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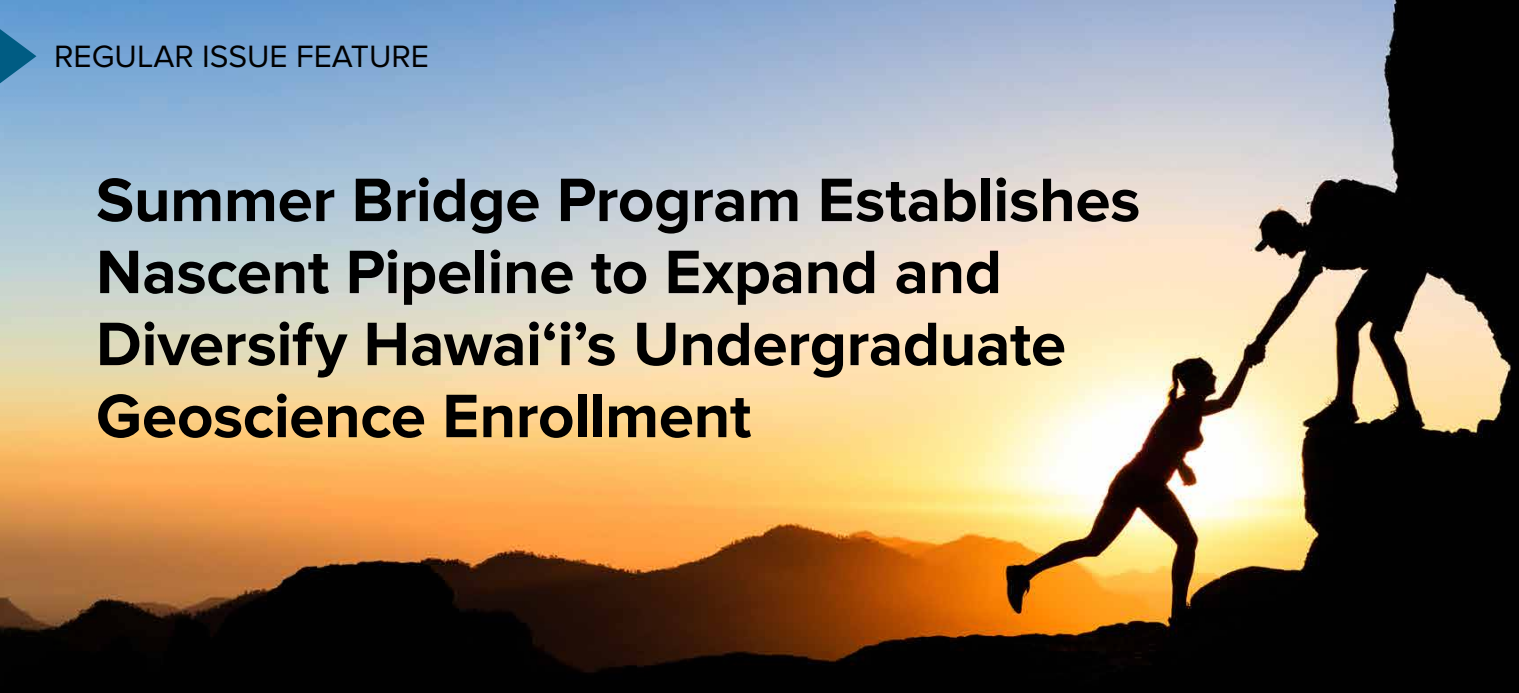
Summer Bridge Program Establishes Nascent Pipeline to Expand and Diversify Hawai‘i’s Undergraduate Geoscience Enrollment



By Barbara C. Bruno, Johanna L.K. Wren, Keolani Noa, Elisha M. Wood-Charlson, Jessica Ayau, Sherril Leon Soon, Heidi Needham, and C. Anela Choy

ABSTRACT. Summer bridge programs can be an effective method of introducing potential science, technology, engineering, and mathematics (STEM) students to majors in geoscience (i.e., ocean, Earth, and environmental sciences) and of expanding and diversifying undergraduate enrollment. This paper focuses on a weeklong summer program offered by a minority-serving community college in partnership with a research university. To evaluate program efficacy, we developed a nine-question survey to measure familiarity with geoscience majors, perceptions about geoscience, self-efficacy, and desire to pursue geoscience majors and careers. Sixty-four students participated in the program over a three-year period. Approximately two-thirds of students are from groups that are underrepresented in STEM and approximately one-third is Native Hawaiian. Only a small number of these students expressed interest in geoscience majors prior to program participation, and many were not even aware that geoscience majors existed. By the end of the weeklong program, the students showed learning gains on all nine questions, and eight of these gains were statistically significant. To date, five summer bridge alumni (four Native Hawaiian) have declared geoscience majors, representing 31% of the University of Hawai‘i at Mānoa’s Native Hawaiian geoscience enrollment. This suggests that partnering with a minority-serving community college may be an effective, time-efficient way of increasing minority enrollment in geoscience majors.

INTRODUCTION

Summer bridge programs vary widely from generally short, focused experiences to summerlong research experiences for undergraduates (REU) programs. Currently, five of 30 National Science Foundation (NSF)-funded ocean science REU sites target early undergraduates, a trend that started in the 1990s (National Science Foundation, 2016). Regardless of duration or target audience, all are aimed at helping students succeed. They can be a bridge from pre-college to college, from minority to majority institutions, or from passive to active knowledge seeking (M. Gilligan, professor emeritus Savannah State University, *pers. comm.*, 2016). Program content may include academic coursework, career counseling, computer literacy, study skills, and the dissemination of other useful knowledge for college. Most programs use the cohort model to help small groups of students build relationships and develop a sense that they belong in college (College Parents of America, 2015).

Summer bridge programs have been shown to provide important mechanisms for improving students’ academic performance, increasing persistence and degree completion, building cultural and social capital, closing the minority achievement gap in science, technology, engineering and math (STEM) fields, and having a transformative influence on students’ careers (Pascarella and Terenzini, 2005; Gilligan et al., 2007; Gilmer, 2007; Tsui, 2007; Stolle-McAllister, 2011; Lenaburg et al., 2012; Raines, 2012).

In this paper, we describe the participation of a large university in a community college-run STEM summer bridge program for the purpose of stimulating interest in geoscience majors and careers. We evaluate our success by analyzing results of pre- vs. post-program student surveys, as well transfer statistics. Additionally, we highlight the need for broadening ethnic diversity in geoscience professions and how targeted summer bridge programs at minority-serving institutions can achieve this goal.

Geoscience Workforce Shortage

Summer bridge programs can be especially important in the geosciences (i.e., ocean, Earth, and environmental sciences) because of an unmet workforce demand. The geosciences offer students a direct pathway into the workforce with a bachelor's degree, and there are simply not enough graduates to fill the available jobs. Although there is some debate as to whether there is a STEM worker shortage in the United States (Salzman, 2013; Mervis, 2014; Zeigler and Camarota, 2014), there is no such debate for geoscience fields. The Bureau of Labor Statistics projects geoscience jobs to grow by 21% by the end of the decade, which is considerably faster than the average rate of STEM occupations overall (16%; Bureau of Labor Statistics, 2012). Based on these and other estimates, the American Geosciences Institute forecasts a shortfall of 135,000 geoscientists in the United States by 2022 (Wilson, 2014).

Why is there a worker shortage in geoscience? Recruiting is one key challenge. There are so many different types of geoscientists (e.g., oceanographer, meteorologist, climate modeler, volcanologist, seismologist, environmental consultant) that it becomes difficult to characterize the broad and diverse profession (including salary and lifestyle expectations) to prospective students—unlike, say, medicine or engineering.

Another key issue is low undergraduate retention, which is pervasive across STEM fields. Of the 560,000 freshmen nationally who express interest in STEM, only 210,000 graduate with STEM degrees: 78% of this attrition occurs before the end of sophomore year (PCAST, 2012). Thus, it is recommended that retention efforts target the first two undergraduate years, including the "critical juncture between community college and University" (PCAST, 2012; Business-Higher Education Forum, 2013)—which is exactly the audience that our STEM-focused summer bridge targets.

Some studies indicate that underrepresented minorities tend to have higher-than-average attrition rates (e.g., Chang et al., 2014). This is problematic because diversity makes us more open-minded and, hence, more innovative. In numerous research studies, socially diverse groups consistently outperform single-gender or single-race teams (see review by Phillips, 2014). Moreover, science benefits from broad-based advocacy. This point is of particular concern in the geosciences, which has the lowest ethnic and racial diversity of all NSF science disciplinary areas (National Science Foundation, 2013; Table 1). Summer bridge programs can be an important way of broadening participation, especially when done in partnership with a minority-serving community college.

Hiring Local Geoscientists—and Growing Our Own

Within one of the nation's most diverse states, a lack of broad participation in geoscience fields is particularly troublesome. In Hawai'i, a majority of residents are ethnic "minorities" relative to the national ethnic landscape (US Census Bureau, 2010). Hiring local geoscientists in Hawai'i will not only serve to broaden participation among underrepresented groups but will also facilitate scientific advancements in the field through the incorporation of place-based knowledge.

Local and indigenous knowledge is widely valued throughout the geosciences—for example, as a key element in conservation (Gadgil et al., 1993; Haggan et al., 2007), resource management (Berkes et al., 2000), environmental mitigation (Haggan et al., 2007; Nyong et al., 2007), and disaster risk reduction (Mercer et al., 2009). As one of our summer bridge alumna put it: "Growing up here in Hawai'i, we already have intuitive knowledge of place. When we learn geoscience, it's like learning another language to explain what we already know." Another local alumna expressed a similar sentiment: "Science doesn't have to start from scratch. We bring in ancestral knowledge and a different perspective, one that local communities can relate to."

Earnest acknowledgment and integration of an indigenous knowledge base (its practices and tenets) in a contemporary geoscience setting requires hiring members of the local community with place-based knowledge and experience. In Hawai'i, where local residents do not generally pursue geoscience professions, we have a clear mandate to grow our own geoscientists. Our approach focuses on community college STEM students.

INSTITUTIONAL CONTEXT: SOEST AND KCC

The University of Hawai'i (UH) at Mānoa is ranked as the fifteenth university in the world for Earth and environmental science (Nature, 2015). Through its School of Ocean and Earth Science and Technology (SOEST), UH Mānoa carries out a broad-based research agenda on topics such as climate change, volcanism on Earth and other planets, water and resource utilization, marine microorganisms, oceanic food webs, and renewable energy.

SOEST offers four undergraduate majors leading to bachelor's degrees: geology, geology and geophysics, global environmental science, and atmospheric

TABLE 1. US bachelor's degrees awarded (*National Science Foundation*, 2013).

NSF Science Discipline	% URM[1]
Agricultural/food sciences	11%
Biological sciences	17%
Chemistry, except biochemistry	11%
Computer/mathematical sciences	16%
Computer/information sciences	19%
Earth/atmospheric/ ocean sciences	**7%**
Engineering (all types)	14%
Environmental life sciences	11%
Mathematics/statistics	10%
Physics/astronomy	13%
Other physical sciences	16%

[1] Underrepresented minorities; includes all racial and ethnic groups except Asian and Caucasian.

science. However, undergraduate enrollment in SOEST tends to be low, perhaps because of SOEST's dominant focus on research and graduate studies. The numbers of SOEST undergraduate majors are about an order of magnitude fewer than in UH Mānoa's other STEM colleges, despite comparable graduate student numbers (within a factor of about two; Table 2).

In SOEST, Native Hawaiians and other ethnic minority groups (including Pacific Islanders, Filipinos, Hispanics, African Americans, and Native Americans) are underrepresented at both the undergraduate and graduate levels. This underrepresentation cannot be simply dismissed as a lack of minority participation in Hawai'i's higher education system. Native Hawaiians and other underrepresented minorities comprise about one-third (28% and 34%, respectively) of the student population at both UH Mānoa and Kapi'olani Community College (KCC; Table 3). Neither can it be simply ascribed to underpreparedness in mathematics, as 13% of the undergraduate and graduate majors in engineering (vs. 6% in SOEST) are Native Hawaiians (Table 2).

In an effort to tap into Hawai'i's local talent pool, SOEST has partnered with KCC. The overarching goal of this partnership is to foster a transfer pathway from KCC to geoscience degree programs at UH Mānoa, with a focus on Native Hawaiian and other underrepresented students. The close proximity of KCC and UH Mānoa (located just four miles, or 6.4 km, apart) facilitates administrative collaboration and student transfer.

Of the seven community colleges within the 10-campus UH system, KCC has both the largest enrollment and the largest number of STEM majors. In recent years, KCC STEM enrollment has more than quadrupled, from 142 students in spring 2009 to 584 in spring 2016 (IRAO, 2016). KCC offers a two-year Associate of Science in Natural Science (ASNS) degree, with tracks in life science, physical science, and pre-engineering. All three tracks articulate well with SOEST majors, allowing students to complete any SOEST bachelor's degree in four years. However, KCC students are generally not aware of SOEST, nor of the diversity of careers available to geoscience majors locally or nationally. Thus, direct exposure through a summer bridge framework is critical to increasing the visibility and feasibility of geoscience career pathways.

In fact, most STEM-interested students never consider geoscience as a career. Even in Hawai'i where people live in highly dynamic terrestrial (volcanoes, earthquakes, landslides) and marine (high surf, tsunamis, coastal erosion) environments, students tend to view the ocean and land as places to recreate, not to build a career. High school and community college students with strong STEM skills tend to major in engineering or a basic science rather than in a geoscience field; many are not even aware that you can get a degree in, say, geology or oceanography. This relatively low background interest (or awareness) among local students in geoscience majors, coupled with SOEST's world-class reputation, results in an enrollment dominated by mainland US and international students. Local students, including Native Hawaiian students, are severely underrepresented.

TABLE 2. Spring 2016 STEM majors at UH Mānoa, listed by college (IRAO, 2016).

	Undergraduate Majors		Graduate Majors		Undergraduate and Graduate Majors	
	All Students	Native Hawaiians	All Students	Native Hawaiians	All Students	Native Hawaiians
SOEST	123	13	140	3	263	16
Engineering	1,284	174	145	8	1,429	182
Natural Science	1,969	197	345	16	2,314	213

TABLE 3. Demographics of KCC, UH Mānoa, and SOEST students (IRAO, 2016) vs. State of Hawai'i (US Census Bureau, 2010)

	Total URM[1]	NHPI[2]	Filipino	Hispanic	African American	Native American
Hawai'i	54%	24%	14%	9%	4%	3%
KCC	34%	18%	14%	2%	1%	0%
UH Mānoa	28%	16%	9%	2%	2%	0%
SOEST	10%	7%	1%	2%	0%	0%

[1] Underrepresented minorities. [2] Native Hawaiian and Pacific Islander

KCC-SOEST SUMMER BRIDGE

Overview of HāKilo

To attract local talent to SOEST, we have partnered with an existing six-week KCC STEM summer bridge program called HāKilo (translated from Hawaiian as "to observe closely"), which serves current KCC students interested in transferring to a four-year university within the UH system. There are three such universities, with most students transferring to UH Mānoa, the largest campus with an enrollment of over 18,000 students. HāKilo is aimed at helping KCC students succeed as they transfer from a small, minority-serving community college to a larger, majority-serving university by providing both academic and non-academic supports.

To be eligible for HāKilo, students must have completed at least one year of KCC coursework. The majority of HāKilo students are underrepresented ethnic minorities and approximately one-third are Native Hawaiian. Students spend morning sessions engaged in intensive mathematics at the appropriate level (ranging from remedial math to calculus 2), for which they can earn college course credit. Afternoon sessions

are spent introducing students to various STEM fields, with each week focusing on a different academic discipline. Departmental faculty serve as instructors and returning students serve as peer mentors, a recommended practice for summer bridge programs (Bhattacharya and Hansen, 2015). Other best practices that inform the HāKilo program include: exposing students to college-level course work and campus support services; providing opportunities to explore STEM careers; creating a sense of cohort through fun extracurricular activities; and providing follow-up academic and non-academic support throughout the year (Pascarella and Terenzini, 2005; Gilligan et al., 2007; Gilmer, 2007; Tsui, 2007; Stolle-McAllister, 2011; Lenaburg et al., 2012; Raines, 2012).

SOEST Week

Since 2013, SOEST has organized the afternoon session for one week of the KCC summer bridge program. Table 4 and Figure 1 provide a summary of the week's programmatic content. SOEST Week taps into students' curiosity about the world around them, stimulates their interest in geoscience majors and careers, and builds their STEM confidence and self-efficacy. We aim to excite students about paid opportunities to do undergraduate research as part of their SOEST degree (C-MORE, 2015; University of Hawai'i at Mānoa, 2015) and develop personal connections with students, so they are comfortable contacting us for more information. Particular emphasis is placed on sharing the important and exciting work that geoscientists do for the local community, and the value of having people with local and/or indigenous knowledge in geoscience professions. We postulate that if SOEST Week is able to achieve these aims, then we will see the establishment of a nascent pipeline of local students transferring from KCC STEM to SOEST.

METHODS

To evaluate program efficacy, we developed a nine-question survey to measure familiarity with SOEST, perceptions about geoscience, self-efficacy, and desire to pursue geoscience majors and careers. All nine questions offered *Yes/No* responses, and four included a third option, *I'm not sure*. We did not offer an *I'm not sure* response option for the five questions that began with "I know…" to avoid potential confusion between the *I'm not sure* and *No* response options.

The survey was administered electronically using personal response systems (i>clickers®) at the very beginning (Monday early afternoon pre-survey) and end (Friday late afternoon post-survey) of SOEST week. Before the pre-survey was administered, students practiced using i>clickers on test questions, to reduce user errors. Each i>clicker was numbered, and each student was assigned the same i>clicker for the pre- and post-surveys, to enable data collection in matched pairs. Immediately after the post-survey, the data table containing student names and i>clicker numbers was destroyed, to protect anonymity.

A total of 64 student respondents completed the survey from 2013 to 2015, although not every student answered every question. Survey responses were coded as follows: *Yes* (2), *I'm not sure* (1), and *No* (0), and mean responses were calculated for each pre- and post-survey question. Thus, a mean response of 1.0 to a particular question could occur in three situations: (a) all students answered *I'm not sure*; (b) half of the class answered *Yes* and the other half answered *No*; or (c) some combination of the above two possibilities (e.g., 25% of the students

TABLE 4. SOEST Week at KCC summer bridge program.

Daily Topic	Summary Description
MONDAY Introduction to SOEST and geoscience	Following an introduction to SOEST geoscience degrees and careers, students identify their STEM interest (e.g., physics) and search online for a relevant geoscience career (e.g., physical oceanographer). Each student then creates and presents a PowerPoint slide on that career, including a brief job description, educational requirements, and starting salary. Many students are surprised to learn of the diverse careers and high salaries associated with geoscience.
TUESDAY Geology field trip	Working in teams led by SOEST faculty and students, bridge program students visit various sites around O'ahu and unravel the geological history of our island based on field evidence and critical thinking. Cultural and historical information is also shared to help students see geoscience in a greater context.
WEDNESDAY UH Mānoa/SOEST campus visit	Bridge program students visit campus to meet with SOEST students (including KCC alumni), academic advisors, and faculty, who share their diverse geoscience interests and career pathways. They explore SOEST facilities (labs, classrooms, data centers) and learn about opportunities to participate in undergraduate research and mentoring.
THURSDAY Oceanography field trip	The oceanography field trip has varied over the years. During the past year, students toured a research vessel, where they met with scientists and crew members and learned about a variety of maritime careers. They deployed instrumentation (e.g., CTD, Niskin bottles, plankton nets), collected data and got a taste of oceanographic research.
FRIDAY Career networking mixer	At this capstone career event, students learn about a range of geoscience careers and begin developing their professional networks. Local and Native Hawaiian geoscientists (including KCC and SOEST alumni) from diverse sectors (industry, government, academia) are invited guests. They sit at tables, and pairs of students rotate through the tables to share their interests and ask questions. At the event's conclusion, each professional shares a key take-home message with the group in a plenary session.

answered *Yes*, 25% answered *No*, and 50% answered *I'm not sure*).

We analyzed the data by comparing pre- vs. post-survey responses using a two-tailed test for matched pairs. We did not use the standard t-test for matched pairs because these data are discrete and not normally distributed. Instead, we invoked nonparametric (distribution-free) tests, which do not assume normality. Two applicable tests are the Sign test and the Wilcoxon signed-ranks test for matched pairs. We applied both of these tests and compared results. To test significance, we used $\alpha = 0.10$ (instead of the $\alpha = 0.05$ value more typically used with t-tests) because nonparametric tests are less powerful than parametric tests. Power (the probability of correctly rejecting H_0 when H_0 is false) is defined as $1-\beta$, where β = probability of a Type 2 error (failing to reject H_0 when H_0 is false). To increase power, one must decrease β, which entails increasing α (the probability of a Type 1 error, that is, rejecting H_0 when H_0 is true), since Type 1 and Type 2 errors are inversely related.

DATA AND RESULTS

The means calculated for all nine questions increased from pre- to post-survey, indicating positive learning gains, and all but one gain was statistically significant (Table 5). In the post-survey, students reported being aware of SOEST (1.90), knowledgeable about SOEST majors and degrees (1.86), and knowledgeable about who to contact (1.93) for more information. Students reported knowing about paid research experiences for SOEST students (1.83) and about the kinds of jobs they can get with a SOEST degree (1.87). They were nearly unanimous (1.98) that geoscience jobs are very important for people who live in Hawai'i, and were confident (1.77) that they have the skills and abilities required to be a geoscience major. Perhaps due to some or all of these factors, there was a significant gain in their desire to become geoscience majors, increasing from 0.87 pre-survey to 1.09 post-survey. Not surprisingly, this last gain is more modest than the gains associated with some other questions. Deciding upon a major is a complex and important decision affected by numerous factors, so achieving a significant gain after a single week is noteworthy. The only question that did not yield a significant gain was the desire to learn more about SOEST majors (Question 4)—possibly because students may have felt that this information was adequately covered during the week. Nevertheless, like all other questions, Question 4 yielded a positive gain.

We note that, for all questions, the results of the Sign and Wilcoxon signed-rank tests for matched pairs were in full agreement. All nine questions showed gains and eight of these gains were found to be significant by both tests. The one question whose gain was shown to be statistically insignificant by the Sign test was the same question that was found insignificant by the Wilcoxon signed-rank tests.

FIGURE 1. Summer bridge students participate in geology and oceanography field trips (top three panels) and interact with geoscientists during the career networking mixer (bottom right) and SOEST tour (bottom left). *Photo collage by Surely Wallace*

DISCUSSION

Of the 64 students who participated during the KCC-SOEST summer bridge week during 2013–2015, none expressed interest in geoscience majors prior to SOEST week. To date, five of these students (including four Native Hawaiians) have declared geoscience majors, representing 31% of SOEST's Native Hawaiian undergraduate student body. This is remarkable, considering that fewer than 3% of Native Hawaiian students transfer from community colleges to UH Mānoa, and only half of the university's Native Hawaiian students graduate on time (IRAO, 2016). This outcome suggests that partnering with a minority-serving community college STEM program may be an effective, time-efficient way of increasing minority enrollment in geoscience majors. Should the reader choose to pursue this route, we encourage you to consider the following recommended practices for university-community college summer bridge partnerships, which we believe to be essential ingredients to our burgeoning success.

1. **Collaborate effectively.** Allow each partner to do what they are best at. In this partnership, the university-based geoscientists focus solely on program content (i.e., the geoscience). They don't get involved in recruiting students or programming logistics, as that is the expertise of the community college partners.

2. **Focus on careers.** Get beyond the science content. Showcase the diversity of job types and people that characterize the geoscience profession. Include a variety of field and non-field experiences as part of the summer bridge, to enable each student to find his or her niche.

3. **Local connections, local role models, local responsibility.** Emphasize the value of the work that geoscientists do for the local community. It is obvious to students how doctors and nurses help people; it is less obvious with geoscience. Whenever possible, have the students directly interact with local geoscientists so they can learn through personal anecdotes of community connections.

4. **Peer mentors.** Each year, former students rejoin the program as peer mentors, and they serve as critically important liaisons. They are often more attuned to students' needs and unvoiced questions than are the program leaders, and they help make key connections. We have also found that being a peer mentor can help solidify a former student's decision to major in the geosciences.

TABLE 5. Pre- vs. Post- survey data on SOEST week at KCC summer bridge.

	Descriptive Data			Sign Test			Wilcoxon Signed-Ranks Test		
Survey Questions	**Pre-survey mean**	**Post-survey mean**	**N[2]**	**Test statistic type[3]**	**Test statistic value[4]**	**Critical value[4]**	**Test statistic type[5]**	**Test statistic value[6]**	**Critical value[6]**
1. I know what "SOEST" stands for	0.62	1.90	39	z	−5.76*	−1.65	z	−5.16^	−1.65
2. I know what majors and degrees SOEST offers	0.27	1.86	47	z	−6.71*	−1.65	z	−5.97^	−1.65
3. Ocean and Earth scientists do work that is very important for people who live in Hawai'i[1]	1.87	1.98	6	x	0*	0	T	0^	2
4. I would like to learn more about majors in ocean, Earth, or environmental science[1]	1.57	1.68	13	x	4	3	T	29	21
5. I know about the kinds of jobs I can get with a degree in ocean, Earth, or environmental science	0.70	1.87	37	z	−5.59*	−1.65	z	−5.02^	-1.65
6. I know people at SOEST that I can contact if I want more information	0.39	1.93	47	z	−6.71*	−1.65	z	−5.97^	−1.65
7. I know what the C-MORE Scholars program is[7]	0.27	1.83	48	z	−6.50*	−1.65	z	−5.78^	−1.65
8. I have the skills and abilities required to be an ocean, Earth, or environmental science major[1]	1.21	1.77	30	z	−4.56*	−1.65	T	23^	152
9. I want to be an ocean, Earth, or environmental science major[1]	0.87	1.09	22	x	6*	6	T	68^	75

[1] These questions offer three response options: *Yes, No, I don't know*. All other questions are *Yes/No*.
[2] Number of non-zero pairs (number of different pre- vs. post-survey responses).
[3] Sign test uses x statistic (if $N \leq 25$), otherwise uses z statistic.
[4] Sign test rejects H_0 (that is, significant result) if the test statistic (x or z) is in the critical region.
[5] Wilcoxon Signed-Ranks test uses T statistic (if $N \leq 30$), otherwise uses z statistic.
[6] Wilcoxon Signed-Ranks test rejects H_0 (that is, significant result) if the test statistic (T or z) is in the critical region.
[7] A paid undergraduate research and professional development opportunity offered to SOEST majors (*C-MORE*, 2015).
* Denotes significant results based on sign test.
^ Denotes significant results based on Wilcoxon Signed-Ranks test.

5. **Follow-up activities throughout the year.** Summer bridge programs can be a great way to "hook" students into geoscience majors and careers, but what next? Connect students with undergraduate research and mentoring programs, geology and oceanography clubs, and people they can call upon for continued help and support.

6. **Adapt, don't copy, models.** We offer the above recommendations to anyone interested in developing a summer bridge program, just as we drew upon the existing literature of best practices when crafting our program (Pascarella and Terenzini, 2005; Gilligan et al., 2007; Gilmer, 2007; Tsui, 2007; Stolle-McAllister, 2011; Lenaburg et al., 2012; Raines, 2012; Bhattacharya and Hansen, 2015). However, we caution against the blind adoption of recommendations and models that have been shown to be successful in other contexts (e.g., Gewin, 2014). Models are best viewed as systems with parts that should be borrowed, adapted, and reassembled, rather than copied wholesale. The one-size-fits-all approach is rarely effective (M. Gilligan, professor emeritus Savannah State University, *pers. comm.*, 2016).

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AUTHORS

Barbara C. Bruno (barb@hawaii.edu) is faculty and **Johanna L.K. Wren, Jessica Ayau**, **Sherril Leon Soon**, and **Heidi Needham** are or were graduate research assistants at the Center for Microbial Oceanography: Research and Education (C-MORE) at the University of Hawai'i at Mānoa, Honolulu, HI, USA. **Keolani Noa** is STEM Coordinator and Native Hawaiian Coordinator, Kapi'olani Community College, Honolulu, HI, USA. **Elisha M. Wood-Charlson** is Research/Communications Program Manager at the Simons Collaboration on Ocean Processes and Ecology (SCOPE) at the University of Hawai'i at Mānoa, Honolulu, HI, USA. **C. Anela Choy** is a postdoctoral researcher at the Monterey Bay Aquarium Research Institute, Moss Landing, CA, USA.

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