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Despite challenges, 2-year college students benefit from faculty-mentored geoscience research at a 4-year university during an extracurricular program

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ABSTRACT

This study details the mentored research component of a program intended to recruit, retain, and transfer students attending a two-year college (2YC) to four-year geosciences programs. Eighteen of 20 students who started the program were from minoritized backgrounds: 12 women, six racial/ethnic minorities, 12 low-income, and 13 first-generation college attendees. During a calendar year, students engaged in faculty-mentored research at a 4-year university (4YU), coursework at the 2YC, and a paid six-week internship in geoscience education. Students were to spend at least five hours weekly on research February-June and make a public presentation of results in December. Of 11 students who completed their research projects, 10 were minoritized students. Eight of 11 transferred into a science major. Students progressed the most in research when working together on a project designed for them and regularly meeting in-person with their mentors. Student exit interviews indicated that they valued the research experience and the skills gained. However, less progress occurred in the summer than planned, and students cited challenges in commuting to the 4YU due to jobs and personal commitments. Mentor-student matching produced mixed success. Based on the findings, we recommend incorporating a mini-internship with each mentor into the spring course, then pairing the students with one project and mentor for the summer and fall. Funding the research hours in addition to the internship would help alleviate financial burdens on students. Finally, all mentors would benefit from training together to better understand the mindsets of 2YC students and effectively accommodate individual needs.

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Two-year college students; diversity; geoscience; undergraduate student research; faculty mentors

Introduction, purpose, and learning goals

Few students enter undergraduate programs understanding what the geosciences are or that geosciences are part of science, technology, engineering, and mathematics (STEM) (Lewis & Baker, 2010). Geoscientists provide key knowledge for environmental issues and natural disaster planning and command high-paying, high-demand jobs (Levine et al., 2007; O'Connell & Holmes, 2011). Much of the geoscience workforce is at or near retirement, exacerbating a shortage of college graduates ready to undertake these jobs (Gonzales, 2010; Gonzales & Keane, 2009). Further, African American, Hispanic, and Native American students earn only a small percentage of bachelor's degrees in geosciences (Baber et al., 2010; O'Connell & Holmes, 2011), and a gender gap in composition of the workforce still persists (Hernandez et al., 2018). Many programs that expose students to the geosciences focus on those enrolled in a 4-year university (4YU) (Hirst et al., 2014; Wolfe, 2018), yet roughly one-quarter of students obtaining a bachelor's degree in geosciences attended a two-year college (2YC) (Wilson, 2018). As 2YCs provide important access points to higher education for minoritized students (Engle & Lynch, 2009), training and retaining 2YC students in the geosciences can help increase and diversify the professional workforce (Huntoon & Lane, 2007).

To address geoscience workforce challenges and lack of diversity in the discipline, we implemented a program designed to support and transfer minoritized undergraduate students, primarily women, racial/ethnic minorities, low-income, and first-generation college students attending a 2YC into a 4-year program while increasing their interest in geoscience-related careers. This year-long extra- and co-curricular program engaged one cohort of participants in each of three years in multiple interconnected components: a) up to three semesters of faculty-mentored research at the 4YU; b) physical geography and seminar-style, cohort-building and career-development courses at the 2YC; and c) a paid 6-week internship at an interactive science learning center (ISLC), where they designed public

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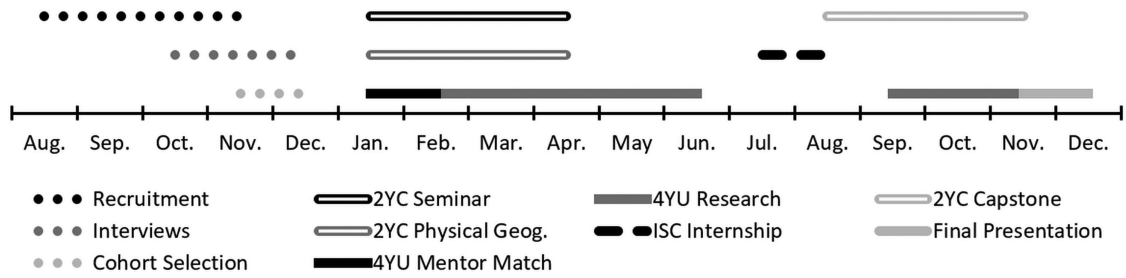

Figure 1. Annual timeline of activities for each cohort from recruitment to final presentation.

programming and teacher professional development materials to promote geoscience education (Figure 1). In this manuscript, we focus on the mentored research component (hereafter, *intervention*) of the program, including its design, outcomes, and recommendations for future programs. We explore successes and challenges in the intervention and how these were perceived by the faculty research mentors and the student participants. Our three goals are to report on 1) differences in demographics and post-program activities (e.g., transfer to a 4YU) among participants who completed the intervention versus those that did not; 2) aspects of the intervention that were associated with participant successes and struggles from the faculty research mentor perspective; and 3) aspects of the intervention that were beneficial or challenging from the participant perspective. We report on the entire program in Judge et al. (2022), including more information on coursework and the internship along with details of the recruitment and evaluation of applicants, design, revisions, and quantitative outcomes. Qualitative insights about the entire program can be found in Stofer et al. (2021).

We designed the intervention to occur throughout a calendar year to foster skill and knowledge development to help participants successfully transfer to a 4YU. Each 2YC student was partnered with at least one other 2YC participant to conduct their research under the guidance of a faculty mentor from the 4YU. Participants were to conduct research five hours per week in the spring semester and the first six weeks in summer with their peer research partner and faculty research mentor, supported by weekly meetings at the 4YU. Participants were to make oral presentations of research progress each semester and were to continue working with their mentors and partners as necessary in the fall semester to prepare for the final presentation. Our goals for the intervention were for the 2YC students to a) learn basic research methods such as reviewing literature and managing a research project, b) develop skills specific to each research project, c) systematically investigate a research question for which there was no known answer (also known as authentic research), and d) present the results of their project to an audience external to the program.

Literature context

Students from 2YCs are more likely than their peers at 4YUs to be low-income, minoritized racial or ethnic background, or first-generation in college (Crisp, 2016; Hillman, 2016). However, Hoachlander et al. (2003) reported that less than 30% of students enrolled in a 2YC transferred to a 4YU and more recently, Shapiro et al. (2017) reported only a slight increase to 31.5%. Moreover, Cohen and Kelly (2019) found that those who do not transfer more often tend to be female, from minoritized race or ethnic background, and have lower economic standing. Given these transfer statistics and the preponderance of geoscientists who started at 2YCs, efforts to recruit and retain diverse students in the geosciences at 2YCs are warranted.

Incorporating research into undergraduate experiences at both 2YCs and 4YUs helps retain students in science-based majors. Undergraduate research participation helps retain low-income and first generation students in particular (Nagda et al., 1998). Along with developing research and communication skills and disciplinary knowledge during research experiences, students interact with other students interested in STEM, increase their enrollment in STEM majors, and increase the likelihood of pursuing a doctoral degree (Davis & Jones, 2017; Kurdziel & Libarkin, 2002; Pallant et al., 2016; Russell et al., 2007). While replicating a previously-conducted project or laboratory experiment typical of some course-based research is becoming more common, authentic faculty-mentored, self-directed research (Kortz & van der Hoeven Kraft, 2016; Wolfe & Riggs, 2017) is not typically included in a 2YC curriculum. Thus, providing this type of research experience to 2YC students could help them be more on-par with their 4YU peers to facilitate successful vertical transfer.

The structure of a research experience is also an important factor in undergraduate programs because it may result in a variety of outcomes. Research experiences can either occur within the curriculum or be extracurricular or occur at different points throughout the year over different durations (NASEM, 2017). Examples include summer programs of six to twelve weeks full-time (Jarrett & Burnley, 2003; Pandya et al., 2007), semester-long course-embedded experiences (Kinner & Lord, 2018), and year-long extracurricular (Blake et al., 2013) and multi-year versions (Pallant et al., 2016). Shorter programs can fully-fund student participation and have high completion rates but may not facilitate the knowledge and skill development that a longer-duration research experience can provide (Powell & Harmon, 2014) that would be most beneficial when transferring in geosciences to a 4YU. Programs spanning

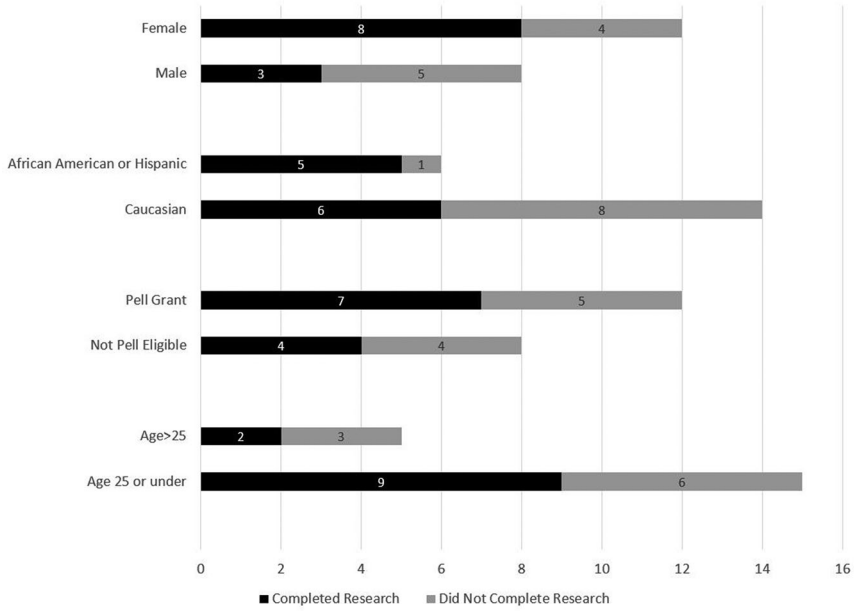

Figure 2. Demographics of 2YC students completing the intervention compared to those that did not complete the intervention. Each couplet's total adds to 20 participants.

multiple semesters demonstrate stronger outcomes in background knowledge and methodologies (Linn et al., 2015; Sadler et al., 2010) but can suffer from high attrition rates due to issues such as scheduling conflicts or loss of interest (Pallant et al., 2016).

Support from faculty mentors is a key component of a research experience, helping students to develop complex reasoning skills and professional identity as well as provide emotional support (Hernandez et al., 2017; Kortz et al., 2020). However, collaborations among faculty at 2YCs and 4YUs can foster additional positive outcomes for 2YC students. This includes providing 2YC students exposure to equipment and lab space not available at the 2YC and motivation to transfer into a 4-year STEM-related major (Hirst et al., 2014; Kortz et al., 2020; Leggett-Robinson et al., 2015). While faculty at 2YC and 4YU mentoring students together increases successful student transitions (Higgins et al., 2011), forming connections with multiple faculty at a 4YU also increases transfer capital to help students make a more informed transition from 2YCs into 4YUs (Laanan et al., 2010; Moser, 2013; Wolfe, 2018).

Research has shown that the characteristics of the faculty mentor(s) with whom the student works are vital for student success. Having active mentors who are readily available to their students and are invested in their work is critical for sustaining a high-quality research experience (Baber et al., 2010; Jarrett & Burnley, 2003; Kurdziel & Libarkin, 2002; Russell et al., 2007). This is especially important for students from minoritized populations, including first-generation college students, who may lack the social capital to know why research is important or how to gain access to these opportunities. Similarly, promoting student interactions with mentors from minoritized backgrounds is important. For example, having female mentors provides an alternate to the male-dominated culture in STEM disciplines to encourage more women to participate in undergraduate research (Hernandez et al., 2018; Pugh et al., 2019).

Study population and setting

Our program engaged 20 2YC students as participants across three years of the project. This included 7 students in 2016, 7 students in 2017, and 6 students in 2018. To accommodate the available funding, we structured the program to offer up to six 2YC students paid internships at the ISLC each summer (18 students total) based on their progress in the spring coursework and intervention. However, we accepted additional participants in the program to extend the benefits of participating in the intervention and coursework to more 2YC students. According to student records, the percentages of our 20 participants in minoritized demographic categories were: 65% first generation college students, 60% female, 60% Pell grant recipients, 30% African American or Hispanic, and 25% older than 25 years (Figure 2). Only two participants did not fit at least one minoritized category of demographics. Half of students joined the program in their second semester at the 2YC; half were in their 3rd-9th semester. On average, participants had accumulated 37 credit hours (range 9-64) through dual enrollment, Advanced Placement, and/or post-high school coursework. At the time of application to our program, six students had declared Associates degree transfer tracks in engineering, six in biology/life science, and one each in math, business, exercise science, and general studies. Only four intended to track into geosciences-related majors.

The program took place in the southeastern U.S., where the two campuses (2YC and 4YU) are in the same city with

a population ~130,000. In 2015-2016, the 2YC campus enrolled ~21,000 students, and of that total, 55% were female, 57% White, 17% Hispanic, and 16% African American. Half of students enrolled part-time rather than full-time. By contrast, the 4YU is a doctoral university with very high research activity (Indiana University Center for Postsecondary Research, 2018) and enrolled 34,000 degree-seeking undergraduate students in the fall of 2015 with 55% female and 57% White as well, but 20% Hispanic, and 6% African American. Only 16% of students enrolled part-time. The total student population was 52,500 at the 4YU. The ISLC is 120 miles away in a metropolitan area of 2,002,000 people.

Materials and implementation

Program personnel

The six-member leadership team came from the three institutions and selected participants, continuously reviewed the program, discussed student challenges, and provided peer-mentoring to each other. A White immigrant female physical geography faculty member at the 2YC and a White female science education faculty member at the 4YU (Intervention Mentor A) co-developed and obtained funding for the program. From the same 4YU, they recruited the third and fourth team members: a White female climatologist (Intervention Mentor B) and a South Asian female soil hydrologist (Intervention Mentor C). The ISLC's White male Vice President for Visitor Experience served as the fifth member of the leadership team. The sixth member was an East Asian male faculty honors program advisor from the 2YC.

Leadership team members all had additional roles. The 2YC physical geographer taught the three program-required courses at the 2YC. Intervention Mentors A, B, and C mentored the participants in the intervention at the 4YU, providing instruction, support, feedback, and assistance to develop their final presentations. The member from the ISLC headed a group who coordinated the internship. The honors program advisor mentored the student participants and helped them schedule courses at the 2YC to minimize conflicts with program activities.

Three additional faculty members from the 4YU served on the program's Advisory Board. Member 1 was a White female fluvial geomorphologist and former undergraduate coordinator in the Department of Geography. Member 2 was a White male lecturer in the Department of Geological Sciences and coordinated undergraduate field research experiences. Member 3 was a African American female professor of science education in the School of Teaching and Learning. Board members conducted the annual student exit interviews, which was their only interaction with the participants. The Board met with the leadership team annually to discuss all program components and provide recommendations based on comments from participant exit interviews and leadership team reflections. The Board also conducted a final evaluation of the program leadership at the completion of the project.

In Years 2 and 3, the 4YU faculty hired students at the 4YU as peer research mentors in response to participant feedback and in consultation with the advisory board. These peer mentors assisted participants with troubleshooting research problems, attended the weekly and monthly research meetings at the 4YU, and answered participant questions about attending a large 4YU. Mentors A and B employed undergraduates. Mentor A employed the same student in both years. Mentor B employed a student in Year 2 who was familiar with the analytical methods. In Year 3, Mentor B employed a participant from the previous cohort who successfully completed the intervention and transferred to the 4YU. Mentor C employed two graduate students as mentors in Year 2 but did not hire a student mentor in Year 3.

Intervention design and implementation

We designed the intervention component similarly to Hunter et al. (2007) in that typically, a faculty member at the 4YU worked with two students from the 2YC and held weekly meetings to provide help with research activities such as protocol preparation, data collection and analysis, interpretation and presentation of results. However, our intervention occurred over multiple semesters (Figure 1) to increase research skill gains rather than only in summer (Haeger & Fresquez, 2016). For example, in spring and summer, students practiced presentations on their research for all students and mentors and received feedback from the research mentors on these presentations via a rubric (Supplemental Materials S1) to help develop oral communication skills prior to their final presentation in December.

The projects that the 2YC students could pursue differed in terms of topic area, whether or not they developed their own research questions, the level of instruction provided, types of skills built, and inclusion of a field component (Table 1). Mentor A's students investigated how the public perceives scientific data visualizations. Over the three years, students used Geographic Information System (GIS) to produce test visualizations and designed a survey instrument (Year 1) and qualitative interviews, then collected data on the 4YU and 2YC campuses and eventually online (Year 2) and analyzed the data (Year 3). Students working with Mentor B used GIS to analyze the rainfall patterns of tropical cyclones that impacted African countries. Students worked together to hone their computational skills as they followed precise instructions to analyze then compare different storms, adding to the database of measurements each year. Students paired with Mentor C selected one of her externally-funded projects in hydrology and remote sensing and developed their own geoscience research questions to pursue within the scope of that project. These participants also performed fieldwork at sites located 40-50 minutes from the 2YC campus; they generally carpooled from the 4YU campus. While Mentor C relied on email to communicate between meetings, Mentors A and B used an electronic project management and collaboration hub (Slack) to post

Table 1. Differences in project guidance, skills, and modes of investigation among the three mentors.

	Geoscience education	Climatology	Soil hydrology
Project Design	Mentor designed new project to dovetail with current research in her lab with visualizations from Mentor B and C's research	Mentor designed project to measure raining areas associated with tropical cyclones over the Indian Ocean and compare storms.	Students designed projects complementary to ongoing federally-funded research led by the mentor and worked on by her 4YU students
Guidance Structure	Students pursued one of two related research methods – quantitative survey or qualitative interviews - and answered co-developed research questions	Provided precise instructions and codes to develop database to answer pre-defined research questions and visualize results	Students select from ongoing projects for which they develop their own research questions and methodologies
Year-to-year Coordination	Students worked on different phases of the overall project each year based on interests and previous progress	Each student utilized the same methods to contribute 1-3 storms to a database that grew each year	As students could select from multiple projects, there was no coordination from year to year
Skills Developed	Visualization design, survey instrument design, interview guide development, interviewing, field-based data collection, IRB proposal preparation, statistical analysis, qualitative analysis	GIS/ spatial analysis, executing Python codes, database design, graphing of results, statistical analysis, data visualization, basic knowledge about how tropical cyclones produce rainfall	Installation, calibration, and analyses for field sensors, micro-meteorological stations, and microwave remote sensing equipment. Soil and vegetation field sampling protocols to enable calibration and validation of hydrology and crop models
Modes of Investigation	Online and in-person surveys, in-person interviews; students work in pairs	Computer-based, accessible via internet; students work in pairs using same methods	Offsite field work with equipment and field sampling; students work in pairs or separately

messages, upload screen captures of error messages, and share presentation drafts.

In August each year, prior to the program's January start (Figure 1), recruitment of 2YC students began through activities such as in-class announcements, tabling at the volunteer fair, and posts in the student newsletter. The application included a section that directed students to the websites of the 4YU mentors and asked them to write an essay describing which mentors they wished to work with and why. In total, we received 34 applications during the three program years. The 31 applicants who would not graduate during the program year and attempted the essay were invited for an interview. Twenty-nine students completed interviews. The leadership team discussed and evaluated applicants based on their suitability for mentored research and stated interest in geosciences. Two students did not demonstrate effort to engage professionally during the interview and were not accepted into the program. We offered 27 students acceptance into the program. Twenty students began the program in January, signing letters of commitment (Supplemental Materials S2) which included the program's weekly research requirement.

In the spring semester starting in January (Figure 1), participants began the intervention while taking two courses as part of the program. They enrolled in a 3-hour Physical Geography course where they were introduced to GIS. They also took a 3-hour seminar for program participants only, whose time commitment included research-related activities such as weekly meetings with research mentors (Supplemental Materials S3). They were to participate in the intervention at least five hours each week of spring semester, including a weekly hour-long team meeting at the 4YU. While spending 10-15 hours per week performing lab-based research is common for undergraduate research experiences during the academic year (NASEM, 2017), we reduced the minimum intervention hours to accommodate student employment, additional program activities, and other commitments, though students could work more.

During seminar class time in January, students traveled to the 4YU to gain familiarity with the campus and learn about the available research projects. The students rode the city bus alongside the 2YC instructor to learn the routes. Frequent public buses offered access to the 4YU campus to 2YC students for free, as parking is scarce and expensive. Regular meetings such as these help familiarize students with a large institution's campus to lower the intimidation factor to promote student transfer (Hirst et al., 2014). Participants also met with other students from each mentor's discipline to grow their networks in geosciences. Once each month, we scheduled the regular weekly meeting with 4YU mentor and cohort research partner(s) during the three-hour seminar class time to reduce the burden on students to find extra time in their schedules to travel to the 4YU for meetings (Supplemental Materials S3). Students had to maintain satisfactory progress in the intervention during spring, as evaluated by the intervention mentors using a rubric (Supplemental Materials S4) and pass both courses to be eligible for the paid summer internship at the ISLC.

The first six weeks of summer semester also featured the intervention. We set a minimum expectation for 5 hours per week of research-related activities, including continued weekly meetings, in anticipation of the likelihood that students would need to maintain outside employment. Due to limited funds, we could not pay students for their time in the intervention. Even though they did not incur fees to undertake research, there was a cost to participants in terms of their time. During the final six weeks of the summer, eligible students lived in the city of the ISLC and worked at the internship full time, receiving a stipend for food, housing, and employment.

In the fall, participants took a 3-hour capstone course where they finished the intervention, took field trips to local

geoscience employers, prepared transfer applications to 4YUs, and assisted recruitment of the next cohort. During this semester, weekly research meetings at the 4YU were not obligated. In December, they presented project results to audiences outside of the program as part of their capstone requirements. We define successful completion of the intervention as delivering final presentations that demonstrated progress each semester.

Evaluation

We collected three types of data to inform the program and its modifications and to evaluate its efficacy. To assess activities of different groups of students (Goal 1), we report student demographics, reasons students left the program, transfer to 4YU majors, and post-program activities. Demographics came from 2YC student records. Reasons for leaving the program were communicated to the 2YC instructor in person or through email. We collected information on transfer and post-program activities via responses to emails sent by the 2YC faculty to all past participants. We also noted when participants contacted the 2YC or 4YU mentors for reference letters to support their post-program activities.

The second set of data was the assessments of research progress that originated from the 4YU faculty research mentors. We examined these assessments to evaluate Goal 2: determine what aspects of the intervention were associated with the most student success from the faculty research mentor perspective. The faculty research mentors each assessed our own students' research progress using a rubric (Supplemental Materials S4) devised collectively with guidance from Singer and Zimmermon (2012) Table 1. We discussed student progress during each semester among ourselves to ensure consistency among the individual ratings and completed the rubrics individually at the end of the spring and summer. We rated each student's progress in four categories: communication, preparation for and participation in weekly meetings, improvement of research skills, and progress in research practice. We based ratings on meetings with students; weekly activities reported on time sheets, at meetings, and in research notebooks; research presentation content and style; reports from 4YU peer mentors; and email and posts to the electronic project collaboration hub. The rubric served as a guide as not all mentors reported every item in each category each semester. For example, Mentors A and C did not require a research notebook. Earning overall satisfactory ratings for each of the four categories resulted in a score of 100%. As we did not require weekly meetings in fall, we only evaluated participants on whether they presented research that showed progress throughout the program. At program's end, we reviewed these data to contextualize the different rates of research progress and completion when data are aggregated by semesters, cohorts, or project characteristics.

To examine the intervention from the student perspective (Goal 3), we reviewed the exit interviews of students conducted by the external advisory board at the end of each year. Mentor A drafted the interview questions using a pragmatic framework (Peirce, 1982) designed to elicit answers about student experiences in the program and areas for improvement. In conjunction with the advisory board, the leadership team reviewed the questions and together finalized the protocol. Questions asked about experience with each of the program components, the mentors, and their fellow participants (Supplemental Materials S5). For exit interview results pertaining to the entire project, please see Stofer et al. (2021). All students in the capstone course, plus two who maintained contact with the 2YC instructor after dropping out of the program, participated in the interviews. The interviews took 20-25 minutes each. The advisory board recorded and transcribed the interviews verbatim and shuffled answers to each question to protect the identity of the participants before providing transcripts to us.

To determine which interview responses included the research experience, Mentor B analyzed the transcripts using inductive reasoning. She searched for keywords of *research*, *mentor*, *presentation*, and *conference*, the name of the 4YU, and the mentor names. She used the context of each statement to determine if the student was describing a benefit or challenge and grouped responses into themes. Once a theme arose about hours required and work commitments, she additionally searched all responses for keywords of *hours*, *time*, *work*, *schedule*, and *job* to identify specific comments about this issue. After identifying the responses about the intervention, she shared the results with her coauthors for clarification and revision of coding process.

Results

Goal 1: Student intervention completion rates, demographics, and post-program achievements

In all, 11 of 20 participants (55%; 78.5% of the 15 enrolled in the fall capstone) met our definition of completion for the intervention. Five of these students identified as African American or Hispanic, eight identified as women, seven were Pell grant recipients, and seven were first-generation students (Figure 2). Eight of the 11 students have transferred to a 4YU, with seven transferring to this program's 4YU. At their transfer schools, three declared majors in geography, two in biology, and one each in aerospace engineering, mechanical engineering, and wildlife ecology. Of the three remaining students, at the time of writing, one was still enrolled at the 2YC, and two were applying to 4-year programs after finishing their AA degrees. The three had intended majors in biology, chemical engineering, and accounting. Although we cannot solely credit the intervention for these outcomes, we do assert that the skills participants gained should benefit them in their 4YU majors.

The following events during and after the program suggest that the intervention helped to increase interest in the geosciences. While nine students shared final presentations at the 2YC, including oral presentations at the Honors Program Symposium and one poster at the Undergraduate Research Symposium, two students presented outside of the

Table 2. Nine students that did not complete the research component and reasons for not doing so that encompass all program elements.

Student	Cohort	Circumstances
1*@	Year 1	Little summer participation due to Study Abroad, final presentation for capstone credit only as it did not demonstrate progress beyond spring
2,3#	Year 1	Two students dismissed after accepting the stipend but not showing up for work at the ISLC and could no longer be contacted
4*	Year 1	Undertook research spring and summer but did not participate in capstone course or deliver a research presentation and dropped out of college
5#@	Year 1	Left in September due to concerns over maintaining 4.0 GPA, little summer research participation due to personal travel prior to undertaking the internship
6*	Year 2	Did not select a research mentor after January 4YU visit, ineligible for internship due to lack of research progress in spring, left the program
7*	Year 2	Ineligible for internship due to poor grade in Physical Geography, did not progress in research during summer due to family reasons; final presentation for capstone credit only
8	Year 3	Ineligible for internship due to poor grade in spring seminar, left program
9*#@	Year 3	Struggled with medical issues and research mentor mismatch in spring, left program

Note. * indicates that the student participated in the exit interviews, # indicates that the student did not get to work with their preferred mentor, @ indicates that the student worked alone.

Table 3. Average 4YU faculty ratings of student research progress spring and summer, and number of students delivering final presentation that demonstrated research progress each semester for each cohort. *n* is the number of students in the program at the beginning of that semester.

Cohort	Faculty Ratings Spring (*n*)	Faculty Ratings Summer (*n*)	Fall Presentation (*n*)
Year 1	79% (7)	43% (7)	2 (5)
Year 2	82% (7)	83% (6)	5 (6)
Year 3	75% (6)	75% (4)	4 (4)
Overall	79% (20)	65% (17)	11 (15)

Note. Overall ratings averaged each score available for that group. Scores were derived from rubric in Supplemental Materials S4.

Table 4. Average (standard deviation) rating for participants showing more progress (75-100%) and less progress (0-50%) for each semester in each of the four rubric categories.

Term	Rating (n)	Quality and frequency of communication	Prepare and participate weekly meetings	Improvement in research-related skills	Progress in research practice
Spring	75-100% (12)	0.83 (0.22)	0.85 (0.17)	0.88 (0.20)	0.79 (0.21)
	0-50% (8)	0.41 (0.35)	0.50 (0.38)	0.66 (0.40)	0.53 (0.41)
Summer	75-100% (9)	0.86 (0.18)	0.86 (0.18)	0.97 (0.08)	0.89 (0.18)
	0-50% (8)	0.28 (0.25)	0.41 (0.33)	0.50 (0.40)	0.28 (0.31)

2YC at a regional Geography conference. After finishing our program, five students, all female, continued mentored geoscience research. One presented their additional research at the Southern Regional Honors Council and another at the annual meeting of the American Association of Geographers. Two applied to participate in Research Experiences for Undergraduates opportunities. Two continued their research with Mentor B, one in conjunction with the McNair Scholars program. Mentor A offered employment to one of her mentees.

In terms of retention, while 20 students began the program, 17 participated in summer, 15 remained at the beginning of fall, one departed in September, and one did not participate in the fall capstone or deliver a research presentation. Two students who did not progress in the intervention beyond spring remained in the program to take the capstone course; they gave presentations to satisfy course requirements, but we did not count these students as completing the intervention as they did not demonstrate progress past spring semester. Participants faced difficulties with each of the three components: the research intervention, coursework, and internship, that ultimately impacted their program completion (Table 2). In all, three students did not make enough progress to complete the intervention, two students did not meet the coursework requirements and did not continue with the intervention, two students left the program for personal reasons, and two students who committed to the internship did not finish it and left the program. We have current information for six of the nine participants that did not complete the intervention. All six have transferred into four-year programs and declared majors in geology, geoscience, environmental geoscience, geography, mechanical engineering, and wildlife ecology. Three of these transfers were to the program's 4YU. The status of the remaining three is unknown.

Goal 2: Faculty perspectives on what led to intervention successes and challenges

Based on our rubric, students had different levels of intervention progress during each semester and among the three cohorts. Student progress was highest during spring with a 79% average score across the three cohorts (Table 3). Twelve students of 20 received a satisfactory rating in all four categories during spring, though only eight eventually completed the intervention. Although scores were lower during the summer overall, summer ratings were higher for Years

2 and 3 compared to Year 1, potentially indicating a better-structured program. Also, five of 11 participants who completed the intervention were unsatisfactory in at least one category in spring and/or summer, suggesting that students were able to overcome struggles and complete their projects.

The research mentors noted characteristics of students that made the most versus the least progress in the intervention as guided by the rubric (Table 4). Participants who had more satisfactory ratings in the category "Quality and frequency of communication" made more progress than those with more unsatisfactory ratings in this category in both spring and summer. Mentors A and B frequently used the Slack electronic collaboration hub to troubleshoot problems between meetings, and participants who posted multiple times between meetings and could effectively articulate their problems made the most progress. Particularly in summer, students making more progress had higher scores in "Progress in research practice." For the geoscience education researchers (Mentor A), students struggling to fulfill the time requirement could not make progress between meetings. Although the data processing tasks in the hurricane project (Mentor B) challenged all students, those who did not ask questions or take notes during meetings made less progress. Students who participated in the soil hydrology projects (Mentor C) made less progress if they did not convene outside of regularly scheduled meetings.

Goal 3: Student perceptions of factors that impacted their intervention success

Sixteen participants gave interviews, including the 11 that completed the intervention. As all comments were anonymous, we cannot separate responses from those who did complete the intervention from those who did not complete the intervention. Only one question and its follow up directly asked about the intervention: "how involved or committed did you feel to the research with 4YU mentors in spring, summer, and the fall semesters? How did that change over the course of the year and why?" However, students frequently spoke about the intervention in response to questions concerning expectations for the program, what they had wished to know before entering the program, and how to prepare future cohorts for the program. Half of the students mentioned an aspect of the intervention in response to the question, "What was the most valuable part of the experience to you? Why?" Given the variable nature of each student's experience even within the same mentor's lab and same program year and the qualitative focus of these results, we do not exclusively report quantitative frequencies but include the breadth of examples forming each theme.

We start with the positive aspects of the intervention that participants mentioned. Students noted increased knowledge of the literature and the scientific method, and enhanced their presentation skills, saying "[I] got a lot of public speaking experience that I didn't have before and presenting experience." They also learned perseverance; "[research] helped me learn more about the scientific method and get more comfortable with the fact that it's not always gonna be right the first time … you're gonna have to keep trying." Participants also cited receiving frequent feedback, encouragement, and career advice from their 4YU mentors as benefits. More specific to our program, they mentioned positive gains from working at the 4YU while conducting their research, learning about both quantitative and qualitative research, interacting with multiple mentors at the monthly project-wide meetings, and learning about types of research that they did not know were a part of the geosciences. One student said, "I liked doing the research portion. I liked how connected all the mentors were, getting to work with just my mentor, but also getting to kind of branch out with the others. … I did not know geosciences were so broad." Students mentioned finding out both what they did and did not want to do in their careers. For example, two students in Year 2 who worked with the same mentor had opposite reactions: "I got to work in the group that I really wanted to work in and really enjoyed the hurricane research … I ended up continuing past it and just doing more," compared with "[I] definitely don't want to do anything with weather, or climate. Because of this program, I realized this doesn't interest me." From the research projects themselves, students reported benefits of learning computer skills and getting hands-on experiences in the field. One student said "the computer databases they were working with all seemed really confusing, but once I understood what they were, and their role in everything, that boosted my confidence."

Student feedback also underscored some of the challenges they faced regarding their success in the intervention. In response to four different questions in the exit interviews, students remarked about the amount of time required for research. The extra hours outside of class time dedicated to research and the need to travel to the 4YU campus posed logistical challenges for half of the participants interviewed, as the comments in Table 5 are from at least eight different participants of the 16 interviewed. The responses reveal that several participants worked full-time jobs.

Participants struggled with the setups of projects and level of mentor guidance. They wanted to know more specifics about the projects and mentor personalities. A Year 1 student said, "have more of a detailed description on each mentor." Some participants wanted more teamwork, as two comments from Year 1 were, "I expected a lot of research to be done with a cohort … I thought teamwork was going to be a vital thing," and, "I didn't have support from my teammate." Students did not anticipate developing their own projects, "I expected I'd do more existing … the professors' research, as far as what they were working on, rather than doing my own." Some wanted more guidance, "I know they can't hold our hands. But with certain steps I think it would be better to be shown what to do and helped along." Others felt surprised that there was a steep learning curve, "It was kind of expected to have some skills I didn't exactly have, and had to kind of learn on the spot, which was difficult," and, "I'm a 20-year-old kid, I should be somewhat sufficient

Table 5. Selected student comments about time constraints related to research. Question numbers correspond to Supplemental Materials S5.

Year 1	Year 2	Year 3
"It was hard to work with the research because … you'd have to retain some amount of hours per week. . . . and you have to keep track of it all." (Q12)	". . . I only work 40 hours a week. That's not that bad. But, then, as summer came, and I had to work 70 hours a week, I didn't have time [for research]." (Q12)	"It took an hour each way for an hour meeting to go meet with my mentor. That was just not feasible for some classes that I had." (Q5)
"It definitely got, summer especially, very busy. Didn't have too much time, but it did get a little better in the fall." (Q12)	"I'd go to work 8-1 Fridays, then we'd have our research meeting I think at 2 or 3 at [the 4YU]. Then I'd have to go to work again at 5." (Q6)	"I thought of course, I could balance this with my class schedule and working full time, but it was a little difficult." (Q5)
"I did not expect the research part to take so much time." (Q1)	" . . . I had taken time out of my schedule, to be able to go [to the 4YU] two days a week." (Q12)	"I think it would be a lot better if there was a way for us to park on the [4YU] campus." (Q17)
"The research took a lot of hours." (Q5)	"I just worked 15-16 hours, I don't wanna [do research]." (Q12)	"I don't really get financial aid so I work like 40 hours a week." (Q5)

Note. Responses to the same question were taken from different respondents.

in technology, so I thought. I felt like the stuff that we were doing was a little bit beyond me."

Some students had good experiences with their mentors. Examples of comments from the exit interviews included "working with my mentor was great," "I really like working with [4YU mentor], "For me working with [4YU mentor], … helped me learn that I really do like research," "meeting [4YU mentor] was huge," or, "I liked my mentor." However less favorable comments included that their mentor seemed "too busy" or "[she] comes across super harsh." One participant wanted "more pushing from the mentors," while another said, "I feel like we need the right mentors." Additionally, a comment from Year 3 was, "one of the mentors kind of stopped mentoring midway through the program."

Interpretation and discussion

Programmatic changes

The leadership team made multiple mid-stream adjustments to the intervention during and after Year 1 to accommodate participant needs based on our reflections, advisory board suggestions, and the exit interviews. The higher progress scores (Table 3) and intervention completion rates for Years 2 and 3 (67-71%) as compared to Year 1 (29%) suggest that the changes we describe below were successful. For example, as some participants did not own computers on which to conduct their research, the program purchased and loaned laptop computers to all students. We used video conferencing for monthly participant project presentations for those who could not attend in person such as ISLC staff. We added 4YU peer mentors and used Slack as a communication hub to share academic and extracurricular opportunities and channels were established for each research mentor's cohort to facilitate communication between meetings. To encourage participants to finish the program, they received $300 of the stipend after their final presentation as opposed to receiving all funds prior to departing for the ISLC in June.

Another important change concerned research mentor selection. In the first year, participants selected mentors at the time of application and the leadership team matched mentors and students prior to January so that equal numbers of participants worked with each mentor. As there are multiple strategies in which mentor-mentee matching can occur (Bell & Treleaven, 2011), we changed our approach based on participant feedback. In Years 2 and 3, participants selected mentors after the 4YU campus visits where faculty mentors presented about the available projects. Although this strategy allowed students to learn more about the projects, and four changed preferences from their initial choice on their application, an uneven distribution of mentor selections caused problems. For example, perhaps due to the active 2017 hurricane season, most of the students in Year 3 wished to research hurricanes, and none of the students selected one of the other mentors as their first choice. That mentor worked with two participants who selected her as their second choice; neither participant completed the intervention with this mentor.

Intervention success and associated factors

More than half of participants completed the intervention (55% overall, 78.5% of students who remained in the program during its last semester) despite drawing from non-geoscience majors. Only four of 20 students were in tracks to transfer into geoscience degrees when they started the program. As described above, we had success when involving minoritized students in geoscience-based research. Over 70% of the intervention completers have transferred to a four-year program with STEM majors, which is comparable to Hirst et al. (2014) 75% transfer rate in their summer research program for geoscience majors. Although we cannot directly connect this success to the intervention for most cases, our results support Hewlett's (2018) statement that undergraduate research experiences at 2YCs benefit diverse groups of students.

We found three key attributes present when participants made the most intervention progress. The first attribute involved project design and teamwork. As shown in Table 1, Mentors A and B encouraged students to work in pairs and offered more structured projects, whereas Mentor C asked students to develop their own research questions and methodologies and they could work separately. Students seemed to be less successful when they worked on different projects and had infrequent interaction with their faculty

mentor. In Years 1 and 3, the students working with Mentor C chose to pursue individual projects. They had little to no communication with Mentor C during the summer, and none in the fall. Two of these students left the program, and one stayed in the program to take the capstone course but did not complete research (Table 2). However, more success occurred when a Mentor C student switched to Mentor B in the summer of Year 3 and completed a project after working closely with Mentor B and the 4YU peer mentor into the fall semester. Also, Mentor C's students both completed the intervention in Year 2 when she encouraged them to work together so that they used common data and methods. That was also the year when Mentor C hired graduate students as peer mentors. Studies have found that undergraduate research experiences improve when students work with teammates (Lopatto, 2010), and our results support a teamwork approach to undergraduate research.

The second attribute that corresponded with increased progress is the amount of time students were able to spend meeting with their 4YU mentor or the other participant working with the same mentor. Mentors A and B met weekly with their participants at the 4YU, or online to accommodate special situations, and these participants made more progress overall. Mentor C was not as consistently available. Less time was spent in meetings during the summer of Year 1, likely accounting for the reduction in student progress (Table 3). In this summer, one student traveled out of state with Mentor C to assist on a project unrelated to our program and was unable to routinely meet remotely with her chosen 4YU mentor (B) or research partner. Her progress slowed and her partner also began communicating less with their mentor. Additionally, one student working with Mentor C elected to earn college credits through a study abroad program, and the other traveled extensively. Thus, neither the mentor nor mentees of this group were available for in-person meetings, and intervention progress slowed. Similar to our experience, Jarrett and Burnley (2003) reported mixed success from a student team whose faculty mentor was less consistently involved. Spencer (2007) found that when mentor-mentee relationships were unsuccessful, mentor abandonment was the most prevalent reason, and participant feedback suggested that they felt abandoned in some cases, particularly in Year 3. Our experiences support studies showing that in-person meetings and participation in group discussions increases student success (Linn et al., 2015), and that undergraduate research mentors should dedicate time to one-on-one hands-on mentoring (Davis & Jones, 2017).

The third attribute was a mutual mentor-mentee match. When creating a match, behavioral patterns and personality are key considerations (Piper-Hall, 2016) and student feedback suggests that we made both successful and unsuccessful pairings. Five students did not receive their first choice of project and mentor, and three of these students did not complete the intervention (Table 2). In Year 3, two students who did not receive their first choice wished to leave the program after spring, citing a lack of communication with their mentor. One of these students switched to her first choice of mentor during summer and successfully completed the intervention. The other participant left the program. One student in Year 2 did not select a research mentor after the 4YU faculty presentations. We paired them with the mentor they indicated on their application, but the participant remained uninterested and did not make progress in the intervention during spring (Table 2).

Issues related to lower student progress rates

The intervention setup differed in spring and summer, with participation and progress highest in the spring (Table 3). Two factors likely account for the higher spring progress. First, we incorporated tours of 4YU mentor labs in January and monthly research group presentations and time to meet with 4YU mentors into the 3-hour block of time for the seminar course. Second, students needed to demonstrate satisfactory intervention progress to qualify for the paid internship, and student comments indicated that this was a strong motivator. Maintaining research throughout the six-week summer session when we offered no other team-building activities or required courses (Figure 1) was more challenging. Students received their living stipend in May so that they could secure lodging for the internship but did not receive salary to participate in the intervention. Problems with mentor-mentee relationships may also have contributed to drop-off during the summer. Additionally, nine of 17 students enrolled in one or more courses at the 2YC, and some worked full-time jobs. Based on prior work indicating that transfer students from 2YC work 20 hours per week (Crisp, 2016), we limited summer research to only 5 hours per week to accommodate work schedules. However, we did not anticipate the 40+ hours of paid work per week that students reported in Table 5. In contrast, only 11% of students reported financial and time commitment issues in Hirst et al. (2014) 2YC summer-only research program, though faculty did notice some impacts of external jobs on research productivity.

We also saw issues with time commitment related to research-based travel which the leadership team could have addressed better. Students struggled to travel to the 4YU for meetings and to undertake the research (Table 5), though we had built in this aspect to the program to familiarize them with the 4YU campus. Although some projects could be worked on via remote access to specialized software, others required field work which increased travel demands. We did not pay enough attention to whether students might have problems with travel when matching participants to projects.

Spencer (2007) found that mentors and mentees often had unrealistic expectations about what would occur during the mentoring relationship. In our program, research expectations differed among the faculty. When participants' mentors offered a different type and amount of guidance than what participants might have needed, or mentors asked participants to perform tasks that they were not well-prepared to perform, such mismatches likely impeded progress. The research mentors were used to working with 4YU students and likely did not handle setbacks in a way that best supported the needs

of the 2YC students. Powell and Harmon (2014) reported differing student abilities in their research experiences for freshmen and sophomores, which were challenges that we faced as well. Also, student comments in all three years stated that they did not realize the time needed for the intervention (Table 5). According to Hewlett (2018), community colleges tend to lack a research culture, so it is understandable that students did not have realistic expectations about the commitment they had made to the intervention.

Limitations

While our program successfully involved 2YC students in faculty-mentored geoscience-based research intervention at a 4YU in addition to undertaking coursework and a paid internship, our funding limitations meant that only 18 students could participate in all three components. Given the diversity of backgrounds and varying degrees of success with different program components within the small sample size, we cannot determine whether the intervention itself or in combination with the other components increased the likelihood of student transfer into geoscience majors at 4YUs. We do not know how pervasive any given benefit or challenge was, and we are missing valuable suggestions for program improvement from the four students who did not participate in the exit interviews. As we protected participant confidentiality, we cannot compare responses of those who did and did not complete the intervention to better recognize participant-identified factors leading to less research progress, and to identify which factors caused struggles even for those that did complete their projects. We also cannot link participant comments to their mentor to explore why pairings were more or less successful. As the intervention mentors provided different types and amounts of guidance, expected different levels of independence when conducting the research, and some students conducted fieldwork while others did not, it is not possible to identify one approach as producing the best outcome. We also did not design our evaluation methods to specifically address the intervention's role in overall program success or to track specific knowledge and skills participants gained. The composition of the 4YU faculty could have affected recruitment and how students interacted with us, as the three women were either white or South Asian so that they did not represent a range of race and gender. As two of the intervention mentors led the writing of this manuscript, our biases may also have influenced the interpretations of the data.

Implications

The following improvements could help increase 2YC student success when undertaking research at a 4YU in a multi-phase program. We designed these suggestions to address challenges experienced with the mentor-mentee matching process, time commitment and summer progress, lack of training for 4YU mentors in preparation for working with 2YC/underrepresented students, and varying levels of commitment by the faculty mentors.

The first recommendation is to have 4YU faculty present their research at the 2YC during the recruitment period so that students have a better idea of the projects they might undertake. Faculty can share their mentoring styles and profile other people the participants would work with such as graduate students. This approach should expose more students to geoscience research even if they do not apply to the program and could encourage more students to apply to the program after connecting with 4YU faculty at the event.

The seminar course featured research-related practice development including library orientation and maintenance of research notebooks. However, it could also serve as a hands-on introduction to each mentor's research. To address the issues with mentor and project mismatch, we suggest allowing students to conduct research with each mentor during the spring semester. Students could spend three classes practicing with equipment and software, rotating to a different mentor each month, to determine if they wish to learn more. At the end of spring, participants could write an essay contrasting their different experiences with the mentors and level of interest in each project, to facilitate matching for summer and fall. As students do not always understand the depth to which they need to comprehend concepts to apply them in research, selecting a research project after a more thorough orientation (Linn et al., 2015) or apprenticeship (NASEM, 2017) could help increase summer commitment.

We recommend that students receive pay for their research time if funds are available. This stipend could increase the number of applicants and also the number of students able to commit to the overall program if it allowed them to reduce off-campus work. It could also increase the hours they could commit to summer research if they did not need to maintain outside employment. In addition, spreading out the stipend to encompass the research time could also help students approach research like a job.

Hayward et al. (2017) recommends that faculty receive specialized training before mentoring 4YU students in research, and Garringer et al. (2015) found that more mentor training led to increased mentor effectiveness. We further recommend that all program mentors undertake professional development *together* to understand better the mindsets of 2YC students and learn strategies to facilitate successful interactions. We received formal and/or informal training relevant to our professional roles separate from this program, but we did not collectively receive training tailored to this program. Faculty at our 2YC participate in college-sponsored workshops that increase mentoring success, student engagement, achievement, and persistence. 4YU faculty and student peer mentors wishing to work with students enrolled at 2YCs should also take these development programs which may be offered by nearby 2YCs, consultants, and professional societies.

Finally, we recommend that the person leading the 4YU efforts in the program not serve as a research mentor. Instead, their role should be to oversee the mentor-mentee matching, coordinate the research projects, and serve as a neutral contact should students have concerns about their mentor(s) or research partner(s). They also, in conjunction with other program leaders, would guide evaluation of the intervention, including selection and both formative and

summative evaluation of the mentors, with the help of an external evaluator. This recommendation echoes that of Piper-Hall (2016) who calls for the hiring of a mentor director for large programs. Faculty research mentors should also participate annually subject to renewal by the leadership team. This affords flexibility to bring in new mentors if fatigue, leave, or involvement in other projects reduces the commitment of a mentor, and/or student interests warrant incorporating another area of geosciences.

Conclusions

Despite the challenges we faced, students and faculty gained invaluable experience from our program. More than half of students completed the intervention despite the extreme pressures of maintaining high academic performance with full course schedules, working part or full time, and commuting across town for weekly meetings at the 4YU. Most students did transfer into science-based majors at a 4YU and some continued to work with their 4YU mentor after the program. Thus, presenting 2YC students with a year-long immersive experience that includes research in the geosciences can lead to successful outcomes. Many of the benefits gained by our students while undertaking mentored research, such as improving presentation skills, are in line with those reported by other studies (Davis & Jones, 2017; Hirst et al., 2014; Sadler et al., 2010). It is clear from the exit interviews that students found the intervention valuable, even in helping them identify what they did not want to do. We saw benefits of increased awareness of variety of student issues identified as challenges, both from the literature and from our experiences with the program. We also gained more direct experience working with students from minoritized groups, with different levels of academic preparation, who attended an open access 2YC. The 4YU research mentors are now better prepared to support future transfer students from 2YCs. We agree with Callahan et al. (2017) that diversifying participation in the geosciences is challenging due to nuanced individual and environmental factors. However, we encourage future programs to incorporate a combination of activities, including faculty-mentored authentic research, to increase the number of 2YC students pursing four-year degrees in the geosciences.

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Data availability statement

Supplemental and additional materials related to the Geoscience Engagement and Outreach program are available at https://osf.io/apbnv/.

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