Authentic Research through Collaborative Learning (ARC-Learn): Undergraduate Research Experiences in Data Rich Arctic Science

Formative Evaluation Report

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I. Introduction

Goal of the report

This report serves the formative evaluation of ARC-Learn. The goal of this document is to support the use of evidence to inform programmatic changes and improvements for year two of the program, during which time Cohort One will complete its second year and Cohort Two will complete its first year of activities.

Goal of the project and program[1]

The three-year project 'Authentic Research through Collaborative Learning (ARC-Learn): Undergraduate Research Experiences in Data Rich Arctic Science' aims to 1) develop and diversify the next generation of Polar scientists by supporting the engagement of underrepresented students in a team-based, long-duration undergraduate research experience (URE); 2) expand knowledge about design and implementation of UREs, specifically what may be gained and what are the significant challenges with a long-duration, lower-intensity, team-based design; and 3) build understanding about how mentors can develop inclusive mentoring competencies and efficacy.

The ARC-Learn program is an 18-month Arctic-science research experience (Table 1) intended for undergraduate students with identities historically underrepresented in Polar science and/or those who have non-traditional educational pathways. Each cohort of approximately 20 students works closely with 10 faculty and graduate student mentors and small peer-teams to conduct Arctic research. The individual and team-based research topics are student-driven. Students are supported through the entirety of the research 'arc', from developing an appropriately-scoped research question through data analysis and disseminating results. Mentors are trained in Inclusive Mentorship practices and engage in continued professional development through quarterly Peer Learning Community meetings. The project research aims to understand program mechanisms that support student achievement of learning outcomes, foster student STEM identities and persistence, and support mentor inclusive mentoring practices and team science skills.

[1] Throughout this report 'project' refers to all aspects of the work supported by this grant; 'program' refers to the ARC-Learn undergraduate research opportunity

Table 1. The project will run from May 2021 through August 2024 (blue indicates 'complete'; yellow indicates 'to come').

Activities	Academic Quarters												
	Sp/Su	F	W	Sp	Su	F	W	Sp	Su	F	W	Sp	Su
	2021		2022				2023				2024		
Cohort 1 Program Activities													
Recruit Students and Mentors													
Mentoring Plans/Curriculum Development													
Cohort One Students and Mentors Invited to Program													
Mentor Inclusivity Training													
Student: Orientation													
Student: Research Planning and Data Gathering													
Student: Data Analysis, Visualization, Interpretation													
Student: Science Communication Training and Practice													
Student: Presenting Results													
Mentor: Peer Learning Community Meetings													
Student enrollment and standing check													
Cohort 2 Program Activities													
Recruit Students and Mentors													
Mentoring Plans/Curriculum Development													
Cohort Two Students and Mentors Invited to Program													
Mentor Inclusivity Training													
Student and Mentor: Orientation													
Student: Research Planning and Data Gathering													
Student: Data Analysis, Visualization, Interpretation													
Student: Science Communication Training and Practice													

Student: Presenting Results													
Mentor: Peer Learning Community Meetings													
Student enrollment and standing													
Research, Management, Evaluation													
IRB, Instrument Development, and Validation													
Full Team Kickoff Meeting													
Student and Mentor Baseline Data (survey)													
Student and Mentor Observations													
Student and Mentor Mid-Program Data (survey)													
Student and Mentor Interviews													
Student and Mentor End of Program Data (survey)													
Advisory Board Formative and Summative Reports													
Analysis, Write Up, Dissemination													

In addition to the critical roles of students and mentors, the ARC-Learn project team (Figure 1) includes many people working together across units, to provide programmatic leadership and coordination, academic support, education research, College of Earth, Ocean, Atmospheric Science (CEOAS)-level support, mentor training and expert recommendations and evaluation.

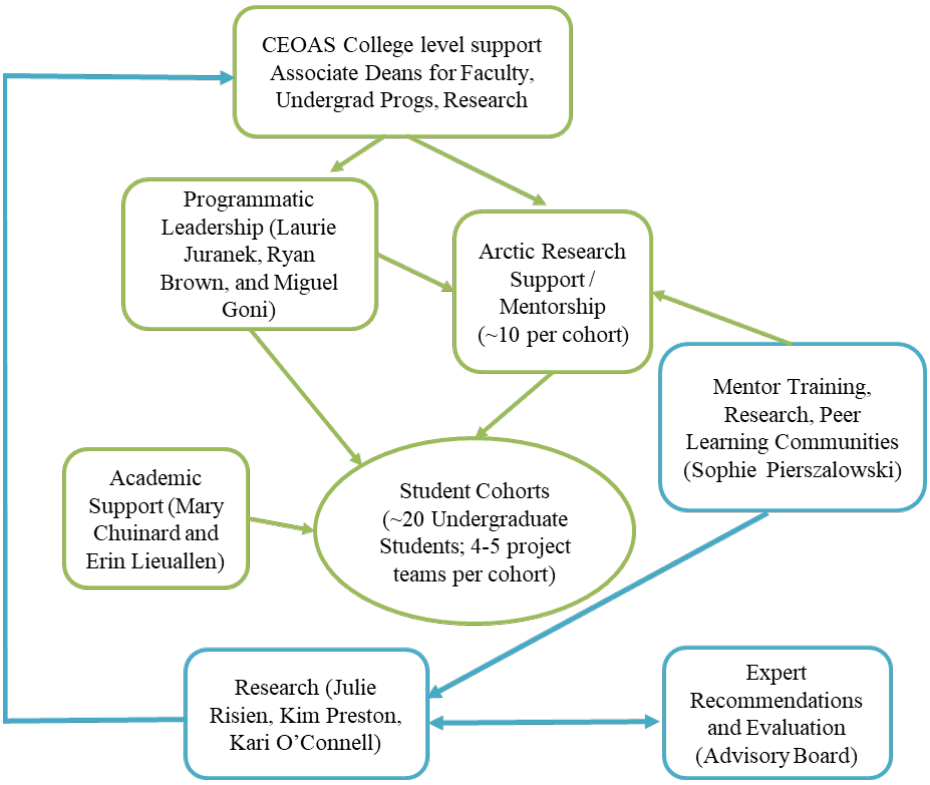


Figure 1 ARC-Learn organizational chart.

II. Evaluation Overview

This formative evaluation, overseen by external advisors, serves to give project team members feedback on overall progress, implementation of Cohort One student and mentor activities in Year One. The evaluation is guided by the following questions:

a) Were project elements appropriately and successfully implemented?
b) What challenges were experienced by the project team, mentors, and students?
c) Did the project team sufficiently adapt to program implementation to address challenges and improve outcomes?

The remaining two evaluation questions will be addressed by a summative report in July 2024:

d) To what degree is the program being integrated into institutional infrastructure?
e) To what degree do student participants achieve each of the learning outcomes?

III. Section 1: Activities, Adaptations, and Recommendations

This section addresses the key activities of the project (supporting evaluation question A), challenges and respective adaptations (supporting evaluation questions B and C) that the project team made, and recommendations (supporting evaluation question C) for Year Two based on project team's lived experiences implementing the program and formal and informal feedback from program participants. This section is organized into three phases of work: before the program launched, during the program's initial launch, and the core Polar Science research activities of Year One.

Pre-Program Launch

This section addresses the major activities, challenges, and adaptations before the ARC-Learn program started, between Spring Term 2021 through early Fall Term 2021.

The Key Activities

- Kick-off the project by setting up team communication channels, meetings, discussing roles and norms.
- Develop and disseminate program advertisements and recruitment material for prospective students and faculty mentors, throughout CEOAS, OSU and local community colleges.
- Coordinate with CEOAS leadership to incentivize faculty and students' participation in the program, ensuring that participants have multiple options for the experience to count towards professional or scholastic development.
- Work with CEOAS to create a program website and online application for students.
- Apply for and receive approval from IRB to conduct research; refine research questions and constructs; initiate research instrument development.
- Prepare a pre-read packet for advisors (including an overview of program design, introduction to project team, and description of research and evaluation elements; Appendix A) and host an advisory board meeting to summarize program launch activities to date and get feedback on upcoming activities, including mentor training plan.
- Develop faculty mentor inclusive mentorship training.

The Key Challenges and Adaptations

- Due to the funding timeline, the project team advanced the program start from the Spring 2022 to Fall 2021, thereby truncating their planning timeline and shifting their initial timing for program activities.
- To ensure the project team had enough mentors, they recruited two graduate students to serve as mentors and have been very impressed with both- they are incredibly thoughtful in their roles and seem to serve as a bridge between the undergraduate student experience and the faculty experience.
- To fill a knowledge gap, the project team brought on a second researcher to help oversee and connect the ARC-Learn research to the broader literature on geoscience undergraduate research.
- To make the research more specific and actionable, with guidance from advisors, the project team fine-tuned the research questions to better understand the relationship between program elements and student development.

Recommendations

- Add mechanism and incentives to encourage CEOAS graduate students and postdocs to apply to be mentors in future cohorts (e.g., advertise on CEOAS graduate student listserv, ask current graduate student mentors to share their experiences).

- Understanding that the program is intended for students with non-traditional academic paths and patterns of enrollment, the project team created introductory activities that celebrate nontraditional paths by highlighting the 'winding' or non-linear career paths mentors, scientists, and project team members have had.

Program Launch, Cohort One

This section addresses the major activities, challenges, and adaptations that occurred as the project team launched the program and engaged the first cohort of mentors and students, in Fall Term 2021.

The Key Activities

- The goal was to support 20-23 students per cohort. Planning for up to a 30% attrition rate, the project team accepted 27 students into the program. These students were selected out of 49 applicants based on a rubric of our goals of the program, including expected graduation year, nature of intersecting identities, undergraduate pathway thus far and polar science and research interest.
- Organize and host student orientation sessions and a strengths quest engagement opportunity.
- On-board eleven mentors through an informational session and inclusive mentorship training.
- Develop (iterative and with feedback from advisors) and deploy pre-program student and mentor surveys for research/evaluation.
- Populate the ARC-Learn program website with mentor profiles.
- Establish multiple transcript-visible enrollment options for students to choose from, including academic credit (maybe used toward degree requirements) or non-credit (tuition-free, may not be used towards degree requirements but is transcript-visible as a Research Fellow).
- Set up the learning management system (Canvas) for students, facilitators, and mentors to communicate, share resources, post discussion, and submit work.
- Prepare content, administrative logistics, and additional details for launching Polar Science content and research project development in Winter Term 2022.

The Key Challenges and Adaptations

- To protect mentors' time and due to the adjusted timeline, the project team decided to do a 'soft-launch' in Fall term 2021, front-loading the student orientation activities to that term and waiting to bring mentors in until the Polar Science research activities started in Winter Term 2022.
- Based on early conversations with mentors at the mentor information session, the project team quickly realized mentors were struggling to think beyond the traditional format of an undergraduate research experience, so the project team integrated more support around this idea in the inclusive mentorship training and Peer Learning Community meetings.
- Continued COVID conditions altered student orientation and location of planned activities; because of exposures, some meetings were shifted to virtual and in-person, causing some disruption to cohort-building.

- Four mentors dropped out Fall Term, generally citing they did not have adequate time to commit to the program, impacting the mentor to student ratio.
- Based on students' altruistic future career values revealed in the pre-program survey, the project team integrated these themes into orientation and early introductions to the types and nature of Polar Science careers.

Recommendations

- Create more social opportunities for students and mentors to build relationships during the orientation term.
- Share and reiterate student and mentor program expectations, with their consent, so everyone understands the nature of the commitment and can plan accordingly.
- If using a hybrid approach (both online and in-person options) for student gatherings, assign (in advance) a project team member to facilitate the online participants (e.g., prompt discussion, support for technical difficulties, etc.)

Year One, Cohort One

This section addresses the major activities, challenges and adaptations as the Polar science research of the program came underway, for Cohort One, from Winter Term 2022 through Summer Term 2022.

The Key Activities

- Continue bi-monthly project team and weekly research team check-ins.
- Commence 2-hour, biweekly student meetings facilitated by project leads to cover Polar science and research content (nature and process of research and data management).
- Assemble program research teams: work with students to identify their research areas of interest and match mentors with the topics that align with mentors' areas of expertise.
- Design and facilitate quarterly Peer Learning Community meetings for mentors.
- Encourage program research team progress by setting up deliverables and timelines, while mentors provide support and guidance for students to accomplish the individual and group research goals.
- Administration of program logistics (meetings, room reservations, student academic standing check, student enrollment, student stipend issuance).
- Disseminate advertisement materials and start recruiting Cohort Two students and mentors
- Populate ARC-Learn website with Cohort One student profiles.
- Conduct mentor and student early-program interviews (February 2022) and mid-point surveys (June 2022); analyze results on a rolling basis and share findings with the project team.
- Plan Cohort One and Cohort Two program activities for Fall Term 2022.
- Meet with CEOAS administrative leadership to reaffirm their engagement with and support for ARC-Learn (Summer 2022).
- Write the formative evaluation report and reflect on preliminary findings in a meeting with the project team (Summer 2022).
- Share formative evaluation report with Advisory Board and an advisory board meeting (early Fall 2022).

The Key Challenges and Adaptations

- The project team underestimated the amount of logistical coordination the program implementation would need. Although students felt supported, PI Juranek had to spend more time coordinating administrative logistics (virtual engagement, classroom space, scheduling and other features that support flexibility and accessibility) than anticipated. The project team has hired a coordinator (Brown) at .2FTE to take lead on these vital activities.
- The project team listened to students' desires/needs and created opportunities for students to acquire additional skills (e.g., python coding and GIS mapping)
- The team's mentor training expert went on maternity leave, impacting our capacity to support mentor growth in inclusive mentorship, though the project team resurfaced these themes in at least one peer learning community meeting.
- Creating the research teams was challenging. The project team gently guided students throughout Winter Term 2022 to narrow their interests, but then realized that the resulting student interests did not entirely fall within the mentors' comfort zones. With help from the mentors, the teams came together, but the project team have recommendations for the next cohort (see recommendations below).
- Initially the project team intended the program and student research teams to continue uninterrupted through summer. However, due to limited mentor availability and changes in students' responsibilities during the summer, the project team had to adjust their expectations for summer work and left it up to each individual group to decide what could be reasonably accomplished over the summer.
- Starting summer term, the project team set up the opportunity for students to enroll for academic or non-academic credit (Research Fellow transcript notation) with individual mentors listed as the instructor of record, rather than the program faculty leads. This arrangement was ultimately too great an administrative burden and proved confusing for students (see recommendations below).
- Some challenges arose due to project team members' seagoing field work throughout the first year.
- As of Summer Term 2022, 21 students remain engaged in the program, six students withdrew overall (22% attrition rate). Research team requested exit interviews with those who withdrew, but only one of the six agreed to an interview (details on p. 14 and 20).
- The research team decided to remove reflective journal assignments for mentors and students as research artifacts, instead integrating time for mentors and students to reflect during the Peer Learning Community meetings and biweekly meetings (respectively).

Recommendations

- Adjust the process of creating research teams. Next year, the project team will first work with the new cohort of mentors to establish the scope of possible research areas, then give students

flexibility to choose within those areas. The project team will begin this process in the first term of the program, to allow more time for the research topics to take shape.

- Give more clear guidance ('early and often') to mentors and students about expectations (e.g., time commitment, deliverables, intended outcomes, academic credit vs non-academic credit).
- Most mentors were recruited from a particular discipline within Polar science (physical oceanographers); this happened incidentally and somewhat impacted the types/topic of the research projects in which students could be supported. Focusing on recruiting mentors from multiple disciplines should be considered in our recruitment efforts for Cohort Two for both students and mentors.
- Create a clearer communication structure (e.g., mentor to project coordinator to academic advisor) for tracking students who disengage and providing supportive intervention.
- Encourage mentors to help students understand their research in a real-world context.
- Use Cohort One student feedback to suggest possibly useful courses for Cohort Two students.
- Support mentors in progressing in their journey to inclusive mentorship more intentionally, through the Peer Learning Community meetings (share some concrete examples of behaviors that promote inclusivity); prioritize time for facilitated peer discussion in these meetings; and shift inclusive mentorship training to Winter Term.
- Incorporate a mentor orientation early in Fall Term, to help mentors connect with each other and program team members, and become familiar with the ARC-Learn URE model/goals.
- Integrate intentional 'inflection' points with mentors, to help them see where we are 'at' in the arc of the program and help mentors work with students to set and reflect on individual goals.
- Continue to have multiple enrollment options for students, denote program leads as instructors of record but provide faculty mentors with language to claim 'credit' for serving as a mentor.
- There appeared to be a lower sense belonging for those participating completely remotely. While the project team will continue to remain flexible with a hybrid approach, the project team will design standard practices around facilitating remote participation.
- Launching surveys during the summer is not something that should be repeated, as it was difficult to get responses. Overall, 16 of 21 students and 4 of 7 (non-project member) mentors responded.
- Some suggestions to reduce attrition include: employ the program coordinator to monitor and create opportunities for student engagement; increase social opportunities for students and mentors; design hybrid events more thoughtfully and with more inclusivity; and open up more regular communication between program team and student services.

IV. Section Two: Early Findings

This section provides an overview of preliminary findings from data collected through the research instruments (pre-program survey, early program interview, mid-program survey, observations) implemented for mentors and students, as well as artifacts (e.g., mentor intake forms, student applications, and Google Jamboards) that have informed and will inform program design, adaptations, and recommendations (many of which were discussed in Section One above).

Cohort One Students

Demographics: The project team reviewed the 49 student applications received, using a rubric based on program goals. Twenty-seven (of the 29 students invited to participate in the program) accepted. Students identified themselves as possessing many intersecting identities: transfer (n=18); person of color (n=5); Indigenous (n=1); woman (n=19); first generation college (n=3); LGBTQ+ (n=16); has dependents or alternative enrollment (n=6). Student majors include Environmental Science, Geology, Ocean Science, Climate Science, Earth Science, Geography and Geospatial Science, Chemical Engineering, and Natural Resources.

Goals and Motivations: Students reported in the pre-survey that a desire to participate in ARC-Learn to learn more about Polar science and build relationships with faculty and peers over time were important to *why* they decided to join ARC-Learn; while the stipend was reported to be the very least important factor in their decision to join ARC-Learn (Figure 2). Understanding the low rating for the stipend as a motivator (e.g., is it too small to be an adequate incentive or simply less important?) will require further investigation.

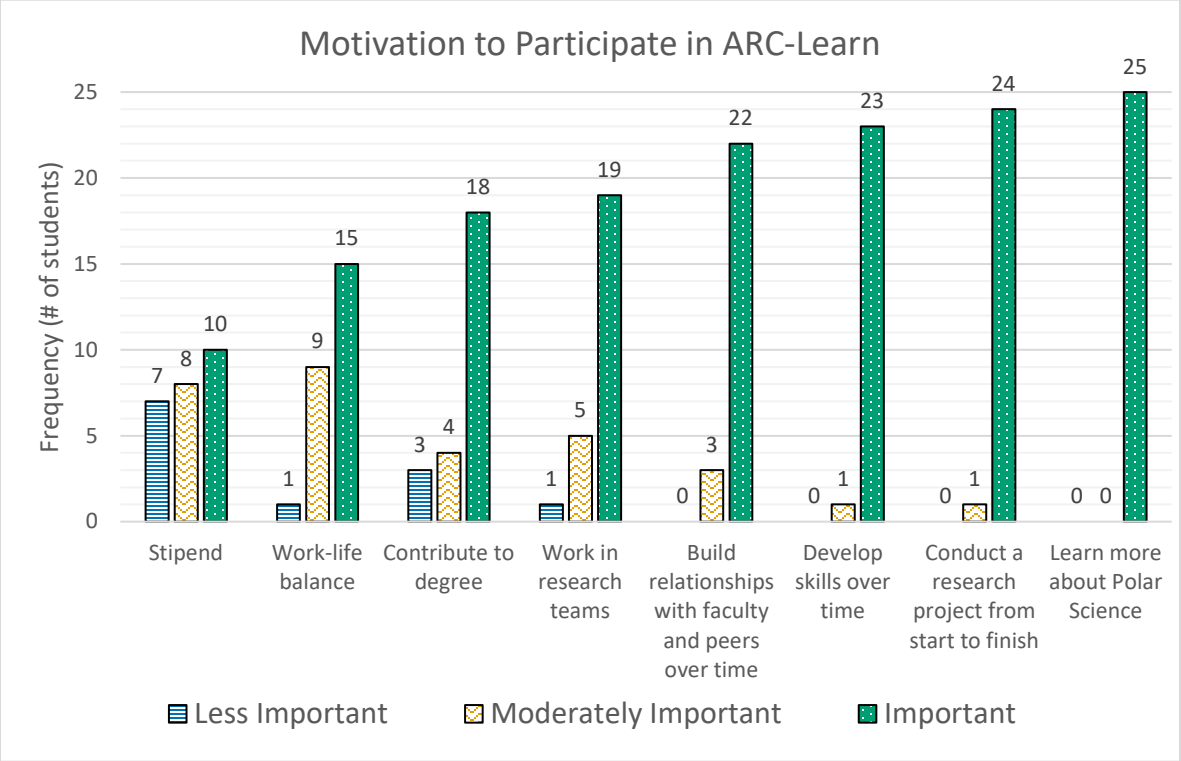


Figure 2 Students rated the importance of each element in motivating them to join ARC-Learn.

When asked about factors that might contribute to their future career satisfaction (Figure 3), students reported Altruistic values, such as *helping people and society* and *helping the environment*, as the most important factors. And while they reported uncertainty about what kinds of careers exist in Polar sciences, they believed that Polar science careers can offer opportunities to help people, society and the environment.

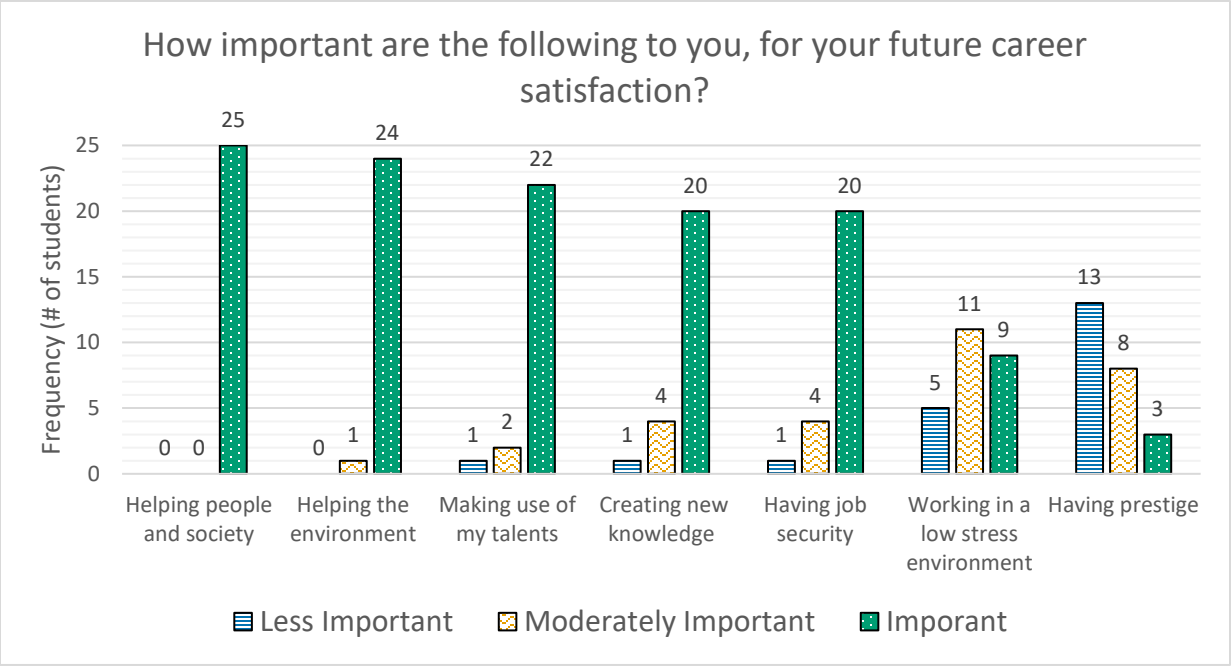


Figure 3 Students rated each elements' importance to their future career satisfaction.

Sense of Belonging: Initially in the pre-survey, students reported feeling a low sense of belonging to the Polar science community (Figure 4; left), citing a lack of knowledge, lack of personal experience, and lack of connections to the field. In the early interviews, they described that they expected to feel more connected to the Polar science community as they learn more about Polar Science and as they meet more people who are connected to Polar Science (e.g., professors or peers). Indeed, as the mid-point survey shows, there was a marked increase in their sense of belonging to the Polar science community (Figure 4; right). When prompted in the survey to explain their response, students attributed their increased sense of belonging the Polar science community was due to their participation in ARC-Learn (e.g., support and welcome from peers and mentors, gaining knowledge from the research process). However some students who reported a lower sense of connection to the Polar science community noted they have had few opportunities to connect with students beyond their own project team or have not had personal capacity to put time into relationship-building.

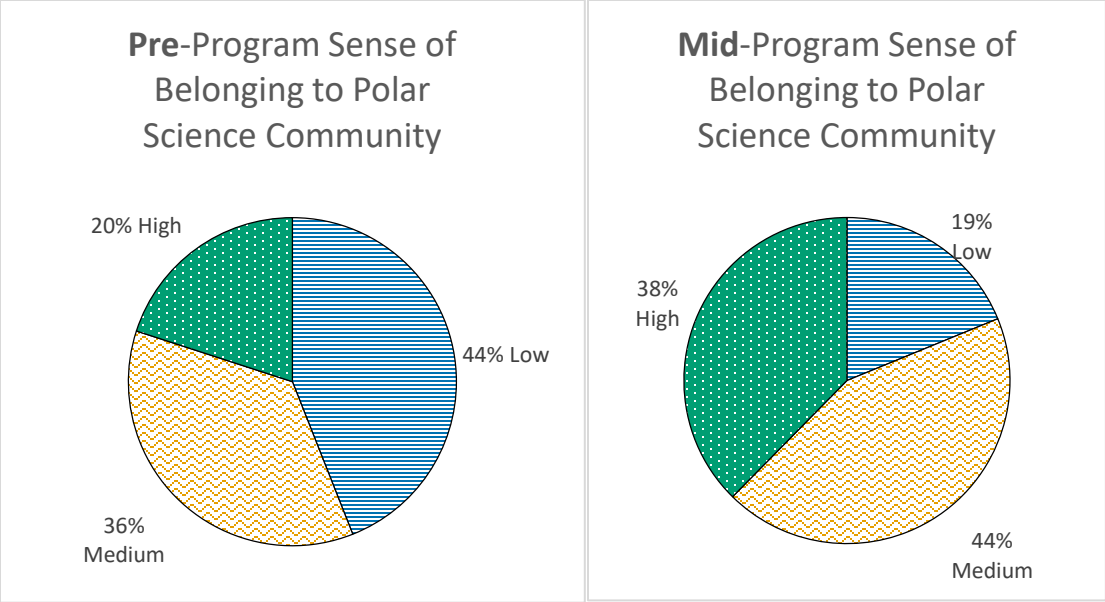


Figure 4 Students' sense of belonging to the Polar Science Community before the program started (left; n=25) and at the mid-point (right; n=16).

Students reported a generally high sense of belonging to ARC-Learn and their Research Team (Figure 5), citing aspects such as friendly, supportive, and equitable group atmosphere as contributing to this sense. Students with a low or medium sense of belonging to their Research Team or ARC-Learn cited a few explanations for this: disconnect between their individual research project and the team research project; personal lack of capacity to devote time to the program/project; or lack of opportunities to socially bond with the cohort.

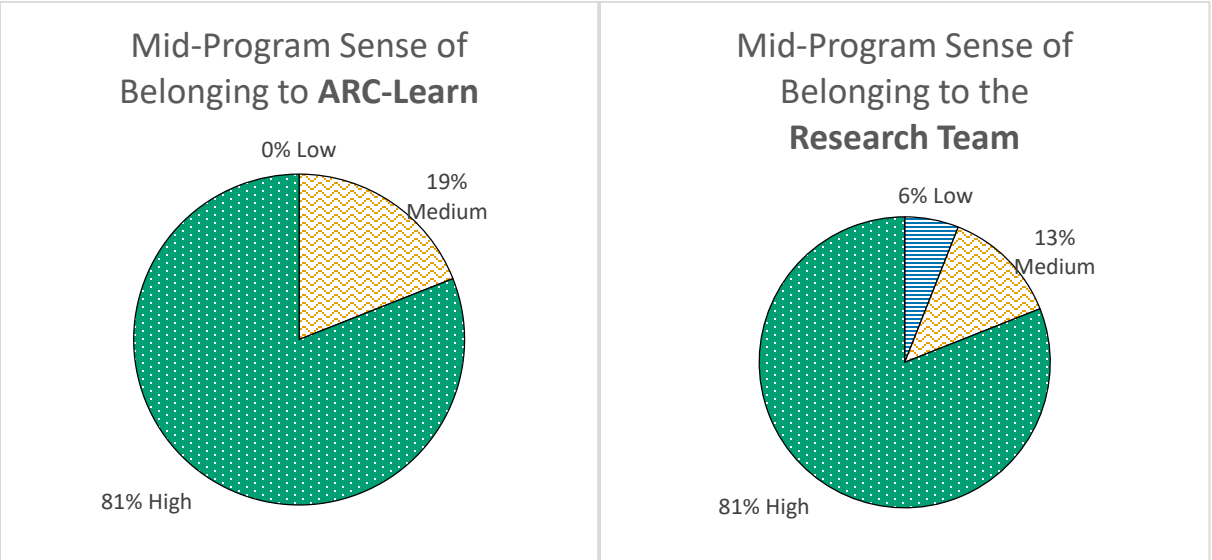


Figure 5 Students' sense of belonging to ARC-Learn (left) and Research Team (right) at the mid-point of the program (n=16).

Self-Efficacy: In the early-program interviews, students were asked what makes them feel confident in their ability to succeed in this program. Overall, students reported that specific skills and knowledge they have; prior research or class projects; positive reinforcement from authority figures; and passion or interest in the field contribute to their confidence. Conversely, they reported feeling less knowledgeable or less prepared than other students in the program or feeling weak in particular skills (e.g., math, physics, and chemistry) might make them feel *less* confident in their ability to succeed.

Skills and Knowledge: Overall, students reported high interest in contributing their existing skills and knowledge to their research team, as well as eagerness to learn and progress in all of the learning objectives of the program. Through observation and the midpoint survey, students reported having applied some skills or knowledge learned through their degree program to their research in ARC-Learn (e.g., data analysis skills, modeling, ecology, statistics, physical oceanography, GIS, and reading scientific articles). Specifically, the statistical courses ST 351 and ST 352 were cited most frequently as useful in ARC-Learn. In feedback for improving the program at the midpoint, students desired more training in coding, the research process overall, and how their research fits into a real-world context.

Attrition: As of Summer Term 2022, 21 students remain engaged in the program. Five of the six students who withdrew were transfer students; six identified as LGBTQ+; and two first generation college students. Only one student agreed to participate in an exit interview, citing change-of-major and increased work responsibilities as why she withdrew. Anecdotally, changes in academic plans (some related to COVID) and shifts in priorities were other reasons cited.

ARC-Learn Overall: Overall, students responded positively to prompts about specific program elements (Table 2). In the free response, students described receiving strong support and guidance from mentors, an enjoyment in connecting with peers and collaborating with the team, and learning about research and gaining research skills. Some recommendations from students included more time for socializing and cohort building; clarity on deliverables; more support in coding and about the research process overall.

Table 2. Students' rating of program elements at the midpoint of the program

Program Element	**Average score***
The amount of time I spend doing meaningful research	3.4
Financial support	3.8
Support and guidance from other ARC-Learn students	4.0
Every-other week all-hands ARC-Learn meetings	4.2
The built-in opportunities to explore my own interests	4.2
Relevance of the knowledge and skills to my academic or professional goals	4.5
Small research team meetings	4.5
Support and guidance from my research mentor(s)	4.6
The research experience overall	4.1
*scale ranked from 1 poor to 5 excellent	

Cohort One Mentors

Demographics: Eleven mentors were recruited (plus two program leads serving as mentors as well), though four deferred to serve in future years, leaving nine mentors (men = 3; women = 6; Caucasian or white = 7, Hispanic, Latino/a/x or Chicano/a/x = 2). Of the mentors recruited, four reported having little to no prior mentoring experience.

Mentor Role: Mentors generally seemed to view their role as a 'facilitator'. Mentors saw their role as facilitating student learning, positive experiences, goal-setting, and discovery and clarification of career goals. Mentors were also asked to rate how important certain items were to their perception of successful mentorship looks like to them (Figure 6). About 75% of mentors rated seeing students *grow in their understanding of the nature of science and research-related work* as *'Extremely Important'*. About 58% of mentors believed that supporting students in *exploring career pathways, goals and interests; develop confidence as a researcher;* and *attain self-defined goals* are 'Extremely Important'. While still considered important, the theme of *building social justice, diversity, equity and inclusion* into students' work seemed somewhat less important to mentors than some of the other items.

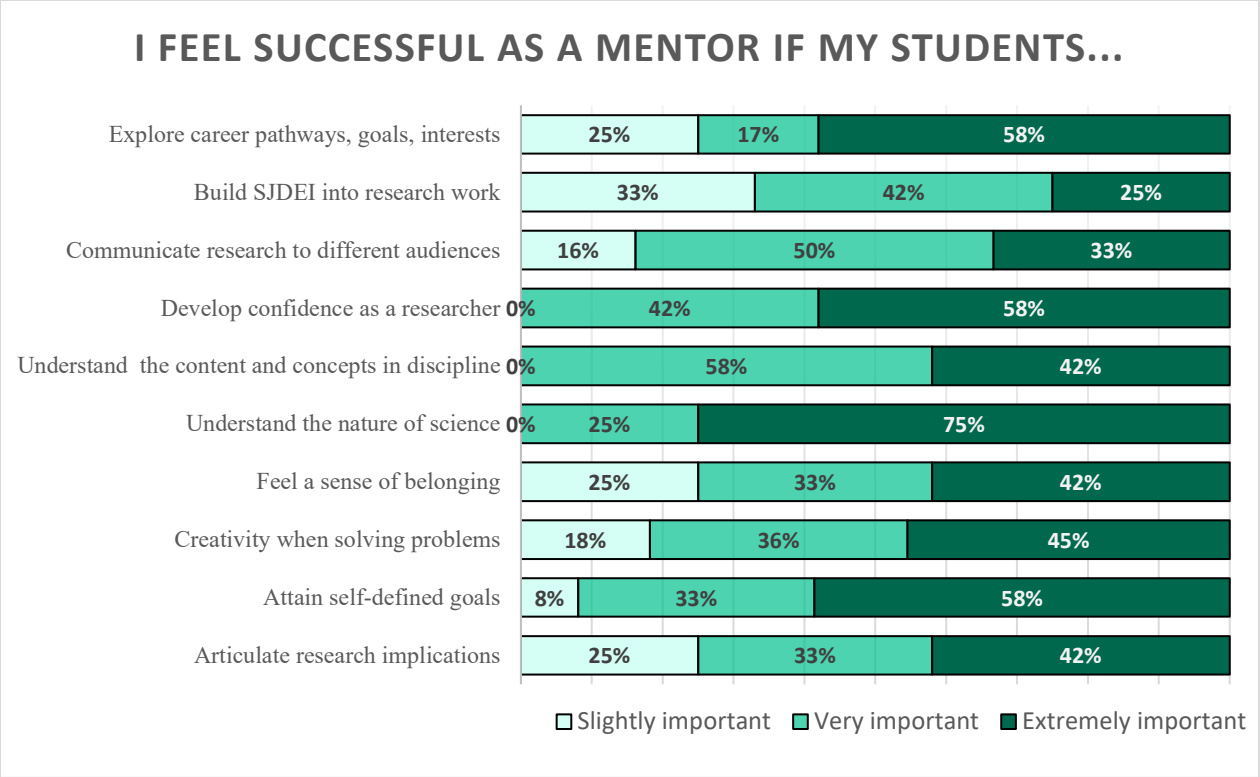


Figure 6 Mentors' reported sense of success.

Inclusivity: Incoming mentors had varied levels of prior inclusivity training, but most reported the opportunity to support students historically underrepresented in polar and inclusive mentorship training as key motivations for deciding to participate in ARC-Learn (Figure 7). And while, from the outset, mentors' attitudes were very positive towards creating mentoring relationships supportive of students holistically, mentors expressed a lack of confidence around practices like 'providing opportunities for mentees to talk about their identity as it relates to their research experience' and lack of experience implementing specific strategies to address identity in students' research experience. At the midpoint, a similar pattern held: positive attitudes toward inclusivity but low self-reported confidence in or experience implementing inclusive behavior.

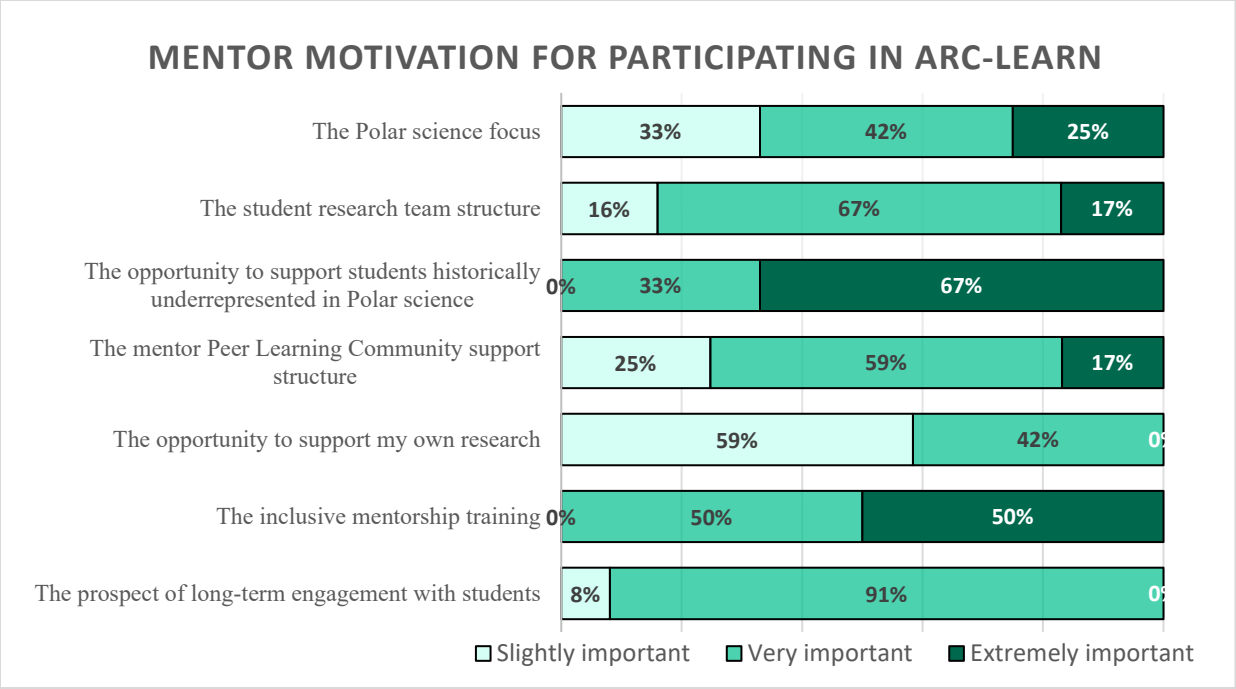


Figure 7 Mentors' motivations for participating in ARC-Learn.

At the mid-point, students were asked to give feedback on mentors' behaviors in certain areas (Figure 8). Students reported that while mentors commonly engaged in project-related mentorship, they were less engaged in mentorship around identity diversity awareness (like *my mentors raise the topic of identity in our research mentoring relationship when it is relevant*). The students' reports are consistent with mentors' self-reported behaviors, that they felt they did not specifically address identity in their mentoring relationships, to a great extent.

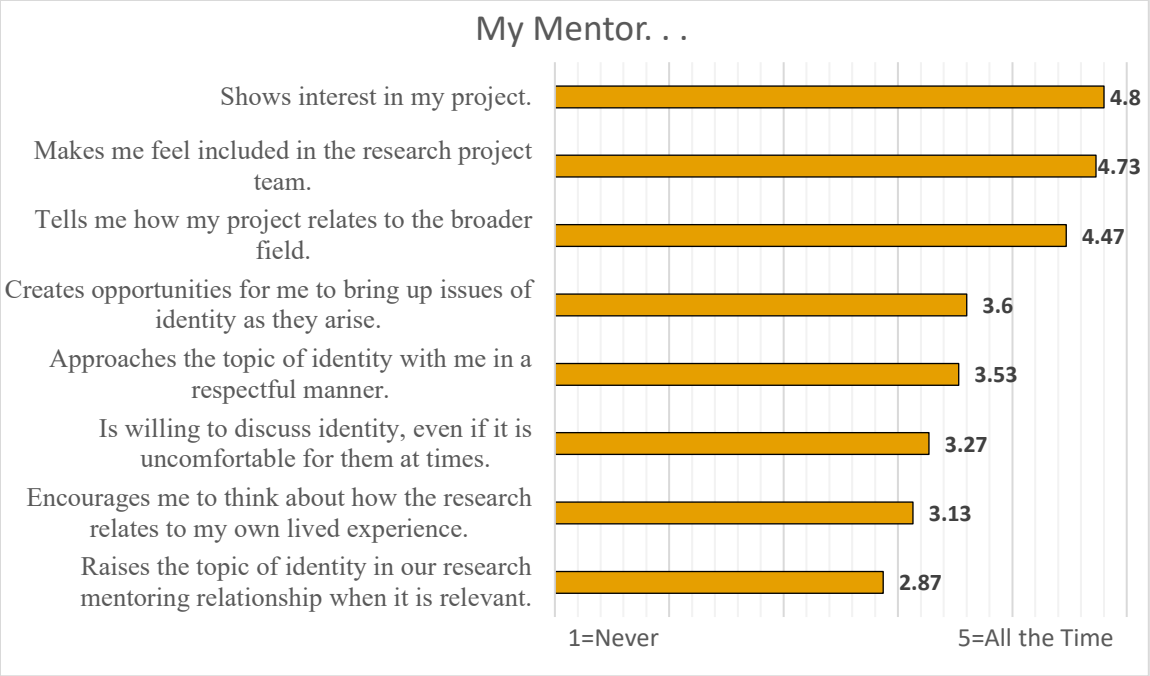


Figure 8 Averaged frequency of student-reported mentor behaviors (scale ranked from 1 never to 5 all the time).

Feedback: Early in Year One, mentors expressed concerns about mentoring students in topics outside of their own specific area of expertise; insecurities about mentoring undergraduates; and uncertainty around precisely what was expected of students and themselves (outcomes or deliverables). At the midpoint, mentors described that students showed lots of enthusiasm and interest in learning about polar research, gaining skills and collaborating. Mentors reiterated a desire for more clearly defined short-term-and long-term goals/deliverables/skill-gains for students (even if individualized); a chance to get to know students earlier in the program; and mentor involvement earlier in the program with developing research topic areas.

V. Conclusion

On October 20, 2022 the Advisory Board (AB) reviewed a draft of this report and participated in a formative evaluation discussion to review and clarify evaluation findings with the project team. Following that discussion the project team updated the report to add clarity based on AB recommendations and the AB drafted the conclusion below that will guide the project team as they iterate on the program design and research plan in year two.

The AB's assessment of the ARC-Learn evaluation questions are as follows.

1. To what degree were project elements appropriately and successfully implemented?

Overall, the project timelines and deliverables are on track. Progress is appropriate given the goals and intended timeline of the project. The project team quickly adapted to a compressed program launch timeline. The group has demonstrated an impressive ability to pivot and deliver quality programming Cohort One, especially considering the challenges described.

2. Did the project team appropriately recognize challenges experienced by the project team, mentors, and students?

This report, as presented by the project team, identifies several important challenges experienced by mentors, students, and the program as a whole. In particular, the challenges around adoption and implementation of inclusive mentoring practices (see recommendations on p. 10) and student expectations on progress/skill level will be important to address moving forward.

3. Did the project team sufficiently adapt to program implementation to address challenges and improve outcomes?

Overall, the team demonstrated a successful recruitment process and program implementation for the first cohort of students and mentors. The evaluation captured important feedback that will be helpful to iterative improvement of the program as it continues. The challenges raised by the project team include appropriate reflections and analysis on the underlying causes of those challenges that will prove useful as the program continues to evolve and recruit additional cohorts.

The AB explored the possible causes and considerations related to student attrition with the program team. We recommend program researchers work with mentors and CEOAS student services to further investigate the conditions under which students left the program and identify any patterns that may be present. The report recommendations on page 20 provide a good description of the measures needed to better understand attrition.

Critical Recommendations

In the paragraphs below the AB highlights critical recommendations and encourages the project team to prioritize adaptive actions with regards to these recommendations.

Hybrid Environment: The impacts of COVID 19 are substantive for Cohort 1 in year one (as described in Section 1), during which the program was adapted to enable hybrid and virtual engagement to accommodate frequent student and mentor household exposures and quarantines. While we expect Cohort 2 will also experience some COVID related disruptions, the implementation team expects more in person engagement and additional opportunities for social interactions (note: students and mentors will continue to have the opportunity to choose in what format they would like to engage). The environment for learning and engagement for students and mentors will potentially be very different for year one of the two Cohorts. The project team should monitor how increased interpersonal access and interactions may change the student and mentoring learning environment. Research results should be presented at the end of the project in the context of this changing learning environment.

Researchers noted a lower sense of belonging for those participating completely remotely or who could not attend many group meetings in person. Activities designed to help students be successful and to build psychosocial skills should be built into future gatherings with hybrid participation. For example, a virtual “host” and technology that supports more seamless interaction between in person and virtual participants can support peer and student-mentor relationships. These relationships can support students to identify and cooperatively tackle shared challenges with their groups. Additional

community building will support student engagement with content related to building research comprehension & communication skills related to their specific research project. The team indicated designs for interactions between Cohort 1 and 2, we support this and see an opportunity for student peer-mentoring across cohorts to support social-relational engagement, belonging, and program retention.

Mentorship: The AB recommends the ARC-Learn team recruit postdocs as mentors by collaborating with the postdoctoral office and/or CEOAS leadership to identify appropriate Postdocs who can serve as mentors. The team reported success with graduate student mentors. We recommend that the team work with CEOAS leadership to incentivize CEOAS graduate student engagement as mentors in future cohorts. Similar to the credit and non-credit opportunities given to undergraduate students, consider how graduate students might be able to reflect inclusive mentor training and other professional development gained through participation on their transcript or CV, either through credit bearing options or through certification.

Attrition: The AB recommends the following efforts to investigate potential patterns linked to attrition.

1. explore why attrition was so high for transfer students;
2. interview students who were invited but did not accept the opportunity;
3. interview students who dropped out of the program either during or after the first session of Cohort 1;
4. examine the participation/engagement in the program activities of those who dropped out;
5. disaggregate the pre-survey data to see if it provides any insight into attrition and if programming was not meeting student needs; compare data of those who persisted versus those who dropped out;
6. re-examine student goals and intended audience of the program and determine whether the program needs to be adjusted to better serve the populations of students who disproportionately dropped out;
7. investigate if the stipend is enough to justify the time spent in the program; and
8. explore if student attrition rates reflect the mentor 'readiness'.

Nature of Science: The AB notes that students report altruistic motivations for joining the ARC-Learn program consistent with research on undergraduate STEM motivations. The program team also indicated that the realities of the scientific process can make it difficult to connect to student altruistic motivations. As students learn more about the research process and narrow in a more modestly scoped project they may be experiencing some dissonance between their desires to solve global problems and the slow and iterative nature of science. Mentors can support students in processing this information by sharing their own experiences including stories of long-term successes that demonstrate how research does support solutions, even if in small ways. Mentors should take care to support the real-world aspirations of student researchers by regularly discussing the connections between student research and back to issues such as climate change, sea level rise, and healthy fisheries. Mentors can play a critical role in contextualizing how research contributes to solving grand environmental challenges of the Arctic.

Psychosocial skills: Reflecting on student interview responses around self-efficacy (p. 14), the AB suggests that program participants might benefit from interventions designed to address the imposter phenomenon and normalizing skill levels and prior experience as emerging researchers. This challenge could be addressed in cohort meetings through activities, and also through frequent reminders that they were intentionally invited to participate in this program because they have what it takes to be successful. Cohort meetings as described on p. 3 suggest that content is primarily focused on research skill building at this point, but additional time spent on the psychosocial elements of researcher development may prove useful in supporting students through the inevitable challenges as they begin their research projects. The AB suggests the program team explore resources and activities related to building and supporting participants' psychosocial skills. For example, mentee training programs offered by WISCIENCE (University of Wisconsin-Madison) include an activity on the imposter phenomenon based on the work of Dr. Valerie Young. Such resources may also be beneficial to ARC-Learn students as they continue to build their confidence and identities as researchers.

Expectations: The AB recommends adding a more structured approach to aligning mentor and student expectations in the program going forward. Although mentors may have their own document outlining student expectations or lab norms, ARC-Learn could benefit from a document that more specifically highlights key components of this unique program design that mentors and students should discuss together. Such guidance will be helpful in making sure that mentors and students develop a shared understanding of the processes and expectations of the program and regularly discuss key indicators of their progress and success and set realistic expectations for their experience.

With regards to the recruitment/application/acceptance process the AB recommends the project team consider making the time commitment explicit during the application and acceptance process. Include the time commitment outside of required meetings. Providing what to expect at the application stage can help establish expectations and help students realistically assess if they can commit.
During the recruitment and on-boarding process of mentors, consider asking them to also share with the ARC-Learn team project(s) what they would like students to work on. The collated list of potential projects with mentors can then be shared with selected students before they accept the opportunity. For future recruitment of students, consider recruiting through current students.

Dissemination Recommendations

The AB recommends that the ARC-Learn team begin planning their research and implementation dissemination strategies immediately. This will maximize program impacts in the field of geoscience education and undergraduate research experiences. Anticipated peer-reviewed manuscripts will be useful across the geological and biological sciences, the AB recommended publishing in key science discipline journals in addition in the science education literature. The AB also supports proposed development of open access program implementation guidance or manuals so other institutions can benefit from their findings.

The AB suggests the following list of possible conferences that are well aligned with the goals of the ARC-Learn program and should be considered in planning to disseminate findings. The AB notes that

abstract submissions should begin before 2023. Key conferences to consider include: Understanding Interventions; Council on Undergraduate Research; ARCUS International Polar Conference; AGU (especially Arctic focused sections); NAGT Earth Educators Rendezvous in broadening undergraduate participation section; and National Association of Black Geoscientists (NABG). It may also be valuable to share stories of ARC-Learn with local publications and news media. Where feasible the team should work with ARC-Learn students to present on behalf of the program either on their own project research findings or on their experience in the ARC-Learn Program.

This document incorporates the AB recommendations and serves, with certification of all the advisors, as the formative evaluation of ARC-Learn (Signatures below)

Name of Advisor: Oludurotimi Adetunji Signature of Advisor: _____ Date: _____

Name of Advisor: Amanda Butz Signature of Advisor: _____ Date: _____

Name of Advisor: Deron Carter Signature of Advisor: _____ Date: _____

Name of Advisor: Thomas Tubon Signature of Advisor: _____ Date: _____

VI. Appendix A.

ARC-Lean Advisory Board Kick-Off Meeting September 15, 2021
Informational Pre-Read Packet

A. Overview
B. People
C. Timeline and Status
D. Student Program
E. Inclusive Mentor Fellows
F. Education Research
G. Evaluation

A. Overview

Access to quality research experience opportunities is a high impact educational practice that supports undergraduates to successfully continue their education in STEM fields. Many of these programs include intensive experiences that occur over the summer months, often requiring students to travel to distant or remote locations to participate. This common structure limits access for many students, especially those who have extended or delayed educational paths as they balance work, family, and dependent care obligations. Authentic Research through Collaborative Learning (ARC-Learn) (a partnership between the Oregon State University (OSU) STEM Research Center and the College of Earth, Ocean and Atmospheric Sciences Polar Research programs) will provide a more flexible, long-term, lower-intensity model to eliminate common barriers to participation. The overarching goals of ARC-Learn are to: 1) develop and diversify the next generation of Polar scientists; 2) expand knowledge about design and implementation of undergraduate research experiences; and 3) build understanding about how mentors can develop inclusive mentoring competencies and efficacy.

Over the course of about two years ARC-Learn students, working within an affirmative science community (including peer teams, faculty mentors, and faculty instructors) will be exposed to the full "arc" of research from understanding scientific challenges to sharing the results of research with the public. The unique design of this program will:

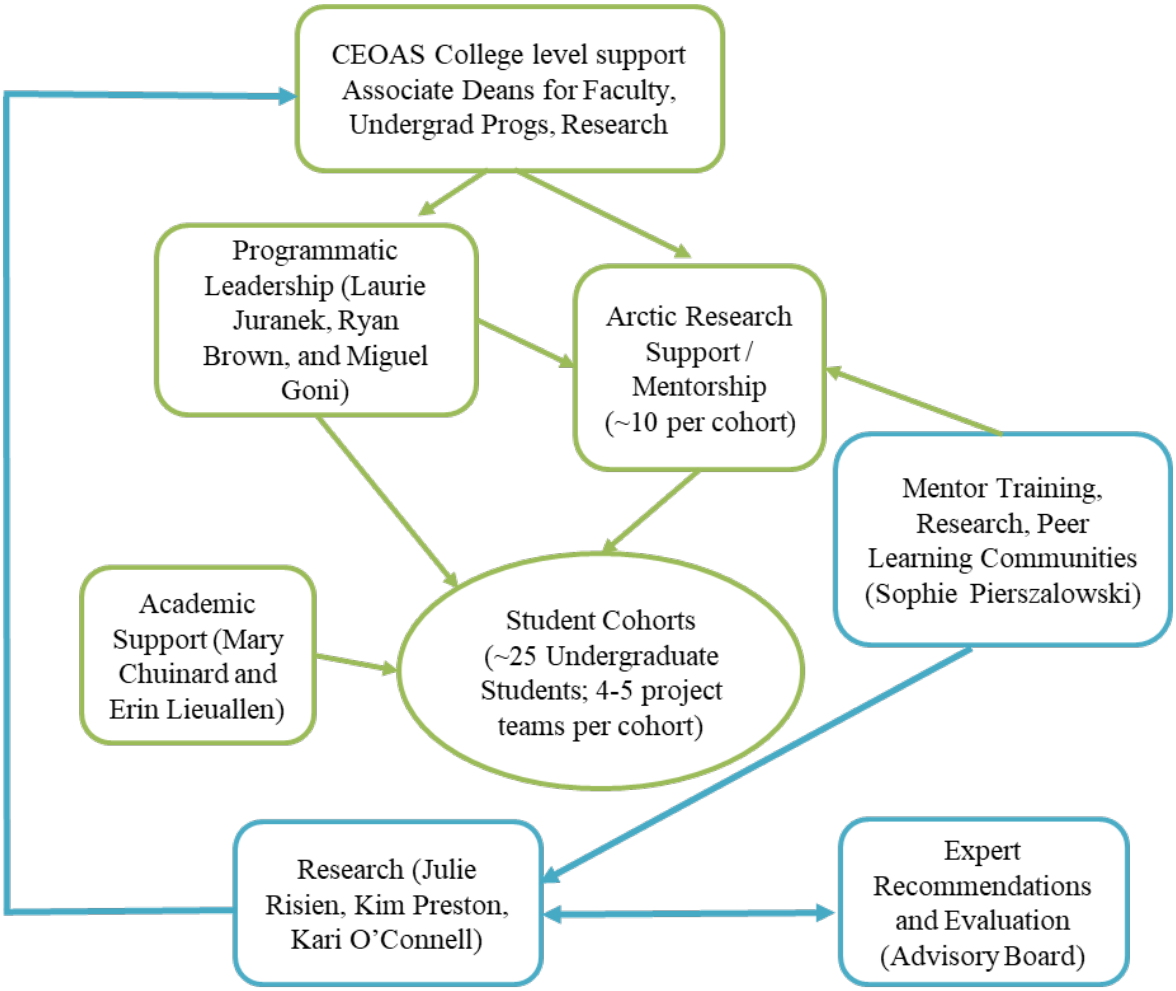
1) Provide critical training to develop the next generation of scientists, who will be charged with solving globally relevant environmental challenges for which the Arctic is ground-zero, through team challenges generated from student interest and approximately 8 hours of seminars each term (with a flexible credit structure)
2) Leverage the vast data resources already available by focusing on developing critical science skills such as data literacy and visualization.
3) Increase access to undergraduate research for students who are underrepresented in the Polar sciences, transferring from two-year colleges, and those who are unable to be away from home and family obligations for extended periods of time. Success among these groups can broaden participation in science and lead to a more diverse future Polar science workforce.
4) Train and support mentors in inclusive and culturally responsive mentoring practices.

The ARC-Learn design combines principles of many different types of UREs. These include course-based undergraduate research experiences, bridge programs, department integrated, cross-disciplinary, wrap-around, apprentice, and capstone (NASEM, 2017 pp. 33-68). This design makes possible achievement and assessment of our broader array of learning objectives:
1. Polar science – understanding the Polar regions, with specific depth in the Arctic, as complex systems and global environmental regulators.
2. Data literacy and integrity – understanding how to find, use, collect, manage, assess and interact with various datasets.
3. Visualization and interpretation – creating digital visualizations for analytical, interpretive, and communication purposes including mapping and storytelling.
4. Team science – experiences with the practices of cooperative and team-based learning, equitable and transparent processes, identifying and leveraging unique strengths of each team member, reflection and adaptation to optimize contributions, sharing workload and credit, and expressing multiple aspects of one's identity while participating in science communities.
5. Science communities and communication – tell the story of research findings, engage peers within and beyond disciplines, connect with public audiences, position findings in terms of social, ecological, and policy contexts.

The IUSE proposal was jointly reviews then eventually funded by NSF Office of Polar Programs. The Broader impacts are: 1) supporting direct and personalized impact on the 50 participating students and mentors in terms of professional trajectories in STEM; 2) development and broad dissemination of an empirically-based framework of research findings and programmatic lessons learned to support propagation and scaling of promising elements of this novel program design; and 3) broadening participation in the Polar science workforce by explicitly supporting underrepresented and non-traditional students in their development of STEM identity and continued pursuit of professional and educational Polar science experiences.

B. People

ARC-Learn is a collaborative project, it requires several people in different roles working together. The PIs are Risien, Juranek, and Goni. Key staff are Preston, Pierzalowski, Chuinard, Brown and Lieuallen. Research consultation also from Pierszalowski and O'Connell (*updated Spring 2022)*



C. Timeline and Status

The official start date is July 1, 2021 with an end date of June 30, 2024. It is already clear that we will not be able to produce scholarship without an NCE. We do anticipate the programmatic activities, data collection and the bulk of evaluation to be completed in the timeline.

We have conducted a series of team meetings, begun student recruitment (11 applications so far), completed mentor recruitment (8 applications, with more interested) and submitted for IRB approval.

The next programmatic steps are to complete student curriculum, student recruitment and selection, select mentors, schedule and conduct both student orientation and mentor training. The immediate research priorities are 1) instrument development and alignment with related scholarship and 2) research participant enrollment and consent documentation. Below is a draft timeline – a few things have already changed (*updated Summer 2022*).

Activities	Academic Quarters												
	Sp/Su	**F**	**W**	**Sp**	**Su**	**F**	**W**	**Sp**	**Su**	**F**	**W**	**Sp**	**Su**
	2021		2022				2023				2024		
Cohort 1 Program Activities													
Recruit Students and Mentors													
Mentoring Plans/Curriculum Development													
Cohort One Students and Mentors Invited to Program													
Mentor Inclusivity Training													
Student: Orientation													
Student: Research Planning and Data Gathering													
Student: Data Analysis, Visualization, Interpretation													
Student: Science Communication Training and Practice													
Presenting Results													
Mentor: Peer Learning Communities													
Student enrollment and standing													
Cohort 2 Program Activities													
Recruit Students and Mentors													
Mentoring Plans/Curriculum Development													
Cohort Two Students and Mentors Invited to Program													
Mentor Inclusivity Training													
Student: Orientation													
Student: Research Planning and Data Gathering													
Student: Data Analysis, Visualization, Interpretation													
Student: Science Communication Training and Practice													
Presenting Results													
Mentor: Peer Learning Communities													
Student enrollment and standing													
Research, Management, Evaluation													
IRB, Instrument Development, and Validation													
Full Team Kickoff Meeting													
Student and Mentor Baseline Data (survey)													
Student and Mentor Observations													
Student and Mentor Mid-Program Data (survey)													
Student and Mentor Interviews													
Student and Mentor End of Program Data (survey)													
Advisory Board Formative and Summative Reports													
Analysis, Write Up, Dissemination													

D. Student Program Structure

We anticipate two full cohorts of 20 students will complete the program (we will enroll up to 25 to plan for attrition). Student recruitment in underway (we have 11 applicants for cohort 1 so far) and we still have time to recruit through October. You can see eligibility and a general description here https://ceoas.oregonstate.edu/arc-learn. We have learned from OSU past programs that increasing and separating the stipend into two payments helps with program retention. The first-year student stipend is $800 and the second-year stipend is $1,200.

Students will engage is a series of 26 gatherings (hybrid planned) over 20ish months. Most meetings will include: 1) invited experts; 2) exposure to and interactive engagement with content specific tools and resources; 3) Formal Cooperative Learning practice; 4) team-based collaborative project development; and 5) individual and team reflection, goal setting and adaptation. Students will spend additional time outside of the scheduled meetings with mentors and advisors and working on team projects. OSU operates on Quarters.

- Fall 2021 – Student orientation and exploration of "Arctic Challenges"
- Winer 2022 – Research planning and team science skills building
- Spring 2022 – Working with data, focus on data literacy and integrity
- Summer 2022 – Data analysis, focus on data literacy, intro to visualization and interpretation
- Fall 2022 – Data visualization and interpretation
- Winter 2023 – Participating in science communities, publishing, collaborative processes (research showcase)
- Spring 2023 – communicating with public audiences (OSU URE Poster Session)

Students will also have regular access to the CEOAS student advising team.

While students will not be required to participate in field work, there are many programs within CEOAS that will provide the opportunity for field work. The budget also will allow for students to participate in conferences as available and interested.

E. Inclusive Mentor Fellows

Mentor training, research, and ongoing peer learning are a large part of ARC-Learn. Previous OSU URE/Bridge programs have reported (in hindsight) lack of mentor training and program structure as presenting significant challenges in their designs. We have met with prospective mentors and discovered some key and pervasive misconceptions about mentoring practice. Below is the response and clarification shared with prospective mentors as part of an interest survey that will help the team select mentors (8 have applied and another 5 who have shown interest – we need a minimum of 5 dedicated mentors to run the program)

Thank you for your interest in becoming and ARC-Learn Inclusive Mentorship Fellow. Here are a few things to know about the program to help you decide your level of interest.

- ARC- Learn is student centered and student driven. Students will work in teams on projects that they design. The program is low intensity and high duration by design so students can experience the full "arc" of the research process in an affirmative community while maintaining their other school, work, and family commitments.
- ARC-Learn mentors are Fellows. They volunteer as student guides with Polar science expertise and knowledge of navigating science education and science communities.
- ARC-Learn is a "design-based experiment", mentors will be asked to consult on program development, lend their expertise to the curriculum, participate in education research, apply thoughtful inclusive mentoring practices, and maintain enough flexibility to ensure continuous program improvement.
- ARC-Learn mentors will receive structured inclusive mentor training and participate in an ongoing peer learning community. This is a professional development program for mentors as well as an undergraduate research program.
- CEOAS faculty with any concerns about how ARC-Learn can satisfy DEIA, teaching, research, and service requirements of individual positions are encouraged to reach out to Associate Dean Adam Kent.
- Mentor Fellows will have opportunities to publish with students, with the project team in discipline-based education journals, or create education focused features for disciplinary journals. Fellows will also be acknowledged for their contributions on a program website and with the NSF Office of Polar Programs.

NSF is particularly interested in mentor mindsets around collaboration and student inclusion. Sophie Pierzalowski has expertise in inclusive mentoring practice and will conduct training and ongoing peer learning with the mentors. She will also play a significant role in the design and interpretation of mentor related research. Below is the working draft of the mentor training for reference.

DRAFT Agenda for Mentor Training
Session 1 - Philosophy (mid-Oct, 2 hours)
Homework (due before session 1):

- Read Collectors, Nightlights, and Allies, Oh My: White Mentors in the Academy by Marisela Martinez-Cola

- Click “start” in online guide and read through Destination 1 (https://broaderimpacts.netlify.app/undergraduate-research/index.html#/)

Agenda:

- Welcome and introductions (group discussion, **20 minutes**)
    - Get to know each other - short prompt
        - Describe one of your most influential mentors. What is one thing that made/makes their mentorship so impactful?
    - Intro to ARIS guide
- Intro to developing a mentoring model - philosophy, process, relationship (PPT slides, **5 minutes**)
- The student experience
    - Breakout groups (**10 minutes**)
        - What barriers might students from minoritized groups be facing at OSU?
        - https://padlet.com/sophiepierszalowski/vkpw8tzz94m2ixz5
    - Group discussion (**15 minutes**)
        - How might those translate into research experiences?
        - How might those translate into experiences in the field of arctic science?
        - Consider intersectionality
        - In what ways can we, as mentors, serve as barriers for students?
            - Individual vs. structural bias (e.g., disciplinary “norms”)
                - Are mentors changing their perception of the importance of doing field work - is it necessary to do fieldwork to be successful?
                - In what ways is a student disadvantaged if they can’t attend a conference or do fieldwork? Is that equitable?
            - Rules of inclusive language
- Supporting equity and inclusion in mentoring practice (**15 minutes**)
    - Equity vs equality
    - Thinking about students holistically
        - Diversity as an iceberg
        - Visible vs. invisible identities & barriers, importance of empathy and getting to know students so you can better support them
        - Importance of welcoming all identities
            - Students do better work when they can be themselves and feel like they belong
    - The value students bring
        - Importance of embracing diverse perspectives (Intemann, NSF broader impacts paper)
        - Deficit perspective vs. emphasizing student strengths
        - Dr. Longmire-Avital’s Community Cultural Wealth Model
    - The Arc-Learn model

        - How is mentoring in Arc-Learn different from mentoring in other forms of undergraduate research?
            - This is not an apprenticeship model - it's a team based model driven by student interests and skills and motivations, not necessarily by faculty research agenda/desires
        - What does it mean to be a mentor in Arc-Learn?
            - Student development comes first
- Break (15 minutes)
- Marisela Martinez-Cola's Mentoring types (nightlights, collectors, and allies)
    - Overview of types (**3 minutes)**
    - Breakout group reflection on mentoring types (**7 minutes**)
        - What comes to mind when you read the paper?
        - In thinking about the mentors in your life in what ways did these categories show up? How did your mentors' behaviors impact you?
        - In thinking about your own mentoring style, in what ways did these categories show up?
        - In what other ways do you personally connect with these mentor types?
    - Group discussion (**20 minutes**)
        - Intent vs. impact
- Closing and plan for next session (**10 minutes**)

Session 2 - Process (late-October, 2 hours)
Homework (due before session 2):

- Read through Destination 4 in inclusive mentoring guide (https://broaderimpacts.netlify.app/undergraduate-research/index.html#/)
- Watch Benitta Love on ally vs. co-conspirator: https://vimeo.com/502300589
- Read "Use microaffirmations and call out microaggressions to help others" by Hannah Roberts

Agenda:

- Welcome and debrief from last session (**10 minutes**)
    - What is one idea/resource/question/etc. that stuck with you or something you've put into practice?
- Guest Speaker - Natasha Mallette (**30 minutes**)
    - Exploring group dynamics
- Examples of effective and inclusive mentoring (**10 minutes**)
    - Examples from award winning mentors (e.g., using preferred pronouns, etc.)
    - Microaggressions and microaffirmations
    - Breakout groups
        - What are examples of microaffirmations you've used in the past?
        - What other effective and inclusive mentoring practice can you share?
        - Talk through ARIS guide destinations - what stood out?
- Using mentoring tools to promote inclusion (**10 minutes**)

    - Inclusive Mentoring Philosophy
    - Sample Mentoring Agreement (see ARIS guide)
    - Additional tools that expose the "hidden curriculum"
        - Authorship agreement (see ARIS guide)
        - Intellectual property agreement
- Guest Speaker - Jeff Kenney (**1 hour**)
    - Balancing advocacy and empowerment
    - Privilege and how we use it
        - What to do (and what not to do) when we mess up (e.g., white fragility)

Session 3 - Relationships (November, 2 hours)
Homework (due before session 3):

- Begin drafting your mentoring agreement

Agenda:

- Welcome and debrief from last session (**10 minutes**)
    - What is one idea/resource/question/etc. that stuck with you or something you've put into practice?
- Guest Speakers - Mary Chuinard & Erin Lieuallen (**40 minutes**)
    - The role of advising
        - What role will they play in supporting the program students?
        - How can they help students navigate the program while balancing coursework, family and social obligations, work, etc. (e.g., midterms, finals)?
        - What is the tempo of student life? When might we need a lighter load for students?
        - How do we balance emotional support with rigorous expectations?
- Mentoring agreement (**40 minutes**)
    - What was challenging about creating this draft?
    - Peer review in breakout groups - read one other person's materials and see what you'd like to adopt or what suggestions you might have
    - Group debrief: What impact might these materials have on your mentor-mentee relationship?
- Mentoring relationship scenarios (**20 minutes**)
    - Breakout rooms - participants work through scenarios together
    - Large group debrief
- Closing and next steps (**10 minutes**)

Potential Professional Learning Community Topics:

- Sharing mentoring challenges and wins
- Developing a written inclusive mentoring philosophy

F. Education Research

The education research objectives are to understand the specific mechanisms and program elements that contribute to 1) achievement of learning outcomes, 2) cultivation of STEM identity and STEM persistence, and 3) mentor development of team science and inclusive mentoring practices and mindsets. Program elements of interest include formal collaborative and problem-based learning, inclusive mentoring, community, science lifecycle, and long-duration and low intensity schedule. We are interested in how they contribute to: achievement of learning outcomes; cultivation of STEM identity and STEM persistence; mentor development of team science and inclusive mentoring practices and mindsets; and shifts in institutional perception of research experiences.

The following research questions will guide development of research instruments (*updated* Fall 2021):

SQ1: In what ways do program elements (such as inclusive mentorship; long-term, low-intensity; whole research arc, team science) contribute to the **development of students' transferable research skills** over the course of the 2-year ARC-Learn Program?

SQ2: In what ways do program elements (such as inclusive mentorship; long-term, low-intensity; whole research arc, team science) contribute to **components of students' STEM identity**, (such as **sense of belonging, self-efficacy**) over the course of the 2-year ARC-Learn Program?

SQ3: In what ways do program elements (such as inclusive mentorship; long-term, low-intensity; whole research arc, team science) contribute to **students' persistence in STEM (clarify/reinforce career goals, self-efficacy, outcome expectations)** over the course of the 2-year ARC-Learn Program?

MQ1: How do mentors' cultural diversity awareness (attitudes, behaviors, confidence) and identity-responsive practices develop over the course of the 2-year ARC-Learn program?

MQ2: How does the ARC-learn program influence faculty mentors' role in and perception of undergraduate success in Polar research?

MQ3: In what ways does mentoring students in collaborative processes improve mentor collaborative competencies?

We will employ mixed methods to explain the program processes that enable (or inhibit) student progress and mentor development. The data sources are outlined below.
Surveys: students and mentors will complete surveys at the beginning, middle and end the experience. Student surveys will include validated measures for STEM efficacy and identity incorporating the Undergraduate Research Student Self-Assessment (URSSA), with validations for underrepresented groups (Byars-Winston et al. 2016) and updated recommendations (Weston & Laursen 2017) and assessment measures (Shortlidge & Brownell, 2016). Mentor surveys will measure mindsets and collaborative capacities using the science of team science framework (NRC, 2015) to explore the emergent properties of small team collaborative practice, including cognitive (e.g., shared mental

models and learning), motivational–affective (e.g., cohesion and efficacy), and behavioral (e.g., coordination, communication and adaptation) factors (Kozlowski et al. 2013). Student and mentor demographic data will be collected through these surveys.

Participant Observations: student cohort activities and mentor peer-learning meetings will be observed to build additional context to support data analysis and interpretation. Observation will be informal and focus on identifying mentor and student collaborative and inclusive practices and student progress on ARC-Learn learning objectives.

Interviews: will provide the most in-depth source of information (Bernard, 2011; Lofland et al., 1984; Weiss, 1995) and will be conducted up to twice with each student, mentor, and other related faculty and administrators. Initial brief baseline interviews will occur at the project start. More in depth interviews will occur with students and mentors near the end of cohort activities to provide data for analysis on STEM belonging and trajectories using open coding techniques (Saladana, 2015). Interviews with relevant OSU faculty and administrators will occur in the second half of the project and focus on listening to their perspectives of the success and potential sustainability of the program.

Journaling: Student and mentor participants will be asked to participate in journaling using a brief set of semi-structured prompts quarterly with more substantial prompts in the spring of each year they are in the program to provide the research team highly individualized context about conditions and lived experiences, which may link outcomes to program activities, institutional or external factors. Journals will help researchers identify key independent variables to consider in analysis.

We have submitted our IRB protocol, addressed their stipulations and we are awaiting final approval. The next major research step is development of the baseline survey instrument in alignment with URSSA and other validated URE instruments.

Below are initial notes for research instrument development – these still need to be compared and aligned with relevant research and existing instruments.

STUDENTS AND MENTORS will be asked some basic demographic questions in the initial SURVEY to enable researchers to identify correlated factors and create comparison groups as applicable to the research. These questions include:

1. Name
2. I identify as (yes no)
    a. A racial minority
    b. A person underrepresented in science
    c. A person who has taken a non-traditional undergraduate path
    d. A transfer student
    e. A person with a gender identity that is underrepresented in science
    f. A person with a sexual orientation underrepresented in science
3. Please (optionally) tell us more about your answers above)
4. In what way do you think your identity and representation impact your overall undergraduate experience?
5. In what way do you think your identity and representation impact your ARC-Learn experience?
    a. Overall
    b. With your student project team
    c. With your mentor (STUDENTS ONLY)

    d. With the program leaders
    e. With your student advisors (STUDENTS ONLY)
    f. With other mentors (MENTORS ONLY)
6. [STUDENTS ONLY]
    a. My current academic standing is
        i. Good
        ii. OK, but I am having some struggles
        iii. Not good.
    b. My current GPA is: _____
7. Series of evaluative Likert scale questions about different aspects of the ARC-Learn program structure and curriculum, e.g.,:
    a. I feel good about my progress in the ARC-Learn program
    b. My project team is successful
    c. My mentor is supporting my success (STUDENTS ONLY)
    d. Program leaders are supporting my success
    e. I plan to continue in the ARC-learn program
    f. If I could change one thing about the program it would be:_____
    g. My favorite thing about the program is: _____

INTERVIEWS and SURVEYS

Students will be asked questions that enable the research team to assess how ARC-Learn contributes to:

- Skills:
    - 21st century skill development (communication, collaboration, reflection, self-assessment, peer assessment, etc.)
    - Disciplinary/content skill development (Polar Science concepts, Arctic challenges, research methods, data visualization, data interpretation)
- STEM Identity
    - Self-concept (I am a scientist, I am a learner, I am a teacher, I am a collaborator, I am a successful student)
    - Sense of belonging (I feel included in STEM, I contribute to science, I have assets that are useful in science, my peers value my contributions, my mentor(s) see my strengths, I can be myself in the ARC-Learn program, my peers/mentors understand me, I am part of the STEM community).
    - Self-efficacy (I believe in my ability to understand and/or contribute to science, conservation, data collect/analysis/visualization/interpretation. I believe non-scientists understand when I explain science concepts to them. I believe in my ability to contribute to solving problems with science. I believe in my ability to collaborate with others to solve problems, etc.)
- STEM Persistence
    - Intention to pursue STEM profession or major (Degree to which students intend to stay in current science major, shift to another STEM major, or shift to a non-STEM major and

why. What are the students developing career or higher education plans and why and how do they intend to navigate. What things about ARC-Learn are supporting student trajectories, and what things about ARC-Learn or other external factors are presenting barriers).

- Undergraduate success (Student self-report on how they are generally doing and progressing in their undergraduate program. Major challenges, needs, obstacles, hopes for change, and plans for completing programs).

Mentors will be asked questions that enable the research team to assess how ARC-Learn contributes to:

- Mentor collaborative competencies/team science practices (I work well in teams, I listen to others, I show up as my authentic self, I am honest with others, I understand privilege and power, I value the expertise of others even if I do not fully understand it, I am trusted by others, I am viewed as a valuable contributor by others, I am regularly available to others, I am flexible in my approach, I am inclusive of those different than me, etc. The degree to which mentors believe that ARC-Learn is teaching students these competencies, what their roles are mentors is in developing these competencies, and how will their mentor experience translate into their collaborative science interaction)
- Perception of underrepresented and non-traditional students (the degree to which such students are competent, have valuable perspective, can/should be themselves, need to assimilate, are likely to be successful, deserve success, and capable of overcoming obstacles, add value to the science enterprise, are good communicators and collaborators, etc.)
- Perception of undergraduate research (what does it mean to prepare students for science, what is the role of undergraduate research in science education/career preparation, degree to which undergraduate researchers can make conceptual and intellectual contributions, what does it mean to learn how to fail and persist in undergraduate research, what do undergraduates need to learn through research experiences, what are the critical aspects of ARC-learn that support this, what is ARC-Learn missing that is needed to support student long-term science success)
- Mentor motivations (why do I want to be a mentor, what are mentoring competencies, the degree to which mentoring is seen as a practice/skill vs. merely an activity, the degree to which mentors understand power dynamics of the mentor/mentee relationship, mentor gains through training on inclusive practices)

Other faculty and administrators [INTERVIEW ONLY, NO SURVEY FOR THIS GROUP] questions that enable the research team to assess how ARC-Learn impacts:

- Perception of URE (what does it mean to prepare students for science, in what ways do you believe ARC-Learn I or is not doing so)
- Value of the program (the degree to which and mechanisms by which they perceive ARC-Learn to add value to: undergraduate education and preparation; college culture of undergraduate success and inclusion; college culture of collaboration/service/teaching; college competitiveness with future NSF or other agency grants

- Sustainability? (to what degree is college investing outside of the grant; how is the college working to integrate ARC-Learn with other undergraduate support activities; does the college admin/faculty feel ownership over ARC-Learn, how should ARC-Learn change and/or grow; what is the future of ARC-learn, etc.

G. Evaluation

Both the formative and summative evaluation processes will be guided by the following questions, which are distinct from the questions described in the Research Plan.

1. Were project elements appropriately and successfully implemented?
2. What challenges were experienced by the project team, mentors, and students;
3. Did the project team sufficiently adapt program implementation to address challenges and improve outcomes?
4. To what degree is the program being integrated into institutional infrastructure?
5. To what degree do student participants achieve each of the learning outcomes?

The evaluation process will be overseen by the 4-person external Advisory Board. They will work with the program and research team to verify that adequate evaluative data will be collected through programmatic participant tracking and research instruments and provided in program status reports. The project team will provide comprehensive data reports to the Advisory Board who will then interpret that data to determine the degree to which ARC-Learn is meeting the stated goals: a) contributing to broadening participation in STEM and Polar Science; b) expanding knowledge about design and implementation of UREs through investigating this alternative model; and c) building understanding of how mentors develop inclusive practice and competence.

The CEOAS Office of Undergraduate Programs will provide supplemental data from institutional student records and the OSU Office of Undergraduate Education will include ARC-Learn students and mentors in their existing evaluative processes. A formative report will inform the team on new actions and adaptations needed for cohort 2. A summative report will synthesize findings to present lessons learned that can be applied to sustain and scale ARC-Learn within OSU and provide guidance for other institutions who wish emulate or build on ARC-Learn.

Below is a list of anticipated Advisory Board meetings and main topics.

a. Sep 2021 – Kick off, program design consultation
b. Dec 2021 – instrumentation review and iteration, focus on ensuring that student/mentor tracking data and research instruments incorporate the appropriate data for use in the evaluation process. First cohort of students begin in Jan 2022
c. Sep 2022 – Formative report development, preceded by program status and data report provided by the program/research team, and succeeded by a formative report to NSF.
d. Dec 2022 – program review and improvement planning, focus on how the team will operationalize recommendations from the formative report. Second cohort of students begin Jan 2023

e. Jul 2023 – Summative evaluation development, preceded by program status and data report provided by the program/research team, and succeeded by a final summative report to NSF.