Successfully Building a Diverse Telescope Workforce: The Design of the Akamai Internship Program in Hawai'i

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Abstract

The outcomes of a longitudinal study of the Akamai Internship Program, a seven week summer internship program in Hawai‘i, demonstrate success in retaining diverse undergraduate participants in science, technology, engineering, and mathematics (STEM). Established in 2003, Akamai partnered with all major astronomical observatories on Hawai‘i Island and Maui and many industry partners to productively engage local college students in workplace projects. Qualified locals are highly desired by island employers including observatories and industry partners who work with advanced technologies while operating in small communities. Over the past fifteen years, Akamai has been recognized for its ability to source and train local talent. The program uses research on persistence, equity, identity, inclusion and self-efficacy from the learning sciences in a suite of program components designed to advance students into STEM careers. Unlike many research experience programs, Akamai accepts students from diverse backgrounds with a wide range of GPAs and early in their college years, when they are most at risk of leaving STEM - 56% are lower division students upon acceptance. Akamai also provides support for mentors to instill inclusive, collaborative mentoring practices and to ensure mentors can effectively prepare interns for integration into the 21st century workplace. To date, Akamai has paired over 350 STEM undergraduates representing the full diversity of the islands including many groups traditionally underrepresented in the STEM workforce such as women, Native Hawai‘ians and other minorities, with professional mentors in their field, with 75-80% of placements directly related to the observatories. A recent analysis tracking 222 alumni three years after leaving the program showed that 87% persisted in STEM as evidenced by either their continued pursuit of a STEM degree (17%) or entrance into the STEM workforce (70%) after graduating. Interestingly, factors that typically predict disparities in persistence were not predictive in this study. Specifically, women and students from underrepresented minority groups persisted at the same rate as majority students. These findings suggest that with support informed by research, students of all backgrounds can successfully persist in STEM. In this paper we discuss key aspects of the Akamai Internship Program model believed to support retention while promoting inclusion to meet the needs of the telescope workforce community. We also recommend elements of the model that can be adapted to inform other workforce development programs.

1 Introduction

1.1 Hawai‘i’s STEM workforce challenges

Hawai‘i is home to over fifteen world class astronomical observatories on the summits of Maunakea and Haleakalā. 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 mitigation efforts have prioritized training local students for technical jobs - a stipulation that has been formalized as part of community benefit packages agreed to by advocates of proposed telescopes and representatives from the local community [1]. Opposition to the observatories has existed since the 1960’s when the governor and legislature, enthusiastic about development, set aside land for construction. Protests, demonstrations and litigation challenging previous and proposed construction of new telescopes in Hawaiʻi have focused on environmental protection and the sites selected as being sacred to natives. For example, controversy over choosing Maunakea for the site location of a new Thirty Meter Telescope emphasizes that this is considered the most sacred mountain of the Native Hawaiʻian religion and culture. Yet a local workforce is also highly desired by employers. 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 [2]. Currently, with the Daniel K. Inouye Solar Telescope (DKIST) under construction and planning for the potential construction of the Thirty Meter Telescope underway, demands on Hawaiʻi's workforce are only increasing. Since a majority of observatory positions are engineering and technology related, demand is highest for individuals with degrees in engineering, engineering technology, and computer science. Further exacerbating relations between telescopes and the community are significant disparities in demographics of telescope personnel. For example, women typically only make up about 10% of engineers working at telescopes. Native Hawaiʻians (~23% of Hawaiʻi's population) working in any STEM position are rare. There is only one known Native Hawaiʻian woman known to hold a STEM position (a recently hired Akamai alumna).

This challenging situation of finding local talent for Hawaiʻi's technical workforce is further complicated by national trends of attrition of undergraduates intending to major in science, technology, engineering, or mathematics (STEM) fields in which different portions of the population are disproportionately affected by attrition. Nationally, less than 40% of undergraduate STEM aspirants graduate with a STEM degree within six years of beginning their degree programs [3]. While six-year graduation rates are 43% and 52% for White and Asian American students, respectively, this figure is less than 30% for underrepresented minorities [3]. Additionally, while women account for more than 20% of the engineering school graduates nationwide, they only comprise 11% of the population of practicing engineers, either never entering the field or leaving after initial employment for a variety of reasons [4]. These troubling retention rates are contributing to the lack of diversity in the STEM fields nation-wide, and strongly suggest the need for interventions at the undergraduate level.

1.2 Engineering skills valued by telescope and industry employers

A previous study began by collating the engineering skills and practices of early Akamai Internship projects together with engineering frameworks from the literature and skills standards from the engineering education community. These formed the basis for a Delphi-like study in which Akamai staff interviewed over forty engineers at a dozen high-tech companies and observatories on Maui and Hawaiʻi Island. From these interviews Akamai developed a framework of the local engineering technology skills needs — which both comported with, and departed from, the standard frameworks.

Some of Akamai's partners' workforce needs that emerged from this framework are not surprising: selecting new technologies, creating new technologies, systems thinking, analyzing tradeoffs, project management, to name a few. Perhaps because of the "leanness" of observatories and many of Hawaiʻi's technology firms, a few interesting engineering practices such as "recognizing the 'good enough' or '80%' solution" came up often. Lines between technician-like maintenance (making existing technology work, or work better) and engineer-like research and development (selecting, adapting, or creating new technology) were often blurred, meaning the technician/engineer dichotomy is not always salient in these workplaces. At the time, this was relevant for the development of local two- and four-year engineering technology programs; in the present study, it may relate to the outcomes for community college and university students. Counter to the idea that entry-level technicians and engineers would simply be "managed," project management and communication/presentation skills were heavily emphasized at many workplaces for all entry-level employees.

1.3 Akamai internship program history and development

The Akamai Internship Program (Akamai) was developed by the Center for Adaptive Optics (CfAO) in collaboration with Maui Community College, the Maui Economic Development Board, and the Air Force Maui Optical and Supercomputing Site. This collaborative envisioned a partnership aimed at increasing Maui's capacity to develop a local workforce and combat attrition rates reflected in both national and local trends. The Center had just launched a new model program that was designed to advance college students into STEM careers, and the first iteration of this program was piloted on Maui in 2003. In 2004, Akamai (meaning "smart" or "clever" in Hawaiʻian) expanded to Hawaiʻi Island in a partnership with W.M. Keck Observatory that soon engaged all of the major Maunakea observatories. Akamai continued to grow and was funded for many years by the Center for Adaptive Optics, and is considered to be an important legacy of the center. The University of California, Santa Cruz continued to play a major role in Akamai, and as the Institute for Scientis and Engineer Educators (ISEE) emerged out of the Center education program, ISEE assumed leadership of Akamai.

Table 1. Telescopes and other organizations hosting 5 or more Akamai interns (2003-2017)

W. M. Keck Observatory
Institute for Astronomy
Gemini Observatory
Akimeka
Subaru Telescope
Trex Enterprises
Smithsonian Submillimeter Array
Adacemia Sinica Institute of Astronomy and Astrophysics
Canada-France-Hawaiʻi Telescope
Oceanit
Hnu Photonics
Pacific Disaster Center
Thirty Meter Telescope International Observatory
Textron Systems
University of Hawaiʻi at Hilo
Maui High Performance Computing Center
Natural Energy Laboratory of Hawaiʻi Authority
Air Force Research Laboratory
Integrity Applications Incorporated/Pacific Defense Solutions
Daniel K Inouye Solar Telescope
2C4/PJITC

Since its inception in 2003, Akamai has grown to include over 20 partners, funders, and affiliates. Today, Akamai continues to offer Hawaiʻi college students summer projects at observatories and industry sites on Maui and Hawaiʻi island (see Table 1). Akamai is intentionally designed to support students from a broad range of underrepresented or under-served groups in or from Hawaiʻi, including those with less access and opportunity to experiences that promote student success in STEM. The program focuses on including students during their early years of college, when attrition from STEM is high, and serving students interested in a broad range of STEM career paths, especially careers at telescopes and in industry requiring 2-year and 4-year degrees.

1.4 Evidence and research-based design and practice

Retention among the many groups that are underrepresented in STEM [5], [6], [7] has become a national imperative as the U.S. becomes increasingly diverse [8]. Providing research opportunities (like internships) early in college has been connected to retention [9] but there is a great deal of variability and quality in what gets defined as a research experience, and what students experience. The Akamai internship program and supporting mentorship training have been carefully designed based on research of teaching and learning, STEM persistence, inclusive education, identity and equitable practices described below, as a means of improving retention in STEM, and ultimately to meet workforce needs.

Teaching and learning engineering practices: Becoming an engineer requires learning to use the practices that engineers use to solve problems. Undergraduate engineering programs all have intended learning outcomes aimed at these practices, such as “an ability to design and conduct experiments, as well as to analyze and interpret data” and “an ability to design a system, component, or process to meet desired needs within realistic constraints” [10]. As noted above, these practices are highly valued by employers, who note that recent college graduates often lack proficiency with these practices [11]. The ideal place to learn these practices is in the real world, making capstone projects, internships, and other activities that require students to work on authentic problems highly valued experiences. However, putting students in the workplace to work on real problems does not necessarily mean that students will learn, or even engage with these practices in a productive way [12]. Over many years, the Akamai program has engaged in studies and developed tools to support students in learning engineering practices. For example, students often struggle with the practice of “defining requirements,” which led to the development of a pedagogical framework and training activities to better support Akamai interns in this key engineering practice [13]. The Akamai program integrates teaching, learning, and assessing engineering practices throughout the program with curricular innovations, targeting mentoring and coaching, and projects that have an explicitly identified focal engineering practice.

Explicitly teaching engineering practices is not just important for producing effective engineers, but has been linked to many other positive outcomes when considering the broader literature on the outcomes linked with inquiry learning. Engaging students in the “doing” of STEM has been linked to increased persistence [14]. Carefully designed experiences can build expertise while simultaneously building an individual’s self-efficacy, motivation, agency in STEM, and identity in STEM (more below) [15]. To facilitate these outcomes, inquiry is widely called for in national reports on STEM education (see, for example, the practices listed by National Research Council) [16], [17] including the 2012 report of the President’s Council of Advisors on Science and Technology [18]. Inquiry is defined in different ways, but the essence of most definitions focus on authentic engagement in STEM practices [19], and promoting learners’ ownership over the learning process [20].

Promoting ownership and agency in STEM education: Akin to ideas about promoting learners' self-efficacy and yet distinct, research focused on how students relate to the work they do has provided compelling evidence that when learners show initiative and take responsibility for not only the results of their work, but also their own intellectual process, they can engage more deeply with sophisticated concepts and practices. The cultivation of ownership in the learning process or "self-determined" learning activity [20] has been recognized as both a process and an outcome of the learning experience [21] and as being largely responsive to what facilitators can do to promote the transfer of ownership by assuming the role of a "guide on the side" or using other strategies associated with "faded scaffolding" [22]. Much of the research on ownership has focused on the micro-dynamics of socio-linguistic interactions taking place in different educational settings or the turn-by-turn instructional moves earlier characterized as "reciprocal teaching" [23] and more recently described as "calibrated guidance" [24]. Staff involved in developing Akamai recognize the concept of ownership in learning as a crucial ingredient to student engagement in STEM.

Developing a 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 factors related to persistence [25], [26]. A study using identity as an lens established a framework for analyzing the factors that affect science identity: students build competency with valued practices in the field when they have authentic opportunities for the performance of these practices, and when they feel recognized for their contributions – that is, "recognition for what matters, by people that matter" [27]. This study also found that recognition was particularly important, and was a missing component for the women of color in their study. As described above, the Akamai program has integrated teaching and learning STEM practices (engineering practices, as well the broader set in science and other technical fields) into the program curriculum. Program components facilitate and scaffold many different opportunities for the interns to perform and get recognized for the practices that matter most, (e.g. defining an engineering problem, and justifying a solution based on meeting requirements while working within constraints).

Developing a sense of belongingness and social capital: Closely related, but not the same as, the development of a positive STEM identity, is a student's sense of how they "fit in" to the STEM community. This sense of belonging encompasses feelings of origination and acceptance resulting from group membership in broad social categories, such as gender, ethnicity, or nationality, or from more narrowly focused occupational, peer-to-peer, and family roles [28]. An engaging social climate that fosters positive interactions among peers and faculty can help [29]. Students' sense of belonging, in turn, influences their motivation and achievement in STEM [30]. Individuals who develop a strong sense of belonging in a particular group have awareness of implicit and explicit expectations or cultural-historical "repertoires of practice" that influence social interactions, social roles and social norms within that group [31]. Making connections within social networks and accruing different forms of "social capital" [32] valued by group members is accomplished through positive social interactions with existing group "insiders" and then leveraging these gains. Both the network itself and social capital (i.e. knowledge of favored implicit and explicit norms and practices) comprise valuable resources that not only contribute to a sense of belonging but can lead to other benefits. Increasingly researchers are acknowledging that that while technical STEM skills and knowledge are necessary for success in the workplace they are not sufficient. The benefits of accruing social capital has been positively correlated with low crime levels, high educational attainment, retention in college and K-12, and perhaps most intriguing for engineering education, innovation and productivity in industry [33]. Akamai works with interns during the program on strategies to gain and leverage valuable social capital in their fields and through their internships. For example, interns get practice and coaching on communication norms, and mentors are encouraged to be explicit about norms and expectations within meetings that interns participate in.

Assessment and fostering a growth mindset: The overall Akamai program, as well as many components of the program, have been designed using empirically tested curriculum design principles. For example, the process of backward design [34] can be applied to shaping and setting up a student intern's project (if a mentor wants the intern to improve her prototyping skills, what does success look like, and what part of the project will be an opportunity for her to practice and get feedback). A crucial part of this is the practice of formative (ongoing) assessment [35], [36], [37] to inform and adjust teaching and mentoring. Akamai staff are trained to use various forms of assessment methods and tools throughout the entire Akamai internship experience. Akamai staff also train and support the mentors to use equitable, inclusive and responsive assessment practices when evaluating and assisting their interns. Practice coupled with responsive 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 [38], [39]. This, in turn, can improve students' performance and sense of competence, fostering a strengthened sense of identity.

Key components of the Akamai Internship Program are described in the next section. For more details on how each of the themes and factors described above have driven the design of these components, please refer to the final discussion section.

1.4.1 Key Akamai internship program components

Supporting mutual investments in the co-development of robust mentored projects: The Akamai Internship Program begins each cycle long before the actual summer experience, starting with project identification and development by Akamai staff and project mentors. Each project is carefully crafted and chosen to be valuable for the host institution ("authentic") while also an educational, career-advancing experience for the intern. The projects must be achievable in the seven-week program, with a clearly defined start and end point, so that interns can make discernable contributions and be properly recognized for their work at the end of the summer.

Available projects inform the intensive recruitment and selection of the next cohort of interns from a diverse population of undergraduates from Hawaiʻi. Since 2003, hundreds of local students have been selected to participate in Akamai through a careful matching process that pairs qualified applicants with specific projects and mentors to fit interests, education, strengths, demographics and personal background. The selection and placement process does not vet students by academic performance alone, but rather the fit with the project needs and the mentor.

Preparation for completing a valuable project in the STEM workplace: At the start of the program, 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 Akamai staff mentors who also integrate teams of PREP instructors into the course. All instructors have had training in how to design and teach inclusive lab activities. These teams work collaboratively with staff mentors to design inquiry activities that give interns practical experience with engineering practices such as defining design requirements, designing solutions within requirements and constraints, and testing prototypes. Emphasis is placed on engineering practices because most of the intern positions are engineering or technical in nature; however, the preparatory course also includes engagement in scientific practices such as defining and solving problems, designing investigations, and explaining results. PREP can be described as a hybrid between a classroom and a real-world STEM environment: interns are challenged during strategically designed inquiry activities as they tackle engineering and scientific problems that are intentionally ill-defined to allow more ownership and emulate workplace experiences more closely than the step-by-step lab activity familiar to most college students. Calibrated guidance from Akamai PREP instructors paying close attention to how interns engage with these challenges allows participants to confront and overcome encounters with uncertainty.

Seven-week co-mentored project supported by a communication course: Project mentors assume the lead as interns transition from the PREP course activities to engaging in and completing their seven-week projects at their designated internship sites. The internship sites include most of the major astronomical observatories on Maunakea and Haleakalā, where a mix of many engineers, technical staff, and scientists work together to maintain and utilize these world-class research facilities. Additional sites include high-tech industry, many of which undertake projects that support the observatories such as designing and fabricating the optics used by astronomical facilities. While project mentors take the lead during this time, Akamai staff continue to support both the project mentors through visits to the sites and direct communication and the interns through a communication course woven throughout the entire summer.

> Example of an intern project at the Canada-France-Hawai'i Telescope (CFHT): A graduate of Honoka'a High, and attending Honolulu Community College at the time of his internship, an intern developed a user interface to set up one of the main instruments at CFHT. His interface automated many steps and saves several hours of setup each time this instrument is put on the telescope. This alumnus now works at CFHT as a system administrator.

The communication course, taught by Akamai staff members, engages interns in assignments related to their projects. Interns work on short "elevator talks" of their projects in order to practice concise and informal communication skills. They write and receive feedback on a technical abstract about their projects. The culminating experience, and a driving force throughout the summer, is a ten-minute formal oral presentation given at one of the Akamai symposia. Presentations are aimed at technical audiences, and Akamai staff spend multiple intensive coaching days during the internship midpoint and before the symposia with interns to make sure that they report their findings in a way that will be valued by the technical community and highlight the most important technical contributions of the intern.

Ongoing career development and support after the summer experience: Over the years, Akamai staff have invited internship alumni back for career development activities, such as workshops and mock interviews. These activities also serve to give employers access to highly sought-after Akamai alumni. To ensure that the needs of all stakeholders are being met, Akamai staff have and continue to work with telescope and industry partners to design these activities. Akamai staff 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 introduce employers and alumni when a promising match has been identified.

As an example, in 2018 Akamai will be convening an event open to all program alumni since inception, targeting those in need of career advancement. Activities will include a resume writing workshop, mock interviews for real technical positions that interns would have applied for, and a networking session with Akamai partner organizations who are looking to hire or can provide valuable insight into the hiring process. In the past, each one of these events has yielded employment for some of the attending Akamai alumni.

1.5 Purpose of persistence study

The purpose of this study is to explore the current status of Akamai alumni in order to determine STEM persistence rates and contribute to the growing body of evidence examining persistence (and in particular differences in persistence rates across different genders and ethnicities) in the context of research apprenticeships or internship experiences. For the purposes of this study assertions about “program design” include everything from intern selection and placement through post-internship career advancement activities, the dual mentorship model which integrates support from both workplace and Akamai staff mentors, and preparations for intentional interactions between mentors and interns. All aspects of the Akamai program design were driven by research-based findings on equitable STEM persistence. Staff hypothesized that implementing research-based practices into a carefully designed program would lead to above-average STEM retention in all participants while reducing disparities between particular groups as seen in both national and local trends.

2 Methods

2.1 Data collection

Interns that participated in the Akamai Internship Program from 2003 to 2012 were asked to participate in the Akamai Intern Tracking Survey at the end of the 2014 calendar year. Participants in these cohort years had completed the program three or more years before the tracking survey, so many had moved on from their undergraduate institution by the time of responding.

Background information about participants had already been collected through program applications. Specifically, applicants provided information about their demographics, enrollment in two or four year institutions, year in college upon acceptance into the program, undergraduate grade point average (GPA), and family educational history. Information about enrollment, college level, and GPA was verified through institutional records collected at the time of application.

The 2014 intern tracking survey was created using free online survey software (Google Forms) and distributed by email to the program alumni. The survey contained a total of 31 questions. However, the survey was created with the intention of allowing the participants to bypass certain downstream questions, depending on their responses to previous questions. The critical questions on the survey were employment information including the name of their employer and their job position or title. For interns that failed to respond to the online survey after multiple reminders, those interns were sent follow up communications to obtain this critical employment information. Significant time was invested in finding as many alumni as possible, using social media and the network of alumni and mentors to help find those not responding to the survey or follow-up emails. The final data set includes 82% of the full cohort. The data set includes responses to both the survey and the direct communication.

2.2 Data coding techniques and defining variables

Participant attributes obtained at the time of application or the start of the program were categorized according to key variables of interest to this research:

- **Gender:** all participants indicated either a male or female gender.
- **Underrepresented minority (URM):** applicants indicated ethnic identification with any number of a large set of ethnic groups. The URM categorization used in this study includes African American or Black, American Indian or Alaskan Native, Fijian, Filipino or Filipino American, Guamanian or Chamorro, Hawaiʻian, Mexican, Mexican American, Chicano, Samoan, "other Pacific Islander," or "other Spanish American or Latino groups (includes Cuban, Puerto Rican, and South American)." Specific ethnic groups excluded from URM status include Chinese or Chinese American, Japanese or Japanese American, Korean or Korean American, and White or Caucasian (includes Middle Eastern).
- **Native Hawaiʻian or Pacific Islander:** included in the URM category above, but also defined separately in our analyses, were individuals who identified with Hawaiʻian, Fijian, Samoan, Guamanian or Chamorro, Tongan, and "other Pacific Islander" ethnicities.
- **College enrollment:** Program participants enrolled as community college students upon acceptance to the program were given the designation "community college upon acceptance." By contrast, the designation of "four-year college upon acceptance" was assigned to program participants enrolled at a four-year degree granting institution upon acceptance to Akamai.
- **College Level:** program participants who were enrolled as first or second year students as recognized by their undergraduate institutions upon acceptance into the Akamai program were classified as *lower-division* students; those in their third or above were classified as *upper-division* students. All community college students were considered lower-division regardless of how many years they had been enrolled.
- **Entering GPA:** the grade point average of the program participant at their current institution at the time of entry into the Akamai program.
- **Family education:** Applicants provided information about levels of college experience for members of their immediate family including parents and siblings. This enabled the program to consider potential family influences related to college in a spectrum of possibilities, not simply whether the applicant was "first generation" or not, a label which does not account for the influence of siblings attending college. Applicants were asked about the highest level of education completed by each parent, whether they had any college-age siblings, and whether any sibling was attending or had graduated from college. A coding system was devised in

which family's educational level was assigned a ranking from 1-9, with 1 representing more formal education experience among family members and 9 representing less. For example, 9 was assigned if neither parent finished high school and the applicant has siblings of college age but not attending college. On the other end, a 1 would indicate that both parents completed college, and one or more siblings completed college. Using this system, those who would fit the commonly used designation "first generation college students" (first in family to complete a degree) would be assigned a score of 5 or higher.

In addition to the data collected from the internship applications, responses from the Akamai Alumni Tracking Survey were separately coded. Alumni responses indicating (at the time of the survey) their current employment, post-secondary education level and discipline of study, or intention to pursue any of these options were coded according to three simple categories: employed in a STEM profession, continuing in school in a STEM major, or in neither a STEM profession nor STEM major. Responses were coded by Akamai staff to indicate persistence in STEM.

- If a former Akamai intern indicated that he or she was currently employed in a science, engineering, computer and information technology, or other job requiring a STEM degree this respondent was coded as "*employed in a STEM profession*." A key factor used in assigning the job as "STEM" was whether the position required a STEM degree: for example, a technician position at a solar energy company requiring a degree in electronics or electrical engineering was coded as STEM, but a panel installer position that did not require an engineering or engineering technology degree was not coded as STEM. K-12 teaching positions were not counted at STEM.
- If the former intern indicated that he or she was currently pursuing a post-secondary degree at any level in a STEM field, that respondent was coded as "*enrolled in STEM program*." Akamai accepts students as early as after their first year of college, so some of the alumni who were tracked were still pursuing their undergraduate degree when they responded, while many had moved on to jobs or to pursue graduate degrees.
- If the former intern indicated that he or she was either employed in a non-STEM profession, was pursuing a post-secondary degree at any level with a non-STEM major, or was currently unemployed, nor was enrolled in school, that respondent was coded as "*in neither a STEM profession nor STEM major*."

In general, persistence of Akamai alumni from 2003-2012 cohorts was defined as the sum of the percentages of respondents coded as "*employed in a STEM profession*" and "*enrolled in STEM program*."

2.3 Data analysis

Chi squares were used to test for any significant difference between staying in or leaving STEM based on gender, underrepresented minority status, Native Hawai'ian or Pacific Islander ethnicity, community college status upon starting the program, and being a lower division student (DV = STEM pathway; 1 = persisted in STEM, 0 = did not persist). All Chi squares were not significant ($p > .05$, see below for more detail). Additionally, two independent samples t-tests were employed to see whether there was a significant difference in entering GPA or educational family experience (ranked from 1-9) of those who persisted in STEM compared to those who did not persist.

3 Results

3.1 Survey response rates

At the time the 2014 survey was sent to Akamai Internship Program Alumni from 2003 through 2012, 222 interns had completed the program between those years; at least three years had elapsed between completion of the program and filling out the 2014 survey. Of the 222 alumni surveyed, 182 (82%) were successfully located to learn about their educational and career status.

Respondents were representative of the overall Akamai alumni population:

- 59% male, 41% female
- 52% underrepresented minorities
- 40% first generation status
- 61% four-year degree students, 39% two-year degree students when they started the Akamai Internship Program
- 58% lower-division students
- 22% Native Hawai‘ian/Pacific Islander

3.2 STEM persistence rates

3.2.1 Overall persistence rate

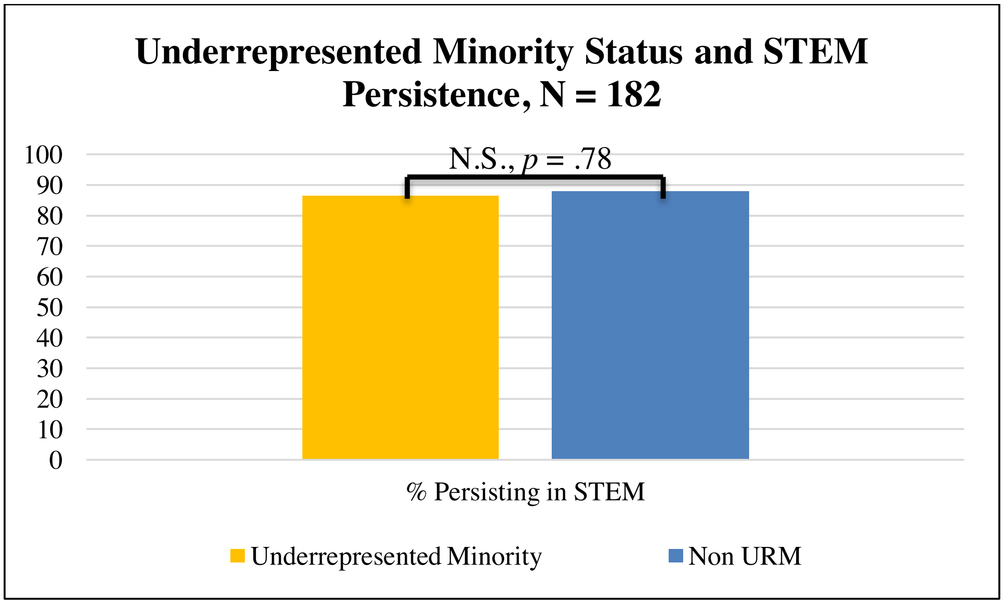
Of the 182 Akamai alumni survey respondents, 127 (~70%) had successfully entered and stayed in the STEM workforce. A remaining 31 (~17%) were continuing to pursue a STEM degree, either as an undergraduate or graduate student. Combined, this indicates that 87% of Akamai Internship Program participants persisted in STEM in either of these two pathways.

3.2.2 Background variables did not predict STEM persistence

We found no significant differences in persistence outcomes across any of the background variables measured. In other words, these variables were not significantly predictive of the likelihood of an Akamai participant staying in or leaving STEM. Results from each variable are presented below.

Underrepresented minority status: There was no significant difference found between those who persisted in STEM and those who did not based on under-represented minority (URM) status; $c^2(1, N = 182) = 0.08, p = .78$ (see Figure 1).

Figure 1. STEM Persistence of Akamai interns by URM and non-URM status. No significant difference was found between these two groups.



Native Hawai'ian or Pacific Islander: There was no significant difference found between those who persisted in STEM and those who did not based on being Native Hawai'ian or Pacific Islander: $c^2(1, N = 182) = 0.19, p = .662$. See Figure 2 for a graphical comparison.

Gender: There was no significant difference found based on gender between those who persisted in STEM and those who did not; $c^2(1, N = 182) = 2.09, p = .148$. See Figure 2 for a graphical comparison.

Community college, 4-year institution, and college level upon acceptance to Akamai: There was no significant difference found between those who persisted in STEM and those who did not based on whether a student was attending a community college upon acceptance; $c^2(1, N = 182) = 0.27, p = .603$. Similarly, there was no significant difference found between those who were designated as lower division students versus those who were designated as upper division students; $c^2(1, N = 182) = 0.82, p = .364$. See Figure 2 for a graphical comparison.

Family educational experience: As described above, we developed a coding system that created a range of 1-9 representing the educational experience of interns' families, which provided a way to go beyond "first-generation" status and include siblings, who also can be very influential in an individual's college plans. We found no significant difference between the median values representing the family educational experience of those who left STEM ($n = 21$, $m = 3.53$) and those who stayed in STEM ($n = 149$, $m = 4.19$); $t\,(168) = 1.34$, $p = 0.18$. The median value for those staying in STEM was 4.2 and for those leaving STEM it was 3.5 (more family experience) and both values are outside the range of what would typically be considered "first-generation" (a score of 5 or higher).

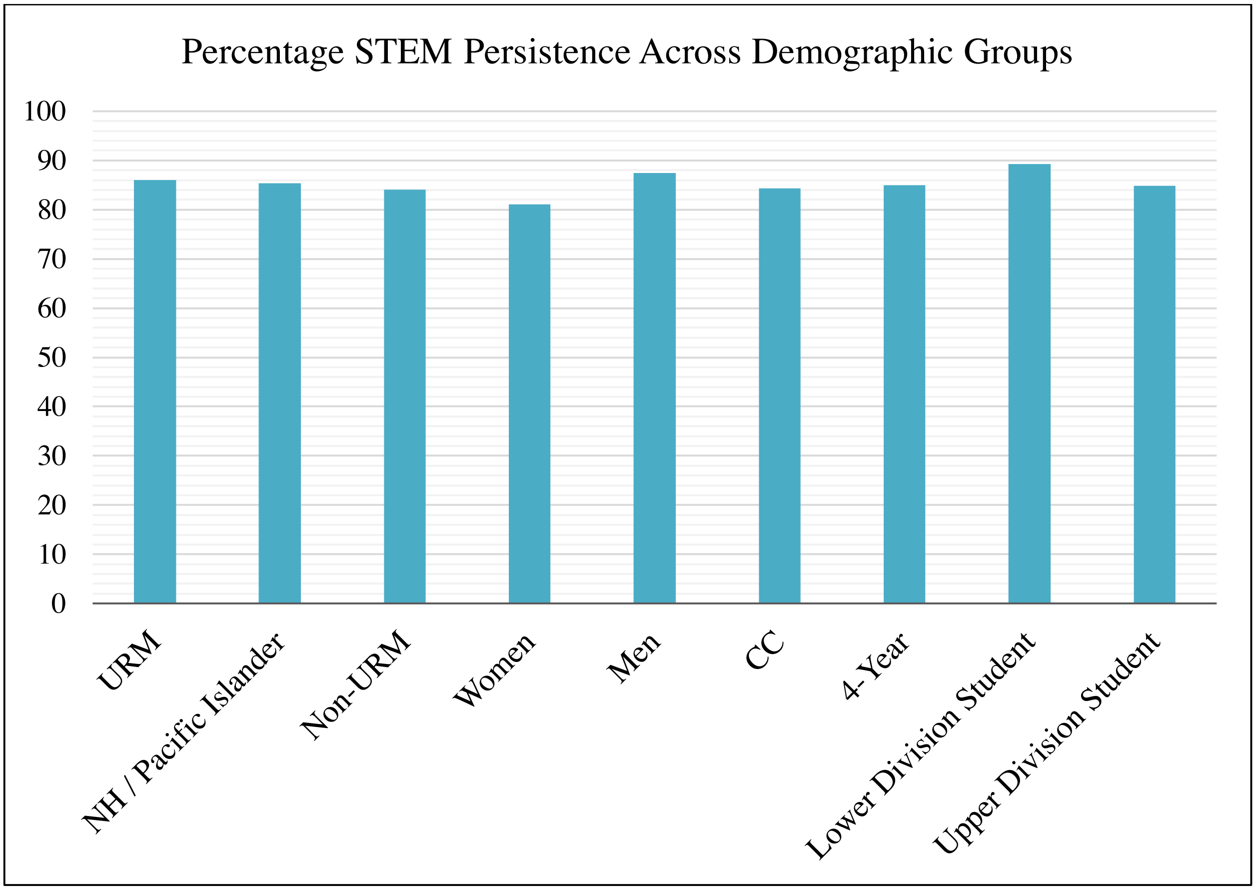
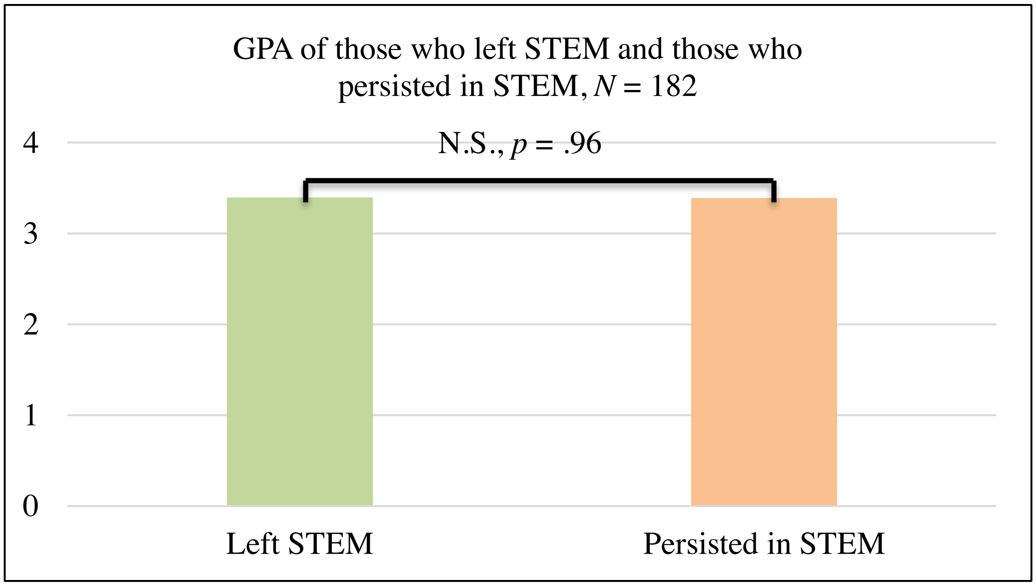


Figure 2. STEM Persistence of Akamai interns based on status as: URM, Native Hawai'ian (NH) or Pacific Islander, non-URM, Women, Men, enrollment in a community college upon acceptance (CC), enrollment in a 4-year institution upon acceptance (4-year), lower division student upon acceptance, and upper division student upon acceptance. No significant difference in persistence was found between any of these group designations.

Entering GPA: Students accepted into the program have a wide range of GPAs, ranging from 2.3-4.0. Almost half of accepted students have GPAs in the 2.3-3.3 range (C+ to B+ students). We did not find a significant difference between entering GPAs for those who left STEM (n = 21, m = 3.40) and those who stayed in STEM (n = 149, m = 3.39); t (168)= -.54, p = 0.96. See Figure 3 for a graphical comparison.

Figure 3. Comparison of GPAs of Akamai interns upon acceptance. No significant difference in GPA was found for those who left STEM and those who persisted in STEM.



4 Discussion

Akamai participants persisted in STEM at a rate of 87%, regardless of their socioeconomic or educational backgrounds. Generally, factors that typically predict disparities in persistence were not predictive in this study of Akamai Internship Program alumni. While other studies have found factors such as ethnicity, gender, progress towards a degree, college enrollment, college level, family educational experience and GPA to be significant predictors, that was not true here.

Typically, ethnic demographics are reported as predictors of retention with many studies providing evidence to support claims that URM students are more likely to leave STEM. As reported in a 2009 *Science* article [40], "although minority students entering U.S. colleges are just as interested as their white peers in these STEM fields, they are only two-thirds as likely as whites to earn bachelor's degrees in those fields within six years." One large scale study using data from the National Student Clearinghouse reported that as of 2004, national six-year graduation rates of STEM aspirants were less than 40% overall and varied significantly by ethnicity: 43% and 52.4% for White and Asian American students, respectively, and less than 30% for underrepresented minorities [3]. The same study also reports that 25% of the national STEM graduates ended up leaving STEM altogether after graduation. Our results cannot be directly compared with studies analyzing data showing national trends because interns are accepted into the program a range of college levels, not as freshmen. Informal comparisons do, however, provide context for the high persistence rate of URM Akamai interns in STEM. Comparisons with national trends suggest that the persistence of Akamai interns, regardless of ethnicity, argues against the results of the program being due to selection bias. If the high persistence rate was due to selecting students that would have persisted anyway, there would likely still be the disparity between demographic groups seen nationally.

To further understand our results we looked at larger quantitative studies examining engineering or technology programs specifically. In one study on retention of engineering students after freshman year, several pre-existing factors were evaluated quantitatively to understand if they had any statistical impact on engineering student success [41]. This study used a multi-university database which contained information on 87,176 students from 9 universities to predict graduation using six variables (ethnicity, gender, high school GPA, SAT Math score, SAT Verbal score and citizenship status). The results of this analysis revealed that high school GPA, gender, ethnicity, quantitative SAT scores, verbal SAT scores, and citizenship were each significant predictors of graduation although different models were fit to each university resulting in different variables being significant for each analysis. While all six variables were significant in at least one model, only two variables, high school GPA and SAT Math score, were significant across all the models. This is consistent with many other studies that have found GPA to be a major predictor for both URM and non-URM retention in STEM [42], [43]. However, findings from these and other national studies contrast with Akamai data in so far as neither gender, ethnicity nor GPA were reliable predictors of retention in STEM for Akamai participants.

Other variables that have often been used to evaluate persistence relate to the educational experience of parents or legal guardians. Research has shown that typically students with parents or guardians that have not graduated from college are not as successful in STEM as their non-first generation counterparts [44]. In general, parents' levels of education have been associated with rates of students' retention and persistence in college, even when controlling for measures of academic preparedness such as rigor of secondary curriculum and college entrance examination [45]. For example, one study found that first generation students earned fewer credits in their first year than non-first generation students [46]. Another study demonstrated that first generation status was a significant predictor of degree completion when considering other student characteristics [47]. Finally, some research has even suggested that first generation students are less engaged in college than non-first generation students [48], [49].

Reviews of research on educational pathways into higher education have also consistently concluded that students ultimately seeking a bachelor's degree but beginning their college career in a two-year public institution are at a disadvantage in reaching their educational goals as compared to similar students enrolled at a four-year institution [50], [51]. Indeed, empirical results suggesting that transfer students are at risk have obliged researchers interested in higher education to look within the community college transfer student population to identify factors that affect these students' educational attainment [52].

Our findings, along with findings from other studies that have considered the effect of the college environment as meaningful to educational trajectories in STEM [27], [53], [54], suggest that with the support of programs informed by research, students of all backgrounds can successfully enter the engineering workforce. As mentioned in the introduction, each of the key elements of the Akamai Internship Program model that are believed to support persistence and promote inclusion have been carefully designed using research in the learning sciences and refined through years of experience with internship participants.

While many studies focus almost exclusively on entry into graduate school as the final measure of success, our work with Akamai leads us to argue that it is just as important (if not more so) to include and look at the entry into the industrial workforce irrespective of their entry into graduate school. Indeed, a poll conducted by the Chronicle of Higher Education indicated that respondents considered the role of college education in preparing students for their future careers as its most important function [55]. The majority of STEM graduates who enter STEM careers will end up in industry, where grades may not be the best predictor of success. Moreover, which measure is ultimately used to determine success in STEM has implications for upstream variables used to predict success. For example, GPA is commonly used to predict success in STEM but is more predictive of acceptance into graduate school than it is of entering and being successful in an industry position. Meanwhile it has become standard practice to refer to some demographic characteristics (e.g. URM and "first generation") as risk factors presumed to predict attrition [56]. However, our study (wherein the pool of evidence used to define persistence was expanded to include entry into the workforce) shows that assumptions that background traits or educational experience can reliably predict attrition should not go unchallenged. Students accepted into Akamai were not exclusively high academic performers (who are typically selected for research experience programs) but came into the program with a wide range of GPAs (2.3-4.0) and yet a high percentage persisted through graduation and were able to find gainful employment in STEM, regardless of their incoming GPA. Our results suggest that studies which rely on information about students' backgrounds, including demographics and prior performance, to predict future performance may underestimate the possible effects of what can be accomplished through positive STEM learning experiences. A further possible consequence is that motivated applicants to STEM internship or research programs could be overlooked based on presumptions about their backgrounds as predictive of their potential or future performance.

5 Implications for practice

5.1 Engaging interns in authentic engineering practices

We know from research that engagement with STEM practices can lead to increased persistence [6]. A study focused on the practice of "modeling" argued that effective engagement with STEM practices involves not only the act of performing the practice but also understanding underlying principles behind the practice [57]. Interns must be given opportunities to engage in authentic, valued STEM practices but also get targeted feedback and insight into the practices from their mentors.

Akamai begins the process of effectively engaging interns in these engineering practices well before the interns arrive. Mentors work with Akamai staff to identify key engineering content and practices with which the intern will fully engage to flag key project points when mentors should have the intern iterate with the practice and give targeted feedback on practice improvement and the underlying principles behind the practice.

Akamai staff also work closely with the PREP instructors who design the inquiry activities for the first week of the program to give interns practical experience with authentic engineering and other STEM practices such as defining engineering requirements, building algorithms, designing investigations, and explaining results. Interns typically come into the program more 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. Akamai prioritizes which STEM practices are taught to interns based on information gleaned from surveys of the Akamai observatory and industry partners [11]. The Akamai staff support interns in comprehending and integrating practices learned during PREP inquiry activities by designing complementary sessions during the PREP course for the interns to reflect on the STEM practices and to be conscious of practices during the internship.

We recommend that other experiential programs work closely with project mentors to identify the most prominent and valuable STEM practices with which the students will engage. Though long-term projects often involve innumerable authentic and generalizable practices, we have found that focusing the mentor's and intern's attentions on one or two increases their abilities to engage deeply and meaningfully. Mentors are able to consciously build in opportunities for practice and feedback when they realize these types of practices can be intentionally mentored rather than picked up "on the job" and are supported with pedagogical methods for transferring these skills.

5.2 Promoting intern ownership and agency over the project

Research-based recommendations for increasing retention of STEM undergraduates include calls for early research and engineering design experiences because they promote learner ownership [18], [58]. Simply putting an undergraduate student into these environments, however, does not automatically guarantee a transfer of ownership to the learner. Research and engineering experiences must be designed to give the learners ownership over the direction of the project and maintain it. While having learners take the lead on organizational or procedural tasks may support initial engagement and interest, promoting "cognitive autonomy" (being an independent problem-solver) more likely impacts longer-term engagement and motivation [59].

Akamai promotes intern ownership and agency beginning with project scoping prior to the internship. Akamai staff work with prospective mentors to make sure that every project is designed so that interns have choice in how they complete at least one major project component. Mentors develop multiple milestone checkpoints throughout the project so that interns are able to suggest approaches to key portions of the project, but are not overwhelmed with its entire scope. Mentors identify sections of the project in which they can give the intern greater choice and challenge by preparing to give more time to the intern to practice cognitive autonomy during these phases, while anticipating compensating during other project sections by providing increased support and direction.

Akamai staff also work with the mentors on their in-person interactions with interns and how these small mentoring moments can have a large cumulative effect on intern ownership. Mentors are encouraged to be conscientious of when to let the intern drive discussions, brainstorms, and problem-solving, and how to support these moments by giving the intern time, space, and the tools (e.g., white board space, the computer mouse and keyboard) to do so.

Finally, through weekly meeting check-ins with Akamai staff and peers, the interns are given a safe space to discuss their project. Interns are asked if they feel ownership over the project, and if not, are given suggestions on how they might approach their mentor to ask for opportunities for more. At the final symposium presentations, nearly every intern refers confidently to "their" project and the work they have done, demonstrating the efficacy of the combination of these strategies for maintaining intern ownership over their summer projects.

Internship programs should encourage mentors to identify project components ripe for student ownership and build in time for challenges and struggle, particularly components that emphasize cognitive autonomy. The extra time allotted to these milestones can be taken from other project components, especially those more organizational and procedural in nature in which the mentor can provide increased guidance for efficiency. On top of designing their project intentionally with these tradeoffs in mind, mentors should be supported with social cues and pedagogical tools for transferring and maintaining learner ownership through on-the-fly mentoring moves.

Other programs can strive to emulate the support Akamai provides to interns directly by creating a community that is open to honest feedback about the projects. Interns should feel supported by the program and able to voice concerns about a lack of project ownership. Direct intervention by program staff with the mentor should be stressed as a last resort, empowering the intern to find ways to ask their mentor for greater choice and challenge.

5.3 Enabling an intern's positive STEM identity

STEM identity is viewed through various lenses in the literature on STEM education and retention, but evidence strongly indicates the link between students developing their own identity as a scientist or engineer and persistence [25], [26]. One popular and useful framework for viewing STEM identity demonstrates three important factors in its development: building competency with valued practices in the field, having authentic opportunities for performing these practices, and feeling properly recognized for valued contributions. A study [27] using this framework found that for the women of color in the study, recognition, or the lack thereof, was particularly important in development of identity as a scientist.

During the Akamai PREP course, the multiple inquiry activities the interns go through are designed to make them aware of the authentic engineering practices they are learning and the opportunities through which they are performing them. Each activity involves reflective components centered around the engineering practices and demonstrated links to how they are used in the workplace. Inquiry facilitators are trained in techniques for properly recognizing the students for their individual and team work throughout the activity, while the culminating component is designed as a large-scale opportunity for group recognition from the peers and Akamai staff.

Given that Akamai mentors are trained to make time to recognize interns for demonstrated competence of engineering skills during the project period, the internship as a whole parallels the emphasis put on providing opportunities for recognition during the PREP inquiry activities. The internship culminates in a final symposium designed largely to give interns recognition for their work among the technical community at large. Akamai staff support each of these opportunities for recognition through the ongoing and integrated communication course. This parallel course focuses on three main opportunities for authentic recognition as an engineer or scientist: informal "elevator talks," technical abstract writing, and coaching for the final technical presentation. The "elevator talk" practice enables interns to be ready for constant, multiple informal interactions with coworkers, friends, and family that provides consistent recognition for their work. Akamai staff also emphasize the authenticity of writing a technical abstract and publish it for the final symposium and on the program's website for recognition years beyond the program. The ultimate venue for recognition, however, is the final technical presentation at the Akamai symposium to the community of mentors, coworkers, and a larger technical and scientific community. Intensive coaching by Akamai staff and mentors results in well-polished presentations highlighting the challenging and impressive parts of the interns' work.

Experiential programs aimed at STEM retention can use a range of strategies to support students developing a positive identity as an engineer or scientist. By engaging interns in authentic engineering practices (discussed above) but also encouraging opportunities for performing and reflecting on them (self-recognition), and then receiving appropriate recognition from the engineering community, three main components of identity development are mutually supported. While there are many ways to give students recognition for their work, it is worth emphasizing recognition for the technical and challenging aspects of their work by the students' future peers.

5.4 Developing an intern's sense of belonging and social capital

Along with enabling interns to develop strong identities as engineers or scientists, it is valuable for interns to develop a sense of belonging in the engineering or scientific workplace, and learn how to accrue and leverage social capital through an internship opportunity. We know from research on undergraduate biology students that a student's sense of belonging influences their motivation and achievement in STEM, in turn affecting their persistence in these fields [30]. A key ingredient to this sense of belonging is the awareness and appropriation of habitual norms and practices exercised and valued within the professional STEM community [31]. The subtlety of these often unacknowledged practices can be challenging for newcomers to navigate but are an example of the types of "social capital" [32] that they must acquire from networks of existing group members.

The Akamai program takes great care to strategically recruit and pair interns from diverse backgrounds with mentors who will be particularly supportive of that intern. The careful matching of interns with projects and mentors is done not only with attention to the mutual fit, but also to the demographics of the cohort. Each cohort is built to be as representative of the local population in Hawai‘i as possible rather than the STEM disciplines from which the applicants are pulled, which suffer from many forms of underrepresentation. For many participants, the Akamai Internship Program is their first opportunity to feel a sense of belonging and be exposed to norms of the workplace and the repertoires of practice within the larger STEM community.

The program also offers space during the preparatory course and throughout the internship for the variety of cultural beliefs and practices to be expressed. Because the astronomical observatories have been built on summits of volcanoes considered sacred by Native Hawai‘ian practitioners, tension and controversy are unavoidable, especially between an intern's ancestry and career interests. Akamai has openly acknowledged this controversy, taken great care to let all participants know how the internship is supported and where they will work, and given space for discussion with expert guest speakers and Akamai alumni now in the workplace during the PREP course. By seeing that practicing engineers and scientists have similar conflicts of interest and a variety of views, the interns can connect their experiences to those of their mentors and see that they, too, can belong in the STEM community.

Experiential STEM learning programs can be intentional in building a cohort of participants that represents the population from which they are drawn to demonstrate that just as the interns belong in their home communities, they also belong in this particular STEM context. Supportive mentors with relatable backgrounds will also strengthen interns' sense of belonging. Programs can also build in opportunities for the cultural norms of the interns to emerge and interact with the norms of the engineering and science community along with genuine examples of how they can and do coexist.

5.5 Encouraging an intern's growth mindset by integrating formative assessment into mentored projects

Formative (ongoing) assessment [35], [36], [37] is not just a means to course correct a learner, but an opportunity to provide valuable feedback and occasions for iterative practice. Studies focused on views of intelligence have shown that feedback to a learner can reinforce either a positive growth mindset, the view that intelligence is malleable and can be improved through practice, or a negative fixed mindset, the view that intelligence is static and cannot be drastically adapted over time [38], [39]. A growth mindset leads to improvement in the face of challenges, and an expansion of problem solving methodologies. As mentioned above in section 5.3, as learners improve their performance and sense of competence in engineering, which comes with experience and a willingness to learn and try new approaches, their identity as an engineer is bolstered, leading to higher retention in the field [25], [26].

The Akamai staff involved in the preparatory course, communication course, and final symposium coaching are highly trained in a variety of equitable and inclusive formative assessment methods, constantly making the interns' thinking visible to both the interns and the facilitators. When opportunities for practice and targeted feedback arise, recognition for an intern's thinking and performance is given in ways proven to strengthen a growth rather than fixed mindset (e.g., praising the correct process rather than the attainment of the "right answer").

Just as importantly, Akamai staff have increasingly worked with the mentors to train them in these same practices and to be conscientious of the use of praise for interns. Mentors also are encouraged to use formative assessment to know how and when to suggest alternative methods for approaching and solving problems, rather than providing the answers or directive instructions for completing a project task. This type of feedback increases an interns' tool belt for future challenges and fosters the valuable growth mindset.

Building in training for staff and mentors on how to assess interns throughout the experience – especially in low pressure formats – is a strategy that other programs can adopt. Mentors can be trained to provide feedback and praise in manners that foster growth mindsets based on the learning sciences' extensive body of research on the topic.

6 Conclusion

The Akamai Internship Program has demonstrated success in retaining a diverse population of undergraduate participants in the STEM fields through graduation and into the workforce. Program outcomes include a high persistence rate (87%) and equivalent persistence rates across groups that typically show disparities in persistence rates. This demonstrates that with the right support, retention of students from diverse backgrounds, including underrepresented and under-served, is possible, and suggests that what students experience in STEM is at least as important as their background. Akamai is a resource intensive program, implemented to meet an urgent workforce need for Hawaiʻi telescopes, and may seem out of reach for those with less available resources or who strive to serve more students than can be accommodated in a program such as Akamai. However, Akamai can be viewed as a collection of student experiences created by research-informed design, that can be adopted and adapted by other programs, as well as by courses, as described in the Implications for practice section (5). Programs like Akamai can play a unique role in transforming educational systems to be more effective and inclusive, demonstrating what can be done, and then through research and evaluation sharing practical implications that can be used more broadly.

Another implication of this study is that simply exposing undergraduates to the workplace or a research venue is not necessarily enough to discourage attrition. The quality of the experience itself also matters. As discussed above, Akamai staff work not only with the interns, but also with members of the local workforce community to conceive, define, and focus the scope of projects to make them win-win. The ability of Akamai staff to find these "sweet spots" – where students can make meaningful contributions to an organization while gaining a valuable training experience – is contingent on the long term investment in partnering with the telescopes. Akamai staff have worked diligently to engage partners, and it is within this larger context of mutual investment in the program model that Akamai interns are succeeding.

An important overarching aspect of Akamai's evidence-based approach has been to learn about and respect how sociocultural backgrounds can lead to regularities in the way that interns work, communicate, and participate in STEM, but avoid making generalizations and assumptions, or treating these traits as static. For some the culture of STEM is very different than the culture they grew up in, and the environment can feel unwelcoming. The program is not designed to specifically support a particular group (e.g. Native Hawaiʻians). The program is designed to support individuals, who are shaped by social and cultural experiences, as they contribute to the STEM enterprise and strive to become productive, valued members of the STEM community.

Akamai partners with, and has placements at all the major telescopes in Hawaiʻi, including telescopes under construction or planned for the future. An anecdote about a recent graduate illuminates the significant impact this program has made in Hawaiʻi in successfully preparing local undergraduates for local jobs in science, engineering, and technology. An Akamai alumna was recently hired to a full-time position as an engineer at a telescope that has had a growth in hiring. She was born and raised in Hawaiʻi, and graduated from Kamehameha Schools Hawaiʻi, a school for people of Native Hawaiʻian ancestry. This Akamai alumna is part of a group of more than a hundred alumni who are now in STEM jobs in Hawaiʻi that have benefitted from the Akamai model. They are changing the demographics of the technical workforce at Hawaiʻi telescopes, where most of the technical jobs in these communities exist, but where women and Native Hawai‘ians are scarce.

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