© Journal of Higher Education Outreach and Engagement, Volume 25, Number 2, p. 187, (2021)

The Coastal Ocean Environment Summer School in Ghana: Exploring the Research Capacity Building Potential of a Higher Education Informal Science Learning Program

Jennifer M. Moskel, Emily L. Shroyer, Shawn Rowe, Mark D. Needham, and Brian K. Arbic

Abstract

The development of informal science learning programs (ISLPs) is a growing strategy among scientists seeking to engage communities. However, little scholarship exists on higher education ISLPs, limiting best practices for program development. This article explores the perceived impacts for student learners and scientist instructors of an international ISLP focused on marine science, using a mixed-methods approach of questionnaires, interviews, a task-based focus group, and participant observation. Learners perceived an increase in research skills and knowledge, and identified positive impacts associated with networking and forming connections. Learners did not significantly change their attitudes toward marine science or beliefs about careers in science. Instructors felt they helped advance their field and perceived positive impacts from cultural exchange, whereas only a few identified professional development impacts. This study suggests that higher education ISLPs should focus on creating space for different types of connections and increasing how scientists' participation is valued within the profession.

Keywords: informal science education, capacity development, higher education outreach, Ghana

In the past decade, the scientific research community has placed a greater emphasis on broader outreach activities beyond fundamental science (e.g., Boyer, 1996; National Science Foundation, 2018; Roberts, 2009). This growing interest may be partially driven by a demand from the public for science to address societally relevant problems (Roberts, 2009). Reflecting this demand, many international and national funding agencies have introduced guidelines that encourage, or in some cases require, a broader outreach component for research proposals (e.g., [South Africa] National Research Foundation, 2017; [U.S.] National Science Foundation, 2018). New funding avenues have also been established for research focused specifically on broader outreach (e.g., National Science Foundation, 2020), such as scientists engaging in K-12 curriculum development (Laursen et al., 2007). As societal and funding demands encourage scientists to become more engaged in their local and broader communities, scientists are increasingly turning to the creation and development of informal science learning programs (ISLPs; Fauville et al., 2013). Informal learning involves voluntary, or "free-choice," participation in educational activities in a variety of settings, such as museums, schools, and nature centers (Falk et al., 2007; Hofstein & Rosenfeld, 1996; National Research Council, 2009). An ISLP differs from other types of free-choice learning (e.g., aquariums, science centers) in that it is a more structured activity with an "organizational goal to achieve curricular ends" (National Research Council, 2009, p. 173).

ISLPs can be designed to achieve a variety of broader outreach goals, such as engaging a nonacademic audience in scientific research or providing continuing education opportunities for K-12 educators (National Research Council, 2009). Given their more structured format and capacity to foster mentorships, ISLPs are also poised to become an effective tool for broadening global participation in science (Hernandez et al., 2013; National Research Council, 2009; Roberts 2009; Strigl, 2003). The disparity in advanced scientific research conducted around the world is remarkable. For example, in 2018, researchers at U.S.-based institutions published 27,758 papers in the natural sciences, whereas researchers at institutions in South America and Africa published 2,663 (Nature Index, 2019). International mentorship and collaboration between established scientists and aspiring scientists via ISLPs could begin to provide the requisite access to methods and technologies to advance global research and scientific understanding (Hernandez et al., 2013; Lewis, 2003).

The objective of this study was to document the range of perceived impacts experienced by participants, both learners and instructors, of one higher education ISLP whose self-identified goal is to develop marine science research capacity in West Africa. Understanding the full range of participant impacts can provide insight into how this scientist-driven ISLP is meeting its stated objective. Findings also offer the potential to provide more general recommendations for the design of other ISLP efforts. This project explored instructor perceptions and assessed learner changes in multiple key indicators. Specifically, this work focused on the ways in which this ISLP influences (a) learners' perceptions of their ability to perform research, (b) learners' attitudes toward marine science, (c) learners' self-assessed knowledge of marine science, and (d) instructors' professional development.

Higher Education Informal Science Learning Programs

Current Research

Although there is considerable research assessing youth and family ISLPs, there has been a "relative paucity" of research on adult programs (National Research Council, 2009, p. 174). Most research on adult ISLPs primarily concerns museums/science centers, citizen science, health, or teacher professional development programs (e.g., Bates et al., 2006; Jordan et al., 2011; Qian et al., 2018; Sachatello-Sawyer & Burton, 2002). Existing research is also often descriptive in nature, with few studies directly assessing learning outcomes (National Research Council, 2009). Moreover, many ISLPs are designed and led by science faculty who lack expertise in educational theory or practice to support developing a strong curriculum with learning outcomes or in the (largely) qualitative methods necessary to evaluate if and how programs are achieving their goals (Fauville et al., 2013). Hence, there is a need for research evaluating the impacts of higher education ISLPs.

Exploring Learner Impacts

Understanding learner perceptions of their experiences is critical for assessing how ISLPs are progressing toward their goal of scientific research capacity building. Indicators of scientific research success include knowledge, attitudes, research ability, and relationship forming. *Knowledge* has "personal, situational, and socially constructed dimensions," which means that it is often subjective (Perry et al., 2014, p. 108). Knowledge, encompassing both scientific content and career awareness, is a foundational component of individual capacity for scientific research (Kennedy & Odell, 2014). *Attitudes* are an individual's evaluations (e.g., favor, disfavor) of an object or issue (Fishbein & Ajzen, 2010). Attitudes toward science may be an even more important indicator since attitudes are often more "enduring" than knowledge (Osborne et al., 2003, p. 1074). Similarly, *research ability*, which encompasses students' perceptions of their ability to conduct research, is a critical indicator of future career success (Stajkovic, 2006). *Relationship forming* is another aspect of scientific research success since "scientific career attainment is a social process" (Lewis, 2003, p. 371). Relationship forming in ISLPs seems to occur in a three-tiered system: (a) socializing (i.e., making informal, cordial connections), (b) networking (i.e., making formal and informal professional connections), and (c) research partnership forming (i.e., making formal, collaborative connections). Research partnership formation, especially with international collaborators, is an important step for increasing scientific research capacity worldwide (Nchinda, 2002).

Exploring Instructor Impacts

In addition to assessing impacts on student participants, improving understanding of impacts experienced by scientist organizers and instructors is another important facet of program evaluation. Although the body of research on scientists and broader outreach is expanding (e.g., Clark et al., 2016; Nadkarni & Stasch, 2013; Roberts, 2009), a gap remains in knowledge of scientists' perceptions of their outreach activities (Johnson et al., 2014). Understanding instructor perceptions of higher education ISLPs and how they are impacted by participation is important for ensuring program longevity.

Case Study: The Coastal Ocean Environment Summer School in Ghana

The Coastal Ocean Environment Summer School in Ghana (COESSING) is an ISLP primarily targeting West African university students and early-career scientists. The mission of COESSING is to develop capacity for advanced oceanographic research in Ghana, ultimately increasing representation of African scientists in the international marine science community. COESSING is organized and taught through a collaboration of primarily North American and Ghanaian ocean scientists. The weeklong program was founded in 2015 by an American oceanographer, supported through the educational outreach component of a National Science Foundation Career Grant. Funding currently draws from several sources within the United States, Ghana, and internationally. As a free-choice learning program (i.e., participation is not mandatory and does not result in formal credentialing), COESSING has seen its audience continue to grow and diversify over time. Beginning with approximately 50 Ghanaian university students, this program's audience has expanded to nearly 100 participants ranging from undergraduate students to senior professors from across West Africa.

Beyond the overall mission statement, COESSING has yet to clearly define learning objectives or outcomes for participants. The general structure of COESSING includes morning lectures on topics in ocean and environmental science (e.g., general ocean circulation, fisheries and aquaculture), afternoon labs (e.g., introduction to Python, physics of fluids), and a daylong field trip with basic oceanographic fieldwork. However, the specific itinerary of the summer school is dynamic and changes annually in response to requests of participants through oral and written feedback. For example, COESSING 2016 increased hands-on labs in response to feedback received after the 2015 program. Based on feedback advocating for a stronger research focus, COESSING 2018 implemented a two-track system. Attendees who chose the overview track participated in all of the scheduled lectures and labs, whereas attendees on the project track worked in small groups on a project with supervision from instructors. Project track participants could also attend lectures and labs that were of interest to them.

Even though COESSING regularly solicits feedback on general content and organization from participants, there was no formal evaluation structure in place to assess the ways in which COESSING is progressing toward its mission of developing scientific research capacity in Ghana. As with many informal science outreach programs, COESSING's organizers are all career marine scientists with limited formal training in educational program design and evaluation.

Methods

Setting and Participants

Ghanaian Host Institutions

COESSING is held annually in Accra, Ghana. The Ghanaian hosting institution alternates yearly between the University of Ghana (UG) and Regional Maritime University (RMU). UG is a public university located in the Legon suburb northeast of Accra's city center. UG is the largest university in Ghana, with more than 38,000 students, and it is among the top research universities in sub-Saharan Africa. UG is currently expanding and increasing its research output to achieve its vision of becoming "a world class research-intensive University over the next decade" (UG, 2018, "Our Vision"). RMU is a private international university located on the coast at the easternmost edge of Accra. Serving the countries of Cameroon, Gambia, Ghana, Liberia, and Sierra Leone, RMU focuses on training maritime professionals and enhancing the regional maritime industry. RMU has a growing focus on research and is expanding its graduate school offerings. Three new master's programs in engineering were launched in 2019, and a hydrography program is in development (J. Adjetey, personal communication, August 2, 2018; RMU, 2019).

Participants

Participants were divided into two categories: learners and instructors. Learners were attendees of COESSING 2018 who participated in lectures, labs, and projects. A total of 103 learners participated in this study, with representation from six West African countries: Ghana (53%), Nigeria (38%), Cote d'Ivoire (3%), Cameroon (3%), Mali (2%), and Sierra Leone (1%). The number of learners reflects the 103 unique respondents across the three surveys administered in this study. There are no data to confirm whether all presurvey respondents attended COESSING 2018. These learners encompassed a diverse group professionally, with 34% undergraduate students, 15% master's students, 15% PhD candidates, 11% university professors or faculty, 13% employed in another science-related job, and 10% unemployed. Approximately 31% of these learners identified as female and 69% as male.

Instructors were participants involved in teaching and/or organizing COESSING 2017 and/or 2018. Nineteen instructors participated in this study, with 58% based at institutions in the United States, 32% in Ghana, 5% in Italy, and 5% in the United Kingdom. Instructors spanned all career stages, with eight early-career scientists (postdoc and assistant professor equivalency), five mid-career (associate professor equivalency), and six late-career (full professor equivalency). Instructors were 42% female and 58% male.

Data Collection

This study used a mixed-methods approach. Qualitative data collection included semi-structured interviews with instructors, a task-based focus group with selected learners, and participant observation field notes. A survey instrument with both open-ended and scaled questions was also administered to learners. Data for this study were collected during COESSING 2018 at UG, with preliminary and background data collected during COESSING 2017 at RMU. All data collection occurred in English and by the primary researcher.

Semi-structured Interviews

Interviews followed a semi-structured format that allowed the flexibility to follow leads, while ensuring all interviewees were asked about the same topics (Bernard, 2011). A total of 18 instructors were interviewed, representing 91% of the instructors who participated in COESSING 2017 and/or 2018. Fifteen instructors were interviewed in person during the program, and three instructors were interviewed by telephone after the program ended. Interviews were conducted using a guide of five multipart, project-specific questions to understand instructor perceptions of the summer school. All interviews were audio recorded with interviewee permission.

Task-Based Focus Group

During the 2018 summer school, a task-based focus group of "repeat learners" (i.e., learners who participated in COESSING in previous years) addressed two project-specific prompts: "Why did you decide to participate in this program again?" and "What are some of the longer-term impacts you have experienced from participating in this program?" Thirteen repeat learners self-selected to participate in the 75-minute session. A focus group method was used because of its ability to explore a particular topic in depth (Bernard, 2011). Repeat learners were randomly divided into three smaller groups of four to five learners each to complete a series of tasks. First, the repeat learners independently wrote down their responses to the first prompt. They next compared their answers with other members of their small groups. After comparing responses, group members compiled similar answers and ranked their final set of unique responses from least important to most important. The series of tasks was then repeated for the second prompt.

Participant Observation

Participant observation was conducted during COESSING 2018 to understand the nuances of interactions, various roles of participants, and "notable nonoccurences" that participants may not be aware of or not be able to clearly articulate (Frechtling & Sharp, 1997, p. 3-3). The participant observation protocol included observation (a) of the learners during lectures, (b) of the instructor–learner interactions during the work sessions for the project track, (c) during the labs and field trip with learners and instructors, and (d) during meals with learners and instructors. Not all lectures, labs, and work sessions were documented because of timing overlap and the interview schedule. Brief handwritten notes were taken during labs, meals, and the field trip. More detailed typed notes that reflected on previous occurrences and documented the lectures were taken during lectures. Field notes included both objective observation and subjective responses of the participant observer to help identify and overcome researcher bias (Spradley, 1980). Field notes were also taken during COESSING 2017, but did not follow a protocol and were predominantly observational in nature.

Surveys

The mixed-methods written survey instrument (i.e., questionnaire) was administered to learners across three points in time: (a) 1 week prior to COESSING 2018 (pre), (b) on the last day of COESSING 2018 (post), and (c) approximately four months after the end of COESSING 2018 (post-post). The pre- and post-post-surveys were self-administered online, whereas the postsurvey was administered on site. Across the three surveys, there were 103 unique respondents. The presurvey had 79 respondents, the postsurvey had 76, and the post-post-survey had 30. Fifty-three respondents completed both the pre- and postsurveys, and only 23 respondents completed all three surveys.

These instruments were developed using program evaluation literature (e.g., Francis & Greer, 1999; Kardash, 2000; Moore & Foy, 1997), 2017 observational field notes, and learner responses to an open-ended feedback questionnaire from COESSING 2016 and 2017. Three Ghanaian instructors also reviewed the instruments to ensure cross-cultural understanding of content and face validity of questions.

The questionnaires measured learner beliefs and attitudes toward science, skills and abilities to conduct science, and perceptions of COESSING (e.g., expected opportunities and outcomes). Questions were grouped into five categories: learner demographics, perceptions of ability to use research skills, attitudes toward marine science, perceptions of scientists and science careers, and evaluation of COESSING. Demographic information was measured from a mix of multiple choice and open-ended questions to ascertain academic or professional level, city and country of origin, gender, and birth month and year.

Learner skills (perceptions of their ability to use research skills related to marine science) were assessed with 15 questions (e.g., understand marine science concepts, think independently) measured on a 4-point scale from 1 = *not at all* to 4 = *very capable of completing the task.* These research skills were closely adapted from Kardash (2000). Learner attitudes (attitudes toward marine science in general) were evaluated using five semantic differential questions (e.g., dislike–like, boring–interesting) measured on a 5-point scale with 1 as the most negative and 5 the most positive. Learner beliefs (perceptions of scientists and science careers) were assessed with a series of 10 statements (e.g., "Scientists work together to solve problems"; "A career in science would be fun") using a 7-point scale of 1 = *strongly disagree* to 7 = *strongly agree*. Belief statements were adapted from Francis and Greer (1999), Gogolin and Swartz (1992), Krajkovich and Smith (1982), and Moore and Foy (1997). Learner beliefs were also assessed with two open-ended questions, one addressing whether respondents intended to pursue a science career and one addressing the ways in which COESSING changed respondent thinking about science careers.

The last category of questions evaluated learner experiences during COESSING. A series of 12 statements (e.g., general marine science concepts from introductory labs, career opportunities outside West Africa) assessed learner expectations and perceived outcomes of general learning content ("learning"). In the absence of preidentified learner content outcomes, the extent of specific knowledge acquisition could not be measured. Learner expectations and perceived outcomes of other opportunities at COESSING ("opportunity") were assessed from 10 statements (e.g., network with Ghanaian professors, form research partnerships with international professors). Responses to both the learning and opportunity statements were measured on a 7-point scale of 1 = *strongly disagree* to 7 = *strongly agree*. These statements were project-specific and were generated from 2017 observational field notes and 2016 and 2017 learner responses to an open-ended feedback questionnaire. Two open-ended questions invited learners to list any other topics they wanted to or did learn about and other opportunities they wanted to or did have. In addition to the learning and opportunity evaluations of COESSING, three open-ended questions on the post- and post-post-surveys assessed why respondents chose to participate in COESSING, why they would or would not participate again, and in what ways they have experienced longer term impacts from participation.

Data Analysis

Qualitative Data

All qualitative data (interviews, task-based focus group, participant observation field notes, open-ended surveys) were analyzed collectively. Interviews were transcribed, and the open-ended questionnaire responses were consolidated into tables. Once the data were digitized and compatibly formatted, they were analyzed using NVivo (ver. 12.3).

The qualitative data underwent three phases of coding (Maxwell, 2013). First, the data were case coded by data collection method and, for the instructors, by individual participant pseudonym. The next phase of coding was categorical, using a predetermined codebook based on research objectives (Appendix A). The categorical coding was an iterative process with new codes added as appropriate. The final phase of coding involved thematic coding within each categorical code. Research memos were then generated for each categorical code, describing patterns and observations about the thematic codes. These research memos were consolidated by research objective to generate theoretical memos. The theoretical memos synthesized themes across all qualitative data related to each research objective.

Quantitative Data

Due to the low number of learners who completed all three surveys (n = 23), only the pre- and postsurveys were analyzed (n = 53). Using SPSS (ver. 25), nonparametric Wilcoxon signed rank tests were conducted to compare the pre- and postsurvey results for the 15 measures of skills, 5 measures of attitudes, 10 measures of beliefs, 12 measures of learning, and 10 measures of opportunity. A significance level of $p < .05$ was adopted, accounting for both the small sample size and Bonferroni correction (i.e., original p-value threshold of .10 due to the small sample size/2 points in time = .05; Vaske, 2008). Cohen's d effect size was used to understand the strength of the relationship, with an interpretation of .20 as a "minimal relationship," .50 as a "typical relationship," and .80 as a "substantial relationship" (Vaske, 2008, p. 109). The internal consistency of each of the five groups of variables measuring each concept was examined with Cronbach's alpha reliability analysis, and overall mean composite indices were computed where justified by an alpha coefficient above .65 (Vaske, 2008).

Results

Perceived Impacts on Participants

Learners

The learner-identified impacts of COESSING 2018 fall into six categories: research skills, attitudes toward marine science, beliefs about science careers, content knowledge, conceptual knowledge, and connections with people (see Appendix A for a definition of each theme). Although most of the data drew from the short-term perceived influences of COESSING on the learners (i.e., postsurvey), speculations can be drawn about longer term impacts from the 30 post-post-survey respondents and the 13 repeat learners from the task-based focus group. All qualitative evidence provided is representative of the data for each category; thus, there are only positive responses because no negative responses were provided (see Discussion section for further details). The method of data collection for qualitative evidence is indicated parenthetically.

Research skills. Prior to participating in COESSING, learners' average perception of their ability to complete the 15 tasks associated with research skills ranged from "slightly" to "very" capable (Table 1). The learners felt least able to "write a research paper for publication" and most able to "collect data." Postsurvey results showed an average range in perceived ability of "moderately" to "very" capable. Learners continued to feel least able to "write a research paper for publication," and they had the same low average for their perceived ability to "design an experiment." The highest average skill observed on the postsurvey was the ability to "orally communicate results."

The matching average means increased from the presurvey to the postsurvey for

Table 1. Wilcoxon Signed Rank Analysis of Pre- and Postsurvey Learner Research Skills

	Presurvey		Postsurvey				
Research skills variables	*M*	*SD*	*M*	*SD*	Wilcoxon-test value	*p*-value	Cohen's *d*
Understand marine science concepts	3.25	0.88	3.53	0.54	2.62	.009	.38
Make use of the primary scientific research literature	3.17	0.98	3.36	0.65	1.31	.190	.23
Identify a specific question for investigation using research	3.08	0.90	3.38	0.72	2.70	.007	.37
Formulate a research hypothesis	2.90	0.89	3.15	0.78	2.22	.026	.30
Design an experiment or theoretical test of the hypothesis	2.81	0.93	3.08	0.84	2.27	.023	.30
Understand the importance of "controls" in research	3.10	0.98	3.29	0.75	1.67	.095	.22
Observe data	3.25	0.84	3.52	0.64	2.43	.015	.36
Collect data	3.40	0.77	3.53	0.78	1.15	.248	.17
Statistically analyze data	3.04	0.83	3.21	0.72	1.44	.149	.22
Interpret data by relating results to the original hypothesis	3.06	0.93	3.36	0.68	2.31	.021	.37
Reformulate your original research hypothesis	2.75	0.96	3.17	0.87	3.09	.002	.46
Relate results to the "bigger picture" in marine science	2.94	0.99	3.32	0.73	2.86	.004	.44
Orally communicate the results of research projects	3.17	0.94	3.60	0.63	3.65	<.001	.54
Write a research paper for publication	2.74	1.10	3.08	1.00	2.50	.012	.32
Think independently	3.28	0.70	3.47	0.67	1.88	.061	.28
Overall	3.06	0.78	3.33	0.58	2.86	.004	.39

Note. Variables are measured on a 4-point scale of 1 = *not at all* to 4 = *very* capable of completing the task. Shaded variables are significant at $p < .05$.

all 15 variables. The standard deviations for each variable decreased from the presurvey to the postsurvey (except for "collect data," which went from 0.77 to 0.78), so there was more consensus in the postsurvey. Wilcoxon signed rank analyses comparing the pre- and postsurvey means showed that 10 of the observed increases were statistically significant (*p*-values between .026 and <.001). The Cohen's *d* effect sizes for the significant increases ranged from minimal to typical. The most significant increase was in "orally communicate the results of research projects" ($\Delta M = 0.43$, $p < .001$), with a typical relationship.

A Cronbach's alpha reliability analysis of the pre- and postsurvey skills variables revealed alpha reliability coefficients above .65 (Table 2). Removing any items from their respective indices would not improve overall reliability. All of the skill variables

Table 2. Reliability Analysis of Learner Research Skills

Research skills variables	Corrected item-total correlation	Alpha if item deleted	Cronbach alpha
Presurvey			.97
Understand marine science concepts	.55	.97	
Make use of the primary scientific research literature	.77	.97	
Identify a specific question for investigation using research	.87	.96	
Formulate a research hypothesis	.84	.96	
Design an experiment or theoretical test of the hypothesis	.86	.96	
Understand the importance of "controls" in research	.84	.96	
Observe data	.81	.97	
Collect data	.83	.97	
Statistically analyze data	.74	.97	
Interpret data by relating results to the original hypothesis	.85	.96	
Reformulate your original research hypothesis	.92	.96	
Relate results to the "bigger picture" in marine science	.85	.96	
Orally communicate the results of research projects	.80	.97	
Write a research paper for publication	.84	.96	
Think independently	.72	.97	
Postsurvey			.95
Understand marine science concepts	.58	.95	
Make use of the primary scientific research literature	.67	.94	
Identify a specific question for investigation using research	.79	.94	
Formulate a research hypothesis	.83	.94	
Design an experiment or theoretical test of the hypothesis	.76	.94	
Understand the importance of "controls" in research	.73	.94	
Observe data	.76	.94	
Collect data	.72	.94	
Statistically analyze data	.72	.94	
Interpret data by relating results to the original hypothesis	.81	.94	
Reformulate your original research hypothesis	.81	.94	
Relate results to the "bigger picture" in marine science	.70	.94	
Orally communicate the results of research projects	.62	.95	
Write a research paper for publication	.66	.95	
Think independently	.66	.94	

within each survey were thus combined and computed into two mean composite indices (i.e., presurvey, postsurvey). A Wilcoxon test of the two indices showed a significant increase in overall self-perceived research skill capabilities from the pre- to postsurvey (p = .004), with a minimal to typical effect size (Table 1).

Qualitative findings further supported these measured changes. For example, several learners emphasized their increased ability to communicate research both orally and in writing. One learner wrote that COESSING taught them "how to take data and make a presentation on the data I have analyzed and worked on" (postsurvey). Another research skill influenced by participation in COESSING 2018 resulted from the perceived opportunity to learn about "software used for conducting marine scientific research" (Table 6). Across the post- and post-post-surveys, 35 learners indicated they learned to use software commonly used for conducting oceanographic research, with 21 respondents indicating they learned an open-source software and 14 indicating they learned a commercial software. The extent of software skill acquisition was not measured, but exposure to new software had perceived impacts on the learners. As one learner reflected, "COESSING has helped to encourage and further motivate me to continue in my chosen career path by exposing me to softwares that make analysis simple" (postsurvey).

Learners also felt their problem-solving skills were impacted by participating in the summer school. For example, one learner commented that COESSING "showed me to a good extent the practical ways of solving scientific problems" (post-post-survey). The learner-identified increases in problem-solving abilities could have resulted from the hands-on components of the program, where learners can work through problems together as well as observe how instructors work through problems. That exposure to different ways of thinking potentially enhances learner abilities to solve problems. For example, a learner wrote in an email to an instructor after the program:

> I have really learnt a lot from you and you have really inspired me from how you handled the projects, even though you did not have all the solutions for the [software] problems you just kept on working, learning more and solving one problem at a time and that has really inspired me. (Field notes)

The perceived improvement and diversification of problem-solving techniques suggests the importance of the hands-on lab and project opportunities provided by COESSING.

Attitudes toward marine science. The presurvey means for learner attitudes about marine science were consistently closer to the more positive word on the semantic differential scales (Table 3). The postsurvey means showed slight increases across all five variables, suggesting slightly more positive attitudes toward marine science

Table 3. Wilcoxon Signed Rank Analysis of Pre- and Postsurvey Learner Attitudes About Marine Science

	Presurvey		Postsurvey				
Attitude variables	*M*	*SD*	*M*	*SD*	Wilcoxon-test value	*p*-value	Cohen's *d*
Dislike–Like	4.49	0.71	4.61	0.61	1.26	.206	.18
Bad–Good	4.61	0.61	4.65	0.56	0.44	.660	.07
Negative–Positive	4.52	0.68	4.56	0.62	0.41	.685	.06
Boring–Interesting	4.55	0.68	4.59	0.76	0.28	.781	.06
Harmful–Beneficial	4.67	0.51	4.73	0.49	0.62	.536	.11
Overall[a]	4.55	0.62	4.60	0.55	0.80	.427	.09

Note. Variables are measured on a 5-point semantic differential scale, where 1 = *most negative* and 5 = *most positive.*
[a] Excludes "Harmful–Beneficial" due to poor reliability.

after participating in the program. However, these increases were not statistically significant based on the Wilcoxon tests.

Cronbach's alpha reliability analyses of the variables for both the pre- and postsurvey attitudes revealed coefficients above .65 (Table 4). Deletion of the "harmful–beneficial" variable resulted in higher reliability, so this was removed from the analyses. The remaining four variables were combined and computed into two mean composite indices (i.e., presurvey, postsurvey). A Wilcoxon test of the two indices showed that, similar to the individual variables, the slight increase observed in overall attitude (ΔM = 0.05) was not significant (p = .427; Table 3).

Although general attitudes toward science did not significantly change, qualitative data suggest that more specific attitude change may have occurred among some learners. For example, one learner wrote:

> I really did not like chemistry from high school because it looked so abstract, but through COESSING I got to understand chemistry is the very existence of nature and the world has developed this far partly because of chemistry. That was great. (Postsurvey)

Another learner reflected, "COESSING has changed my view and way of thinking in a way as to go beyond the physical observation to 'application of softwares and models'" (postsurvey). These positive changes in attitudes toward chemistry and modeling reflected the attitude change that some learners experienced toward specific scientific topics.

Beliefs about science careers. Presurvey learner beliefs about scientists and science careers revealed a large range of means, with high standard deviations (Table 5). The range of postsurvey means was similarly large, and the spread of the means widened. Seven of the variable means increased from pre- to postsurvey, two decreased, and one remained the same. However, results from Wilcoxon tests revealed that the observed decrease in means for "Scientists do NOT have enough time for their families" was the only significant difference (ΔM = −0.67, p = .010), with a minimal to typical effect size. Cronbach's alpha reliability analyses of the belief variables revealed low alpha reliability coefficients of .50 for the presurvey and .32 for the postsurvey. Thus, overall indices were not calculated because belief variables were not measuring the same concept (Cortina, 1993).

Furthermore, how learners wrote about their intention to pursue a science career did not vary greatly over time. The explanations for career intentions likely reflect learner general beliefs about science careers. Learners most often identified the applicability of science to solving problems as why

Table 4. Reliability Analysis of Learner Attitudes About Marine Science

Attitude variables	Corrected item-total correlation	Alpha if item deleted	Cronbach alpha
Presurvey			.94
Dislike–Like	.86	.92	
Bad–Good	.85	.92	
Negative–Positive	.89	.91	
Boring–Interesting	.81	.93	
Postsurvey			.88
Dislike–Like	.72	.85	
Bad–Good	.80	.83	
Negative–Positive	.77	.83	
Boring–Interesting	.71	.87	

Note. Indices exclude "Harmful–Beneficial" variable.

Table 5. Wilcoxon Signed Rank Analysis of Pre- and Postsurvey Learner Beliefs About Scientists and Science Careers

Belief variables	Presurvey *M*	Presurvey *SD*	Postsurvey *M*	Postsurvey *SD*	Wilcoxon-test value	*p*-value	Cohen's *d*
There is NO need for science in most of today's jobs[a]	6.67	1.04	6.75	0.93	0.55	.581	.08
Scientists work together to solve problems	6.46	1.21	6.46	1.42	0.12	.905	0
A career in science is NOT interesting to me [a]	6.42	1.40	6.46	1.34	0.60	.550	.03
A career in science will support me	6.28	1.34	6.24	1.55	0.20	.986	.03
Scientists help their local community	6.27	1.12	6.49	1.05	1.33	.182	.20
Only the smartest students can have a career in science	2.17	1.57	2.33	1.72	0.50	.620	.10
A career in science means having to work in a laboratory	2.51	1.95	2.90	2.11	1.33	.183	.19
It is important to know science to get a good job	2.51	1.62	2.98	2.04	1.44	.150	.26
Scientists do NOT have enough time for their families [a]	5.75	1.63	5.08	2.03	2.57	.010	.36
A career in science would be fun	6.10	1.36	6.24	1.01	0.37	.715	.12

Note. Variables are measured on a 7-point scale of 1 = *strongly disagree* to 7 = *strongly agree*. Shaded variables are significant at $p < .05$.
[a] Reverse coded.

they wanted to pursue a career in science. Career intention explanations such as "to contribute my quota to my community and the world through solving pertinent issues" (presurvey) and "because I see science as the practical solution to most of the problems holding down the under-developing nations" (post-post-survey) were common across all three surveys. Thus, the widely held learner belief that scientific careers will benefit society was seemingly not affected by participation in COESSING 2018. Other reasons that remained constant before and after participation included the opportunity to learn and discover new ideas, a passion for or love of science, an interest in science, an enjoyment of scientific work, and an uncertainty about the financial stability of science. Two new beliefs emerged postparticipation in COESSING 2018: the diversity of career opportunities and the difficulty of science. The new belief that there are many options in science careers is a favorable belief change, whereas believing science careers are too difficult represents an unfavorable belief change. The one learner who commented that a science career "seems a bit difficult for me" also changed their career intention from "yes" on the presurvey to "unsure" on the post- and post-post-surveys. Thus, COESSING participation largely seems to have had no perceived effect on learner beliefs about science careers, with a few exceptions.

Content knowledge. Mean values of the 12 variables assessing perceptions about learning expectations during COESSING (i.e., presurvey) ranged from moderately to strongly agree (Table 6). Learner per-

Table 6. Wilcoxon Signed Rank Analysis of Pre- and Postsurvey Learner Expectations About Learning Outcomes

Learn variables	Presurvey		Postsurvey		Wilcoxon-test value	*p*-value	Cohen's *d*
	M	*SD*	*M*	*SD*			
General marine science concepts from introductory lectures	6.06	1.14	6.33	1.13	1.12	.242	.24
General marine science concepts from introductory labs	5.82	1.61	6.22	1.27	1.31	.191	.28
Specific marine science concepts from intermediate lectures	5.94	1.38	6.26	1.03	1.28	.200	.26
Specific marine science concepts from intermediate labs	5.74	1.50	6.26	0.94	2.06	.039	.42
The technology used for conducting marine scientific research	6.12	1.13	6.35	1.16	1.18	.239	.20
The software used for conducting marine scientific research	6.02	1.30	6.49	1.17	2.15	.032	.38
Academic opportunities in West African countries	6.14	1.24	5.29	1.76	2.85	.004	.56
Academic opportunities in countries outside of West Africa	6.22	1.16	5.53	1.77	2.44	.015	.46
Tools that can be used in my own research	6.21	0.96	6.42	1.09	1.27	.203	.20
The applicability of science to my current or future career	6.35	0.99	6.54	0.83	0.89	.375	.21
Career opportunities in West African countries	6.17	1.17	5.29	1.60	3.01	.003	.63
Career opportunities outside of West Africa	6.19	1.15	5.51	1.63	2.20	.028	.48
Overall	6.09	0.98	6.06	0.93	0.57	.566	.03

Note. Variables are measured on a 7-point scale of 1 = *strongly disagree* to 7 = *strongly agree*. Shaded variables are significant at $p < .05$.

ceptions about what they learned during COESSING (i.e., postsurvey) had a slightly larger range of means. Eight of the learning variables saw an increase in mean values between pre- and postsurveys of at least 0.19, with the highest observed increase in "specific marine science concepts from intermediate labs" (ΔM = 0.52). The remaining four variables decreased in mean value, with changes between -0.68 and -0.88, with the greatest observed decrease in "career opportunities in West African countries" (ΔM = -0.88). Wilcoxon tests showed that only two of the observed increases were significant (*p*-values between .032 and .039), with minimal to typical effect sizes, whereas the four observed decreases were all significant (*p*-values between .003 and .028), with typical to substantial effect sizes.

Results from Cronbach's alpha reliability analyses justified computing two mean composite indices from the 12 learning variables, and removing any items from their respective indices did not improve overall reliability (Table 7). However, a Wilcoxon test of the pre- and postsurvey overall learning indices showed that the slight de-

Table 7. Reliability Analysis of Learner Expectations About Learning Outcomes

Learn variables	Corrected item-total correlation	Alpha if item deleted	Cronbach alpha
Presurvey			.97
General marine science concepts from introductory lectures.	.77	.97	
General marine science concepts from introductory labs.	.74	.97	
Specific marine science concepts from intermediate lectures.	.75	.97	
Specific marine science concepts from intermediate labs.	.74	.97	
The technology used for conducting marine scientific research.	.90	.96	
The software used for conducting marine scientific research.	.91	.96	
Academic opportunities in West African countries.	.86	.96	
Academic opportunities in countries outside of West Africa.	.89	.96	
Tools that can be used in my own research.	.91	.96	
The applicability of science to my current or future career.	.88	.96	
Career opportunities in West African countries.	.82	.96	
Career opportunities outside of West Africa.	.89	.96	
Postsurvey			.89
General marine science concepts from introductory lectures.	.71	.86	
General marine science concepts from introductory labs.	.63	.89	
Specific marine science concepts from intermediate lectures.	.57	.76	
Specific marine science concepts from intermediate labs.	.42	.78	
The technology used for conducting marine scientific research.	.54	.84	
The software used for conducting marine scientific research.	.52	.81	
Academic opportunities in West African countries.	.69	.80	
Academic opportunities in countries outside of West Africa.	.62	.78	
Tools that can be used in my own research.	.58	.63	
The applicability of science to my current or future career.	.57	.66	
Career opportunities in West African countries.	.71	.72	
Career opportunities outside of West Africa.	.70	.64	

crease observed in the means (ΔM = -0.03) was not statistically significant (p = .566; Table 6).

Although the extent of specific content knowledge acquisition was not measured, many learners mentioned learning about marine science–related topics through their participation in COESSING 2018. Learners documented their learning of specific topics 61 times, with topics including mining and geochemistry, ecology and fisheries, satellite oceanography, biogeochemistry, and chemistry. Learners also mentioned general ocean science knowledge acquisition 30 times. For example, one learner commented on the postsurvey, "This has strongly deepened my knowledge and understanding about the marine [environment] and the seas."

Another indication of scientific content knowledge acquisition is the perceived influence on individual research projects. For example, one repeat learner wrote during the task-based focus group, "The knowledge I gained from last year's summer school on oil and gas lectures helped me build more ideas about my MSc." Another repeat learner revealed, "The school influenced my choice of project topic for my undergraduate research project" (task-based focus group). The influence of participation on outside research project topics, therefore, suggests that some content knowledge acquisition occurred.

Knowledge of career and academic opportunities in science is another important component of building individual capacity for scientific research (Kennedy & Odell, 2014). The extent of learner perceived changes in knowledge of scientific opportunities, however, was unclear. Even though measured learner expectations were not met, learners still "slightly" to "moderately" agreed that they learned about academic and career opportunities (Table 6). However, this result needs to be viewed in light of an unplanned schedule change that resulted in the postsurvey being administered prior to the presentation on graduate school opportunities, and post-post-survey qualitative data suggested that a few learners increased their knowledge of scientific opportunities. As one learner commented, "COESSING revealed so many opportunities in science apart from the basic ones [I] am aware of." Hence, a knowledge increase of scientific opportunities is a perceived result of COESSING for some learners.

Conceptual knowledge. In addition to the perceived content knowledge acquisition, learner responses indicated a perceived increase in conceptual knowledge. Several learners felt they became more aware of connections between humans and their natural environment. As one learner wrote, "I was able to realize how anthropogenic activities over time affect the environment" (postsurvey). Learners also documented an increased knowledge of the importance of different scientific disciplines in understanding the ocean. One learner reflected, "COESSING has made me understand that satellite imagery together with our normal in situ data collection can really help us achieve and make better decisions, especially in fisheries and water management" (postsurvey). The comment that "now [I am] able to better appreciate other disciplines like mathematics in the learning of the ocean" (task-based focus group) suggested longer term impacts of COESSING on learner conceptual understanding of the marine sciences. Other learners reflected on how their overall conceptualization of marine sciences changed. For example, one repeat learner wrote, "The summer school gave me a different dimension in understanding oceanography outside the university classroom" (task-based focus group). The perceived improvements in learner conceptual understandings of human–environment interactions, interdisciplinary research, and marine science indicated that conceptual knowledge acquisition occurred for some learners.

Connections with people. During COESSING, learners interacted with each other, Ghanaian instructors, and international instructors. Learner perceptions about interaction opportunities they expected to have during COESSING (i.e., presurvey) were relatively consistent across the 10 variables (Table 8). On the other hand, learner perceptions of the opportunities they had during COESSING (i.e., postsurvey) were more varied. Four of the variable means had observed increases, whereas the remaining six had observed decreases. Wilcoxon tests revealed that "participate in hands-on labs" was the only significant observed increase (p = .024), with a minimal to typical effect size. Five of the observed decreases were significant (p-values between .002 and <.001), with typical to substantial effect sizes. The expectation to "form research partnerships with Ghanaian professors" had by far the largest observed negative change

Table 8. Wilcoxon Signed Rank Analysis of Pre- and Postsurvey Learner Expectations About Opportunities

Opportunity variables	Presurvey *M*	Presurvey *SD*	Postsurvey *M*	Postsurvey *SD*	Wilcoxon-test value	*p*-value	Cohen's *d*
Participate in hands-on labs	6.00	1.13	6.51	1.21	2.25	.024	.44
Network with university students from across West Africa	6.25	0.90	6.34	1.26	1.25	.211	.08
Network with Ghanaian professors	6.32	0.89	5.40	1.68	3.42	.001	.68
Network with international professors	6.33	0.90	6.25	1.27	0.26	.799	.07
Socialize with university students from across West Africa	6.26	0.90	6.45	1.01	1.26	.209	.20
Socialize with Ghanaian professors	6.26	0.94	5.55	1.60	3.04	.002	.54
Socialize with international professors	6.26	0.92	6.34	1.04	0.27	.785	.08
Form research partnerships with university students from across West Africa	6.30	0.87	5.36	1.82	3.10	.002	.67
Form research partnerships with Ghanaian professors	6.28	0.90	4.64	2.10	4.12	<.001	1.02
Form research partnerships with international professors	6.29	0.92	4.98	2.06	3.42	.001	.82
Overall [a]	6.29	0.84	5.71	1.16	2.88	.004	.57

Note. Variables are measured on a 7-point scale of 1 = *strongly disagree* to 7 = *strongly agree.* Shaded variables are significant at $p < .05$.
[a] Excludes "Participate in hands-on labs" due to poor reliability.

($\Delta M = -1.64$, $p < .001$) with a substantial effect size.

Cronbach's alpha reliability analyses of the 10 variables for the pre- and postsurvey opportunity statements showed alpha reliability coefficients above .65 (Table 9). However, coefficients increased when the "participate in hands-on labs" variable was removed, so it was not included in the final indices. The remaining nine variables within each survey were combined and computed into two new mean composite indices (i.e., presurvey, postsurvey). Results from a Wilcoxon test of the two overall opportunity indices showed that the observed decrease in means ($\Delta M = -0.58$) was significant ($p = .004$), with a typical to substantial effect size (Table 8).

Overall, learners felt they had more opportunity to interact with other West African learners than they had expected. Learner expectations about interacting with Ghanaian instructors were not met, whereas expectations about interacting with international instructors were generally met. The quantitative data, however, did not indicate the value of each interaction. Qualitative results suggest positively perceived impacts and outcomes from interactions experienced among the three groups. The types of interactions that occurred were categorized into three levels—social, networking, and

Table 9. Reliability Analysis of Learner Expectations About Opportunities

Opportunity variables	Corrected item-total correlation	Alpha if item deleted	Cronbach alpha
Presurvey			.99
Network with university students from across West Africa	.95	.99	
Network with Ghanaian professors	.96	.99	
Network with international professors	.95	.99	
Socialize with university students from across West Africa	.94	.99	
Socialize with Ghanaian professors	.92	.99	
Socialize with international professors	.95	.99	
Form research partnerships with university students from across West Africa	.96	.99	
Form research partnerships with Ghanaian professors	.95	.99	
Form research partnerships with international professors	.93	.99	
Postsurvey			.88
Network with university students from across West Africa	.66	.87	
Network with Ghanaian professors	.72	.86	
Network with international professors	.55	.88	
Socialize with university students from across West Africa	.60	.88	
Socialize with Ghanaian professors	.66	.87	
Socialize with international professors	.61	.87	
Form research partnerships with university students from across West Africa	.64	.87	
Form research partnerships with Ghanaian professors	.77	.86	
Form research partnerships with international professors	.66	.87	

Note. Indices exclude "Participate in hands-on labs" variable.

research partnership forming—with different perceived impacts experienced at each level.

At the basic, social level of interaction, learners "slightly" to "strongly" agreed that they had the opportunity to socialize with one another and the instructors (Table 8). The perceived impacts of the social opportunities of COESSING include increased cross-cultural understanding and stronger social skills. For example, one learner identified the "cultural diversity encountered" as their longer term impact of participation (post-post-survey). In terms of social skills, a self-identified "quiet" repeat learner perceived her participation in COESSING as allowing her to "now [be] able to open up to others with ease and make friends" (task-based focus group). Another repeat learner explained that their approach to socializing was affected: "I now see conversations with other people as an opportunity to share knowledge as I got to learn a lot from other participants in last year's summer school" (task-based focus group). The opportunity to casually socialize with colleagues and instructors thus appears to have been an impactful component of the summer school.

Learners "slightly" to "strongly" agreed they had the opportunity to network during COESSING 2018 (Table 8). Many learners mentioned again in their open-ended responses the opportunity to network with their fellow learners. As one learner emphasized, networking "with colleagues across West Africa . . . is a rare opportunity!" (post-post-survey). One of the small groups of repeat learners in the task-based focus group even ranked the academic connections made among learners as the most important long-term impact of their participation. Thus, COESSING provided a needed platform to facilitate professional connections among the West African learners. Learners also perceived outcomes from their networking opportunities with the instructors. One learner commented that networking with the instructors "motivated [them] to aspire" (post). One of the female instructors also shared that a female learner studying physics at the graduate level was struggling as a female in physics (interview). The learner indicated that the instructor's professional interactions provided a role model, potentially reassuring her that women can succeed in physics.

Learners felt they had fewer opportunities to form research partnerships than expected. Survey results showed learners were between "neither" agreeing nor disagreeing and "moderately" agreeing they had the opportunity to form any research partnerships, albeit with low consensus (Table 8). Similarly, several instructors observed that they did not maintain contact with any of the learners following previous COESSING programs (interviews). Some learners, however, did form research partnerships. A few learners mentioned building research partnerships in general, with comments such as "I had the opportunity of meeting Ghanaian teachers and students who are willing to help me in my final year research work" (postsurvey). Other learners acknowledged specific instructors with whom they collaborated or are planning to collaborate in the future. A substantial research partnership was formed between an early-career Ghanaian instructor and a late-career American instructor (field notes). In this outlier example, the Ghanaian instructor is now a master's student working with the American instructor in the United States. Thus, at this stage, COESSING's facilitation of research partnership formation is relatively low, with minimal perceived impacts on learners.

Instructors

The impacts of participating in COESSING identified by instructors can be divided into three categories: professional development, cultural exchange, and advancing the field (see Appendix A for a definition of each theme). The method of data collection for provided evidence was the interviews, unless indicated otherwise parenthetically.

Professional development. Only four of the 18 instructors discussed their perceived professional development from participating in COESSING. Three American instructors (two early-career, one late-career) mentioned the opportunity to improve teaching skills. One of the early-career Americans also indicated that COESSING provided them with the opportunity to work on their leadership skills. The three American instructors who identified professional development impacts from COESSING did not discuss their experiences in detail. For example, one instructor simply stated, "I've been wanting to work on teaching and communicating science, and this was an opportunity for me to get to work on that," without elaborating further. On the other hand, one of the early-career Ghanaian instructors discussed in detail how their career advanced. The instructor discovered a new "niche between profession and academia itself" and is now pursuing another postgraduate degree internationally in that "niche" field because of their participation in COESSING. Thus, although some of the instructors experienced professional development, it does not appear to have been perceived as a primary impact of participation.

Discussion around why instructors chose to participate in COESSING suggested an explanation for why they may not have been perceiving professional development impacts. Qualitative data indicated consensus among the instructors that COESSING is an opportunity for them to "give back" to their communities and that "everyone is volunteering their time" (field notes). For example, one of the late-career Americans identified the "appealing" aspect of COESSING as "the potential for me to get involved in a program where we actually go and make meaningful impactful change in the lives of folks." Similarly, a late-career Ghanaian instructor explained their motivation for participating as "helping to develop the next crops of scientists in oceanography and fishery." Hence, the instructors appeared to primarily frame COESSING as altruistic volunteerism instead of as part of their own career development. Another late-career American instructor even commented, "It's good broader outreach. But that's not really why I do it because I could do other things with that time." Regarding COESSING as a form of volunteerism could hinder instructors from identifying the potential professional development impacts.

Cultural exchange. The majority of instructors identified cross-cultural exchange and awareness as an outcome of their participation in COESSING. Many of the instructors highlighted the opportunity to see how scientists from different cultures and backgrounds conducted their science. For example, an early-career American reflected, "I don't know if it helped my science, but just seeing how things are done differently I think is helpful to me too." The Ghanaian instructors similarly perceived impacts stemming from the cultural diversity of COESSING. As a mid-career Ghanaian observed:

> People are learning, and we are also learning from them because of course I am in Ghana. I've been to Senegal, I've been to Nigeria, I've done research in those countries, but of course I'm not abreast with their system like I am here in Ghana. So, I teach you, you learn from me, I also learn from you.

This Ghanaian instructor thus perceived that their overall knowledge increased because of exposure to how science is conducted in different countries. A mid-career American instructor suggested a potential longer term impact of the cultural exchange offered by COESSING:

> I think this school will increase the ability of Africans to do oceanography, but it also increases the network of US and European scientists that are aware of conditions in Africa and are maybe willing to collaborate with them knowingly, with realistic expectations with what kind of African resources are available here.

The American instructor, therefore, believed that the widely perceived increase in understanding of science in different contexts could encourage other researchers to be more open to international collaborations.

Advancing the field. A third cross-cutting theme related to the idea of "advancing the field," or progressing their field of science. Specifically, five instructors observed that the global nature of oceanography should mandate a global workforce of oceanographers. For example, one early-career American instructor felt that it was "really important" for marine science to be more global in nature because "we all have oceans." A late-career American further reflected:

> I really do feel strongly that we need to do a better job of involving, in whatever form is appropriate, scientists on the African continent if we're really going to say that we study the global ocean. I mean it just seems so silly that we would not involve an entire continent in our work.

Thus, some of the instructors perceived their participation as potentially increasing and diversifying the global oceanography workforce. A diversified workforce will, in turn, advance the field of oceanography because people from different backgrounds conceptualize ideas differently, encouraging different types of questions being asked and different connections being made (Kaplan, 2015).

Discussion

Implications for Higher Education ISLP Design

The perceived impacts of the learners and instructors in the COESSING case study exploration have many implications, discussed below, for designing future higher education ISLPs.

Incorporating Hands-On Learning to Build Confidence in Research Skills

The research skill, content knowledge, and conceptual knowledge acquisition identified by the learners are already understood to be important components of a successful ISLP (National Research Council, 2009). Their presence in COESSING, however, indicated that even programs developed and taught by career scientists can achieve curricular learning outcomes. Moreover, since learner confidence in their ability to conduct research is a "critical" component of future scientific research career success

(Stajkovic, 2006, p. 1209), the increased confidence in research skills immediately following COESSING suggests that the program has been making progress toward its goal of increasing the quantity and quality of West African scientists. Learner emphasis on the hands-on learning opportunities offered during COESSING through the labs and projects reinforced the value of hands-on learning for higher education (Ma & Nickerson, 2006). The findings further suggested the potential significance of more process-focused, experiential learning opportunities for the development of problem-solving skills in adults (A. Y. Kolb & Kolb, 2005; D. A. Kolb, 1984).

Creating Space for Connections Among Participants

Learner emphasis on forming connections with other participants (both learners and instructors) indicated that having the opportunity to meet and interact with other people in their field has been a valuable outcome of COESSING. This perceived value is reflected in the capacity development literature, which identified the importance of both scientist networks and the relationship between established and aspiring scientists in determining research success (e.g., Pillai et al., 2018; Sachatello-Sawyer & Burton, 2002; Strigl, 2003). Learners particularly identified the value of connecting with other West African university students and early-career scientists, indicating the importance of the peer-to-peer contacts formed during ISLPs. On the other hand, learner identification of positive impacts from interacting with instructors reinforced the importance of forming connections with facilitators for adult learners (Sachatello-Sawyer & Burton, 2002).

The connections identified and observed within the proposed three-tiered system—socializing, networking, and research partnership forming—had different perceived impacts experienced at each level. Positive outcomes from socializing indicated that this common, base-level interaction is still valuable and should be considered in designing future higher education ISLPs. Networking, which was also commonly identified and observed, often occurred during the labs and projects where professional discussions were already occurring. The rarity of forming research partnerships (i.e., measured expectations on research partnership forming were not met and were not qualitatively identified), on the other hand, demonstrated the need for a more research-focused program design with more collaborative projects to facilitate future partnerships.

Both learners and instructors identified and valued the cross-cultural interactions they experienced during COESSING. Instructors specifically credited the program's international nature with increasing their understanding of how to conduct science and potentially increasing their willingness to collaborate internationally. For all participants, the opportunity to be exposed to new ways of thinking could ultimately affect how they approach their future scientific research (Kaplan, 2015). Having a diversity of participants in higher education ISLPs can thus offer another dimension of research capacity development.

Valuing Scientist Instructors' Participation

Instructors' not identifying professional development as an important impact also has implications for future higher education ISLP design. Instructors essentially discussed COESSING in much the same altruistic way as volunteers discuss their volunteerism (e.g., Burns et al., 2006; Carpenter & Myers, 2010), indicating that the instructors saw their participation primarily as service, and not as an opportunity for career development. Scientists' not valuing their broader outreach activities as an avenue for professional development is likely linked to this type of work not being prioritized by the academic community. For U.S. instructors in particular, broader outreach has long been relegated to service and is not valued much in the current publication-driven university system (Boyer, 1996). A 2017 National Alliance for Broader Impacts (NABI) forum with 120 participants from U.S.-based institutions found that most scientists felt "academic culture does not reward" their participation in broader impact activities (NABI, 2018, p. 4). Thus, despite the societal and funder-driven push for scientists to engage more in broader outreach activities, the current structure of academia does not provide much professional reward or recognition for this kind of work.

The disconnect between outreach and science likely hinders the ability of higher education ISLPs to recruit and retain scientist instructors. Prior research has shown that scientists prioritize their more clearly required responsibilities of teaching at their home institution, conducting their own research, and procuring funding for their own research (Andrews et al., 2005). Thus, to encourage this change in instructor perceptions, future program designs should explicitly identify the potential professional development impacts for instructors. On a larger scale, however, there is still a need for the broader scientific community to more formally value this type of work, perhaps as a criterion for hiring and promotion or as its own form of scholarship (Andrews et al., 2005; Boyer, 1996; Johnson et al., 2014; NABI, 2018).

Reflections on Null Results and the Positive Bias

The lack of statistically significant changes in learner attitudes toward marine science and beliefs about science careers was not expected (Osborne et al., 2003). However, as a free-choice learning program dealing with advanced scientific concepts, it is likely that the program attracted only learners who already had positive attitudes toward marine science and favorable beliefs about science careers. This absence of perceived change suggests that changes in attitudes and beliefs may be more difficult to achieve with an audience that is already interested and embedded in the field.

Overall, the overwhelmingly positive qualitative responses provided by the learners likely resulted from a combination of the questionnaire structure and cultural differences. The structure of the qualitative questions on the questionnaire did not readily lend itself to critical answers. For example, on the postsurvey, learners were asked, "What other topics did you learn about during COESSING?" This question does not encourage learners to indicate topics where their learning expectations were not met (i.e., topics they expected to learn about, but did not). Moreover, culturally different understandings of how knowledge sharing relates to respect and politeness may have led the West African learners to not provide negative responses (Boateng & Agyemang, 2015).

Areas for Continued Research

Future research on international collaborative programs should use a team of multicultural data collectors to obtain a more complete picture of the program. During COESSING, learners communicated with one another in a mix of English, French, and various West African languages, which inhibited the monolingual primary researcher's ability to be a full participatory observer. Similarly, although all learners were fluent in English, the socioculturally relevant nature of language may have led to misinterpretations of meaning by both the learners and the researcher during conversations and on the questionnaires (Adika, 2012). Time was another limitation, because only the primary researcher engaged in data collection. Thus, not all aspects of the school were observed due to the interview schedule and the program's two-track design, which limited the representativeness of the field notes. Employing a team of data collection personnel who are representative of the diversity of program participants could overcome these limitations in future research.

Continued research on instructor impacts from participation in higher education ISLPs is needed. The initial design of this study focused primarily on understanding learner impacts. Thus, the instructor interview question guide focused on instructor perceptions of learner impacts and on the program structure in general. Quantitative data were also not collected from instructors. However, it is important to understand instructor impacts so that programs can be designed with instructor recruitment and retention in mind (Andrews et al., 2005).

Additional research should also explore and assess the longer term impacts of programs on their participants, especially since research has shown that learner outcomes can grow and change over time (Sachatello-Sawyer & Burton, 2002). Longitudinal studies with larger samples are also needed to explore how ISLPs are building the capacity for local scientific research in the regions where ISLPs occur. This study largely assessed short-term impacts from participation since data were limited by the small number of learner respondents in the post-post-survey.

Conclusion

As scientists increasingly engage in higher education ISLPs as a form of broader outreach, understanding of how these programs function must also increase to ensure their effectiveness and longevity. The COESSING case study adds to collective understanding by exploring a more complete range of impacts experienced by both learners and instructors. Findings suggested the need for future program designs to foster a diversity of connections because the range of potential outcomes differed depending on the relationship pairing (learner–learner, learner–instructor, instructor–instructor) and the level of connection (socializing, networking, research partnership forming). Programs should also strive to improve instructor perceptions of how their outreach participation relates to their research and career. Although instructors have positive perceptions of their outreach in general, the lack of direct career connection often relegates outreach to an "important, but . . ." sentiment (Andrews et al., 2005, p. 286). Reconciling the disconnect between the funder-driven push for increased broader outreach activities and the insufficient value attributed to broader outreach participation by the academic community is vital for ensuring the future success of scientist-driven higher education ISLPs.

About the Authors

Jennifer M. Moskel *is the STEM Program Coordinator for the Girl Scouts of Greater New York.*

Emily L. Shroyer *is an associate professor in the College of Earth, Ocean, and Atmospheric Sciences at Oregon State University.*

Shawn Rowe *is an associate professor at Oregon Sea Grant and the Department of Science and Mathematics Education at Oregon State University.*

Mark D. Needham *is a professor in the Department of Forest Ecosystems and Society at Oregon State University.*

Brian K. Arbic *is a professor in the Department of Earth and Environmental Sciences at the University of Michigan.*

References

Adika, G. S. K. (2012). English in Ghana: Growth, tensions, and trends. *International Journal of Language, Translation and Intercultural Communication, 1*, 151–166. https://doi.org/10.12681/ijltic.17

Andrews, E., Weaver, A., Hanley, D., Shamatha, J., & Melton, G. (2005). Scientists and public outreach: Participation, motivations, and impediments. *Journal of Geoscience Education, 53*(3), 281–293. https://doi.org/10.5408/1089-9995-53.3.281

Bates, I., Akoto, A. Y. O., Ansong, D., Karikari, P., Bedu-Addo, G., Critchley, J., Agbenyega, T., & Nsiah-Asare, A. (2006). Evaluating health research capacity building: An evidence-based tool. *PLOS Medicine, 3*(8), Article e299. https://doi.org/10.1371/journal.pmed.0030299

Bernard, R. (2011). Interviewing I: Unstructured and semi-structured. In *Research methods in anthropology: Qualitative and quantitative approaches* (5th ed., pp. 210–250). Rowman & Littlefield.

Boateng, H., & Agyemang, F. G. (2015). The role of culture in knowledge sharing in a public-sector organization in Ghana: Revisiting Hofstede's model. *International Journal of Public Administration, 38*(7), 486–495. https://doi.org/10.1080/01900692.2014.949743

Boyer, E. L. (1996). The scholarship of engagement. *Journal of Public Service and Outreach, 1*(1), 11–20. https://openjournals.libs.uga.edu/jheoe/article/view/666

Burns, D. J., Reid, J. S., Toncar, M., Fawcett, J., & Anderson, C. (2006). Motivations to volunteer: The role of altruism. *International Review on Public and Nonprofit Marketing, 3*(2), 79–91. https://doi.org/10.1007/BF02893621

Carpenter, J., & Myers, C. K. (2010). Why volunteer? Evidence on the role of altruism, image, and incentives. *Journal of Public Economics, 94*(11–12), 911–920. https://doi.org/10.1016/j.jpubeco.2010.07.007

Clark, G., Russell, J., Enyeart, P., Gracia, B., Wessel, A., Jarmoskaite, I., Polioudakis, D., Stuart, Y., Gonzalez, T., MacKrell, A., Rodenbusch, S., Stovall, G. M., Beckham, J. T., Montgomery, M., Tasneem, T., Jones, J., Simmons, S., & Roux, S. (2016). Science educational outreach programs that benefit students and scientists. *PLOS Biology, 14*(2), Article e1002368. https://doi.org/10.1371/journal.pbio.1002368

Cortina, J. M. (1993). What is coefficient alpha? An examination of theory and applications. *Journal of Applied Psychology, 78*(1), 98–104. https://doi.org/10.1037/0021-9010.78.1.98

Falk, J. H., Storksdieck, M., & Dierking, L. D. (2007). Investigating public science interest and understanding: Evidence for the importance of free-choice learning. *Public Understanding of Science, 16*(4), 455–469. https://doi.org/10.1177/0963662506064240

Fauville, G., Säljö, R., & Dupont, S. (2013). Impact of ocean acidification on marine ecosystems: Educational challenges and innovations. *Marine Biology, 160*(8), 1863–1874. https://doi.org/10.1007/s00227-012-1943-4

Fishbein, M., & Ajzen, I. (2010). *Predicting and changing behavior: The reasoned action approach*. Taylor & Francis Group.

Francis, L. J., & Greer, J. E. (1999). Measuring attitude towards science among secondary school students: The affective domain. *Research in Science & Technological Education, 17*(2), 219–226. https://doi.org/10.1080/0263514990170207

Frechtling, J. A., & Sharp, L. M. (Eds.). (1997). *User-friendly handbook for mixed method evaluations*. National Science Foundation.

Gogolin, L., & Swartz, F. (1992). A quantitative and qualitative inquiry into the attitudes toward science of nonscience college students. *Journal of Research in Science Teaching, 29*(5), 487–504. https://doi.org/10.1002/tea.3660290505

Hernandez, P. R., Schultz, P. W., Estrada, M., Woodcock, A., & Chance, R. C. (2013). Sustaining optimal motivation: A longitudinal analysis of interventions to broaden participation of underrepresented students in STEM. *Journal of Educational Psychology, 105*(1), 89–107. https://doi.org/10.1037/a0029691

Hofstein, A., & Rosenfeld, S. (1996). Bridging the gap between formal and informal science learning. *Studies in Science Education, 28*(1), 87–112. https://doi.org/10.1080/03057269608560085

Johnson, D. R., Ecklund, E. H., & Lincoln, A. E. (2014). Narratives of science outreach in elite contexts of academic science. *Science Communication, 36*(1), 81–105. https://doi.org/10.1177/1075547013499142

Jordan, R. C., Gray, S. A., Howe, D. V., Brooks, W. R., & Ehrenfeld, J. G. (2011). Knowledge gain and behavioral change in citizen-science programs. *Conservation Biology, 25*(6), 1148–1154. https://doi.org/10.1111/j.1523-1739.2011.01745.x

Kaplan, R. (2015). The joys and struggles of building mental models. In *Fostering reasonableness: Supportive environments for bringing out our best*. Maize Books. https://doi.org/10.3998/maize.13545970.0001.001

Kardash, C. M. (2000). Evaluation of undergraduate research experience: Perceptions of undergraduate interns and their faculty mentors. *Journal of Educational Psychology, 92*(1), 191–201. https://doi.org/10.1037/0022-0663.92.1.191

Kennedy, T. J., & Odell, M. R. L. (2014). Engaging students in STEM education. *Science Education International, 25*(3), 246–258.

Kolb, A. Y., & Kolb, D. A. (2005). Learning styles and learning spaces: Enhancing experiential learning in higher education. *Academy of Management Learning & Education, 4*(2), 193–212. https://doi.org/10.5465/amle.2005.17268566

Kolb, D. A. (1984). *Experiential learning: Experience as the source of learning and development*. Prentice Hall.

Krajkovich, J. G., & Smith, J. K. (1982). The development of the image of science and scientists scale. *Journal of Research in Science Teaching, 19*(1), 39–44. https://doi.org/10.1002/tea.3660190106

Laursen, S., Liston, C., Thiry, H., & Graf, J. (2007). What good is a scientist in the classroom? Participant outcomes and program design features for a short-duration science outreach intervention in K–12 classrooms. *CBE—Life Sciences Education, 6*(1), 49–64. https://doi.org/10.1187/cbe.06-05-0165

Lewis, B. F. (2003). A critique of literature on the underrepresentation of African Americans in science: Directions for future research. *Journal of Women and Minorities in Science and Engineering, 9*(3–4), 361–373. https://doi.org/10.1615/JWomenMinorScienEng.v9.i34.100

Ma, J., & Nickerson, J. V. (2006). Hands-on, simulated, and remote laboratories: A comparative literature review. *ACM Computing Surveys, 38*(3), Article 7-es. https://doi.org/10.1145/1132960.1132961

Maxwell, J. (2013). *Qualitative research design: An interactive approach* (3rd ed.). SAGE Publications.

Moore, R. W., & Foy, R. L. H. (1997). The scientific attitude inventory: A revision (SAI II). *Journal of Research in Science Teaching, 34*(4), 327–336. https://doi.org/10.1002/(SICI)1098-2736(199704)34:4<327::AID-TEA3>3.0.CO;2-T

Nadkarni, N. M., & Stasch, A. E. (2013). How broad are our broader impacts? An analysis of the National Science Foundation’s Ecosystem Studies Program and the Broader Impacts requirement. *Frontiers in Ecology and the Environment, 11*(1), 13–19. https://doi.org/10.1890/110106

National Alliance for Broader Impacts. (2018). *The current state of broader impacts: Advancing science and benefiting society*.

National Research Council. (2009). *Learning science in informal environments: People, places, and pursuits*. National Academies Press.

National Research Foundation. (2017). *NRF overview of funding opportunities, grant management, and the rating of researchers*. https://www.nrf.ac.za/sites/default/files/documents/Overview%20of%20Funding%20Opportunities.pdf

National Science Foundation. (2018). NSF proposal processing and review. In *Proposal and award policies and procedures guide*. https://www.nsf.gov/pubs/policydocs/pappg18_1/pappg_3.jsp

National Science Foundation. (2020). *Science of Science: Discovery, Communication and Impact*. https://www.nsf.gov/funding/pgm_summ.jsp?pims_id=505730

Nature Index. (2019). *Annual tables*. https:// www.natureindex.com

Nchinda, T. C. (2002). Research capacity strengthening in the South. *Social Science & Medicine, 54*(11), 1699–1711. https://doi.org/10.1016/S0277-9536(01)00338-0

Osborne, J., Simon, S., & Collins, S. (2003). Attitudes towards science: A review of the literature and its implications. *International Journal of Science Education, 25*(9), 1049–1079. https://doi.org/10.1080/0950069032000032199

Perry, E. E., Needham, M. D., Cramer, L. A., & Rosenberger, R. S. (2014). Coastal resident knowledge of new marine reserves in Oregon: The impact of proximity and attachment. *Ocean & Coastal Management, 95*, 107–116. https://doi.org/10.1016/j.ocecoaman.2014.04.011

Pillai, G., Chibale, K., Constable, E. C., Keller, A. N., Gutierrez, M. M., Mirza, F., Sengstag, C., Masimirembwa, C., Denti, P., Maartens, G., Ramsay, M., Ogutu, B., Makonnen, E., Gordon, R., Ferreira, C. G., Goldbaum, F. A., Degrave, W. M. S., Spector, J., Tadmor, B., & Kaiser, H. J. (2018). The Next Generation Scientist program: Capacity-building for future scientific leaders in low- and middle-income countries. *BMC Medical Education, 18*(1), Article 233. https://doi.org/10.1186/s12909-018-1331-y

Qian, Y., Hambrusch, S., Yadav, A., & Gretter, S. (2018). Who needs what: Recommendations for designing effective online professional development for computer science teachers. *Journal of Research on Technology in Education, 50*(2), 164–181. https://doi.org/10.1080/15391523.2018.1433565

Regional Maritime University. (2019). *We are the Regional Maritime University*. https://rmu.edu.gh/

Roberts, M. R. (2009). Realizing societal benefit from academic research: Analysis of the National Science Foundation's Broader Impacts criterion. *Social Epistemology, 23*(3–4), 199–219. https://doi.org/10.1080/02691720903364035

Sachatello-Sawyer, B., & Burton, H. (2002). *Adult museum programs: Designing meaningful experiences*. Rowman Altamira.

Spradley, J. (1980). *Participant observation*. Holt, Rinehart and Winston.

Stajkovic, A. D. (2006). Development of a core confidence–higher order construct. *Journal of Applied Psychology, 91*(6), 1208–1224. https://doi.org/10.1037/0021-9010.91.6.1208

Strigl, A. W. (2003). Science, research, knowledge and capacity building. *Environment, Development and Sustainability, 5*(1), 255–273. https://doi.org/10.1023/A:1025361122767

University of Ghana. (2018). *Overview*. https://www.ug.edu.gh/about/overview

Vaske, J. (2008). *Survey research and analysis: Applications in parks, recreation and human dimensions*. Venture Publishing.

Appendix A. Qualitative Codebooks

Table A.1. Categorical Codebook for Qualitative Data			
Code name	Description	Frequency	Example
Background info*	General information about Ghana and the state of its marine resources, management, and research	22	"People believe dilution is the solution to pollution so they take boatloads of trash out and empty it."
Capacity individual	Mentions of individual capacity that do NOT relate to child codes; definitions of capacity building	42	"Being able to provide that link between the great possibilities and what they can really achieve."
Instructor capacity	When instructors discuss building their own capacity, directly or indirectly	27	"I've been wanting to work on teaching and communicating science and this was an opportunity for me to."
Learner capacity	Parent code	0	N/A
Knowledge*	Knowledge or information learned; NOT a tangible skill or ability	164	"Marine biogeochemistry and concepts of tides."
Research partnerships	Building capacity by developing research partnerships; includes ALL mentions of relationships, communicating, networking, and making friends	97	"Get to know people from other countries I can count on if I need data from their country."
Research skills	Learners' perceptions of their ability to conduct research; a tangible skill or ability, NOT just knowledge or information	107	"Python programming language."
Science attitudes	Learner attitudes and beliefs toward science careers	77	"The organism in the ocean are more important and need preserved."
Career intention pre*	Responses to presurvey question: Do you intend to pursue a career in science, why or why not	60	"Because science carries the solution to the world's problem."
Career intention post*	Responses to postsurvey career intention question	78	"Because it seems a bit difficult for me."
Capacity institutional	Mentions of extent of impacts on an institutional/ university level	20	"We have realized that we also have to start oceanography and hydrography course."
Capacity systemic	Mentions of extent of impacts on societal/systemic level	16	"At a higher level, at the society level, we may not see it now."
Methods	Researcher notes about method plan and execution	36	"After lunch I interviewed [name] over in the neighboring courtyard."
Improvements	Researcher notes about what could have gone differently	2	"Recording conversations could have provided interesting data."
Program evaluation	Parent code	0	N/A

*Indicates code was not a part of the initial code book.

Table continued on next page

Table A.1. Categorical Codebook for Qualitative Data *cont'd*

Code name	Description	Frequency	Example
Instructor expectations	Parent code	0	N/A
Future direction	Instructor expectations for direction program should take in the future	81	"Going forward I am looking forward to a school that is focused."
Instructor pre	Instructor expectations of the program, their role, and what they would take away from it	41	"I expected to interact with undergrads primarily and teach oceanography at the intro level."
Instructor post	How instructor expectations compared to their experiences; outcomes for the program, their role, and themselves	47	"It's really much bigger than I thought it would be initially."
Perceived learner pre	Instructor perceptions of why learners attend the program; NOT instructor expectations for the program structure	21	"They want to learn about what is being done in other countries."
Perceived learner post	Instructor perceptions of what learners are taking away from the program	29	"So I think that it gives them the sense of here's what these people do outside of teaching."
Learner expectations	Parent code	0	N/A
Learner pre	Expectations for the program that do NOT relate to child codes	27	"To enhance my knowledge and build more guile in problem solving."
Learn pre*	Responses to presurvey: what other topics do you expect to learn	65	"Ways by which participants can help protect marine lives in our various countries."
Opportunity pre*	Responses to presurvey: what other opportunities do you expect to have	47	"How to get funding for research."
Learner post	Self-perceived outcomes from attending	22	"How to use Python."
Learner post-post	Self-perceived longer term outcomes/impacts from participating	47	"It has aided my level of thinking and its application to my dissertation."
Researcher observation	Field notes not directly related to the other categories	47	"The instructors rode separate from the participants on the way back because the other buses dropped the participants off at the hostel."

* Indicates code was not a part of the initial code book.

Table A.2. Thematic Codebook for Qualitative Data

Code name	Description	Frequency	Example
Professional development	Instructor perceptions of increased ability in career-associated skills and general career advancement	5	"I think just from a very basic gain is additional teaching experience."
Cultural exchange	Instructor mentions of their relative understanding of different cultures	11	"We are interacting with people from different countries so we have culture impact."
Altruism	Instructor mentions of "helping" or "volunteering" or other altruistic motivation	14	"That felt like they were going to be meaningful contributions and not charity projects."
Advancing the field	Instructor mentions of perceived and potential progress made in the field of oceanography	18	"It's really important to have international collaborations, we all have oceans."
Research skills	Learner perceptions of their ability to conduct research; ONLY include tangible tasks or skills learned	79	"I learned how to download oceanography data, how to use Python, MatLab to analyze those data."
Attitudes and beliefs	Learner perceptions of marine science, scientists, and science careers	194	"I believe science is very applicable in solving many real life problems."
Content knowledge	Learner perceptions of their basic understanding of scientific information and opportunities	121	"The school influence my choice of project topic for my undergraduate research project."
Conceptual knowledge	Learner perceptions and ability to make connections between ideas and across disciplines	22	"I am now able to better appreciate other disciplines like mathematics in the learning of the ocean."
Connections among people	Parent code	0	N/A
Socialize	Learner mentions of socializing or interacting with other learners or instructors; NOT networking	25	"I was able to make friends which I kept in touch with till this year."
Networking	Learner explicit mentions of "networking" or of implied professional connections with learners or instructors	22	"Got the chance to network with other students from different countries."
Research partnerships	Learner explicit or general mentions of forming research partnerships with learners or instructors	9	"Connecting with [instructor] to work on a project."