of unique faculty participants with the CTLO have been full professors, 26% assistant professors, and the rest a mix of lecturers, instructors, visiting faculty, faculty associates, and others.[2] While the CTLO offers a workshop specifically for new incoming faculty, many of whom begin at the assistant professor rank, overall only 16% of CTLO services to faculty have been to assistant professors. Full professors and lecturers/instructors engaged with the CTLO more frequently—7.5 and 6.2 mean services per unique faculty member respectively—than assistant professors, who had on average 1.7 services per unique faculty member. Considering the research demands on early career, tenure-track faculty and the need to balance teaching with research in this critical pre-tenure stage, this pattern of engagement seems appropriate. Robust participation by full professors is also a promising indicator of overall culture change toward embracing regular work on teaching and outreach as important, career-long endeavors.

In order to better understand the patterns and pathways of engagement among faculty, the CTLO examined individual records of participation in our programs and services for particular faculty members who engaged with the CTLO less frequently than the averages mentioned above, near average frequency, and more frequently than average. We found a wide range of entry points and progressions, with no clear pattern emerging: some began with an individual consultation and progressed to participation in other stand-alone or cohort programs, while others first worked with the CTLO through a large campus event or short course, and then sought other opportunities or followed up with consultations. Caltech does not require faculty participation in CTLO programs and services, so we have found that having this variety of entry points, meeting individual faculty needs and interests, has been helpful in generating self-motivated, voluntary engagement. We will discuss several cases of faculty engagement in greater depth in Part 3, along with associated impacts and outcomes.

STUDENT AND POSTDOCTORAL SCHOLAR PARTICIPATION

Undergraduates:
The CTLO worked with a total of over 850 unique undergraduate students in the first seven years of operation. Undergraduates engaged with the CTLO mainly in the following ways:
- 60% of undergrad CTLO participants completed TA training, an institute requirement for all first-time TAs; CTLO offers a specialized undergraduate version of TA training that addresses near-peer teaching challenges and evidence-based strategies.
- 19% of undergrad CTLO participants did course ombuds training; this is a student-led program in which student representatives in larger courses serve as liaisons with the faculty, voicing suggestions and concerns from students' perspectives to help address issues and improve course climate.
- 15% of undergrad CTLO participants engaged in K-12 educational outreach.

[2] Note that associate professor is no longer a regular faculty rank among tenure-track faculty; instead, Caltech faculty progress from assistant to full professor with the awarding of tenure. A new "teaching professor" track was approved in 2018-19, but not implemented until the 2019-20 academic year, so those titles do not yet appear in our data for this report.

In addition, the CTLO advised and mentored undergrad student leaders, such as the student Academics and Research Committee (ARC), to support their work on improving courses and preparing for student-faculty conferences and discussions.

Graduate Students and Postdoctoral Scholars:
The CTLO provided nearly 4,700 services to a total of nearly 1,900 graduate students in our first seven years of operation. On average, each unique graduate student made use of 2.5 CTLO services during their time at Caltech; approximately 20% of graduate students participated in three or more CTLO services, going well beyond any institute requirement to attend the Teaching Conference as part of incoming graduate student orientation.

In addition to pedagogical training focusing on effective approaches to serving as a TA while at Caltech, graduate students and postdoctoral scholars are increasingly seeking teaching-related professional development. For example, the CTLO has provided nearly 600 services to graduate students, postdoctoral scholars, and

**Number of Services Per Unique Grad Student, All 7 Years**

some research staff, on the subject of writing effective teaching statements—a required document for most US faculty position applications. This population started requesting individual consultations on teaching statements nearly from the beginning and we began to hold workshops in year 3, often in collaboration with the Graduate Student Council, Caltech Postdoctoral Association, or both. While we try to limit individual consultations to those who have attended a workshop and therefore done substantive work on their own, and refer those with more general writing-related questions (e.g., structure, clarity) to the Hixon Writing Center, discussions with peer institutions have indicated that the CTLO does substantially more work on teaching statements than centers at much larger universities.

Another form of advanced professional development for graduate students and postdocs, the Certificate of Interest and the Certificate of Practice in University Teaching, are overseen by the CTLO and co-led by a graduate student leader under the auspices of CPET, the Caltech Project for Effective Teaching. CPET was originally a graduate student group before the CTLO's founding and was then incorporated into the center. Participation in the two certificate programs has been growing. The Certificate of Interest (CoI) was started by CPET before 2012-2013 and involves a self-directed choice of six seminars on teaching, followed by reflective writing, culminating in an overview reflection and recognized by a letter from the CTLO and Graduate Dean's office. The Certificate of Practice (CoP), launched in 2015-16, is a more in-depth experience requiring a quarter-long course on pedagogy; two cycles of planning, implementing, obtaining feedback, and reflecting on teaching (e.g., via TA experiences); and creation of a
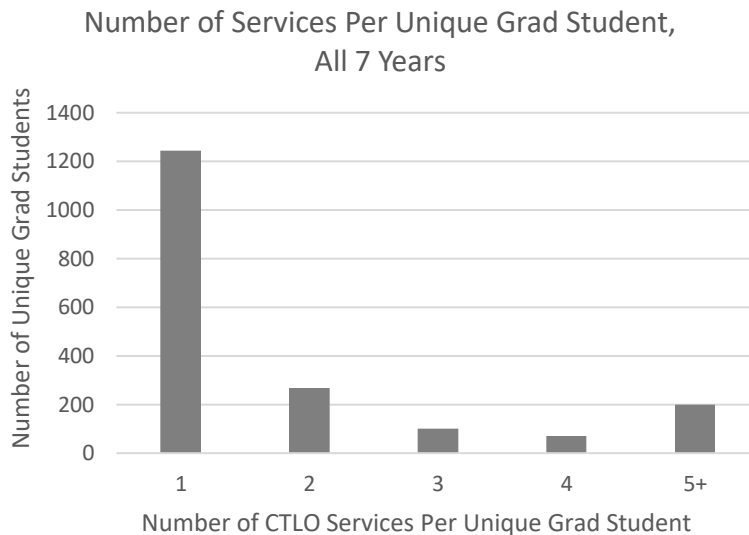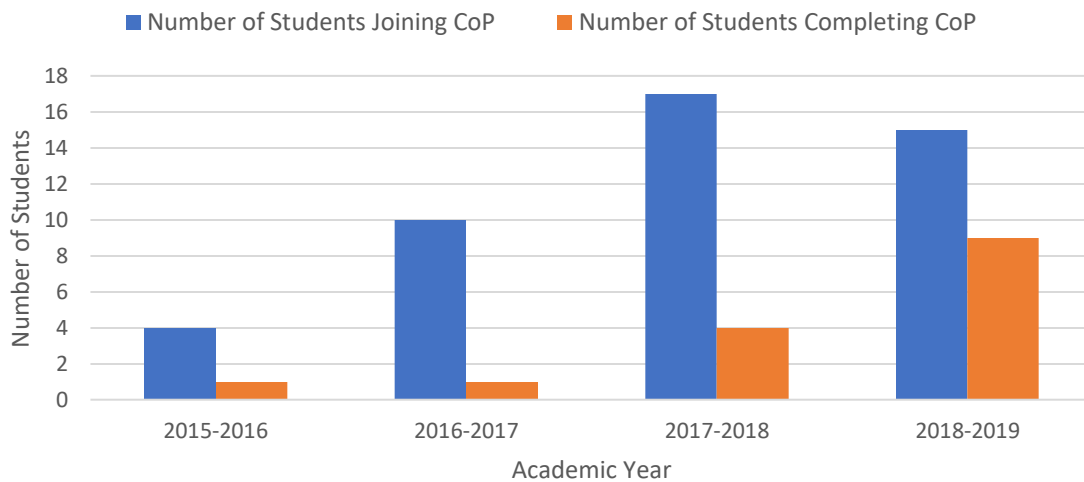
comprehensive teaching portfolio. The CoP is acknowledged with a transcript notation (for graduate students) and a letter as for the CoI. The fact that the in-depth, high time commitment Certificate of Practice program now has a similar number of participants and completions as the more flexible Certificate of Interest program speaks to the recognition that a growing number of graduate students and postdoctoral scholars have regarding the importance of teaching-related professional development to their careers and plans.

Certificate of Interest Participants

■ Number of Students Joining CoI   ■ Number of Students Completing CoI
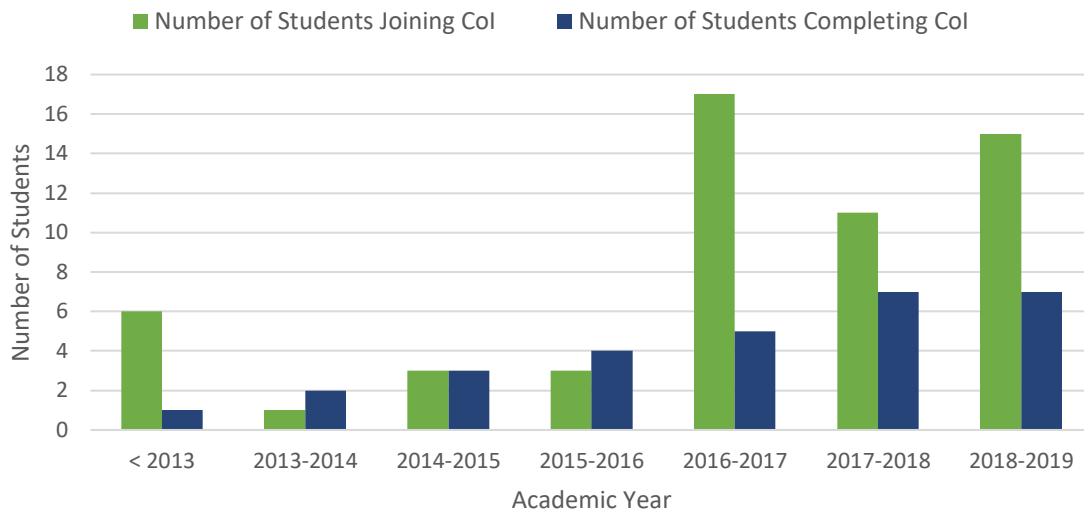
Certificate of Practice Participants

■ Number of Students Joining CoP   ■ Number of Students Completing CoP

Graduate students and postdocs also engage in K-12 educational outreach through CTLO partnerships with local schools and teachers. For example, nearly 200 unique graduate students participated in outreach programs in the CTLO's first seven years. As will be discussed in Part 3 with other outcomes and impacts, many do so based on a combination of motivations—to give back, mentor, and have a positive influence on younger students, and for their own professional development.

As shown above, CTLO rates of reach and engagement with key populations at Caltech have been quite high and these results have not been accidental. CTLO programs on university teaching have been tailored to the population and have evolved with the changing teaching culture. Initially, CTLO work with faculty emphasized individual consultation and a small number of group forms of engagement, such as the annual new faculty workshop. Broader group engagement with faculty grew first in collaboration with options and divisions, for example, by co-hosting teaching-related talks within disciplinary colloquia and seminar series. We believe that these venues helped normalize the presence and engagement of faculty, graduate students, and other members of academic communities in discussions on teaching. For example, the CTLO's in-depth faculty cohort programs, developed and led by Dr. Jenn Weaver, Associate Director for University Teaching, such as the Faculty Summer Short Course, became fully subscribed. Research elsewhere has indicated that multi-part, cohort-based, in-depth programs are likely to produce more sustained changes in use of inclusive, evidence-based teaching methods (Wright et al. 2018). We now view our suite of programs as complementary, each serving distinct purposes:

- Large-scale, campus-wide events raise the profile on teaching and generate new interest through exposure and a sense of excitement.
- Division and option collaborations situate teaching within relevant academic communities and highlight discipline-specific expertise.
- Cohort-based programs provide forums for deeper learning, application, and feedback.
- Educational outreach opportunities provide practice and professional development, as well as documented forms of public engagement now expected for many research fellowships and grants.
- Individual consultations allow for customized exploration, discussion, design, implementation, and support of teaching methods tailored to specific courses and instructors, as well as in-depth feedback on teaching (e.g., via observation and follow-up or mid-quarter student feedback).

Part 3: Assessment of Impacts and Outcomes

Assessment of impacts and outcomes for centers such as the CTLO may include measures and indicators at several levels of depth, shown below (Marbach-Ad et al., 2015; Beach et al., 2016). In general, obtaining and analyzing assessment data beyond outputs such as participation and use of resources becomes more difficult, complex, and time-consuming as measures move away from indirect assessments such as surveys and self-reported outcomes, to more direct approaches such as observation and analysis of student learning.

- **Satisfaction:** perceived experience in the program/service, typically via exit surveys.
- **Instructor Learning:** conceptual change, typically via pre/post or exit surveys.
- **Application:** implementation of methods, typically self-reported or observed.
- **Student Outcomes**: impacts on student learning, grades, persistence, self-efficacy, etc., typically via institutional data or in-depth learning outcomes assessment.

- **Teaching Culture:** changes in support, openness, value, recognition, and other practice/discourse across the organization, typically via proxies/indicators, institutional data, and/or surveys.

Larger teaching centers often have dedicated staff working on assessment of program impacts and outcomes; in addition, some measures, such as student learning, are subject to many influences, and tracing the impact of teaching center programs can be challenging, particularly with small populations and limited statistical power (Collins-Brown et al. 2018). Few if any centers are able to assess at all of the levels described above for all programs. CTLO relies on established evidence and research on effective practices in the design and implementation of our programs and services (Wright et al. 2018), preferring and moving toward methods shown to have greater impacts on teaching practices and student outcomes. In alignment with our staffing levels and resources, the CTLO conducts in-depth assessment strategically and selectively to ensure quality and answer salient questions about impacts at Caltech. In the following sections, we present highlights of some of the assessments we have done, showing examples of impacts and outcomes at various levels of depth.

INSTITUTION WIDE IMPACTS

We have noted several indicators, albeit qualitative and each limited in its own ways, of broad change in the teaching context and culture at Caltech:
- **New press coverage and publicity related to teaching:** CTLO programs and people have been in the news, both Caltech Strategic Communications stories, and other publications, representing a new, positive contributor to institutional reputation and pride. Strategic Communications included "Excellence in Teaching" in the 2019 Caltech Communications Framework, articulating as a priority that Caltech should be perceived for accomplishments in education and teaching—a major cultural development.
- **National rankings:** Caltech has steadily moved from regular appearance on national ranking lists of institutions with worst teaching (e.g., Princeton Review "Professors Get Low Marks" list, 2012 and earlier), to no longer appearing on such lists, to appearing for the first time in 2020 on a national ranking for institutions with best teaching (US News "Best Undergraduate Teaching").
- **Reductions in student concerns about courses and teaching**: The undergraduate student government's Academics and Research Committee proactively accepts concerns from other students about their courses and works with them, sometimes liaising with the faculty or option, to help solve problems. The number of concerns each term has dropped dramatically between 2012 and 2020.
- **Greater success with research grants including educational components:** The CTLO has consulted and assisted faculty with a total of 93 research grants that have components related to educational outreach, university teaching, or a combination of both. NSF in particular expects strong, well-assessed "broader impacts" contributions in research grants, which are often met through educational programs. Before CTLO grant consultation services were available, a needs assessment conducted in 2012 indicated that faculty regularly received negative peer reviews and/or were declined funding on the basis of insufficient broader impacts and educational components in grant proposals. Since the CTLO began providing consultations and support, the award rate on

grant proposals involving CTLO in the preparations—38% in total, and over 50% in some years and for NSF CAREER grants—has consistently been higher than average grant funding rates across Caltech, and also higher than national funding success rates. For proposals that were declined, a high proportion of those with available feedback had only positive reviews on educational components, with only a few (0 to 2 per year) receiving mixed reviews on educational components.

- **Inclusion of pedagogical and educational development expertise in committees and deliberations**: CTLO staff regularly serve on or consult with a variety of committees, and educational expertise is more routinely viewed as essential in institutional discussions. Committees with CTLO participation include search committees for teaching faculty positions, the Resnick Sustainability Institute Education Committee, accreditation steering and subcommittees, Core curriculum and undergraduate education committees, and online education committees.

In response to the COVID-19 global pandemic, starting in winter 2020, the CTLO was able to be of service to the institution in a time of critical need. When Caltech made the decision to move instruction to remote formats, the CTLO worked closely with the Office of the Provost, Information Management Systems and Services (IMSS), and Student Affairs to quickly deploy a model for best practice in remote course design and instruction that could be implemented in approximately two weeks to move all spring quarter courses online, and an integrated model of scheduled and on-demand support and training. CTLO quickly launched a new website, http://teach.caltech.edu with approximately 6,000 visits per week just prior to the start of the spring term. Through division meetings and town halls, we met with over 115 faculty and instructors, trained over 30 new TAs for remote teaching, and supported over 130 unique individuals, mostly faculty, through office hours, individual online meetings, assistance via email, and phone calls to help accomplish this rapid pivot.

In the third week of the spring quarter, CTLO worked closely with Institutional Research and the Provost's Office on surveys of faculty, TAs, and students about their remote teaching and learning experiences. Intended for quick turn-around, communication, discussion, and action to meet unanticipated needs, themes were quickly synthesized by CTLO and presented to Student Affairs, various faculty groups, and other offices, with several immediate actions and improvements resulting from these discussions. Surveys showed a remarkable smooth early transition with specific points of high challenge and several key mismatches between instructor and student perspectives, which we have worked to bridge. In addition, CTLO is leading an effort to evaluate the Learning Management System (LMS) to ensure that needs for remote/online instruction in the future can be met.

FACULTY IMPACTS

The CTLO engages faculty in multiple ways, as described in Part 2. Below we highlight strategic assessment of three of these: 1) the Faculty Summer Short Course; 2) the Inclusive Caltech Core faculty learning community; and 3) individual consultations, which are all offered in addition to multiple pedagogy seminars throughout the year.

1) **The Faculty Summer Short Course (FSSC)** helps faculty to design or redesign a university course that they will be teaching in the following quarter or academic year, through four sessions offered annually, beginning in summer 2016. Topics include: devising learning outcomes, creating course syllabi, incorporating active learning, designing assessments, curriculum mapping, teaching transparently, motivating students, and fostering an inclusive classroom. By the end of the four sessions, faculty have a solid plan for their class, with constructive feedback from the CTLO and colleagues. By the conclusion of the short course, faculty participants are able to evaluate current course strengths and weaknesses in terms of student learning; identify active learning approaches and pedagogical strategies that can revitalize their course; critically evaluate current assessment strategies to determine whether they meet learning outcomes; articulate the value and benefits of student engagement in their course; and (re)devise a course syllabus and content and activity plan for their course. Shorter versions are offered as a Course Design Workshop in some fall quarters and a Course Syllabus Design Workshop offered in some spring quarters.

   Since 2016, 67 faculty members and 11 postdoctoral instructors have participated in the FSSC. For this in-depth program, which represented a new format for faculty engagement at Caltech, the CTLO assessed participant satisfaction, instructor learning, and self-reported application of methods in teaching.

   Post-course surveys, showed high levels of satisfaction with FSSC instruction and content, with all participants saying that they would recommend participation in this course to other faculty (with the exception of one who disliked the four-session format, but said that the content was worthwhile). In self-reflective surveys, faculty provided evidence of meeting the program's goals and learning outcomes – for example:
   - In recognizing the value of learning outcomes and content - *"I learned that it's best to define learning outcomes and design the course around them. It's obvious in retrospect, but it's not the way I was designing courses. Along those lines, it's almost relieving to be "given permission" to push the less important material to the margins of the course to make more room for the core learning outcomes"*,
   - In the need to assess students' prior knowledge and foster an inclusive classroom – the course was most effective and helpful in me *"learning about outcome-focused approach to course design, ways to engage/encourage students that is (sic) more inclusive, realizing my own assumptions about my students may be wrong and deleterious to the learning environment, realizing my own privilege";* and
   - In strategies for engaging students – *"I found the concrete suggestions for incorporating active learning activities in the classroom most helpful…. The differentiation between learning objectives and assessments was also helpful to me. Those have been rather backwards for me in the past – 'I want them to do well on this assessment so I need to have them learn x,y,z skill' rather than 'I want them to know how to do these skills so need to design an assessment to support that' (which is how I now plan to approach it)."*

2) **Inclusive Caltech Core,** or IC^2 (IC-squared) project—funded by the Association of American Universities (AAU)—created a faculty learning community involving those teaching Caltech's STEM Core courses and/or advising incoming students. IC^2 activities focused on exploring

up-to-date student data to give faculty a new window into student learning in the Core, alongside inclusive teaching practices as they were implemented in real time, with input from external experts as well as exchange of ideas among faculty. The project involved academic and student affairs staff from the offices of the Provost, Dean of Undergraduate Students, Caltech Center for Inclusion and Diversity, and the Center for Teaching, Learning, and Outreach (CTLO worked on the grant proposal and served as the primary organizer and convener during the project).

While not every faculty member teaching in the Core came to every meeting, many attended regularly. Each project year's activities engaged 40-50 faculty, with some turnover in that group due to changing teaching assignments, plus about 20 staff, deans, and colleagues from offices supporting instruction and inclusive practices in some way. Relative to the total number of faculty, this project engaged a substantial fraction of our instructional community in a relatively sustained and substantive manner.

Each of the two years of the project included:
- An opening retreat and workshop, with discussion about student data, an up-to-date profile of the incoming first year class, and either a guest speaker or working sessions examining recent Caltech student data from the prior year. The retreats were successful, appreciated by faculty, and well-attended.
- Quarterly discussions (three to four per year), interspersed: internal discussions among faculty, prompted by new student data and showcasing their own implementation of evidence-based, inclusive teaching practices; student panels and discussions; and external speakers. Whether an internal discussion or an external speaker, the quarterly meetings were also well-attended. In the end, the faculty participants rated the internal discussions as a high priority to continue.
- A resource page for faculty, TAs, and peer tutors outlining curricular themes and information across different Core courses. This weekly schedule allowed for an easy way for instructors to connect themes and topics in their course planning and discussions with students, which we hoped would lead to a more cohesive curricular experience.
- Mid-quarter feedback implemented every term, in all of the main STEM Core courses, which (a) provided real-time feedback about student learning and allowed faculty and TAs to adjust strategies, address student misconceptions, and encourage students to use available resources (such as office hours and group study sessions), and (b) enabled the project to track students' evolving academic self-concept and confidence, knowledge of and use of resources, self-efficacy, and sense of belonging. At the end of the project, the faculty rated the mid-quarter feedback as the most helpful and high-priority part of the project to continue.

Over the course of the project, as recorded in detailed notes from each discussion, faculty questions and ideas for follow-up progressed; as a community, participants gained familiarity with students' learning experiences and patterns. Reflections shared during the final meeting, for example, included nuanced discussions about the relationship between student gender, student experience, and faculty gender in the Core; the complex pre-college and early college changes in confidence and self-efficacy; and potential interactions between confidence and when/how students receive feedback, both in their classes and

overall with their academic advisors. In this way, the project has demonstrated the value of faculty engagement with such evidence.

We regularly observed faculty participating in the IC^2 program implementing and discussing their experience with inclusive, evidence-based teaching practices. They routinely followed up with the CTLO, through mid-quarter feedback and other assessments, as well as general advice and support. For example, faculty experimented with collaborative exams, low-stakes assignments, transparent assignment design, backward design of courses (starting with learning outcomes), various active learning methods, and other techniques. The project helped to make these practices more familiar and prompted peer-to-peer sharing of implementation experiences and advice.

The IC^2 project directly impacted the design and implementation of several other programs, which can be seen as spill-over effects. These included student-facing orientation programs, which, based on data from this project, now more directly address student help-seeking (academic and non-academic) and normalize practices such as going to office hours and working with peer tutors. During the project, the design of the pre-fall orientation discussions with faculty serving as freshman academic advisors, a program of the Undergraduate Dean's Office, also evolved and incorporated insights and data from the project.

During the final meeting with Core faculty in May 2019, we asked faculty to rank the main IC^2 project activities in terms of the level of priority to continue in some form. Regular mid-quarter feedback and internal discussions were the top priorities, with online materials and guest speakers ranking as lower priorities.
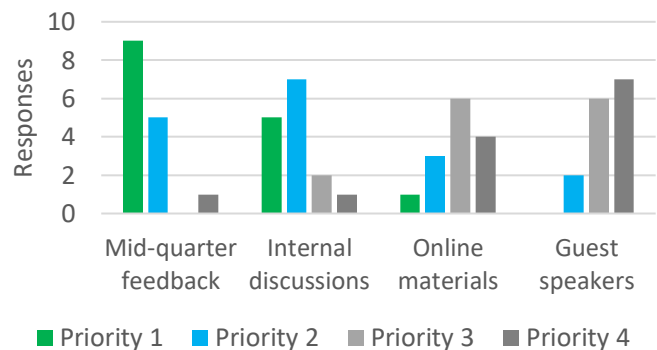
Given this information, we sought internal Caltech resources from the Provost's Innovation in Education fund to work with colleagues in IMSS to build mid-quarter feedback templates into the campus-wide learning management system, which now allows the CTLO to help faculty deploy early feedback questionnaires with less ongoing staff time. In addition, we continue to discuss with the Core Curriculum Steering Committee ways to build on IC^2's internal discussions among Core faculty in an ongoing way.

3) **Consultations** – The majority of Caltech faculty and lecturers have sought guidance from CTLO staff about their teaching and courses. There have been multiple entry points for engagement with the CTLO and for these deeper dive consultations, including the aforementioned programming. CTLO does not require faculty who make use of consultations to collect or share specific data about how they have applied the methods discussed, or their impact on student learning, but faculty often volunteer such information or share in response to informal follow-up contacts. Faculty have reported changes such as increased student learning, improved course evaluations, increased course enrollments, and

receiving teaching awards. While our larger examination of faculty pathways through CTLO programs shows many possible routes, we highlight the role of consultations in two distinct patterns of participation below.

Participation in pedagogy short courses resulted in deeper-dive consultations with 21 faculty, where they asked for further assistance with course design, observations by CTLO staff of their teaching, and help in designing mid-quarter feedback surveys. Some notable examples of further faculty engagement, with self-reported application, student learning impacts, and contributions to teaching/organizational culture, include:

- A faculty member who participated in the Faculty Summer Short Course, and learned more about two-staged exams in which there are individual and group components, and which the pedagogical research has supported in increasing student learning and performance. This faculty member then engaged their teaching fellows and teaching assistants, in addition to CTLO, in redesigning the assessment and examination formats in a large physics class.
- A faculty member who participated in the Faculty Summer Short Course, and then consulted with CTLO staff multiple times in re-designing an unpopular chemistry course to be more inclusive, more organized and more transparent in expectations than its previous iteration.
- A faculty member who participated in the Faculty Summer Short Course and then invited CTLO to advise and participate (without voting rights) in the hiring process of new lecturers in Computer Science, where discussions of the teaching demonstrations went far beyond content delivery to discussions of lecture design, active learning and learning outcomes.

In another pattern of participation, faculty accessed individual consultation services first, and then moved on to participate in other CTLO programs and services. Here are several such cases, also with associated impacts and outcomes:

- A faculty member reached out to the CTLO for assistance redesigning a Core course that they were about to take over from a colleague. The redesigned course resulted in increased enrollments and ultimately, increases in the number of undergraduates majoring in the field of study that the course introduced. This faculty member continued to engage in deeper CTLO programs, including IC^2 and a variety of stand-alone workshops and events, ultimately working with the CTLO in some way every year.
- A faculty member became interested in implementing a particular instructional technology consulted with CTLO. This faculty member accessed the Provost's Innovation in Education Fund to support the effort. They reported strikingly increased student grades in the course using comparable assessments and were confident that the increased student engagement mediated by the technology contributed to these gains.
- A faculty member learned about the CTLO through a Faculty Board presentation and regularly consulted with center staff on both educational outreach and course redesign, as well as attended workshops and events on a regular basis. This faculty member implemented a semi-flipped model for an upper level undergraduate/graduate level course, with students working in class on collaborative problems using portable whiteboards. The faculty member collected evidence in the form of student

achievement on assignments and exams, where the assessments were held comparable to prior years, and observed substantial improvements in student learning.

STUDENT AND POSTDOCTORAL SCHOLAR IMPACTS

As discussed above, the CTLO's work with undergraduates revolves around TA training and supporting student-led initiatives. While these have not been areas for in-depth, systematic assessment, we have observed that these collaborations with the undergraduate Academics and Research Committee, via their course ombuds program, course concerns committee, and student-faculty conferences, have facilitated communication between undergraduates, teaching faculty, and administrators. In addition, there are now far fewer course concerns submitted to ARC than in the first few years of the CTLO.

The CTLO supports graduate students and postdocs by providing resources, consultation services, courses, seminars, and certificates, which are all possible entry points for deeper engagement in teaching after the initial Teaching Conference experience that is part of graduate orientation at Caltech. Examples of assessment beyond participation and use rates are included below for the following: 1) the Teaching Conference; 2) E110 graduate course, "Principles of University Teaching and Learning in STEM;" 3) Short courses such as "ABCs of Course Design;" 4) Certificates in University Teaching, and 5) Educational Outreach (which also engages undergraduates).

1) **Teaching Conference** - Each fall since 2013, the CTLO has held a day-long Teaching Conference during orientation week, which is mandatory for incoming graduate students. The Teaching Conference, along with an online module about Institute policies related to teaching, fulfills Caltech's TA training requirement, but all incoming graduate students participate in the conference regardless of whether they will act as a TA at Caltech (there are broadly applicable professional development sessions to choose from, in addition to TA-specific workshops). Approximately 250 incoming graduate students and 75-100 other members of the Caltech community (faculty, graduate students, postdocs, staff) have attended each year. The Teaching Conference includes a large opening session, which is followed by several concurrent blocks when participants can choose which sessions are of most interest to them. Sessions are facilitated by current and/or former teaching assistants and some Caltech staff (e.g. from the CTLO, Library, and Hixon Writing Center). Many of the graduate students on the Teaching Conference planning committee and who act as Teaching Conference session facilitators have previously participated in other CTLO offerings, including seminars and/or E110.
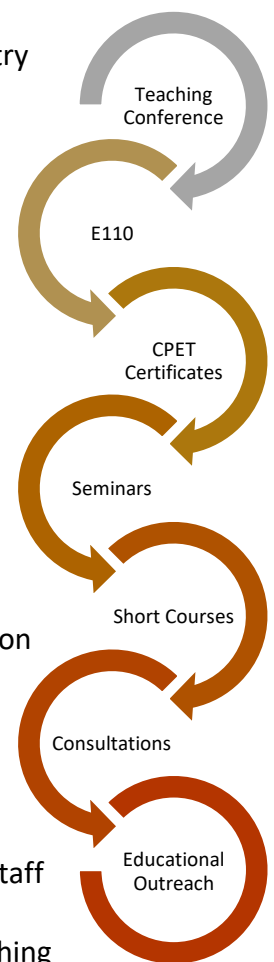
We monitor the quality of this program through satisfaction surveys annually; as the survey is combined with feedback on graduate orientation and serves in part to confirm graduate students' participation, it typically receives a high response rate (>90%). In years 2014 – 2019, when we asked a question about overall quality on a 5-point scale (1=poor, 2=fair, 3=good, 4=very good, 5=excellent), the modal response was "very good" each year, with a six-

Teaching Conference

E110

CPET Certificates

Seminars

Short Courses

Consultations

Educational Outreach

year total of 94% of respondents indicating that the quality of the Teaching Conference was excellent, very good, or good. We have noticed a small decline in perceived quality in the most recent conferences and are investigating further.

Post-surveys after the 2014 and 2015 Teaching Conferences also asked participants to self-evaluate several characteristics related t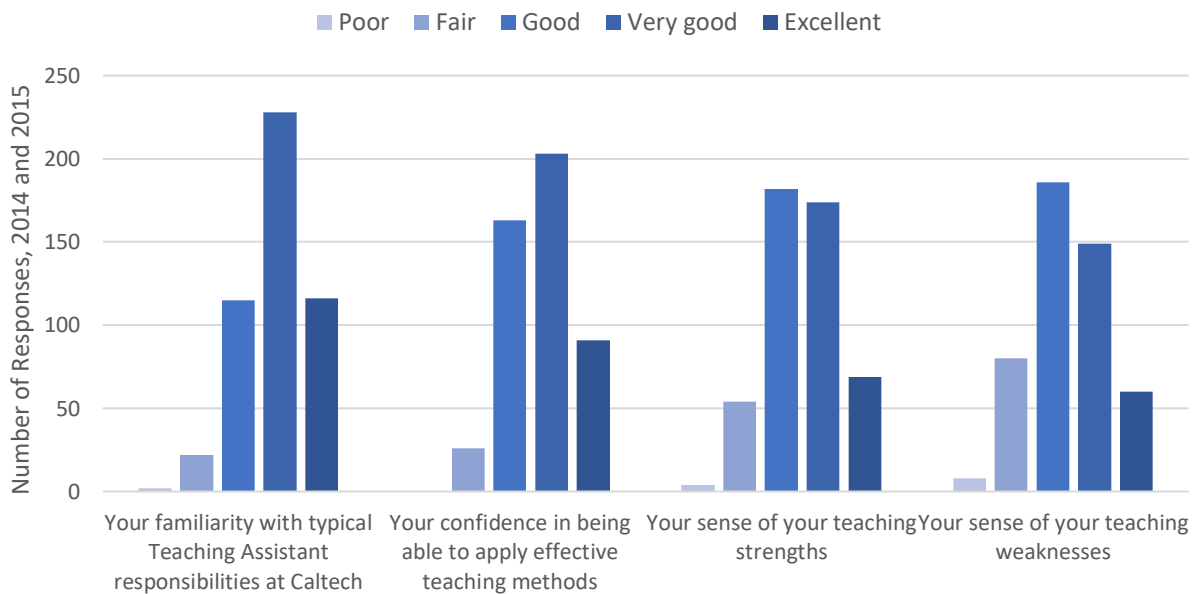o teaching, using the same 5-point scale above. We found that the participants rated their familiarity with TA responsibilities at Caltech (mean=3.9) and confidence in being able to apply effective teaching methods (mean=3.7) somewhat more highly than their sense of their teaching strengths (mean=3.5) and weaknesses (mean=3.4). We have wanted to follow up on these findings with longitudinal surveys tracking changes in TA self-efficacy and confidence during initial and later TA assignments, but this larger assessment project has not been possible to date.

Overall, how would you rate the quality of the Teaching Conference?

excellent, very good, or good — very good (modal response) — fair or poor
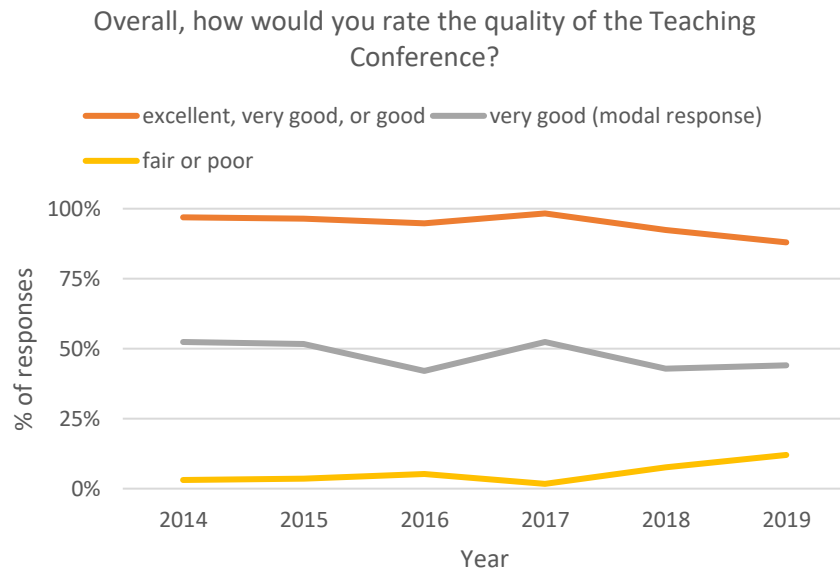
How would you rate the following areas after attending the Teaching Conference?

Poor Fair Good Very good Excellent

In qualitative responses on Teaching Conference follow-up surveys, participants frequently remarked that the modeling of excellent pedagogical strategies within each of the sessions was very effective and appreciated. Participants have consistently remarked, too, that having the opportunity to choose sessions of interest was a meaningful part of orientation. Session facilitators have also filled out qualitative surveys and their feedback about potential improvements has been incorporated into the Teaching Conference.

2) **E110 – Principles of University Teaching and Learning in STEM** is a credit-bearing, graduate course, which is also open to postdoc auditors who commit to full participation. This graduate course examines the research on university-level STEM (science, technology, engineering, and mathematics) teaching and learning, which has been used to inform a well-established body of evidence-based teaching practices. Weekly interactive classes provide focused overviews and guided application of key pedagogical research, such as prior knowledge and misconceptions, novice-expert differences, and cognitive development as applied to university teaching. This class explores the roles of active learning, student engagement, and inclusive teaching practices in designing classes where all students have an equal opportunity to be successful and feel a sense of belonging. E110 functions as an entry point for further engagements with the CTLO, whether as a participant in a short course, as members of the Teaching Conference planning committee, as a presenter at the Teaching Conference, or as a participant in the Certificate of Practice.

This course is usually taught twice per year and has been well-subscribed, with 189 students having completed it to date, along with several dozen auditors. Course evaluations provide measures of participant satisfaction; cumulative ratings have been between 4.5 and 5.0 on a 5-point scale (1=poor, 2=fair, 3-good, 4=very good, 5=excellent) every term, and have always been well above division and institution-wide averages.

E110 includes several opportunities for direct assessment of student learning, and as students are also TAs and often future faculty, of instructor learning and application. E110 students work toward a teaching statement through multiple drafts and iterations with feedback, as well as completing a final project. E110 instructors, Drs. Weaver and Horii, have observed substantial conceptual changes among participants each term as their teaching statements progress. Many students elect to make their E110 final project as impactful as possible by working on a project that will improve a course for which they are currently or will be a TA. Examples of impactful E110 projects include: revising all assignments for a Computer Science course to follow the Transparency in Learning and Teaching framework; creating an optional pre-assignment for a Computer Science course to ensure students have adequate prior knowledge for a particular coding language; transforming an astronomy field trip to meet key learning outcomes for the course; and creating an inclusive exam with a variety of genders and pronouns among the exam questions. E110 graduates go on to impact peers, professors, and the institution with enhanced knowledge of and ability to implement evidence-based, inclusive teaching practices.

3) The **ABCs of Course Design** is a short course for graduate students, postdocs and others at Caltech who are hoping to be the instructor of record for a course or who are interested in
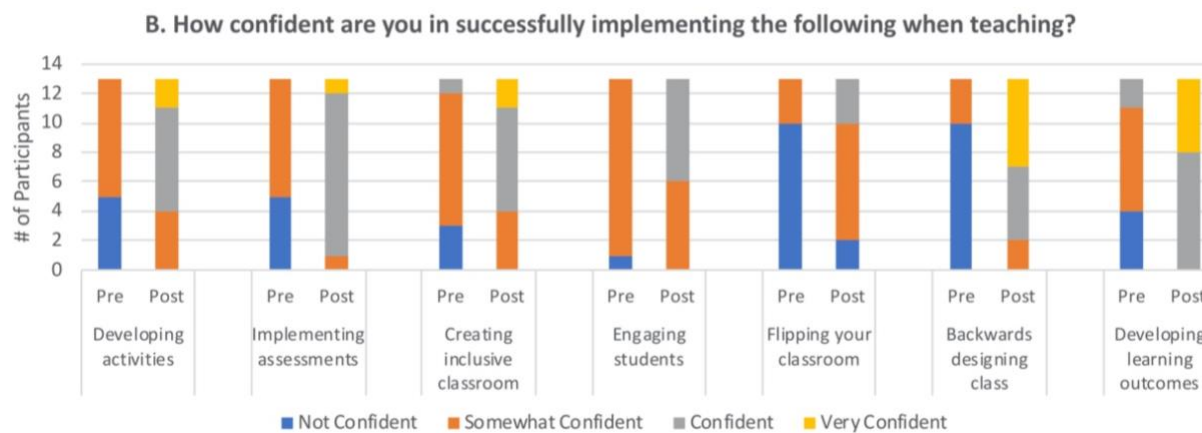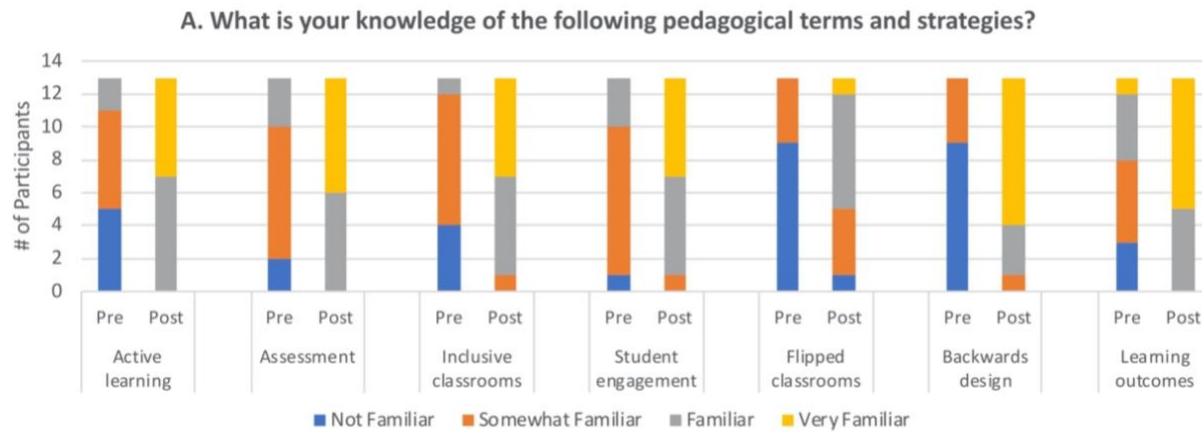
course design. 184 graduate students and postdocs have completed the short course since 2016. The initial iteration in 2016 had an overwhelming response, in which seventy-five students RSVP'd and the class was capped at forty students. The short course has been offered six times, with all classes full. Composed of two or three 1.5-hour classes, the overarching goals for participants are that they will have an awareness of pedagogical strategies that they can apply in their classrooms, a deeper understanding of active learning, and an increase in confidence such that they will be more likely to successfully implement these practices in their classrooms. The main learning outcomes of the short course are that participants will be able to identify active learning approaches and pedagogical strategies to be used in a hypothetical course, critically evaluate assessment strategies to determine which will meet their learning outcomes, articulate the value of student engagement in their courses, and devise a course syllabus and activity plan for their course.

The CTLO assessed the short course in October 2018 via pre/post surveys, focusing on participant satisfaction, learning, and confidence; this iteration of the short course had 24 participants who completed both self-evaluations. The in-depth assessment was part of a national effort to assess and publish assessment results across a variety of graduate student educational development formats, and will be discussed in a forthcoming special issue of New Directions for Teaching and Learning.

Qualitatively, three main themes emerged from this assessment:
● Participants valued modeling of evidence-based teaching strategies. *("Excellent example of good and well-structured teaching in action"; "Great to actively practice examples of the active learning techniques.")*
● The course was a productive use of time. *("It was very comprehensive for the limited amount of time;" "I wanted to let you know that this was one of the most (if not the most) useful class I took for years. I really feel that I learned something helpful, I could apply and use easily.")*
● Participants articulated a need for more opportunities to apply what they learned in the short course. *("Awesome! I just need more practice.")*

Participants reported considerable gains in knowledge of pedagogical terms and strategies, including active learning, assessment, inclusive classrooms, student engagement, flipped classrooms, backward design, and learning outcomes. Pre- and post-surveys indicate that there was a noticeable gain in self-reported knowledge and confidence in implementation of all pedagogical strategies, as shown below. The most notable gains in both knowledge and confidence were for backward design, active learning, and learning outcomes. This is likely related to the amount of time spent on these topics in the course, but also reflective of these concepts being completely new to most participants.

A. What is your knowledge of the following pedagogical terms and strategies?

Legend: ■ Not Familiar ■ Somewhat Familiar ■ Familiar ■ Very Familiar

B. How confident are you in successfully implementing the following when teaching?

Legend: ■ Not Confident ■ Somewhat Confident ■ Confident ■ Very Confident

4) **Caltech Project for Effective Teaching (CPET)** – As described in Part 2, CPET is a graduate student-led group offering seminars and discussion groups on teaching several times each quarter. In conjunction with the CTLO, CPET offers two certificate programs, the Certificate of Interest (CoI) and the Certificate of Practice (CoP) in University Teaching; the CoI is self-directed and involves participation in and reflection on six seminars or workshops, typically over the course of a year, whereas the CoP involves a more in-depth process over the course of one to two years, culminating in a teaching portfolio. The CoP program seeks to achieve three major outcomes for participants: i) synthesis and application of effective methods for teaching and learning; ii) assessment and implementation of a teaching philosophy; and iii) refinement of pedagogy through feedback and self-evaluation.

Participation in both certificate programs has steadily increased, as noted in Part 2 above. As these certificates include in-depth participant reflection on their learning via seminars and discussions (CoI) and on the application of evidence-based, inclusive teaching strategies in their teaching (CoP), the programs inherently produce authentic, direct evidence of participant learning and application to teaching practice. While the CTLO has not had available time to carry out a systematic qualitative analysis of CoI and CoP participant reflections and portfolios, informal review indicates that participants frequently make substantial progress on conceptual change and implementation of effective teaching practices, with a high degree of metacognition evidenced in their work.

5) **K-12 Educational Outreach** – During the 2018-2019 academic year and summer 2019, the CTLO employed a half-time, temporary assessment and evaluation specialist to gather data on the impacts of outreach programming for K-12 participants, as well as Caltech students and postdocs engaged in these programs as mentors, guides, and teachers. Survey items were developed addressing Caltech participants' self-reported gains in pedagogical skills, ability to explain concepts, skills in lesson planning, answering questions, keeping students engaged, classroom management, and contribution to their career plans and professional development. Results are discussed for each outreach program below.

Science Nights:
Caltech undergraduates, graduate students, and postdocs bring science and engineering demonstrations to local schools and community events. In 2018-19, 26 Caltech community members participated in 15 science nights, some just once and some multiple times; six of them provided in-depth feedback as part of the assessment effort.

Participants responded enthusiastically when describing what they enjoyed most about the Science Nights. One commented that "I enjoyed the moments at science nights when a particularly curious child or adult would become fascinated by some aspect of the presentation and hang around for an hour or more just to talk and ask questions and comment upon other people's questions." Two mentioned that they enjoyed watching the students' reactions to the presentations, with one commenting on "Watching them light up when they feel their curiosity being validated." Another presenter said, "I always hope that each person learns something new, something they didn't know before, an idea they hadn't thought of, a preconception dispelled, and goes away excited to look up more information. I hope that they expand their ideas of what a scientist looks and sounds like. I hope they smile."

Visiting Scientists:
A team of Caltech graduate students teaches hands-on science classes weekly at a local elementary school, with lesson preparation in collaboration with elementary school teachers. This program involved a team of five Caltech visiting scientists in 2018-19. In the end-of-year survey, the visiting scientists were asked to rate various aspects of the experience on a 7-point Likert scale. Responses regarding increased feelings of efficacy in lesson-planning, pedagogical skills and classroom management, including "I have a greater understanding of how younger students may process scientific information," "I feel more confident as an instructor," and "Participating in the program helped to improve my ability to explain scientific concepts to a lay audience." averaged between 6 ("agree) and 7 ("strongly agree").

Coding in the Classroom:
Caltech undergraduates, as part of a Caltech computer science course, collaboratively create coding lessons and teach them to 2nd-5th graders at two local elementary schools throughout the year. This program involved 21 undergrads as coding instructors in spring 2019.

All 21 responded to a survey at the end of the term asking them to rate statements on a 1-7 Likert scale with 7 being "strongly agree," along with several open-ended questions. Responses to statements about gains in efficacy and ability to help students understand the material averaged 5.0 or higher, indicating positive impressions about the instructors' own ability to teach effectively. Instructors' favorite aspects of the program, mentioned in 55.6% of the surveys, was the excitement and enthusiasm that the children showed towards coding. As one instructor described, "My favorite thing was the general engagement and genuine interest that these 3rd and 4th graders had. It was quite inspiring to teach them." Instructors also articulated the methods they used to improve their own teaching, including consulting with fellow instructors within or outside the program and, as one described, "Trying to recall what concepts I knew when I was their age, to use language they would be familiar with."

Summer Research Connection

Local high school students and teachers spend six weeks on campus participating in a research project, mentored by Caltech graduate students and postdocs. In the 2019 post-program survey, the eight participating mentors described their experience of working with students as rewarding and stated that by mentoring students, they gained confidence and experience in breaking down complex scientific concepts. Some particularly enjoyed working with a diverse group of students, as well as seeing the mentees grow in skill level and confidence throughout the course of the program. 75% of the respondents listed teaching as part of their career goals, and 50% have goals of becoming academic scientists. 62.5% of the graduate student mentors surveyed agreed that they learned how to assess the learning experiences of their mentees. One mentor explained, "SRC helped me practice adapting to students' backgrounds, a skill which I hope to use more in the future as a teacher and mentor." Similarly, another mentor mentioned, "I have a better understanding of what is a good balance between giving the students independence to work and learn and research things on their own and providing direct guidance and instruction."

83.3% felt that at the end of the program they had a better understanding of the needs of teaching and mentoring students. "This experience helps me with my presentation of research goals, interaction in both social and professional cases, and project management when working with high school students. It increases my confidence in working with a more diverse group of students." Another said, "The SRC program reminded me how rewarding it is to work with students. Specifically, their enthusiasm for their project and associated science reminded me why my field is exciting (at a time when my enthusiasm was waning). It is also incredibly rewarding to have a positive impact in these students lives, no matter how small."

Part 4: Conclusion

The CTLO has established a respected and well-integrated presence at Caltech during its first seven years of operation and has cultivated strong, positive relationships with faculty, students, postdoctoral scholars, institutional leaders, divisions, staff, and the community. The center

made substantial progress on the short- and mid-term outcomes articulated in its start-up phases for university-level teaching and educational outreach.
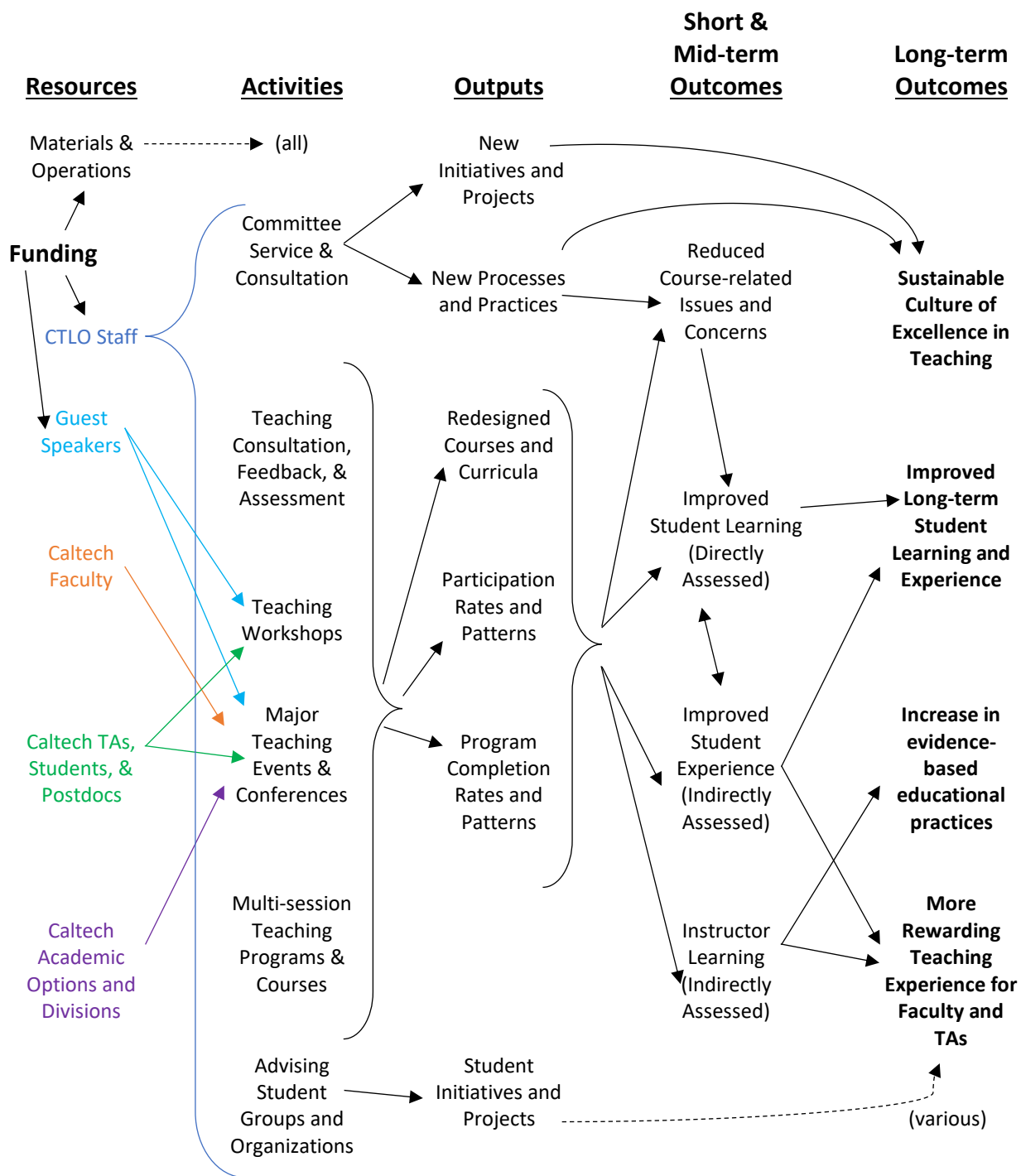
Challenges have largely concerned funding and staffing. Current use donor funds tend to cover short durations (one to three years) and small increments of the budget. Revenue can vary, is limited given campus space for summer outreach programs, and is subject to disruption, as during the current pandemic. CTLO staff time, particularly for university-level teaching support, has been insufficient relative to the needs of the Institute and relative to peer institutions, given the scope of responsibilities. As the Institute has identified additional needs, which are important uses of CTLO time and expertise (e.g., input to committees working on educational issues, expertise applied to institutional policies and processes, responding to the COVID-19 pandemic, updating and supporting instructional use of technologies), the CTLO has simultaneously struggled to meet the ongoing requirements for foundational training and programming, and to conduct assessment at the level a data-driven institution requires.

In light of progress to date, institutional leaders and CTLO have an opportunity to work with the faculty advisory committee on defining and prioritizing updated goals and evaluate the resources that are needed to reach those goals. Formalizing the faculty advisory committee's structure in alignment with other Caltech faculty or administrative committee norms would clarify its role and provide clearer pathways for input—not only on CTLO programs, but on teaching-related questions of importance to faculty and students. As we find our way through the global pandemic, maintaining and enhancing Caltech's ability to innovate and advance its educational work takes on greater significance for the long-term health of the Institute. Teaching and educational outreach are integral to the practice of scientific discovery and innovation that are at the heart of Caltech's identity, and the next phase for the CTLO provides an opportunity to better link the center's work with the Institute's strategic directions.

Appendix 1: CTLO Logic Models

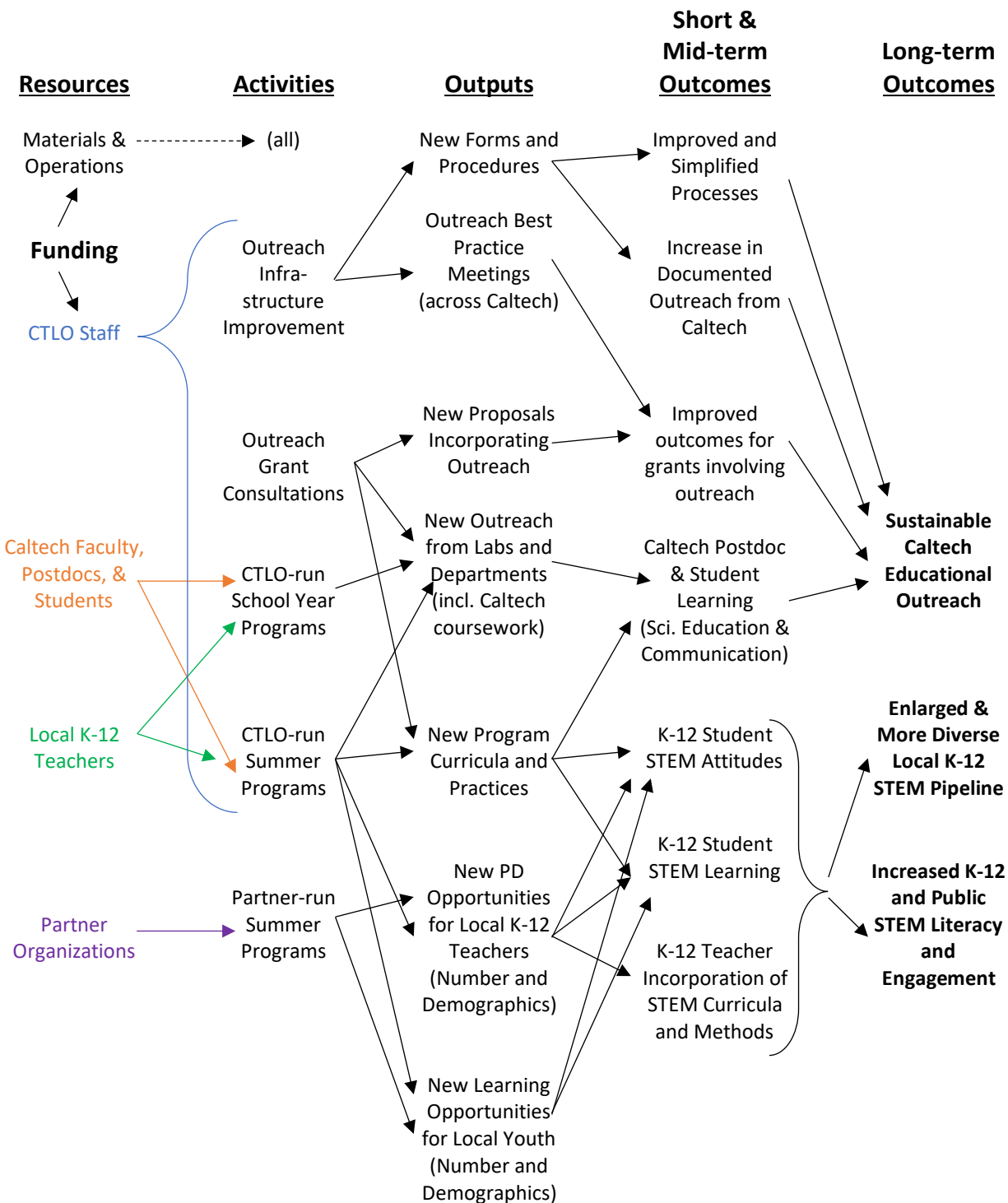CTLO employs resources and activities purposefully to achieve short, mid-term, and long-term outcomes. Though the picture of all programs and services together is complex, it realistically represents the process of organizational change and is aligned with modern research and practice, customized to Caltech's institutional structures and context.

a. Logic Model for Impact on University Teaching:

b. Logic model for impact on K-12 education

Resources | Activities | Outputs | Short & Mid-term Outcomes | Long-term Outcomes

Materials & Operations — (all)

Funding

CTLO Staff

Caltech Faculty, Postdocs, & Students

Local K-12 Teachers

Partner Organizations

Outreach Infra-structure Improvement

Outreach Grant Consultations

CTLO-run School Year Programs

CTLO-run Summer Programs

Partner-run Summer Programs

New Forms and Procedures

Outreach Best Practice Meetings (across Caltech)

New Proposals Incorporating Outreach

New Outreach from Labs and Departments (incl. Caltech coursework)

New Program Curricula and Practices

New PD Opportunities for Local K-12 Teachers (Number and Demographics)

New Learning Opportunities for Local Youth (Number and Demographics)

Improved and Simplified Processes

Increase in Documented Outreach from Caltech

Improved outcomes for grants involving outreach

Caltech Postdoc & Student Learning (Sci. Education & Communication)

K-12 Student STEM Attitudes

K-12 Student STEM Learning

K-12 Teacher Incorporation of STEM Curricula and Methods

Sustainable Caltech Educational Outreach

Enlarged & More Diverse Local K-12 STEM Pipeline

Increased K-12 and Public STEM Literacy and Engagement

Appendix 2: Comprehensive List of CTLO Programs and Services

UNIVERSITY TEACHING

Events, Seminars, and Workshops

- Annual Teaching Conference – a one-day event during orientation week, featuring a keynote opening session and concurrent discussions and workshops on a wide range of teaching topics and practices for new TAs through experienced instructors. Attendance is typically over 300.
- TeachWeek – a campus-wide celebration of teaching and learning, featuring events and discussions with Caltech faculty and students, as well as distinguished guest presenters. All events are open to the entire Caltech community. Innovative TeachWeek events have also included open classes, a photographic exhibit, recognition of all campus-wide teaching awards, and collaborations with the Caltech Archives, Libraries, Hixon Writing Center, and various Divisions and Options.
- New Faculty Workshops – by invitation to new full-time faculty as part of the Vice Provost's series of discussions, CTLO offers a start-up workshop on teaching and outreach; versions have also been offered to incoming part-time faculty, lecturers, and other instructors.
- Seminars and Workshops – Typically several times per year, CTLO offers stand-alone seminars and workshops on educational topics of interest to the community, often inviting guest speakers who may also consult with academic leaders, students, and instructors while visiting.

Programs: Training, Courses, Short Courses, Discipline/Core Programs

- TA Training – an institute requirement for new TAs, the CTLO maintains an online module about teaching policies and offers in-person training via the Teaching Conference (for graduate TAs) or specialized sessions (for undergraduate TAs) near the beginning of each quarter.
- Course Ombuds – an undergraduate Academics and Research Committee program, for which the CTLO provides training and advisement.
- E110 Course – a 3-unit graduate course, "Principles of University Teaching and Learning in STEM," typically taught twice per year.
- ABCs of Course Design – a multi-session short course on course design open to graduate students, postdocs, staff, and others planning to serve as an instructor of record or interested in course design.
- Faculty Summer Short Course – a multi-session short course on course design for Caltech faculty and instructors.
- CPET Certificates in University Teaching – two versions, the Certificate of Interest and Certificate of Practice, resulting in a letter and/or transcript notation.
- CPET Seminars and Discussions – offered several times per quarter, addressing topics of interest among graduate students and postdocs related to teaching.
- Teaching Fellows and other Division/Option Programs – a variety of disciplinary collaborations, including training and guiding advanced graduate TAs to serve as mentors for other TAs, customized discussions and presentations, etc.

- Inclusive Caltech Core – a two-year faculty learning community program for faculty teaching in the Core Curriculum.
- Undergraduate Research Mentoring Series – an 8-session summer series of workshops for graduate and postdoctoral summer research mentors, facilitated in partnership with the Student Faculty Programs Office.

Consultations and Feedback
- Teaching Observations – visits to classes and recitations, with a variety of observation techniques (video recording, quantitative and qualitative protocols), with subsequent feedback and discussion to the instructor or TA.
- Early/mid-quarter feedback – customized surveys and focus group discussions with students, with subsequent feedback and discussion with the instructor or TA.
- Course planning/design consultations – individual, customized support.
- Inclusive teaching methods – individual, customized support.
- Assessments and assignments – individual, customized support.
- Instructional technologies – individual, customized support
- MOOCs – liaison work with MOOC platforms (edX and Coursera) and support for open online course design and planning.
- Research grant proposals (educational components) – expert consultation on educational program design, assessment, planning, budgeting, and associated topics.
- Innovation in Education proposals – consultation on project ideas and proposals for the Provost's Innovation in Education Fund, with ongoing support for implementation.

Other
- National organizations – CTLO staff have served in leadership positions with the POD Network, National Academies Roundtable on Systemic Change in Undergraduate STEM Education, and have presented regularly at AAU STEM meetings, AAC&U, Network of STEM Education Centers, and other conferences.
- Disciplinary new faculty institutes – CTLO staff have served as faculty at the Summer Institutes on Scientific Teaching and AAPT New Faculty Workshop, as well as hosted the ACS New Faculty Workshop at Caltech.
- Committees – service and consultation with a wide variety of institutional committees related to teaching, instructional technology, online education, the Core curriculum, undergraduate education, and sustainability education.

EDUCATIONAL OUTREACH

Academic Year Programs
- Visiting Scientists – Caltech graduate students teach weekly hands-on science lessons in in local elementary schools.
- Coding in the Classroom – Caltech undergraduates provide weekly coding instruction to local elementary school classes.
- Ask a Caltech Student – COVID-19-inspired Facebook group connecting Caltech students with K-12 students nationwide.
- Hosting field trips – local school groups visit campus for lab tours and STEM activities.

- Supporting student group outreach programs – guidance, logistics and financial support for Chem Club, Science Olympiad, Math Club, Robotics Club, SWE, CPA, Graduate Student Council and other Caltech group programs.
- Science Nights – hands-on demonstrations and talks at local school science nights and community events.
- Classroom Visits – guest discussions at local schools about current research.
- Teacher Professional Development – curriculum development and practice for local STEM teachers.
- Solar Energy Activity Lab (SEAL) – high school clubs develop techniques to convert sunlight to consumable energy.

Summer Programs

- Summer camps – multiple summer day-camps and a limited number of overnight STEM enrichment camps; some include Caltech students/researchers as presenters, while others bring in specialized instructors from partner organizations. In-person summer camps are suspended for 2020 due to COVID-19; some are offering online versions.
- Summer Research Connection – opportunities for high school students and teachers to conduct research in Caltech labs and research groups. Online for summer 2020 due to COVID-19. Additional information.

Consultations and Feedback

- Research grant proposals (outreach components) – expert consultation on educational outreach program design, assessment, planning, budgeting, and associated topics.
- Feedback and planning – consultations with Caltech community members planning to interact with K-12 students; support on lesson planning, engagement techniques, and related topics.