Outcomes from the CfAO Research Internship Program

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The NSF Center for Adaptive Optics (CfAO) developed a program model for advancing science, technology, engineering, and math (STEM) college students into STEM careers, and implemented the model in three programs. The program model was designed to engage students in research early in their college education, and to include students from a broader range of backgrounds, including students from community colleges. The programs had a specific goal to increase participation from groups underrepresented in STEM, and in particular the physical sciences, engineering, and computing fields relevant to the CfAO. This document reports on the outcomes from the 214 students participating in the program from 2002-09, which include:

- **Advanced diverse students into STEM:**
  - 71% of the 214 participants were from groups underrepresented in STEM
  - 42% of the 214 participants were community college students
  - 84% of participating students remained on a STEM pathway
  - 87% of "mainland" participating students now have a STEM BA/BS
- **Developed new tools and strategies:**
  - Program elements implemented for 18 cohorts of students: communication course, research preparation course, selection and placement processes, processes and strategies for working with mentors
  - Research studying the internship model provided evidence that program elements are effective in helping students succeed
- **Generated new knowledge to inform mentoring and course curriculum:**
  - Documentation of effective mentor-student interactions that are now being incorporated into mentor training workshops
  - An engineering technology skills framework generated from students research projects and mentor interviews now used to inform course development
- **Established a program sustainable after STC funding:**
  - Now funded with multiple sources, including institutional funds
  - Serves ~30 students/year
  - Continue to train new professional staff in program strategies

Program model:

The program model developed by the CfAO was strategically designed to bolster the traditional research experience format that often employs a "sink or swim" approach, in which a student's background will have a significant influence on their chances of success. The norms and practices of research environments are new to many students, but for some students the situation may be significantly different and even perceived as contradictory to their social and cultural background. Expecting that the students targeted for the program would likely have had less exposure to research environments, fewer role models, and range of educational experiences that would not give them the advantages of students from dominant groups, the CfAO designed two program components: 1) an introductory five-day lab intensive "Short Course" and 2) a technical communication course integrated across the entire length of the program. In addition to the two major components, a wide range of other tools and strategies were developed and over the course of engaging 18 cohorts of students refined to support the highly successful program. Figure 1 shows the program components.

Figure 1: CfAO internship model

Students served:

The CfAO program model was implemented through three different programs that used the same program components, but with modifications to adapt it to somewhat different environments. The CfAO "Mainland" program attracted students from across the U.S. and placed them in academic and national lab research positions at CfAO sites located at multiple site throughout the U.S. The "Maui Akamai" program recruited students from Hawaii and placed them in industry and academic positions. The "Hawaii Island Akamai" program also served Hawaii students, but placed them at Mauna Kea observatories. Both Akamai programs were aimed at a state of Hawaii need to produce a local workforce, thus placed a high priority on including local students of backgrounds that reflect state demographics (e.g. approximately 25% of Hawaii's population is Native Hawaiian). The internship model also includes extensive and highly targeted recruiting, to ensure that students from diverse backgrounds are participating. As shown in Table 1, 42% of participating students started at community colleges; 41% were women; 57% were underrepresented minorities; and 71% were underrepresented (either women or underrepresented minorities.

Table 1: Demographics of CfAO Interns 2003-2009 Cohorts

	Hawaii Island Akamai (n=64)	Maui Akamai (n=78)	Mainland (n=72)	Total (n=214)
Men	43 (67%)	51 (65%)	33 (46%)	127 (59%)
Women	21 (33%)	27 (35%)	39 (54%)	87 (41%)
Underrepresented minority[1]	28 (44%)	41 (53%)	53 (74%)	122 (57%)
Other ethnicity	36 (57%)	37 (48%)	19 (26%)	92 (43%)
Underrepresented group[2]	46 (72%)	55 (71%)	68 (94%)	169 (78%)
Native Hawaiian or Pacific Islander	15 (23%)	17 (22%)	n/a	32 (23%)
Hawaii Born[3]	29 (45%)	53 (68%)	n/a	82 (58%)
Community college students	19 (30%)	40 (51%)	32 (44%)	91 (42%)

1. Includes Native Hawaiian, Pacific Islander, African American, Hispanic, and Native American, Filipino (does not include other Asians); 2. Women and/or underrepresented minorities; 3. Note: all students in the Akamai program have ties to Hawaii

Innovative program components:

The CfAO internship program includes two innovative components developed by the CfAO. The first component is a 5-day intensive preparation for research, called the "Short Course." Taught by graduate students and postdocs trained in the CfAO Professional Development Program (PDP), the Short Course uses inquiry learning to enhance students' research, problem-solving, communication, and collaboration skills.[i] Throughout the short course students gain extensive practice in working on teams to conduct investigations, solve problems, and communicate findings. The course includes a series of well-designed inquiry activities designed through the PDP, in which students learn scientific concepts and gain practice with science and engineering skills.[ii,iii] The second innovative component in the model is a communication course, which is integrated throughout the program. The communication course begins in the short course and then continues through weekly meetings and assignments for the remainder of the program, requiring that students communicate about their projects in a range of formats and to different audiences. Students gain practice with informal communication, explaining results, and effectively interacting with mentors, and over the course of the program produce an abstract, oral presentation, poster presentation, resume, and personal statement. Communication (including within the Short Course) was chosen as a focus in order to encourage reflective thinking, foster learning, to help students negotiate differences in cultural norms as experienced in the STEM workplace versus their everyday life, and to facilitate ongoing assessment by program staff. A study of the program which included extensive observations, recordings, and interviews provides evidence that the program model promoted student engagement in reasoning processes, and facilitated students' taking initiative in the research environment.[iv]

Retaining and advancing students:

The CfAO internship model includes important roles for professional staff, who develop activities to help students be successful during the program, identify unmet needs or challenges, and who maintain contact with students after the program. Students are contacted by program staff at least once a year to learn about their education and

career progress, and to identify any additional support or advice needed by the student. For example, students who are looking for jobs are connected with openings, and those interested in graduate school often get assistance in the application process. The overall goal of the program is to retain and advance students into STEM, thus the success of the program is evaluated on the number of students that continue to enroll in STEM undergraduate or graduate programs, or who have entered the STEM workforce. In 2010, we made contact with 200 of the 214 (93%) participating students. Table 2 shows the status of all students contacted, indicating the 84% of students have remained on a STEM pathway (enrolled in STEM program or in the STEM workforce).

Table 2. Status of Interns 2002-2009 Cohorts, by program

	Hawaii Island (64)	Maui (78)	Mainland (72)	Total (214)
Participants maintaining contact	60 (94%)	72 (92%)	68 (94%)	200 (93%)
%'s below calculated from 93% of students maintaining contact				
A. In STEM workforce (not enrolled)	12 (20%)	26 (36%)	21 (31%)	59 (30%)
B. Enrolled in STEM program - ugrad	27 (45%)	26 (36%)	9 (13%)	62 (31%)
C. Enrolled in STEM program - grad	12 (20%)	7 (10%)	24 (35%)	43 (22%)
D. On STEM pathway (A+B+C)	52 (85%)	61 (83%)	54 (79%)	167 (84%)

STE=science, technology, engineering, math

The Mainland program provides a longer-term longitudinal outlook on the CfAO internship model, as the program was the first program implemented (2002), and was terminated in 2007. Many of the students in the program have now had ample time to complete their undergraduate degree and move to the next education or career phase. In 2010 we contacted 68 of 72 (94%) of the alumni of this program, and results are shown in Table 3. Of those we contacted 87% have graduated with a STEM BA/BS degree. Of these graduates, 54% entered STEM graduate programs, and 22% entered the STEM workforce. For those that entered STEM graduate programs (32), all but one (97%) have either graduated or are still enrolled.

Table 3. Post-baccalaureate persistence in STEM for Mainland participants

Total Mainland Interns maintaining contact (68)	
A. Total graduated with STEM BA/BS	59 (87%)
%'s below calculated from 59 graduated interns	
B. Entered STEM workforce	13 (22%)
C. Applied to STEM grad school	36 (61%)
D. Entered grad school after BA/BS	32 (54%)
%'s below calculated on 32 entering grad school	
E. Currently enrolled in STEM grad school	24 (75%)
F. Graduated with STEM Masters	7 (22%)
G. Graduated with STEM PhD	1 (3%)
H. Graduate studies retention (E+F+G)	31 (97%)
% below calculated on 8 graduating with STEM MS/PhD's	
I. Full time in STEM workforce (already graduated with grad degree)[1]	8 (100%)

Disseminating new knowledge learned from program model:
A two-year study of the CfAO internship program was initiated in 2006, documenting and observing interns throughout their program experience. The focus was on how, when, and under what conditions undergraduate interns come to engage in scientific argumentation during learning activity in classroom and research settings. The full study was published by Tamara Ball in her dissertation,[v] as well as a paper describing the institutional context and outcomes[vi] and a second paper reporting on the efficacy of the program in supporting reasoning skills and initiative in participating students.[vii] Findings from the project revealed different aspects of the learning environments that mediated opportunities for interns to formulate, articulate, and defend in scientific explanations. These "conditions" ranged from persistent cultural/institutional norms in the research and classroom environment, to the more immediate context of face-to-face interactions between students and mentors, as well as the changing dynamics of those interactions. Evidence from this research indicates that research experience alone is not enough to ensure that undergraduates will have opportunities to explain their work, and that learning experiences can be created to create opportunities that promote student engagement in explaining their findings. The project has many practical implications, including strategies for how mentors and instructors can support opportunities for students to participate in scientific argumentation and to take more initiative in research environments.

A second study was conducted from a practical perspective, which tapped into program documentation of student projects and long-standing relationships with mentors in the Akamai internship program to assess workforce skills desirable to industry and observatories in Hawaii. CfAO program staff reviewed student abstracts and presentations, and interviewed mentors and other personnel to learn about desirable skills for entry level technical employees. Three technical reports[viii] outlined the findings from this study, which are now being used to develop courses for a new engineering technology degree at University of Hawaii Maui College. An important finding from this work is the value placed on problem solving and critical thinking skills, communication skills, and engineers "ways of thinking." A new framework was created which outlines three major skill areas, and how these skills can inform curriculum development.[ix]

Additional lessons learned are continuing to find their way into practice (see below), and more publications are planned, through the continuation of CfAO education in the Institute for Scientist & Engineer Educators and the Akamai Workforce Initiative.

Continuation of internship programs after STC funding:
The Akamai internship programs have become highly valued programs within the state of Hawaii and are at the heart of the Akamai Workforce Initiative, which is funded by the National Science Foundation, the Air Force Office of Scientific Research, University of Hawaii, and Thirty Meter Telescope Corporation. Each year approximately 30 students are accepted into the program, participate in the full program model, and are supported for many more years through a range of informal activities.

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[viii] Technical reports are available at: http://kopiko.ifa.hawaii.edu/akamai/resources/index.html

[ix] Seagroves, S., and Hunter, L., 2010. An Engineering Technology Skills Framework that Reflects Workforce Needs on Maui and the Big Island of Hawai'i. (in press) in Learning from Inquiry in Practice, Astronomical Society of the Pacific.