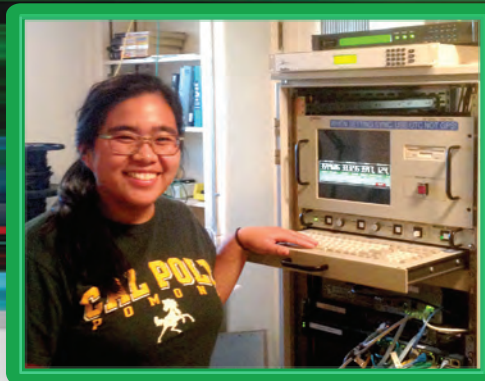# ISEE's Contributions to STEM Persistence and Effective Mentoring Practices: A Report Summarizing Fourteen Years of Design, Practice and Outcomes Studies

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ISEE

Institute for Scientist & Engineer Educators

ISEE's Contributions to STEM Persistence and Effective Mentoring Practices: A Report Summarizing Fourteen Years of Design, Practice and Outcomes Studies

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Authors' note: This report has been compiled by members of the Research and Development arm of the Institute for Scientist & Engineer Educators with the goal of highlighting ISEE's notable successes in STEM mentoring and training STEM mentors. These efforts have, in turn, had significant positive impacts on the persistence of STEM undergraduate students, particularly those who have participated in ISEE's Hawai'i-based Akamai internship program. This report honors the work of the many ISEE staff members and collaborators who have designed, coordinated, and carried out ISEE's internship programs and curriculum; the companies, observatories, and other institutions that have hosted Akamai interns; the professionals at those host institutions who have mentored interns' projects; graduate students and postdoctoral researchers who have developed and taught short courses to bolster interns' training; and the undergraduate students who have completed internship projects through the Akamai program and contributed to ongoing refinements of the program.

1. The Institute for Scientist & Engineer Educators[1]

The Institute for Scientist & Engineer Educators (ISEE), headquartered at the University of California, Santa Cruz (UCSC), is a dynamic organization that runs a suite of programs to create a diverse and effective workforce. ISEE has mentored hundreds of undergraduates pursuing science, technology, engineering and mathematics (STEM) degrees through an innovative internship program, now known as "Akamai" (the Hawaiian word for smart or clever). Akamai has been key in Hawai'i, where the advancement of Native Hawaiians and other underrepresented groups into STEM careers is essential to the state's economy and to the success of U.S. astronomy. In Hawai'i, as well as nationally, ISEE is also developing current and future mentors: through its Professional Development Program, ISEE trains graduate students and early-career professionals across the U.S. to be inclusive mentors and educators, and makes a long-term impact as these individuals advance in their careers. Although ISEE is involved in mentoring at multiple levels and has a national impact,[2] this report focuses on ISEE's intensive mentoring effort in Hawai'i through the Akamai internship program.

ISEE integrates three themes in its mentoring work: Inquiry, Equity & Inclusion, and Assessment. Inquiry is widely called for in several national reports,[3,4,5] including the 2012 report of the President's Council of Advisors on Science and Technology.[6] Inquiry is characterized by authentic, research-like engagement in STEM content and practices,[7] and by learners' ownership over the learning process.[8] A focus on Equity & Inclusion is also needed[9] to improve retention among the many groups that are underrepresented in STEM[10,11,12] as the U.S. becomes increasingly diverse.[13] ISEE's focus on Assessment entails backward design[14] and formative[15,16,17] (ongoing) assessment to inform and adjust teaching and mentoring.
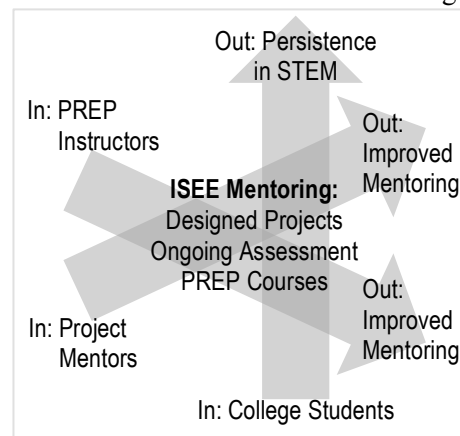
1.1 The History of ISEE

ISEE was formally established in 2008, and grew out of the pioneering work of the Center for Adaptive Optics (CfAO) Education program, under the consistent direction of Lisa Hunter, who is also ISEE's Director. The CfAO was a Science and Technology Center, funded by the National Science Foundation from 2000–2010 (AST#9876783), that focused on technology used by both astronomers and vision scientists to sharpen imaging. Sustained funding from the NSF allowed for creativity and flexibility,

including the development of the education and mentoring programs discussed in this report. Partnerships with telescopes in Hawai'i, which have now spanned thirteen years, were one of several important CfAO outcomes that stimulated institutional support from UCSC to launch ISEE. ISEE is a rare example of an NSF Center education program that has been sustained and institutionalized. Combining ten years of NSF Center funding, and over five years of continuation and expansion through diverse funding sources, ISEE has demonstrated success in the field of mentoring, and is positioned to make an even more significant contribution in the future.

1.2 ISEE's Focus on Hawai'i

ISEE's mentoring and workforce development in Hawai'i grew out of close ties to the astronomy community and history with the CfAO. The University of California Observatories, also at UCSC, is a partner in the largest optical/near-infrared telescopes in the world, which are located in Hawai'i: the twin 10-meter Keck Telescopes and the upcoming Thirty Meter Telescope. Siting telescopes in Hawai'i is crucial to U.S. astronomy, but places unique demands on developing a local workforce. A history of using culturally significant mountaintops for telescopes has met resistance, and training local students for technical jobs is widely called for as mitigation. A local workforce is also highly desired by employers. However, the islands' technical industries struggle to fill positions with local qualified talent, while personnel hired from off-island have twice the attrition rate as local hires.[18] With the Daniel K. Inouye Solar Telescope (DKIST) and TMT under construction, demands on Hawai'i's workforce are increasing.

2. ISEE's Mentoring Philosophy

2.1 Mentoring as a "designed" STEM experience

A key premise of ISEE's philosophy is that a mentored STEM experience can be intentionally designed to be a productive, authentic contribution to the workplace, _and_ to support factors known to influence persistence in STEM. ISEE applies the "backward design" approach,[14] often used in developing classroom curriculum, to design project experiences for interns who are working in research, laboratory, observatory, and/or industry environments. As with classroom instruction, effective mentoring starts with identifying desired outcomes for the learners/mentees, and then designing a learning experience that will to lead to those outcomes.

One of ISEE's overarching goals is to increase persistence of undergraduates, particularly from groups underrepresented in STEM.[a] Attention to STEM's _retention_ highlights the disciplines' climates, cultures, and practices, while attention to _persistence_[19] highlights student attributes such as agency and motivation. While both perspectives are necessary for a more inclusive STEM experience, this report focuses on ISEE activities that most directly impact individuals and can contribute to their persistence. The literature on STEM persistence and inclusive education highlights overlapping factors that can be fostered through mentored interventions, or what ISEE calls _designed_ STEM experiences. These factors include:

- **STEM practices:** Engaging students in the "doing" of STEM can lead to increased persistence.[19] Key to this is providing research opportunities early in college,[20] and scaffolding research-like opportunities into coursework (as with ISEE's emphasis on inquiry). Interns' experiences with these research opportunities vary, however, and meaningful work with STEM practices does not come automatically. Carefully designed experiences can build expertise while simultaneously building an individual's self-efficacy,[21] motivation, and agency in STEM.
- **Growth mindset:** Practice and feedback through ongoing assessment can help students to build a "growth mindset," or a view of their own intelligence as something that can be improved, rather than a fixed trait.[22,23] This, in turn, can improve students' performance and sense of competence.
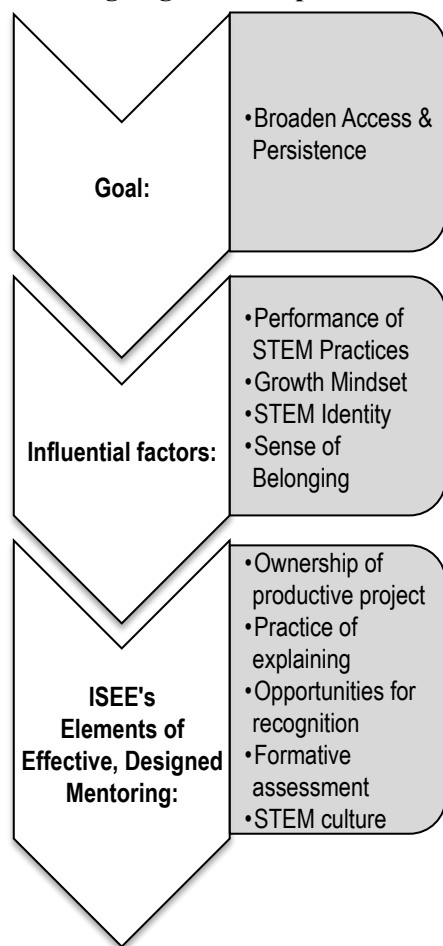
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[a] Groups underrepresented in STEM as compared to the general U.S. population include Native Hawaiians and other Pacific Islanders, Blacks or African Americans, Hispanics, Native Americans, Alaska Natives, and women.

- **Positive STEM identity:** Literature on STEM retention and student persistence has pinpointed the importance of the student building an identity as a "STEM person" in addition to her/his other identities.[24,25] Identity development is fostered when students build competency with skills valued in the field, when they have authentic opportunities for the performance of STEM practices (see above), and when they feel recognized for their contributions.[26]
- **Sense of belonging in the larger STEM community:** Closely related, but not the same as, the development of a positive STEM identity, is the students' sense of how they "fit in" to the STEM community. An engaging climate that fosters positive interactions among peers and faculty can help.[27] Students' sense of belonging, in turn, influences their motivation and achievement in STEM.[28]

These factors are closely connected to ISEE's themes of Inquiry, Equity & Inclusion, and Assessment. ISEE has extensive experience integrating these themes into the design of STEM curriculum and mentoring experiences. In ISEE's Akamai program, multiple mentors work with interns, including:

- **Staff Mentors**, who manage all aspects of the Akamai internship program, directly mentor interns throughout the program, and train others who are involved in mentoring interns.
- **PREP instructors**, future faculty members and professionals who are trained to teach and mentor through ISEE's Professional Development Program. They put what they learn into practice by designing and instructing short, mentored inquiry activities in a multi-day, intensive "short course" before interns begin their projects. This short course is known as PREP (Preparation for Research Experiences and Projects).
- **Project Mentors**, who participate in ISEE's Mentor Program before working with interns. Through the program, Akamai Project Mentors not only learn effective mentoring strategies, but also work with ISEE Staff Mentors to design the projects their interns will carry out.

2.2 Ongoing research paired with iterative practice

Goal:
- Broaden Access & Persistence

Influential factors:
- Performance of STEM Practices
- Growth Mindset
- STEM Identity
- Sense of Belonging

ISEE's Elements of Effective, Designed Mentoring:
- Ownership of productive project
- Practice of explaining
- Opportunities for recognition
- Formative assessment
- STEM culture

ISEE's approach to mentoring can be described as *design-based research*, a "systematic but flexible methodology aimed to improve educational practices through iterative analysis, design, development, and implementation, based on collaboration among researchers and practitioners."[29] ISEE's work draws from the literature as well as extensive experience working directly with interns, instructors, and project mentors. As Staff Mentors develop, implement, and train others in effective mentoring practices, they evaluate (and often formally research) the effectiveness of those practices; then they improve and evaluate again. In this way, ISEE's work is not only rooted in the real-world needs of interns, instructors, and project mentors, but also iteratively contributes to and is influenced by the body of knowledge on mentoring.

2.3 Designed elements of effective mentoring

ISEE has pinpointed five elements of a designed STEM experience that, through effective mentoring, support the factors noted in §2.1 that are linked to persistence:

1. Fostering ownership of a contribution to the STEM workplace: ISEE Staff Mentors work with Project Mentors and interns to make sure that interns engage in "real" projects — projects that are valuable to the intern's host company/institution as well as to the intern. Furthermore, co-mentoring ensures that internship projects are challenging, and offer opportunities for interns to make choices about how to proceed (rather than always being told what to do). Interns gain a sense of ownership and agency over their work, building competence in STEM practices, building identity as

contributors to STEM, and building growth mindsets as setbacks occur and new learning ensues.

2. Teaching the practice of explaining: ISEE Staff Mentors train PREP Instructors and Project Mentors to explicitly teach STEM practices to interns. A key practice in both science and engineering is *explaining*, which involves justifying results or solutions based on evidence. PREP Instructors coach interns in explaining results and supporting solutions during the PREP course before the internship project, Project Mentors support interns in using practices during the project itself, and Staff Mentors provide ongoing opportunities for interns to practice explaining. Interns gain mastery and have opportunities to demonstrate their competency — key ingredients for bolstering STEM identity.

3. Creating opportunities for interns' contributions to be recognized: ISEE Staff Mentors create "performance" opportunities, or opportunities for interns to demonstrate their knowledge and share their work with people whose recognition counts — colleagues at work, peers, and the larger technical community. By coaching interns to communicate effectively about their work in different ways (e.g., "elevator talks" and symposium talks), ISEE mentors ensure that interns present the aspects of their work (such as results and their implications) that are most valued by the audience and most likely to be recognized, bolstering interns' STEM identity and sense of belonging.

4. Formatively assessing interns' progress: ISEE gives interns multiple assignments that provide opportunities for interns to explain their understanding of their project and describe their progress. Staff Mentors assess and give feedback on interns' work, and interns improve. Project Mentors concurrently assess and respond to interns' work. This constructive feedback helps interns to develop growth mindsets.

5. Making the norms of STEM culture accessible: ISEE Staff Mentors work with project mentors to make workplace expectations and broader STEM cultural expectations clear to interns (e.g., interns are prepared to justify their work and regard questions as indicative of interest, not as a personal challenge). Staff Mentors also prepare interns to communicate with colleagues and receive feedback. This helps interns gain a sense of belonging and a larger sense of identity as a "scientist", "engineer" or STEM person.

3. ISEE's Mentoring Accomplishments

3.1 The History of the Akamai Internship Program

The internship program that later became known as "Akamai" was originally developed in 2002 through the CfAO Education program. This program placed undergraduate students in summer research positions at academic institutions in the Mainland U.S. that were affiliated with the CfAO. The internship program served students of many backgrounds, including many who were from groups underrepresented in STEM. In 2003, the internship program was expanded to include intern placements on Maui and the Big Island of Hawai'i. There the more traditional academic summer research experience was expanded and found success at observatory and industry sites, which demonstrated that the program works in multiple contexts. Akamai has run continuously since 2003, and under ISEE's leadership has expanded upon the mentored student supports and design-based approach of the CfAO's original internship program (see §3.3 and §3.4). Recognition of ISEE's achievements through Akamai has come from over 25 companies, labs, and observatories in Hawai'i that have hosted interns, many for multiple years, and from the funding organizations that have supported and continue to support Akamai: UCSC, University of Hawai'i, the National Science Foundation, TMT International Observatory, Hawaii Community Foundation THINK Fund, Air Force Office of Scientific Research, and the National Solar Observatory/DKIST. An external evaluation of Akamai identified the program as "a long-term, cumulatively building, successful effort that goes far beyond what most short, episodic grants are able to accomplish" that "continued to assess and improve its own design and efficacy."[30]

3.2 The Need for Akamai Mentoring

3.2.1 The need for a local, highly trained STEM workforce in Hawai'i

Hawai'i is a vital resource for advancing U.S. research, technology, and national security. The summit of Haleakalā on Maui includes Mees/SOLARC observatories, the Maui Space Surveillance Site

> Training and retaining STEM college students is the **"lowest-cost, fastest policy option to providing the STEM professionals that the US needs."**
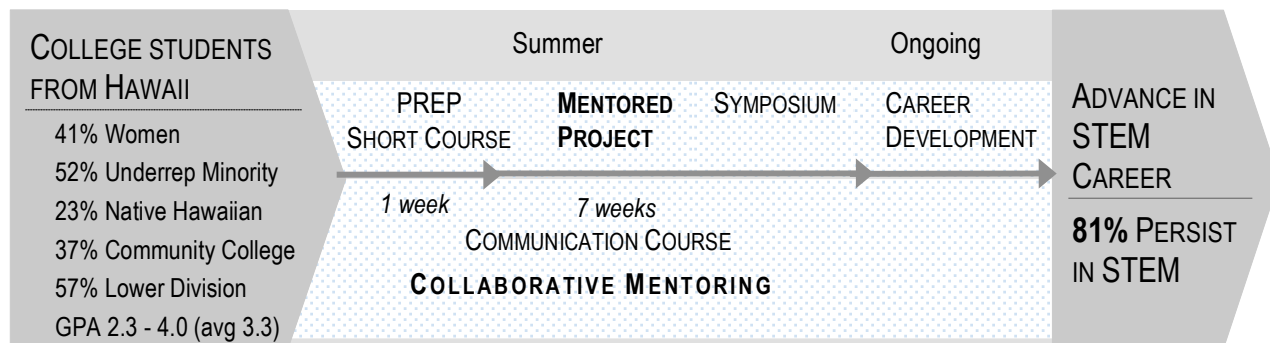> *President's Council of Advisors on Science and Technology (2012)[6]*

(MSSS), and PanSTARRS, and DKIST has begun construction. The Maui High Performance Computing Center, Pacific Disaster Center, and a growing number of high-tech companies are also located on Maui. On the Big Island of Hawai'i, the summit of Maunakea hosts state-of-the-art astronomical facilities, including the W. M. Keck Observatory, Gemini Observatory, Subaru Telescope, the NASA Infrared Telescope Facility, and the Smithsonian Submillimeter Array. TMT has also recently broken ground. In Hawai'i and across the U.S., the need to grow the STEM workforce requires training today's students. Hawai'i features a particularly diverse population, but without programs like Akamai, STEM professionals lack preparation for mentoring that engages and retains diverse, local talent, and interns lack the mentored experiences that provide them with the skills they need to enter the workforce.

3.2.2 The students Akamai serves

Akamai internships are open to college students from Hawai'i who plan to pursue careers in STEM fields. Akamai places an average of 30 interns per year, depending upon funding. Though students' grades are considered, priority is placed on attributes that are valued by employers, such as motivation and work ethic, as noted in applicants' essays and in letters of recommendation. Students who are selected and participate in the Akamai internship program (see demographics below) are typically in the course of pursuing engineering or computer-oriented degrees. Interns come from community colleges as well as four-year colleges and universities; many come to Akamai early in their college careers (57% lower-division students). Some are interested in pursuing an advanced degree, but many wish to move into the workforce after completing an associate's or bachelor's degree. A number of interns are interested in working at telescopes in Hawai'i as engineers, technicians, programmers, or in information technology.

3.3 Akamai Mentoring Activities

The Akamai internship program begins long before the actual summer experience, with project identification and development by ISEE Staff Mentors and Project Mentors. Next, ISEE intensively recruits and selects from a diverse population of undergraduates from Hawai'i to secure a cohort of interns. Interns' projects obviously provide a focus for the internship, but Akamai is characterized by a great deal of "co-curricular" mentored structures that incorporate design elements (see §2.3) to ensure the interns' success. Ongoing support continues after the summer internship.

COLLEGE STUDENTS FROM HAWAII	Summer			Ongoing	ADVANCE IN STEM CAREER
41% Women	PREP SHORT COURSE	**MENTORED PROJECT**	SYMPOSIUM	CAREER DEVELOPMENT	
52% Underrep Minority	*1 week*	*7 weeks*			**81%** PERSIST IN STEM
23% Native Hawaiian		COMMUNICATION COURSE			
37% Community College		**COLLABORATIVE MENTORING**			
57% Lower Division					
GPA 2.3 - 4.0 (avg 3.3)					

- **PREP short course:** Interns participate in a one-week preparatory short course (called the Preparation for Research Experience and Projects, or "PREP") before embarking on their summer internship project. PREP is designed and taught by ISEE Staff Mentors, who also integrate teams of PREP Instructors into the course instruction. These teams work collaboratively with Staff Mentors to design inquiry activities that give interns practical experience defining and solving problems, designing investigations, and explaining results. Interns typically come into the program more

> **Research findings on PREP:** "…[PREP] was successful in engaging interns in scientific argumentation not only because it presented situations that were sufficiently different as to be recognizably challenging, but because it also included structural supports and pedagogical scaffolds that enabled interns to effectively confront and overcome their initial feelings of doubt, uncertainty, or frustration. These examples also demonstrate how [PREP] was particularly effective in challenging institutionalized approaches to learning that the interns carried over from their experiences in school."
> *T. Ball, Ph.D. Dissertation, UCSC (2009)*[33]

comfortable with highly directed classroom experiences, and may be unprepared to tackle ill-defined problems or participate in the norms and ways of working that lead to success in the STEM workplace. PREP challenges interns and can be described as a hybrid between a classroom and a real-world STEM environment, where interns are supported as they tackle new problems in strategically designed inquiry activities.

> "It forced me to be frustrated, but then proud of myself for figuring out … a complex problem."
> *Intern's perspective on an inquiry activity mentored through the Akamai PREP*

- **Collaboratively mentored project:** Interns are guided by ISEE Staff Mentors and Akamai Project Mentors as they complete a seven-week project. Well before the summer internship begins, ISEE Staff Mentors meet with prospective Project Mentors to establish intern projects that will be valued contributions to the supervisors' organizations *and* productive educational experiences for the interns (see examples in box below). When Akamai interns are selected, they are carefully matched to projects that best fit their interests, education, and strengths. Projects are designed so that interns have ownership and choice in how they complete a major project component. Staff Mentors conduct site visits, and collaboratively mentor interns throughout the summer through a communication course (see next).

> The following projects have been completed by Akamai interns at Canada-France-Hawaii Telescope (CFHT):
> - **Going Green—the CFHT Data Center Cooling Dilemma:** An intern designed and tested a prototype ventilation system for the CFHT computer room. His system uses outside ambient air to cool the room, and includes a range of other modifications that decrease CFHT's electricity cost by roughly $30K per year.
> - **Automating Astronomical Instrument Setup:** An intern developed a user interface to set up an instrument at CFHT. His interface automates many steps and saves several hours of setup each time this instrument is put on the telescope.
> - **Improving Aluminizing Procedure:** An intern improved the process of applying an aluminum coat to CFHT's primary mirror. She performed tests with a vacuum chamber and dummy mirrors at the summit that improve the reliability and quality of CFHT's coating process.

- **Communication course:** Throughout the Akamai program, interns participate in a communication course taught by ISEE Staff Mentors, engaging in assignments related to their projects. This course gives Staff Mentors ongoing opportunities to assess interns, and interns self-assess. The culminating experience, and a driver throughout the summer, is a ten-minute formal oral presentation given at a symposium. Presentations are aimed at a technical audience, and ISEE Staff Mentors spend an intensive coaching day with interns to make sure that interns report their findings in a way that will be valued by the technical community. Though communication is an extremely important skill in and of itself, this component of the program goes far beyond simply teaching skills, to affect larger factors associated with STEM persistence (see §2.1). For example, an assignment to give "elevator talks" at the work site opens informal opportunities

> **Research findings on communication course:** "In particular the results suggest that one advantage of the design to the communication course is that it helped interns to attain and retain a sense of ownership in relation to their research projects and thus propelled them to demonstrate more initiative and agency in their interactions at the host research site."
> *T. Ball, Ph.D. Dissertation, UCSC (2009)* [33]

for interns to be recognized for their work. Interns do not simply prepare and give an oral presentation, they engage in an iterative process that includes their Project Mentor and Staff Mentors and that *by design* builds interns' identity, belonging, and growth mindset.

- **Mentoring after the summer experience:** After the summer program, ISEE Staff Mentors invite internship alumni back for career development activities, such as workshops and mock interviews. Staff Mentors work with telescope and industry partners to design these activities and give employers access to highly sought-after Akamai alumni. Staff Mentors connect alumni with continuing education and career opportunities, sustaining the Akamai community and keeping in touch with alumni for many years. Alumni are notified of job openings, and Staff Mentors introduce employers and alumni when a promising match has been identified.

> **One Intern's Success Story**
> Chriselle Galapon grew up on Maui and moved to Oahu for college, where she majored in mechanical engineering. In 2013, she was selected for the Akamai internship program. With guidance from her Project Mentor, Galapon designed a prototype for a baffle that would reduce stray light entering the sensor of a telescope. After she graduated and returned to Maui, Akamai program staff got in touch with Galapon upon being notified that there was a job open for an employee with her background. Galapon applied and got the job and is now an engineer for the Daniel K. Inouye Solar Telescope, and this coming summer will be a mentor for an Akamai intern. Galapon's story demonstrates unique aspects of Akamai — the commitment to mentor alumni as they graduate and enter the job market, and the potential for alumni to support future interns.

3.4 Assessment, Evaluation, and ISEE's Research on Mentoring Methods

ISEE's design-based approach involves multiple ways of appraising Akamai mentoring efforts. ISEE Staff and PREP Instructors assess interns' work, and Staff Mentors also conduct internal evaluation and work with external evaluators to study ISEE's mentoring methods, using the results of both the assessment and evaluation work to improve mentoring strategies. ISEE has also conducted formal research on mentoring methods, as well as research on interns' mentoring needs.

ISEE integrates formative assessment throughout the Akamai program as described in §3.3, closely monitoring interns' progress through many strategically designed program components. The primary means of evaluating program outcomes have been direct measures rather than self-reported perspectives; however, interns are surveyed at various points in the program. Many survey questions have remained consistent over a number of years, which has enabled ISEE to analyze trends in interns' attitudes and self-reported experiences. See §3.5 for a discussion of outcomes.

ISEE's research includes formal studies of mentees' needs, as well as studies of mentors' methods. Research on the needs of Akamai interns from employers' perspectives has included formal interviews of professionals at sites that have hosted interns, and the development of a framework of skills that are highly desired by high-tech employers in Hawai'i.[31] Other studies have included observations of interns' engagement in problem-solving skills, in an effort to delineate the "sub-skills" that are needed to succeed but that interns find challenging. Findings indicate that interns struggle with *defining requirements* of a problem, which is a key aspect of understanding, completing, and communicating their project.[32] These studies have implications for mentoring, and have resulted in adjustments to the learning goals of PREP inquiry activities and to the Akamai communication curriculum, in order to better support interns as they learn the skills that they will need in the workplace.

A major, formal study of the Akamai program analyzed interviews with interns and observations of their engagement in their work.[33] This study showed that the inquiry-intensive PREP short course strongly promotes interns' engagement in scientific argumentation, and their overall initiative as they engage in their work. The same study looked closely at the communication course and how involvement from ISEE Staff Mentors enhanced interactions between interns and Project Mentors, and found that interns "developed a sense of ownership and demonstrated more agency." Furthermore, this study showed that intentionally designing mentored experiences, and promoting interns' work even through informal, on-the-fly interactions, had positive impacts on mentors' work. These findings have led ISEE Staff Mentors to share mentoring strategies with Akamai Project Mentors, so that workplace skills, initiative, and productive communication can be fostered as interns work on their summer projects.

3.5 Impacts and Lessons Learned from 14 Years of Mentoring

3.5.1 Broadening Access

In 14 years, ISEE has worked with 372 interns. The demographics of the interns differ in important ways from the typical demographics of students with access and opportunity in STEM careers, as shown in the table below. The internship serves more women, more students from underrepresented minority groups, and specifically more Native Hawaiians than the underlying population of (mostly engineering) college students. In addition, the program draws from students who have just finished their first or second year of college, including a large proportion who are at community colleges. This is in contrast with the typical

conception of an "REU"-style summer experience, which often targets students finishing their junior year. In addition, the program defines "success" more broadly than simply a graduate school pipeline, to include entry into industry careers after an associate's or bachelor's degree.

Group	Akamai interns	Discussion
Women	41%	Most Akamai interns are engineering majors, fields in which women typically make up only 19% of students, both nationally[34] and locally at UH Manoa.
Underrepresented minorities	52%	Most Akamai interns are engineering majors, fields in which underrepresented minorities make up ~17.5% of students.[34]
Native Hawaiians	23%	At the UH Manoa College of Engineering, ~13% of students are Native Hawaiian / Pacific Islander, whereas Native Hawaiians make up ~23% of Hawai'i's overall population.
Community college students	37%	It is typical for competitive summer research internship experiences to serve students from 4-year institutions.
Lower-division students	57%	Often "REU"-style summer experiences serve students at the ~junior level; however, studies indicate that early college research opportunities lead to persistence in STEM[27].

3.5.2 Broadening Persistence

In 2013, intern alumni from the 2002–2010 cohorts were surveyed and/or located in order to assess outcomes three or more years beyond the internship experience. Due to our ongoing contact with alumni, and a commitment to the time intensive effort needed to track participant outcomes, 92% of them were located. Key findings[35] include:

- **81% of alumni tracked by ISEE persisted on a STEM pathway.** All alumni who were in the STEM workforce, still enrolled in a STEM undergraduate program, or now enrolled in a STEM graduate program were counted as being "on a STEM pathway." Since interns span a range of backgrounds including community colleges, and have a range of aspirations from immediate workforce entry to graduate school, there is no simple comparison persistence figure. However, this 81% persistence rate is significantly higher than typical 5- and 6-year persistence rates among STEM college students, which are only as high as 33–41% for White and Asian American students and as low as 18.5–23% for underrepresented minority students.[11,36]
- **Women and students from underrepresented minority groups persisted at the same rate.** Even more remarkable than the overall high STEM persistence rate, there was no significant difference in persistence rates of men compared to women or of majority compared to minority groups.
- **Other reported predictors *did not* predict persistence.** Among alumni, neither the intern's GPA upon program entry nor the intern's family's educational background predicted whether the intern would persist on a STEM pathway. For instance, the average GPA upon beginning the internship for those who ultimately persisted was 3.40, while for those who were not retained in STEM the average GPA was 3.32.

Self-reported evaluation of the internship experience yielded some insights. In a standard "REU"-style summer experience, an intern's interaction with their immediate Project Mentor is the dominant aspect of their experience. In self-reported reflections on their experiences, alumni's satisfaction with their Project Mentor did *not* correlate with persistence. This could indicate that the large network of mentors and the many other aspects of the program (PREP course, communication course, weekly meetings with ISEE Staff, etc.) are such significant components that they actually dominate over the day-to-day interactions about the intern's project.

Akamai alumni 3+ years after internship (n=241)	Persistence rate of the 223 (92%) located
Now in STEM workforce	43%
Enrolled in undergrad STEM program	16%
Enrolled in grad STEM program	23%
Total on STEM pathway (women) (Native Hawaiians / Pacific Islanders) (all underrepresented minorities)	81% (80%) (79%) (79%)

Furthermore, in intern alumni's self-reports, the only aspect of the internship that strongly correlated with their ultimate persistence was how challenging they perceived their project to be. Of those that had left STEM, a much higher fraction reported that their project was "not challenging enough." This finding matches anecdotal observations of ISEE Staff Mentors, who have witnessed the negative effect of unchallenging projects on interns, and how even all the co-curricular activities included in Akamai cannot counterbalance it. Internship projects need to be "productive" for both the intern and the workplace in which they are situated. Mere shadowing experiences or "busywork" that fails to engage in authentic STEM practices does not suffice. ISEE is planning future studies to learn more about this interesting finding.

3.6 Wider Implementation of ISEE's Mentoring Model

3.6.1 PREP: A mentored support that can be implemented at any internship site
While ISEE has a significant focus on Hawai'i through Akamai, in recent years, ISEE has expanded to include Chapters across the U.S. and in Canada. Expansion has given ISEE the opportunity to train PREP instructors from a number of institutions (now typically 70/year from ~10 universities). As part of their training, many PREP instructors have taken the initiative to develop and implement PREP short courses at their home institutions, to serve undergraduate students who are embarking on summer research or other internship experiences. To date, ISEE PREP instructors have taught PREP short courses for 14 programs at 11 institutions (not including Akamai). These PREPs have each centered on an inquiry activity that taught students concepts and practices relevant to their summer projects. Disciplinary focuses of the PREPs have ranged from astronomy and physics to engineering, chemistry, and biology. While a PREP course may take a full week, many have been implemented in two or three days.

3.6.2 "Productive projects" and ISEE's Mentoring Program
Designing a project for an undergraduate intern is not easy — a summer project in particular takes place over a relatively short timescale, so it may be difficult for a mentor to ensure that the project is both educational for the intern and a valuable contribution to the larger efforts of a research group or company. In ISEE's view, the practical elements of effective mentoring described in §2.3 are key to ensuring that a project is *productive* for an intern, their project mentor, and the work site. Over the past four years, ISEE has disseminated the elements of mentoring productive projects through a Mentor Program for Akamai Project Mentors.

4. Summary: ISEE's Contributions to STEM Persistence and Effective Mentoring Practices

Akamai interns' impressive rate of persistence in STEM demonstrates that ISEE's mentoring model is extraordinarily effective, and has a long-term, positive impact on interns' education and career decisions. Key lessons that have come out of ISEE's formal studies and practical mentoring experience include:

ISEE Study	Mentoring and Persistence Findings
Hawai'i Workforce Skills Survey[31]	• STEM <u>practices</u> are highly valued in the workplace; many are related to explaining
Tools for Supporting Explanations[32]	• Tools (such as a framework of key elements of explanations) help interns learn this valued STEM practice, and help Project Mentors teach the practice to interns • "Defining requirements" is a particularly challenging aspect of problem-solving and explaining solutions
Inclusive Teaching and Mentoring Strategies[37]	• After ISEE training, PREP Instructors understand how to <u>incorporate inclusive strategies</u> into their teaching • Repeat training further increases understanding

Study of CfAO/Akamai Internship Program[33]	• Carefully <u>designed curriculum</u> can be an important bridge between the college experience and the workplace • Mentoring in the <u>PREP course</u> prepares students for success in their internship project • Strategic communication assignments interns' engagement in <u>explaining and taking initiative</u> • The way a <u>student's project</u> is designed, and on-the-fly <u>mentor moves</u> can either promote or constrain explaining, and students' initiative – even brief, informal mentoring interactions make a difference
Longitudinal study of interns' persistence in STEM	• Effective mentoring can lead to ~<u>80% persistence rates</u> in STEM for students of all backgrounds • Traditionally-regarded indicators of success (e.g., GPA) do not necessarily predict persistence when students have carefully designed STEM experiences • Interns' perception of <u>being challenged</u> by their project correlates with persistence

ISEE's unique approach regards mentoring as a discipline to be studied, practiced, learned from, and improved upon. Mentors require ongoing training so that they can effectively support mentees. Mentees benefit from multiple approaches and from intentionally designed supports for their learning, performance, and sense of belonging within the larger STEM community. These key ingredients, which have been so successful in Hawai'i, are relevant to college mentoring experiences throughout the U.S. and are now having a national impact through ISEE's expanded work. The cornerstone is ISEE's philosophy that mentoring a student project can be, and should be, designed.

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