



# Harnessing the Data Revolution (HDR) Institute for Data-Driven Dynamical Design (ID4): Phase 2 Evaluation Report

Prepared by the ID4 Evaluation Team  
March 2024



THE UNIVERSITY OF UTAH

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**Note:** All photos in this report were provided by ID4 leadership.

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## Table of Contents

Introduction .....	1
Background and Context .....	1
Evaluation Overview .....	1
Methods .....	2
Findings: Implementation & Effectiveness .....	3
Leadership and Management .....	3
Collaboration .....	7
Institutional Culture .....	17
Student Support and Engagement .....	19
Broader Impacts .....	24
Findings: Outcomes .....	27
Collaborative Products .....	27
Learning and Skill Development .....	28
Relationships .....	30
Findings: Diversity, Equity, & Inclusion .....	32
Diversity .....	32
Equity .....	33
Inclusion .....	36
Considerations .....	37
References .....	41
Appendices .....	42
Appendix A: Full List of Evaluation Questions (Phases 1-5) .....	42
Appendix B: Evaluation Framework .....	43
Appendix C: Phase 2 Methods .....	45
Appendix D: Comparisons of 2022 and 2023 Student Survey Data .....	48
Appendix E: Brief on the ID4 Student Experience .....	52

## Tables and Figures

Table 1. Number of ID4 collaborators in the past year reported by student survey respondents .....	10
Table 2. Student survey topics and example items .....	45
Table 3. Number of student survey participants by gender and race/ethnicity.....	46
Table 4. Number of student survey participants by event attendance and first semester in ID4 .....	46
Figure 1. Student perceptions of ID4 leadership .....	5
Figure 2. Student perceptions of communication and interactions with others in ID4.....	13
Figure 3. Student perceptions of ID4's cultural alignment and value involving multiple institutions...	17
Figure 4. Student perceptions of ID4 support.....	20
Figure 5. Students' mean ratings of ID4 student support, comparing Fall 2022 and Winter 2023 survey data.....	21
Figure 6. Student perceptions of opportunities for engagement provided by ID4 .....	22
Figure 7. Student perceptions of learning opportunities provided by ID4 .....	30
Figure 8. Student perceptions of opportunities provided by ID4 to build relationships and learn about career pathways.....	31
Figure 9. Students' mean ratings of opportunities provided by ID4 to build relationships and learn about career pathways, comparing Fall 2022 and Winter 2023 survey data.....	31
Figure 10. Student perceptions of diversity in ID4.....	33
Figure 11. Students' mean ratings of satisfaction with ID4, by gender, in the Fall 2022 and Winter 2023 student surveys .....	35
Figure 12. Student perceptions of equity in ID4.....	35
Figure 13. Students' mean ratings of characteristics of ID4's culture (on a scale of 1-4).....	36
Figure 14. Students' mean ratings of ID4 leadership, comparing Fall 2022 and Winter 2023 survey data .....	48
Figure 15. Students' mean ratings of communication and interactions with others in ID4, comparing Fall 2022 and Winter 2023 survey data.....	49
Figure 16. Students' mean ratings of ID4's cultural alignment and value involving multiple institutions, comparing Fall 2022 and Winter 2023 survey data.....	49
Figure 17. Students' mean ratings of opportunities for engagement provided by ID4, comparing Fall 2022 and Winter 2023 survey data.....	50
Figure 18. Students' mean ratings of learning opportunities provided by ID4, comparing Fall 2022 and Winter 2023 survey data.....	50
Figure 19. Students' mean ratings of diversity and equity in ID4, comparing Fall 2022 and Winter 2023 survey data .....	51

# Executive Summary

The Institute for Data-Driven Dynamical Design (ID4) was funded by the National Science Foundation beginning in the fall 2021. The external evaluation of ID4 is conducted by the Utah Education Policy Center (UEPC), a university-based research center at the University of Utah, in collaboration with Dr. Ayesha Boyce. The Phase 2 evaluation report presents findings and considerations from the second phase of ID4's external evaluation, which spanned from February 2023 through February 2024, with additional data collected during the April 2024 full-Institute meeting. The Phase 2 evaluation questions focused on the Institute's implementation; effectiveness; outcomes; and diversity, equity, and inclusion. Findings and considerations based on the evaluation data are outlined below.

## Findings

### *Implementation & Effectiveness*

#### Leadership and Management

- ID4 leadership met regularly with the Institute's executive board, communicated with ID4 members, and implemented new organizational structures and practices that were perceived as effective.
- ID4 leadership is communicative and responsive to student and faculty needs.
- Ongoing challenges for ID4 leadership include delegating tasks and workload, establishing and communicating ID4 priorities, and scheduling full-Institute meetings.

#### Collaboration

- Cross-disciplinary collaborative research is occurring as planned, with most senior personnel engaged in multiple collaborations involving different individuals/teams, different levels of formality, and different stages of progress, including ideas for new collaborations.
- Over the past year, ID4 collaborations have evolved through the refinement of research topics and compatible teams, with a general shift from brainstorming to "working mode."
- Much of the work in collaborative projects is driven by graduate students and post-docs through consistent and frequent communication, while the pace of collaborations not involving students is influenced by project deadlines and faculty availability.
- Cross-Institute connections have progressed through Slack communications, the virtual NSF site visit, and small-group meetings, though the challenges of virtual collaboration underscore the importance of full-Institute meetings and other in-person opportunities.
- Senior personnel highlighted the unique value of ID4 collaborations for themselves and their students, and students reported positive perceptions of their ID4 interactions.
- Challenges related to collaboration in ID4 have revolved around learning "different discipline languages," identifying ways to collaborate and write papers across groups, and managing resources and bandwidth.

#### Institutional Culture

- Students and senior personnel described their ID4 work as generally aligned with the culture and expectations of their own institutions.
- Senior personnel identified some challenges related to collaborative research and academic schedules, as well as opportunities to enhance industry partnerships.

## **Student Support and Engagement**

- Ratings of student support and training increased over the past year, while engagement in research collaborations and in-person meetings remains high.
- Structured support and activities for students are expected to increase with the implementation of subcommittees and other initiatives from ID4 leadership.
- Students and senior personnel suggested that additional student supports could include increased onboarding, targeted mentorship, and more intentional small-group and in-person meetings.

## **Broader Impacts**

- ID4 has increased outreach and educational activities, using new processes to improve communication about Broader Impacts opportunities.
- Senior personnel questioned the level of visibility and cohesion of ID4 Broader Impacts activities, though existing programs were perceived as successful; many faculty are already engaged in outreach that is not connected with ID4.

## ***Outcomes***

### **Collaborative Products**

- ID4 members identified collaborative research, publications, and published code as key outcomes of their Institute work.

### **Learning and Skill Development**

- Students and senior personnel reported gaining knowledge and skills through ID4, highlighted by interdisciplinary thinking and problem-solving.

### **Relationships**

- Student ratings of opportunities to build relationships with faculty and learn about career pathways have increased in the last year, while relationships and networking connections remain important outcomes of ID4 involvement for both students and senior personnel.

## ***Diversity, Equity, & Inclusion***

### **Diversity**

- Students and senior personnel see diversity as a strength of the Institute but suggested that there is an opportunity to increase visibility and evidence of ID4's commitment to diversity.

### **Equity**

- Senior personnel pointed to the accessibility of ID4 for students, as well as outreach activities, as examples of ID4's equity efforts.
- Students perceive ID4 as equitable, and gender-based differences in student satisfaction with ID4 that were found in the Fall 2022 survey are no longer present.

### **Inclusion**

- ID4 provides an open and inclusive culture, highlighted by leadership's ability to foster a welcoming environment among students and faculty.

## Considerations

### **Continue to cultivate and communicate the importance of ID4's collaborative culture.**

- A1) Continue individual check-ins with senior personnel by the ID4 Director to discuss research progress and any logistical concerns (e.g., faculty sabbatical, student schedules, funding), and consider check-ins with collaborative student teams to support research momentum, alignment with Institute priorities, and resolution of student concerns
- A2) Organize additional student-focused events to support engagement, networking, and career development among students in ID4, such as structured discussions or mentoring opportunities for new students to learn from those with more ID4 experience, informal "coffee hours" for students to build community, social events for VPRTT fellows in ID4, and career development events/resources informed by ID4 faculty
- A3) Continue providing regular opportunities and resources for in-person interactions among ID4 members, with particular emphasis on biannual full-Institute meetings and other timely in-person events to onboard and engage new students soon after they join ID4
- A4) Develop a repository of cross-disciplinary resources to support ID4 members learning about other domains and terminology, as well as strategies for publishing joint papers in ID4, and consider organizing related educational events for students (e.g., discussions hosted by ID4 labs, student-focused workshops or tutorials)
- A5) Create a database and process for updating documentation of current ID4 students/faculty and areas of expertise, as well as collaborative teams and research projects, made available to all ID4 members

### **Make the implicit more explicit: clarify ID4's roles, processes, and values.**

- B1) Continue to discuss and share ID4's primary research priorities and measures of success with both faculty and students, along with processes to document and monitor individual contributions and collective progress (i.e., a tracking system for each of the convergence success activities)
- B2) Share with faculty the importance of the advisor's role in supporting new ID4 students establishing initial collaborations (e.g., making introductions to other ID4 faculty/students and existing projects, generating ideas for an initial collaborative project), and identify expectations for and communication pathways with VPRTT fellows' advisors who are not directly involved in ID4 to help them support their students' engagement in the Institute (e.g., alerting them about upcoming ID4 meetings to promote conversations with their students about potential collaborative research topics)
- B3) Develop plans and protocols for industry collaborations that reflect the realities of the industry context, such as the importance of client feedback/utility and information security, especially as industry relations become increasingly critical for pilot testing and disseminating ID4 research and products
- B4) Increase communication and visibility of ID4's efforts and values related to diversity, equity, and inclusion (DEI), such as publicizing data about the diversity of ID4 members, discussing the importance of DEI in ID4 more regularly, sharing with all members about Institute efforts to promote DEI internally (e.g., student recruitment) and externally (e.g., outreach), and clarifying how outreach activities at participating institutions support ID4's DEI goals



**Leverage resources to support coordinated processes and engagement around Broader Impacts activities.**

- C1) Continue to gather information about community education and outreach activities that are already being implemented in ID4 institutions and by ID4 faculty/students, leveraging opportunities to expand the reach and scope of activities that are formally affiliated with ID4
- C2) Dedicate time during full-Institute meetings and other ID4 gatherings to share, celebrate, and promote Broader Impacts work, with regular invitations to all members of the ID4 community (e.g., new students, VPRTT fellows, senior faculty) to become involved in Broader Impacts activities and subcommittees
- C3) Organize seminars dedicated to Broader Impacts activities that provide opportunities for ID4 members to learn about current initiatives and opportunities, share successes and challenges from recent events/efforts, find collaborators or solicit input for upcoming events/efforts, and expand ID4 outreach and education models to additional institutions and communities

# Introduction

## Background and Context

In 2016, the National Science Foundation (NSF) unveiled their 10 “[Big Ideas](#),” including “[Harnessing the Data Revolution \(HDR\)](#)” aimed at innovative data-driven discovery. The HDR Program features initiatives such as the Institute for Data-Driven Dynamical Design (ID4), which began in the fall of 2021. Additional information about ID4’s mission, goals, structure, and activities can be found in the Phase 1 Evaluation Report (McDowell, Acree, Boyce, & Rorrer, 2023).

## Evaluation Overview

The external evaluation of ID4 is conducted by the Utah Education Policy Center (UEPC), a university-based research center at the University of Utah, in collaboration with Dr. Ayesha Boyce. The evaluation team aims to integrate formative and summative evaluation into the general operations of ID4 through a mixed-methods approach to data collection, ongoing collaboration with ID4 leadership, and an emphasis on issues related to culture, diversity, equity, and inclusion.



## Evaluation Questions & Data Sources

ID4’s evaluation is being conducted in five phases between 2022 and 2027. The evaluation is guided by a series of questions that address ID4’s program theory; implementation; effectiveness; outcomes; diversity, equity, & inclusion (DEI); and sustainability. There are different areas of emphasis in each phase of the evaluation based on the Institute’s timeline of implementation. The full list of evaluation questions and associated emphasis in each evaluation phase is outlined in Appendix A.<sup>1</sup>

This report is based on data collected during Phase 2, which spanned from February 2023 through February 2024. The Phase 2 evaluation questions focused on implementation, effectiveness, outcomes, and DEI, as outlined below.

- **Implementation:** How and to what extent are ID4 activities being implemented on schedule and as planned, both within and across participating institutions? To what extent has implementation been sensitive and attentive to the various cultural complexities of the multiple institutions?
- **Effectiveness:** Are key components of ID4 operating effectively, both in person and virtually, within and across participating institutions? What is working well and for whom? Are participants from different backgrounds/identities having different experiences? How might effectiveness be improved?

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<sup>1</sup> The information in this section and Appendix A reflects the revised evaluation phases and timelines, which were updated after Phase 1.

- **Outcomes:** What outcomes are associated with participation in ID4? How do experiences differ by participant backgrounds/identities? To what extent has the Institute reached its goals?
- **Diversity, Equity, and Inclusion (DEI):** How and in what ways are ID4 leaders attending to diversity, equity, and inclusion (DEI) for participants, in activities, and across the Institute as a whole? What opportunities and barriers exist?

Each evaluation area is connected to specific indicators (i.e., information used to answer the corresponding evaluation questions), data sources, and data collection methods. Appendix B shows the complete evaluation framework. In Phase 2, data sources included ID4 senior personnel, participating students and post-doctoral researchers (“post-docs”), and Institute documents. Data collection methods included surveys, interviews, and document review.<sup>2</sup>

### ***Report Organization and Audience***

The remainder of this report includes the methods, findings, and considerations from Phase 2 of the evaluation. The findings are organized by the key evaluation areas—implementation & effectiveness,<sup>3</sup> outcomes, and DEI—with topical subheadings driven by the evaluation questions and themes that arose in the data. Key findings are presented as secondary subheadings. Finally, the considerations offer formative, data-driven recommendations based on the strengths and opportunities identified through the evaluation. The primary intended audience of this report is ID4 leadership, including the Director, Research Manager, and other members of the executive board.

## **Methods**

To gather evidence relevant to the evaluation questions in Phase 2, the evaluation team utilized three data collection methods: interviews with ID4 senior personnel, a survey of participating students and post-docs, and a review of Institute documents. A summary of these methods is provided below, and a full description can be found in Appendix C.

- **Senior personnel interviews** involved 14 of the 18 senior personnel, including the ID4 Director and Research Manager, as well as faculty from 11 of the 12 Institute sites. The interview protocol included questions about the implementation and effectiveness of collaborative research teams and ID4 activities, program outcomes, and the ways that diversity, equity, and inclusion were incorporated into the vision and implementation of ID4. The interviews were coded and analyzed in tandem with other data sources to generate key findings, and illustrative quotes from the interviews are included throughout this report.
- **The student survey** was distributed to all students, post-baccalaureates, and post-docs who were involved in ID4, and responses were submitted by 24 of the 58 recipients (41% response

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<sup>2</sup> Additionally, Phase 2 was designed to include focus groups with students/post-docs and focus groups with collaborative research teams, held in person during the annual full-Institute meeting. However, due to a schedule change, this meeting and the focus groups were delayed until April 2024. The evaluation team plans to conduct these focus groups at the meeting in April and will summarize the results as two topical briefs (one about the ID4 student experience and one about collaboration in ID4), which will ultimately be appended to this report.

<sup>3</sup> While implementation and effectiveness are distinct areas of the evaluation, they are presented together because they address the same topical subheadings (e.g., Leadership and Management, Collaboration, etc.), and this structure allows for connections to be drawn in the findings between what was implemented and how effective it was.

rate). Most respondents were PhD students/candidates, had been in their graduate program for three or more years, and had been involved in ID4 for more than a year. The survey items about students' education level/status, their involvement in ID4 events, demographic information, and Likert-type items used to gauge their perceptions of and satisfaction with ID4. Analysis of survey items included descriptive summary statistics and coding of open-ended responses to support, contextualize, and add to the findings from the perspective of ID4's student community. Throughout this report, results from the Fall 2022 student survey (Phase 1) and Winter 2023 student survey (Phase 2) are compared and discussed when appropriate.

- **The document review** included internal notes from meetings with ID4 leadership, notes and materials from ID4 events, [ID4 website](#) content, and ID4 Slack channel communications. These documents were used to contextualize and enhance findings from interview and survey data.

## Findings: Implementation & Effectiveness

### Leadership and Management

We identified three key findings related to the implementation and effectiveness of ID4's leadership and management:

- ID4 leadership met regularly with the Institute's executive board, communicated with ID4 members, and implemented new organizational structures and practices that were perceived as effective.
- ID4 leadership is communicative and responsive to student and faculty needs.
- Ongoing challenges for ID4 leadership include delegating tasks and workload, establishing and communicating ID4 priorities, and scheduling full-Institute meetings.

***ID4 leadership met regularly with the Institute's executive board, communicated with ID4 members, and implemented new organizational structures and practices that were perceived as effective.***

ID4 leadership has continued key activities from Phase 1 such as **monthly executive board meetings** and **regular communication via Slack** with Institute members. Board meetings and Slack communication have been implemented as planned over the last year and have served as the primary means of bringing attention to general ID4 issues or concerns as well as planning and coordinating across the Institute. As one faculty member said, board meetings involve *"discussion about where we are, where we need to be, things that we need to discuss, [and] things that we need to improve on."* Communication via Slack was cited as a strength of ID4 leadership in the Phase 1 evaluation report and has continued as planned, with regular updates from leadership and engagement from ID4 members.

Over the past year, leadership has also started to implement new management strategies such as subcommittees and individual faculty meetings. Based on feedback from ID4 members and as part of efforts to distribute leadership activities across students and faculty, ID4 developed **four subcommittees**, which began meeting in late 2023. The subcommittee focus areas include: Outreach and Education; Student Recruitment, Onboarding, and Training; Meetings (e.g., seminars, all team

meetings); and Cyberinfrastructure and Data. In interviews and meetings, ID4 leadership described the subcommittees as a way to facilitate greater involvement in ID4 activities for students and senior personnel. Students and senior personnel were invited to join the subcommittees on a voluntary basis, with the expectation that committee membership would require one hour of effort per month for at least one year.

Additionally, the ID4 Director held **meetings with individuals and small groups of senior personnel** to monitor collaborative research progress and gauge challenges and needs for support. In an interview, the ID4 Director indicated that these meetings will continue on a roughly quarterly basis, serving as a way to better understand ID4's progress toward outcomes and ongoing areas for improvement. Faculty described these meetings as opportunities to share progress about their ongoing work and explore possibilities for extending and identifying new collaborations.

Interviews with senior personnel suggest that while executive board meetings and Slack communication provide effective means of communication within ID4 leadership and externally to the Institute as a whole, the establishment of subcommittees addresses a need for more structured inclusion of students into decision-making processes, and small-group meetings with faculty provide a desired system for discussing progress toward research goals and ongoing support needs. As of the time of reporting, both practices are being implemented as planned by leadership, and they are expected to continue for the foreseeable future. Further analysis of the success and effectiveness of these leadership strategies will be discussed in later sections of the report.

### ***ID4 leadership is communicative and responsive to student and faculty needs.***

ID4 leadership's **communication and responsiveness** continues to be a strength of the Institute. In interviews, senior personnel described the ID4 leadership as accessible, communicative, and attentive to Institute members.

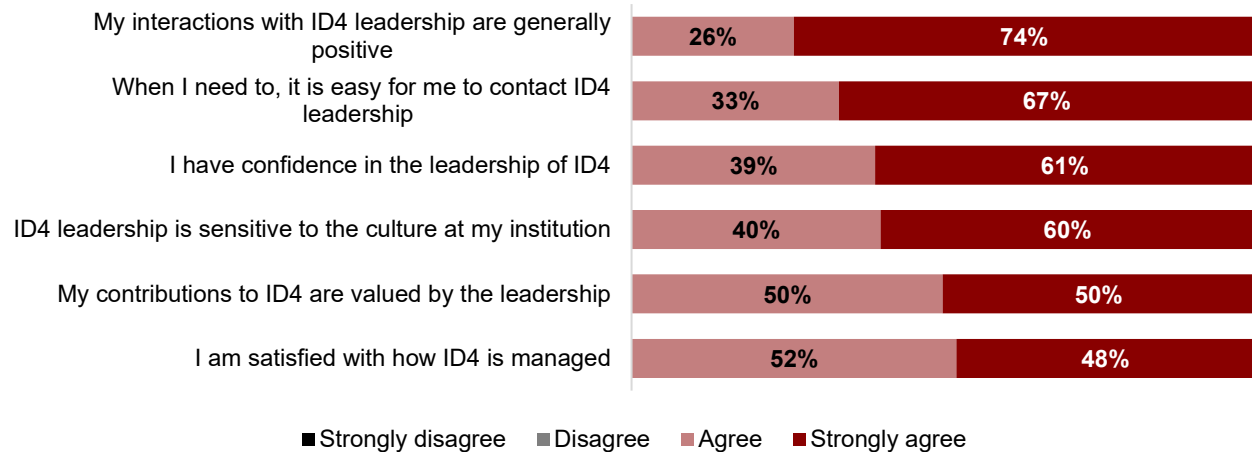
- *It really is inspiring. [The ID4 Director] is the most accessible, approachable director of an [Institute] I've ever come across.* (Senior personnel interview)
- *Somehow [the ID4 Director] simultaneously feels a huge amount of personal investment in this... while also still bringing a ton of humility to it in the way he leads it. And boy, I don't know that there's very many people who can pull that off.* (Senior personnel interview)

Analysis of interview data suggests that ID4 leadership is invested in the success of the Institute while also making significant effort to **ensure that individual members feel supported** and set up for success. This was evident in the way senior personnel described the Director's leadership approach, including minimizing organizational and logistical requests, allowing faculty to focus on research, and facilitating connections between faculty that were relevant and mutually beneficial. As one senior personnel described:

*I think [the ID4 leaders] are very good and I think they're very supportive. They encourage making connections. The communication is very clear... They're not overbearing. They don't administer the kind of bulldozers with all kinds of stuff that's not really necessary. So, I found that it's run in a really, really good way so that we can just do our work. And I think the activities, like the workshops that they organize, they're always very interesting. There's lots of room to talk and lots of room to think of new projects.*

Student perceptions of leadership align well with those of senior personnel. Figure 1 shows that 100% of students agreed or strongly agreed with all survey items related to ID4 leadership, including feeling that their contributions are valued by ID4 leadership and that their interactions with leadership are generally positive. This was consistent with data from the Fall 2022 student survey, which also showed very positive student perceptions of ID4 leadership (see Figure 14 in Appendix D for comparison data).

**Figure 1. Student perceptions of ID4 leadership**



Source: Winter 2023 student survey (n=24).

***Ongoing challenges for ID4 leadership include delegating tasks and workload, establishing and communicating ID4 priorities, and scheduling full-Institute meetings.***

While senior personnel described the investment and support from ID4 leadership as a strength of the Institute, they also suggested a **need for increased delegation or distribution of leadership tasks**. Some interviewees cited the new subcommittee structure as a shift toward more distributed leadership responsibilities, while others indicated that the executive board is continuing to think through ways to reduce the leadership burden for the ID4 Director.

- *It's something we've been kind of worried about. [The ID4 Director] pulls the whole train.* (Senior personnel interview)
- *I think it's a good idea to introduce some kind of structure, and you are talking to not a structure person. But I think having some kind of structure and subcommittees with somehow more well-defined roles and responsibilities makes sense. We had an executive board... and everybody kind of had a role or a job, industry liaison, lots of different roles. But I think there wasn't—somehow it was just kind of okay for us to all be friends and get on the meetings and hang out and there wasn't that much of a recording. It wasn't kind of, 'let me take charge of these activities.'* (Senior personnel interview)
- *It's just tricky to figure out. At the site visit, the recommendation that we got was subgroups based on domain area, but I think all of us felt like this was not a good idea. It just doesn't make sense for who we are and the type of vision for convergence that we have in mind. It just really is different from that perspective. And so that doesn't quite make sense or fit. And so, what exactly that structure would look like is hard. That's kind of tricky.* (Senior personnel interview)

Another challenge relates to senior personnel’s sense of connectedness across the Institute. Multiple interviewees expressed **interest in a more focused set of priorities for ID4** generally, suggesting that having a clearer sense of the “*big problems that are being solved*” might help generate a stronger sense of collective purpose for such a diverse faculty. Some faculty described feeling that their own research and collaboration within ID4 was strong and productive, but that they were less engaged in and aware of Institute-wide events and work.

- *I think there's real opportunities for centralizing our efforts and being a little more strategic as a whole Institute rather than sort of locally responsive to needs. I think there's the opportunity to be more than additive, but actually learn from each other and grow with each other and create opportunities that take less effort individually, because we're doing them collectively. (Senior personnel interview)*
- *There's definitely room for more [faculty] involvement... It just would be nice to understand what the main focus points will be in the future. This is something that I personally am not very clear on. There's many groups working on different things... but there are many, many different things happening. And it would be nice if there's a clear signal, like, let's all work on this very important problem. Then I can sort of see myself getting a little bit more involved. Otherwise, it's just too hard to follow too many threads. (Senior personnel interview)*

Lastly, some senior personnel expressed a **desire for more advanced planning for ID4 events**, although they acknowledged that Institute-wide organization can be difficult. One ID4 subcommittee was designed in part to address meeting-related challenges. As part of their efforts, the subcommittee distributed a survey in December 2023 asking about availability for an in-person event in the fall of 2024, suggesting an increased level of advanced planning.

- *I can only be gone once a month from family perspective. And so if there's an ability to try and get meetings settled on a calendar a little bit further in advance, it would probably mean that I could get to more of the in-person meetings, which I would prefer. (Senior personnel interview)*
- *It's just that getting everybody to respond has been historically, I bet, pretty challenging. And I bet if I was in [ID4 leadership's] shoes, I might also delay a little bit... So I don't know exactly a good solution for it, but definitely having more notice would be good for me. (Senior personnel interview)*



## Collaboration

We identified six key findings related to the implementation and effectiveness of collaboration in ID4:

- Cross-disciplinary collaborative research is occurring as planned, with most senior personnel engaged in multiple collaborations involving different individuals/teams, different levels of formality, and different stages of progress, including ideas for new collaborations.
- Over the past year, ID4 collaborations have evolved through the refinement of research topics and compatible teams, with a general shift from brainstorming to “working mode.”
- Much of the work in collaborative projects is driven by graduate students and post-docs through consistent and frequent communication, while the pace of collaborations not involving students is influenced by project deadlines and faculty availability.
- Cross-Institute connections have progressed through Slack communications, the virtual NSF site visit, and small-group meetings, though the challenges of virtual collaboration underscore the importance of full-Institute meetings and other in-person opportunities.
- Senior personnel highlighted the unique value of ID4 collaborations for themselves and their students, and students reported positive perceptions of their ID4 interactions.
- Challenges related to collaboration in ID4 have revolved around learning “different discipline languages,” identifying ways to collaborate and write papers across groups, and managing resources and bandwidth.

### ***Cross-disciplinary collaborative research is occurring as planned, with most senior personnel engaged in multiple collaborations involving different individuals/teams, different levels of formality, and different stages of progress, including ideas for new collaborations.***

Collaborative research is one of the hallmarks of ID4’s mission. As stated in the original NSF proposal, “*the Institute converges eleven stakeholders from the design and discovery community with six leaders from the data and computer science community to address...challenging design problems.*” In interviews with senior personnel, most indicated **formally collaborating** with one or two other faculty members. These collaborations were often described as bringing together data scientists and domain scientists, and several senior personnel noted the unique nature of their ID4 collaborations.

- *I collaborate a lot with [senior personnel name]. That's the main collaborator that I have in ID4. We're collaborating in something completely different. Well, it's really interesting because it's very different to what I do, but it's actually very similar. We're utilizing data science to make predictions about Moth crystals. So that's been my role in the Institute, is working with the data scientists who know how to handle the large and vast amount of data. We provide the domain expertise on the kind of questions that we're trying to answer. (Senior personnel interview)*
- *I think for me, the biggest success has been being able to interact with [senior personnel name], for example... Even despite the distance, I think the interactions have been very, very valuable... The interactions were new, and they started because of ID4. (Senior personnel interview)*
- *We have some collaboration with [senior personnel names]... I also started working more with the ontology team to learn more from them how to use these capabilities for, say, getting more information about new materials. These are the main collaborations that I have currently. (Senior personnel interview)*



In addition to formal collaborations, some senior personnel indicated that they interact with other individuals and research groups across ID4 in **less formal ways**, such as sharing code and methods, or having general conversations about their work and interests.

- *...We have been interacting with a number of groups at the [Institute], essentially providing methods to maybe three, four different efforts within the [Institute] that essentially just use our code and methods for running calculations. (Senior personnel interview)*
- *But for the most part...there was not a huge need for collaboration, like official collaboration. I guess there are some unofficial collaborations that happen because the conversation that I have with domain scientists and knowing what work other people are doing are somewhat...they're guiding the type of research that I do. So there isn't a collaboration on paper. But definitely I think having these conversations, knowing the interests that they have, and having an insight into the types of data sets that are important to the domain scientists, that guides the kind of data that I then use in my projects. (Senior personnel interview)*

Most collaborative work was described by senior personnel as involving graduate students and post-docs in lead or support roles. However, some ID4-related projects do not involve students and only involve faculty or external collaborators. The **range of project structures and student involvement** is captured in the following quote from one senior personnel:

*So we have one [project] that is pretty far along, we hope, that is primarily driven by one of [senior personnel name]'s students and then with a couple of my students in more like a consulting kind of role. And then there are a couple of things that we just work on together, just the two of us [senior personnel], because it's fun. And then there's another project or two that involves a collaborator friend of mine who's not a part of ID4 but is in the UK. And then there's another project that involves another faculty member at [university name]. And then we've been talking about doing something with [senior personnel name] too, but we haven't yet.*

As alluded to in the quote above, while most senior personnel have multiple ongoing collaborations, ideas and discussions about **new collaborations** are also still occurring.

- *I've also participated in a lot of recent... brainstorming sessions with other [senior personnel] that are more on the computer science side, trying to find new collaborations to initiate or to provide some insight from a synthetic experimentalist perspective on some of the other projects that are ongoing in the [Institute], which I think has been really interesting and will likely lead to next projects after this one completes. (Senior personnel interview)*
- *I'm excited about this potential new collaboration together with [senior personnel name] and then...another machine learning and visualization group. Because I think there, we could develop some very kind of meta-level approaches to how to deal with not having all the data... And I think this will be very useful to the engineering design community. So whereas before within my group, we've been looking at very specific problems and how to solve them, I think with [senior personnel name] and this other group, we will work at a higher level, engineering problems in general, like how do we solve them? So I'm excited about that collaboration. (Senior personnel interview)*

This momentum to continue establishing new collaborations and to expand existing collaborations is **consistent with the ID4 Director's vision** for the Institute. As the ID4 Director explained:

*On the science side of things, I want to see more connections between research groups where let's say an existing pairwise collaboration pulls in one person to help them with something and*

*pulls in another person to help them with something and starts to build more of a cluster rather than a pair. So sort of like from pairs to clusters is my main scientific goal this year.*

However, in one group interview, senior personnel noted that the movement “*from pairwise interactions to bigger team efforts*” may not be necessary for all collaborations:

*You can't really...force a team to come together in this strict scripted and planned manner. Maybe some interactions stay pairwise and that's fine. They do cool work and maybe some of them do grow and that's good also. And so I think we are kind of putting a bit of a bet on a bottom up structure. I think that there may be, in some circles, a tendency to associate bottom up with unintentional. But I think we have actually been very intentional about trying to create spaces and environments that allow that type of structure to work and to flourish.*

***Over the past year, most ID4 collaborations have evolved through the refinement of research topics and compatible teams, with a general shift from brainstorming to “working mode.”***

When senior personnel reflected on their past year of involvement in ID4, they often discussed the trajectory of their collaborative work. As described in the Phase 1 Evaluation Report, when ID4 began, collaborations among senior personnel were sparked by their existing relationships, connections during the initial full-Institute meeting, and the research objectives stated in the original Institute proposal. Some senior personnel described their collaborations as **fairly stable** since then, as exemplified by the following quote:

*So when [ID4 leadership] put this whole proposal together, there were four areas of focus in terms of the examples that they wanted to do. And my view is that our contribution in terms of one of those areas of focus has been exactly what was planned. So in terms of my group being the experimental team that understands these materials and identifies the interesting questions, and then [senior personnel name]'s group has these amazing methods to be able to address these questions. So, from my perspective... it works really well.*

Most senior personnel noted some degree of **evolution in the focus and nature of their research**, as well as who they are collaborating with. Specifically, after identifying initial teams and generating ideas based on the original objectives in the first year, research topics and teams were refined, and they transitioned into “*working mode.*” ID4 leadership credited senior personnel with being “*involved enough in ID4 to continue to evolve its scientific direction and its scientific collaborations.*”

- *I think what happened is...we first had a set of objectives. We want to do these objectives, but then when we met and we started along collaboration, this new idea arose, and then the research took naturally that course. (Senior personnel interview)*
- *[My role has] changed, but mostly changed due to how the collaborations evolved. At the beginning we were meeting with different groups to see, how do we start collaborating together. Then it took a little bit to find which team in which subgroup we're working. I think that's where most of the changes were—related to finding the right team for the right collaboration. (Senior personnel interview)*
- *I feel like there's the kind of expansion and contraction phases where you think about a lot of different things and then hopefully some interesting stuff kind of coalesces out of that. And we're definitely in this sort of coalescence phase right now, which is great and fun. (Senior personnel interview)*

While the evolution of collaborations was primarily described in a positive light, senior personnel acknowledged that a few individuals who were initially collaborating did not have compatible personality types. However, these issues were resolved with **changes in collaborative teams**, as ID4 leadership explained:

*...There were a couple of people who probably don't have personality types that work well with each other. And those misfits emerged within the first year and a half... But I think the positive is that they've managed to find other collaborations that are resonant, and that seems to be succeeding.*

***Much of the work in collaborative projects is driven by graduate students and post-docs through consistent and frequent communication, while the pace of collaborations not involving students is influenced by project deadlines and faculty availability.***

Senior personnel highlighted the **important role of graduate students and post-docs** in many of their ongoing collaborative ID4 projects. As shown in Table 1, in the past year, student survey respondents had strong collaborations with an average of two ID4 faculty members and two ID4 students. Overall, students reported collaborating with similar numbers of faculty and students at all levels of collaboration (i.e., casual, moderate, and strong).

**Table 1. Number of ID4 collaborators in the past year reported by student survey respondents<sup>4</sup>**

Level of collaboration	Type of collaborator*	Mean number of collaborators	Median	Range
<b>Casual</b> (e.g., occasional help and possible acknowledgment on a product)	Student	2.4	2	0-8
	Faculty	2.8	2	1-9
<b>Moderate</b> (e.g., regular help exchanged that might lead to a joint product)	Student	1.9	1	0-7
	Faculty	2.0	1	1-5
<b>Strong</b> (e.g., working together on a joint product with co-authorship)	Student	2.3	2	1-5
	Faculty	2.1	2	1-7

\*Student collaborators included post-baccs and post-docs, and faculty collaborators included all ID4 senior personnel.

Source: Winter 2023 student survey (n=22).

Students were described as **“driving” the tasks and activities** related to specific collaborative projects and products. Several senior personnel noted students’ contributions to collaborative work in terms of their engagement in ID4 events, and the frequency of their meetings and communication. Most commonly, students meet on a regular basis, and senior personnel join the meetings at least occasionally and are available to help as needed.

<sup>4</sup> One individual indicated having 10 collaborators for every type and level of collaboration. This response was removed as an outlier.

- *So typically in a week, my students are in constant communication... They're meeting once a week with [senior personnel name]'s student to touch base and catch up in the activities of the week. Then as things are progressing, we start actually meeting in person to start planning on the next steps of the project... Well, we [senior personnel] make ourselves available if they need any help... (Senior personnel interview)*
- *...The students have every other week meetings on Zoom, and we [senior personnel] also dial in on a semi-regular basis. (Senior personnel interview)*
- *And then of course, the students are more in touch than we are. I think it's the collaboration. The students are the ones who I would say drive a lot of the collaboration activities. (Senior personnel interview)*
- *We have another batch of students who are more on the method development and software implementation side. They are in touch with the other group of students to guide them and to help them get things done with the methods. (Senior personnel interview)*
- *...That's coming from going to the annual meetings or at one point in time we had weekly seminars, and when I could go, I would go and my student, I think attended way more than I did. So he had a tighter connection with the group. (Senior personnel interview)*

When discussing collaborations that do not involve graduate students and post-docs, senior personnel described a more variable project flow that is primarily influenced by project deadlines and faculty availability. For example, as one senior personnel explained, *“Sometimes it goes faster, sometimes slower. It depends actually on priorities and time, the speed for different projects.”* Another senior personnel noted specific factors that affect the pace of the projects they work on with a faculty collaborator: *“And then the projects we do ourselves are sort of—they're a little bursty depending on if we're excited about a deadline, or we're both teaching right now, we're both stretched pretty thin at the moment, and that's kind of a different dynamic than during the summer.”*

***Cross-Institute connections have progressed through Slack communications, the virtual NSF site visit, and small-group meetings, though the challenges of virtual collaboration underscore the importance of full-Institute meetings and other in-person opportunities.***

Senior personnel highlighted several ways that they have stayed connected to the Institute-at-large over the past year. For example, one senior personnel explained how the **ID4 Slack channel** is used for communication across different collaborative teams: *“I think the ID4 Slack channel has also been a great resource for just bouncing quick ideas off of one another, hearing about some of the challenges that some of the other collaborative teams are having and seeing if you can weigh in. So I think that that's been used as a good resource from my perspective.”* Another senior personnel mentioned the value of the **virtual NSF site visit**, which was a one-day event held on Zoom that involved a series of presentations from ID4 faculty about their collaborative research in the Institute's key areas: *“The site visit was a good opportunity to just get a large overview of what other people are doing. A lot of times we focus on these explicit collaborations, like people being on papers and stuff like that. But what often gets missed is that implicit collaboration and how the ID4 just implicitly guide the things that we do.”* These opportunities to communicate with and hear from ID4 members across a variety of collaborative teams were noted as being particularly important in lieu of full-Institute meetings and weekly virtual seminars, which had taken place during the 2022-2023 academic year but did not occur during the summer and fall of the 2023-2024 academic year. Finally, some senior personnel also

mentioned staying connected with their direct collaborators by **finding times to meet in person**, either through university visits or during other events, as illustrated in the following quote:

*And then we also look for opportunities to get together in person, more or less as often as we can, given various constraints. So we were just in person together last week because we were at this event that had nothing to do with the science, but that I think we both were more excited to go because we knew we'd be able to sneak off and do science. And we're trying to put together something for [next month] and then we're both going to the same sort of workshop in [a few months]. And so I think we sort of look for—or we have been looking for excuses to do this scheduling.*

Overall, both students and senior personnel discussed virtual collaboration as a challenge, and they noted the **benefits of in-person collaboration**. Consistent with findings from the Phase 1 evaluation report, in-person full-Institute meetings are highly valued and desired across the ID4 community. These meetings provide opportunities to establish new collaborations, make progress in existing collaborations, develop a sense of belonging in ID4, and learn about the full Institute (which is especially important for students who are new to ID4).

- *[The student experience in ID4 can be improved] With more person-to-person interaction. Those moments of hands-on work have been incredibly valuable. (Student survey)*
- *I think with the limited frequency of meetings, the size of ID4, and the physical distance between universities, it can often be challenging to keep up with the current status of ID4 members' works. (Student survey)*
- *So without these direct connections [during in-person meetings], it's hard to know—it's hard to find opportunities to collaborate... (Senior personnel interview)*
- *I find the yearly all-hands-on meeting, in-person meeting, to be most effective. And if you don't go to those, then you miss out on a lot. And I think I wasn't able to travel for the last two or three of them. I've just had conflicts and I couldn't be there. So it's very easy to feel isolated if you don't go to these meetings. (Senior personnel interview)*
- *My previous students, who now graduated, were able to participate in these in-person meetings. For them, it was really important... Now, since then, these students graduated and they moved on. The new students, in fact, I can explain [ID4] to them, but I think the only real way to engage them is for them to be able to participate in an activity—an in-person activity. (Senior personnel interview)*

***Senior personnel highlighted the unique value of ID4 collaborations for themselves and their students, and students reported positive perceptions of their ID4 interactions.***

Overall, collaborative work in ID4 has been perceived as both valuable and enjoyable. Senior personnel highlighted the ways that ID4 collaboration has provided opportunities for them to make unique connections across disciplines (e.g., computer science and physical sciences) and contexts (e.g., academia and industry), which has sparked **new questions, approaches, and research directions**.

- *I think between [my collaborators] and myself, there's two or three different projects that have emerged, none of which were written in the project in the original grant, but I think they're really high quality research-wise because they all came out of us teaching each other what we're good*

at, and also what the biggest and most important problems in the field are. (Senior personnel interview)

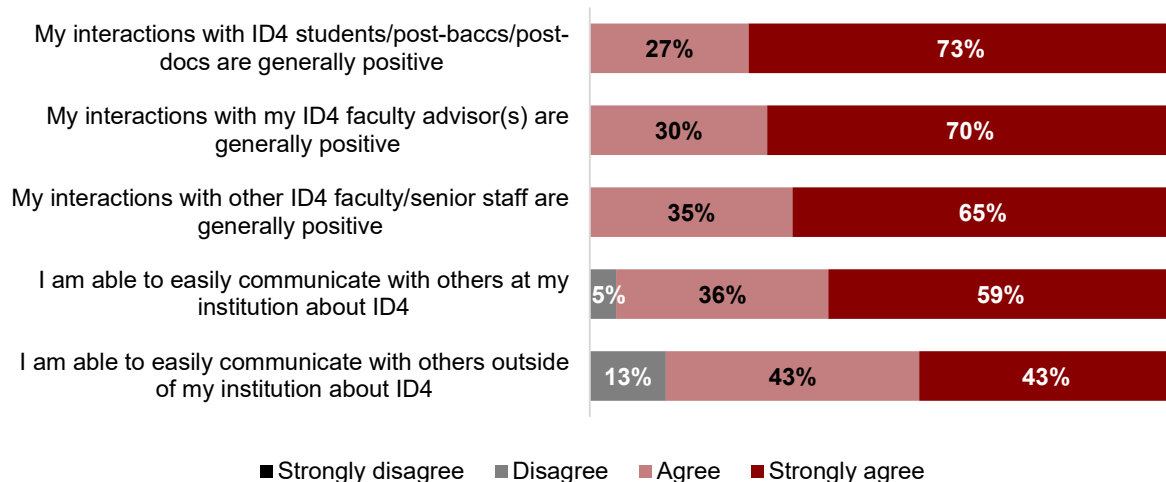
- *For me, it's like a reflected excitement in that I haven't been thinking about these problems for a long time, but I've been thinking about a certain class of methods for a long time that turn out to appear to just dovetail really nicely. And so it's just a lot of fun.* (Senior personnel interview)
- *I think [my ID4 work has] provided a unique opportunity for my group to really interact with experts in data science and methodologies, computer science, that eventually shaped the research that we are doing.* (Senior personnel interview)

One senior personnel specifically noted the mutual benefits for faculty and students of learning about other research areas and how to work effectively across fields:

*I think it's been super valuable for both the students and the faculty to really fully get a sense of what other research areas are like. To have a better sense of what it's like to not only work with computer scientists from my end, but also what is it like to be a graduate student over there? What are your needs? What are your challenges? How do I work with a computer science group in a way that is mindful of how comp sci grad students value their time and effort and what their goals are? ...And I think it's good for the students to learn about this. I think it's just as good for the faculty to learn about this. I mean, most of the faculty in ID4 have never had to collaborate this far from a field.*

From students' perspectives, most survey respondents reported that their **interactions and communication with ID4 members have been positive**, as shown in Figure 2. This is consistent with student responses to the same items in the Fall 2022 survey, which were also positive and had similar mean ratings (see Figure 15 in Appendix D for comparison data). Across both years, students had slightly lower mean ratings for the two items about communication (3.4) in comparison to the items about interactions with various ID4 members (3.7). This pattern aligns with specific challenges related to communication in ID4 that were shared by students and senior personnel and will be discussed in the next section.

**Figure 2. Student perceptions of communication and interactions with others in ID4**



Source: Winter 2023 ID4 student survey (n=23).

**Challenges related to collaboration in ID4 have revolved around learning “different discipline languages,” identifying ways to collaborate and write papers across groups, and managing resources and bandwidth.**

The most salient challenge of collaboration in ID4, highlighted by both senior personnel and students, has been learning the language of and communicating with individuals from the **many different disciplines represented in ID4**. While this was discussed by senior personnel in the Phase 1 evaluation, it emerged more clearly as a widespread challenge in the Phase 2 evaluation. As one senior personnel noted, this is “*the design feature and flaw of ID4*,” because the cross-disciplinary nature of the Institute is also part of its design, what makes it unique, and was cited as the primary success of collaborative work in ID4 (see previous finding). Senior personnel described this “*language barrier*” as something that they have been able to overcome through persistence and open conversation, while students conveyed this as an ongoing challenge.

- *...We all speak different discipline languages. So, [senior personnel name] and I can both look at a shape, a molecule or whatever, and we both immediately know what we're talking about, but then someone else who has to be reminded of some traumatic high school chemistry class now has to relive that. So that can be kind of challenging, but nonetheless, I've still managed to publish with people outside [of my field]. I feel like it's usually one PI that's really pushing it over the finish line. These things can get stuck, I think. (Senior personnel interview)*
- *I think the language barrier is challenging with the diversity of disciplines represented within ID4 and just takes some persistence of, yeah, all right. What do you mean by that? And I don't understand what the goal is, why is this challenging or interesting? But everyone has been very open to having those conversations, which I think is a big first step. And so I think so far I haven't encountered cases where we couldn't push things beyond that initial barrier. (Senior personnel interview)*
- *Trying to get people in the theory realm to really understand the domain science and how the problems are approached has been very difficult. (Student survey)*
- *[The most significant challenge of my work with ID4 has been] Overcoming the disciplinary and terminological barriers between information science and materials science (Student survey)*
- *Communication can be challenging when team members come from different areas, particularly during the initial conversation about a new project. (Student survey)*

In addition to learning new terminology, some students felt that it was **difficult to determine how to collaborate** with others outside of their domain. For example, when asked about the most significant challenge of their ID4 work, one student said, “[*how to*] *figure out what project to work on and decide how to coordinate the joint efforts*,” and another student said, “*determining ways to collaborate with researchers who are far outside my domain*.” Similarly, some senior personnel noted examples of their students having trouble collaborating beyond their primary research group or team. One senior personnel explained that the “*meshing*” of students across groups “*hasn't exactly happened in the same way*” as it has within groups. Another senior personnel provided insight into why it has been difficult for students in her group to find cross-group collaborations that are interesting and worthwhile:

*...Students can have meetings on their own without [faculty] and they understand each other. They're speaking the same language now that they've worked on this topic for a while. But in terms of connecting to other groups, that's more difficult. Everybody's detached and working on their sort of things, at least for us. In a way, we definitely have*

*discussions, but they're not regular with other groups in the technical support role and assisting with codes. But this is maybe a problem specific to us. There's a lot of people that come and ask for advice on how to train this kind of model around this kind of simulation. So supporting is something that the students enjoy a little bit, but not too much. They have their own projects and their own scientific questions to answer. So...I have a hard time going to somebody in my group and saying, "Oh, look, there's this interesting problem that is being pursued [in ID4]. Let's just drop everything and go work on that." It's hard, right? People cannot multitask too much.*

Specifically, one type of collaborative work that has been challenging for senior personnel and students is the **writing and publication of joint papers**. One student survey respondent explained that the most significant challenge of their work with ID4 is *"luring the interest of people from computer science (data domain) to actually write papers together."* Senior personnel focused more on the challenges associated with the process of writing joint journal articles, including collaborating with students on papers and tailoring cross-disciplinary papers for journals that are discipline-specific.

- *So we're also learning about how to collaborate on papers, because a lot of it's been conference papers. Conference papers and workshop papers, you're just getting your ideas. It's really for reaction and sharing. It's maybe, I want to say, not as high stakes, but we wanted to go up the notch and do a journal... So we're learning about doing that together, which is pretty much the way we have all operated in our other collaborations, but it's new students and making sure that they learn those protocols. So that's one thing. We're growing together. (Senior personnel interview)*
- *Of course, if you publish a joint paper, especially if it's between different disciplines, it's always harder, because where is this going to go, in the civil engineering [journal], or is this going to go in the language one? So it is harder...but it can also be much more innovative, because now all of a sudden we're using this new technique, so that's very innovative... But it's just harder to write it because there is not so much a precedent of how we write. It's not like we do yet another analysis and everybody understands how this analysis works... It's just, I think intellectually more challenging to think about, "How are we going to present this new thing?" Because the reviewers will not have seen this before. (Senior personnel interview)*

ID4 leadership noted that the expectation for students is to create two separate papers for each of their collaborative projects—*"one that's really focused on the computer science methods side of things, and one that's cool scientific discovery, so that the work kind of gets broadcast to both communities."* This expectation was not discussed by other senior personnel or student survey respondents. However, asking students to write multiple papers for a given project may contribute to the general concerns that faculty expressed about **bandwidth for collaborative work**, particularly for students. One senior personnel summarized this challenge: *"I think there's a lot of exciting stuff going on and also things that I'd like to do, but resources are a bit limited as it is in terms of how many collaborations you can undertake without pushing students to be spread too thin."* Another senior personnel framed this as an issue that is inherent to the funding structure of Institutes like ID4. With limited funding spread across many people, and the importance of focused effort to produce papers, senior personnel and students do not have the time and bandwidth to pursue as many collaborative opportunities as they would like to:



*One challenge I would say is that...the structure of the funding for these kind of [Institutes] is really not sufficient for having wide collaborations. I mean, we have a student, let's say, that's dedicated to this collaboration. [Senior personnel name], she needs to focus to get enough simulations done to publish a paper. There's very little bandwidth left for exploring wider directions. There's many questions. So in the beginning we had lots of fun discussions, brainstorming a lot of different ideas that could be done... But then somebody has to pursue them, and there's just not enough funding and bandwidth to do anything beyond what can actually lead to substantial progress and a paper, which is important for students. So I would say that this is maybe a typical NSF issue, is that very little funding for too many people in one [Institute] leads to a lot of discussion, but not too much in possibilities in joint collaborations... I often feel like I personally don't have enough time to join all the different things, and I don't have enough students and post-docs that can pursue all these different ideas, but there's a lot of demand, a lot of questions. So that's sort of the tension.*

Relatedly, another senior personnel shared an example of how the flow of ID4 funding for particular individuals/positions can affect the pace and completion of collaborative work:

*The only challenge is the post-doc that was working on [the paper], her funding ran out. So now we're just kind of trying to get this paper together without her, or not without her on it, just not participating actively. So it's been a little bit slow going, but I suspect this will come out or at least get submitted this year, I'm sure.*

Finally, challenges related to bandwidth for collaboration also stemmed from **changes in schedules and other commitments** among students and senior personnel. For example, students had limited availability for ID4 work when they had internships, and senior personnel noted that their own collaborations were affected by the demands of non-ID4 work (e.g., client work), sabbatical, travel, and summer schedules.

- *The biggest challenge that we encountered, it was during the summer because some students have other commitments. I think that this semester, the student had an internship, so we could only talk to a student after certain hours because of the commitment. But it's not a bad thing. It's part of the student training. So we have to adapt for that for the time being, but I think that's been the only major setback or issue. (Senior personnel interview)*
- *I feel guilty sometimes because I have this idea. It's like, 'Hey, we need to do it,' but most of the time it's eaten by the client work. (Senior personnel interview)*
- *...During the summer, we let the students talk to each other, and then they were talking to each other, but then [senior personnel name] and I did not communicate at least on a regular basis. I think that's why the students—maybe they felt that they were a little bit without direction... (Senior personnel interview)*

## Institutional Culture

We identified two key findings related to the implementation and effectiveness of ID4’s responsiveness to different institutional cultures:

- Students and senior personnel described their ID4 work as generally aligned with the culture and expectations of their own institutions.
- Senior personnel identified some challenges related to collaborative research and academic schedules, as well as opportunities to enhance industry partnerships.

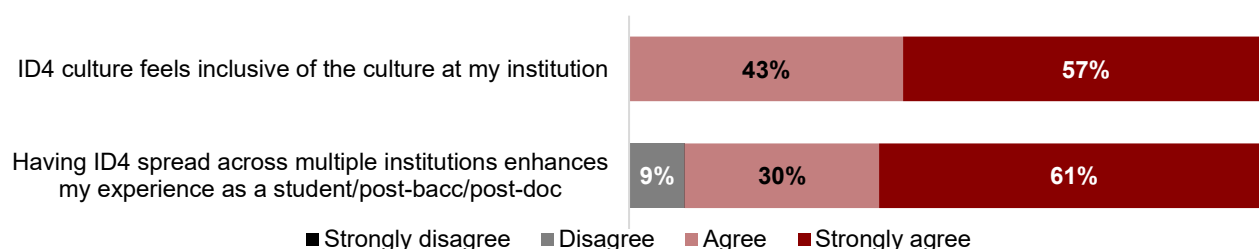
### ***Students and senior personnel described their ID4 work as generally aligned with the culture and expectations of their own institutions.***

When senior personnel were asked about the alignment between ID4 activities and the culture at their own universities, they described ID4 work as complementary to their existing research agendas and **aligned with expectations from their institutions**. Multiple senior personnel noted that cross-disciplinary research was viewed positively by their colleagues, department chairs, and/or deans, and that for their own research, the exposure to new disciplinary viewpoints has been beneficial.

- *I think it aligns well. I mean, yeah, we've always got lots of demands on our time, but I think all of us are in this job because we like research and moving beyond our comfort zone in science, and that's certainly what we're hired to do as well. And having a mechanism like that in place with ID4 to enable us to think a little bit beyond what our expertise is and what we might be able to do by bringing in different expertise, different research ideas, hearing about challenges in other fields and how they might relate to what we do is, I think, really exciting and certainly fits very much within the broader picture of what we're trying to achieve as scientists. (Senior personnel interview)*
- *I think it fits in perfectly... [My university] is explicitly encouraging cross-disciplinary research. And so, some of the stuff that I'm doing at ID4, I have other people at [my university] that are interested in some of the same problems. And so, I could see how even solutions that we [develop through ID4] would be applicable to people at [my university] and beyond that as well. (Senior personnel interview)*

As shown in Figure 3, students also had **positive perceptions of ID4’s cultural alignment and value across multiple institutions**—a finding that was consistent with Fall 2022 survey data (see Figure 16 in Appendix D for comparisons). Students agreed or strongly agreed that ID4 culture feels inclusive of the culture at their own institution (100%) and that having ID4 spread across multiple institutions enhances their experience (91%).

**Figure 3. Student perceptions of ID4's cultural alignment and value involving multiple institutions**



Source: Winter 2023 student survey (n=21).

## **Senior personnel identified some challenges related to collaborative research and academic schedules, as well as opportunities to enhance industry partnerships.**

While perceptions among students and senior personnel were generally positive about the alignment of ID4 with their universities' cultures, some concerns were noted in interviews. Senior personnel again brought up **challenges related to cross-disciplinary research and publishing** (see previous section of this report), particularly in relation to faculty seeking tenure positions.

- *... There are indeed some considerations to have, especially for junior faculty and also even maybe in the data science realm where we have to make sure that we are doing work that is publishable in our specific areas. That's how you get known in your community, and that's how you get good letters for tenure. And so when you're doing application-style work, that's actually kind of hard to do. (Senior personnel interview)*
- *It's me building a tool that [another ID4 faculty] can use in [their] lab. It doesn't necessarily mean that I'm building a tool that could be published in my area because it might not be novel. And so, I struggled with that a lot. I struggled with, do I do work that is collaborative and might check ID4 and NSF boxes, or do I do the work that might personally... give me success. And so, one of the things that I had to do was to maybe have undergraduate students that would do the more development-side work and then have my PhD student focus on the more publishable work, but then ID4 only funds one student. So yeah, it is what it is. (Senior personnel interview)*

One senior personnel also suggested that differences across fields/domains may contribute more to challenges than differences across institutions. This comment was made primarily in reference to computer science students, who often take internships during the summer, which pauses their ID4-related work. As this senior personnel explained:

*I think more it's the cultural differences or just procedural differences between computer science and other disciplines... the most glaring version of that being student internships. We started collaborative projects with comp-sci grad students... and we're trucking along, we're trucking along, and then you're two-thirds of the way towards a publication. And the student's like, "Well, I'm going to be at Facebook for the next three months working full-time there. I'll see you in the fall." And you're like, "What? What's this?" So that was pretty wildly new to us and we didn't know that was going to happen and are still kind of confused by it.*

Additionally, senior personnel identified opportunities to enhance industry relations and the application of ID4 research to industrial needs. While industry partnership was not a common theme across interviews, such opportunities may be important to leverage as the Institute progresses and industry relations become more critical for pilot testing and utilizing Institute research and products. Senior personnel specifically highlighted considerations such as how to manage differences between commercial and academic timelines, as well as how to meet customer needs while fulfilling research expectations.

- *... While solving problems for our customers, I cannot share any of their data with my colleagues from ID4. Moreover, I often cannot describe a specific problem in sufficient detail. One potential solution I find is to reformulate these challenges into more generic problems that can be shared. This approach works well at the initial development stage. At a later stage, enhancing security protocols for the developed [machine learning] tools might become a crucial requirement. (Senior personnel interview)*

- *...In a company, we must optimize how we allocate our employees' time and determine how quickly we need to solve a problem, considering the risk that it may not be resolved within the desired timeframe. This often differs from academia, where deadlines are less stringent, allowing for the pursuit of more challenging problems and the adoption of riskier approaches. I am still in the process of finding a balance between these two realms that would enable me to address both important and urgent problems simultaneously. (Senior personnel interview)*
- *...In academia, you might complete a project, publish a paper, and then move on. In contrast, in industry...you develop something to demonstrate, you have a set of test clients willing to try your alpha version of the product, you give it to them, observe their reaction, and based on that, decide whether to proceed with the development or not. Even if the idea behind a particular tool is excellent, sometimes I need to halt its development if there is not enough interest. Conversely, I might develop tools that do not attract much research interest but are useful for the clients. In this context, I see a significant opportunity in leveraging ID4 capabilities as a core research center that generates ideas. At the same time, it would be interesting to explore mechanisms for productizing these ideas. (Senior personnel interview)*

## Student Support and Engagement

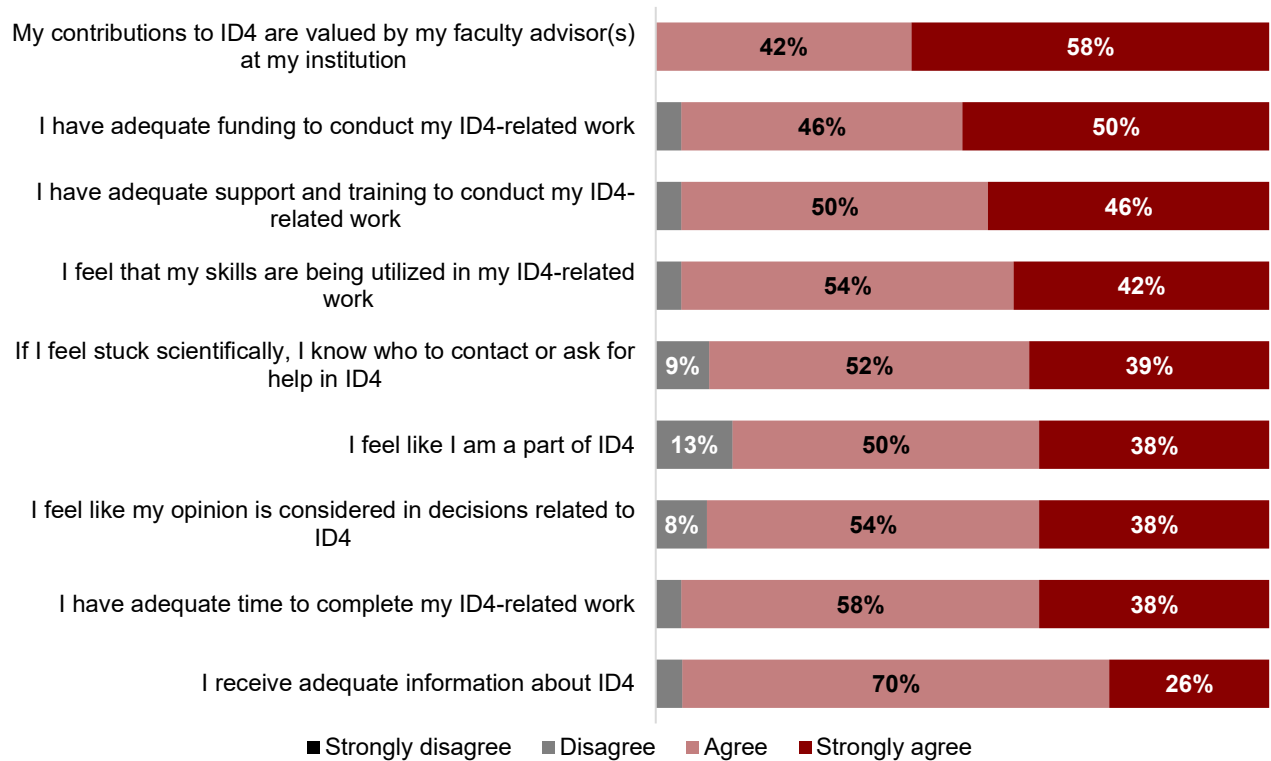
We identified three key findings related to the implementation and effectiveness of student support and engagement in ID4:

- Ratings of student support and training increased over the past year, while engagement in research collaborations and in-person meetings remains high.
- Structured support and activities for students are expected to increase with the implementation of subcommittees and other initiatives from ID4 leadership.
- Students and senior personnel suggested that additional student supports could include increased onboarding, targeted mentorship, and more intentional small-group and in-person

### ***Ratings of student support and training increased over the past year, while engagement in research collaborations and in-person meetings remains high.***

Student survey responses suggest that students feel satisfied with the support they receive related to their work with ID4 and that they have opportunities to engage in ID4 activities. Specifically, Figure 4 shows that more than 95% of students agreed or strongly agreed with a series of items indicating that they have **adequate funding, support, training, and time to conduct their ID4 work**. Additionally, all students agreed or strongly agreed that their contributions were valued by their faculty advisor at their institution.

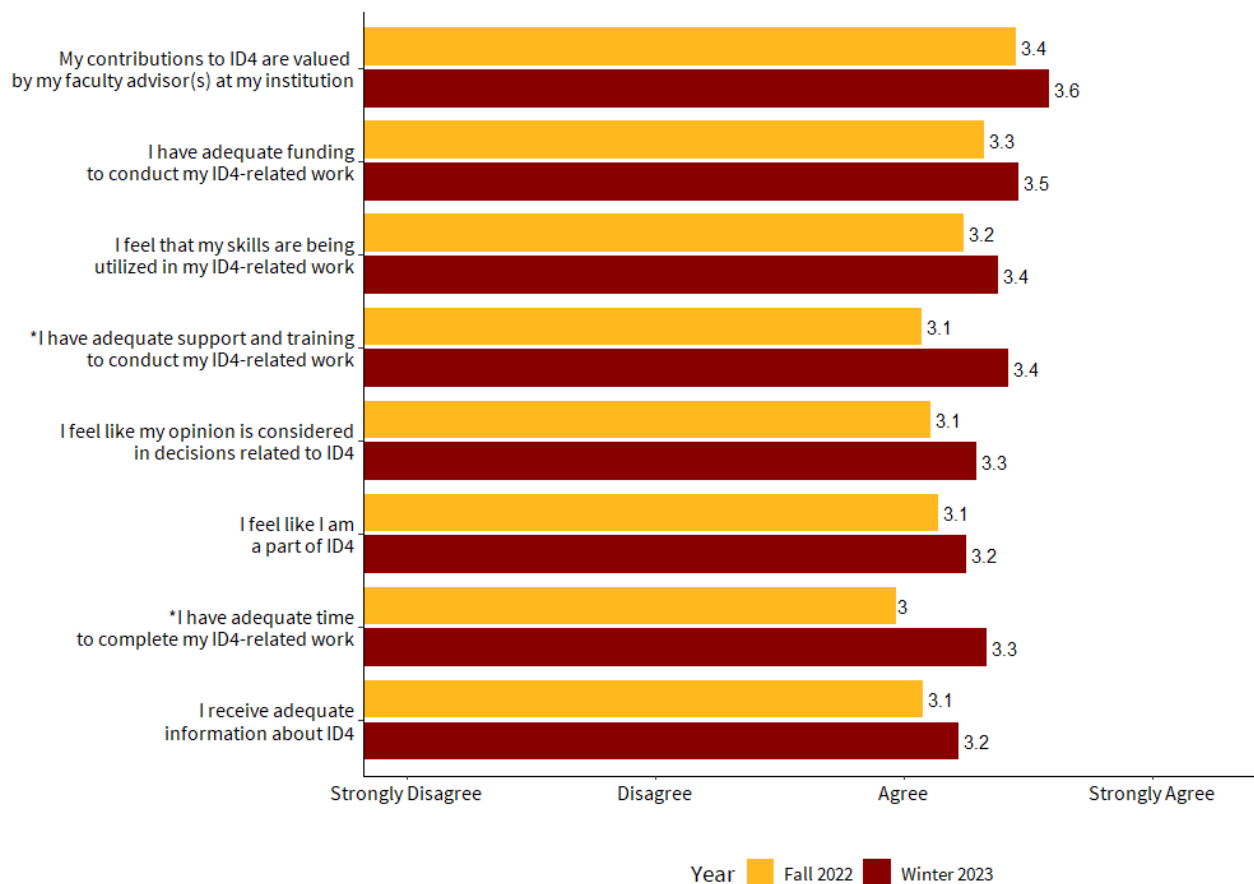
**Figure 4. Student perceptions of ID4 support**



Source: Winter 2023 student survey (n=24).

Figure 5 shows that **mean ratings of student support increased** in the Winter 2023 survey when compared to data from the Fall 2022 survey. T-tests found significant differences for two items ( $p < .05$ , indicated with an asterisk in Figure 5): “I have adequate support and training to conduct my ID4 work” and “I have adequate time to complete my ID4-related work.” This finding may suggest that ID4 faculty and institutions are providing better support for students. It may also indicate that students, as they spend more time in ID4, are better managing their time and responsibilities across their graduate and post-doc studies and thus feel better prepared to complete their ID4 work.

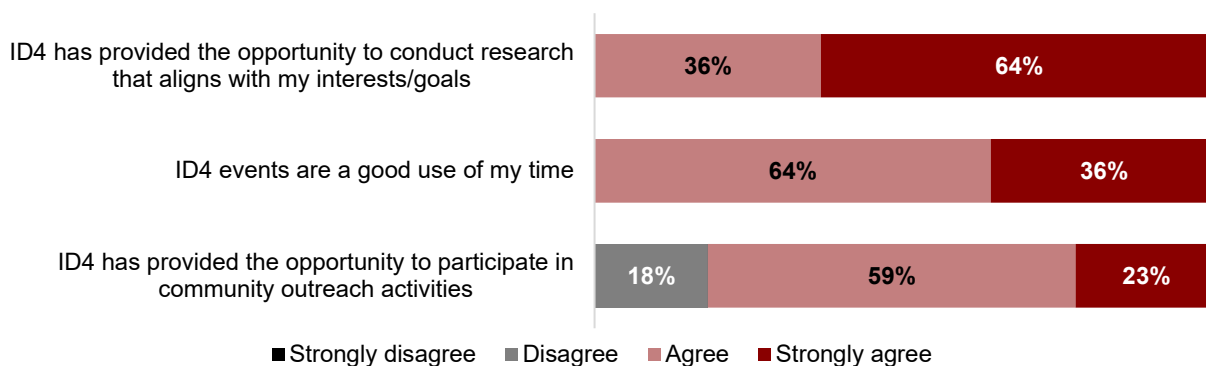
**Figure 5. Students' mean ratings of ID4 student support, comparing Fall 2022 and Winter 2023 survey data**



**Source:** Winter 2023 student survey (n=24); Fall 2022 student survey (n=29). Note: One item from the Winter 2023 survey (“If I feel stuck scientifically, I know who to contact or ask for help in ID4”) is not shown here because it was not included in the Fall 2022 survey.

Figure 6 shows that all student survey respondents agreed or strongly agreed that ID4 provides opportunities to engage in research that aligns with their goals, and that ID4 events are a good use of their time. Most students (82%) also felt that they had opportunities to participate in community outreach activities through ID4. While evidence from meetings with ID4 leadership and document review suggests that specific opportunities for student engagement have declined (e.g., discontinuation of virtual seminars and the Student Leadership Council), student survey data indicates that, similar to 2022 survey findings, students generally feel **satisfied with the support and engagement opportunities** that ID4 provides (see Figure 17 in Appendix D for comparison data between Fall 2022 and Winter 2023).

**Figure 6. Student perceptions of opportunities for engagement provided by ID4**



Source: Winter 2023 student survey (n=24).

**Structured support and activities for students are expected to increase with the implementation of subcommittees and other initiatives from ID4 leadership.**

In interviews, senior personnel described renewed efforts to increase student engagement in ID4 decision-making. As mentioned earlier in this report, ID4 leadership recently established four subcommittees and invited students to join. Senior personnel also expressed interest in renewing ID4 seminars, which were previously held virtually on a weekly basis and provided the opportunity for students to share their ongoing work with others across the Institute. Leadership indicated, however, that they do not plan to continue with a weekly seminar series due to low attendance, but they will continue to integrate occasional student-led seminars into virtual and in-person Institute meetings. Additionally, ID4 leadership recently released an application for an ID4 Excellence Award, described as an annual monetary award for graduate students and post-docs who have contributed to “fostering a collaborative, interdisciplinary scientific community, contributing to collective efforts in broader impact activities, and growing our research community beyond ID4.”

As the quotes below highlight, faculty believe that subcommittees will enable students to play a larger role in making decisions related to key issues in ID4, and senior personnel have been considering how to make seminars more engaging and well-attended.

- *So in the past, for instance, there are things that we need to accomplish like cyber infrastructure, getting everything on the website, getting all of their data sets and stuff like that that we have available referenced on our website, and so forth. And we talked about not just having a group of people who are responsible for that, but also recruiting students. So letting students have more responsibility...that's something that I believe that we'll be putting into place going forward. (Senior personnel interview)*
- *The site visit pretty much took up everybody's time from February to July, and I think that went as smoothly as possible. All of the faculty were engaged, grad students and post-docs were engaged. I think, in general, we did a good job communicating everything around that... I think since the site visit, things have been too quiet, but with the launching of the subcommittees and the new quarterly report and relaunching of a seminar series, I think we will see a change. (Senior personnel interview)*

- *Part of the reason no one would sign up for seminars is because even though we sent out a survey saying, "What do you want to see on the seminar series?" and people said, "We want to see this," then sent out emails saying, "Hey, you all said you wanted to see this in the seminar series, please sign up," like two people did. So kind of rethinking what's most useful, and not just restarting the activities, but kind of more of a reboot to make sure it's useful and that people are engaged. (Senior personnel interview)*
- *...We did, I think, a very good job of onboarding our first cohort of students. We kind of haven't done such a good job of onboarding the next cohort, but that is also on the list of things we need to fix. We're going to reboot some version of the [Student Leadership Council] and make sure that new grad students and new post-docs get onboarded and know what's going on and feel included. (Senior personnel interview)*

***Students and senior personnel suggested that additional support for students could include increased onboarding, targeted mentorship, and more intentional small-group and in-person meetings.***

While students and senior personnel generally expressed positive views of student engagement and support, many also had **ideas for increasing engagement and better supporting students in ID4**. In the student survey, respondents were asked how the student experience could be improved. Their comments included suggestions for more student-centered collaborative activities and finding ways to meet in person more often. Specific ideas included annual reviews of ID4 students, discussion-based seminars, student “coffee hours,” and structured onboarding for newer graduate students.

- *I think there's a focus on automatically adding new members of involved research groups to ID4, but as people's research projects evolve/change, there may need to be a form of annual review where students/post-docs who initially thought their research would align with ID4 activities get phased out. (Student survey)*
- *[The student experience in ID4 can be improved by] Trying to foster stronger collaborations between the groups. More consistent check-ins between ID4 leadership and groups that are collaborating together would help to push projects forward more efficiently. (Student survey)*
- *I think that there are greater opportunities for students and post-docs to work across disciplinary divides, which could be facilitated by more focused colloquia or workshops that are less dominated by PIs/senior faculty. A more closed setting might allow for more candid discussions and networking by grad students and early career researchers. (Student survey)*
- *More structure to help early grad students get involved in collaborations. I think this was present in the site-visit planning meeting, and it came about organically the fall before in Princeton, but more structure could have been helpful as I was intimidated by people who were experts in fields I knew nothing about. (Student survey)*

Senior personnel also described the types of support they provided for their students. Multiple faculty members described efforts to improve students’ writing, while others reminded students to be patient in their research process and helped them with problems related to other ID4 faculty/groups. As noted in the Phase 1 Evaluation Report, ID4 has not implemented formal mentorship training for faculty, and most advisors described **varied strategies for supporting their students**. For example, some faculty said that they set office hours and let students ask for support as needed, while others said they met regularly with student research groups (as frequently as multiple times per week).



- *I often find that I am, when I'm working with students, I'm trying to get them to slow down... It's kind of slow down to go fast because otherwise, you wind up with a big mess of ideas and code and math that actually doesn't really hang together and it's very hard to reason about. And so if you sort of really build it brick by brick, then you kind of always know where you are. (Senior personnel interview)*
- *So the students are the ones on the ground doing the work. We are giving lots of time to our students, teaching them how to write, oh my God, and giving them time. Both of us check in with our students regularly, weekly definitely, and multiple times during the week. (Senior personnel interview)*
- *I think if I was a student, my view would be that there's not a lot of value in talking to somebody outside of my own institution about these problems because there's so much nuance in a given problem that somebody outside of it may not either be able to do anything about it, or the amount of effort you'd have to do to onboard them to the problem might be significant. For example, I know that when challenges have happened at institutions that have more than one ID4 faculty member, students in one research group will go to the faculty members in other research groups and talk to them about the problem, but they've kept it local to the institution rather than going to [ID4 leadership]. (Senior personnel interview)*

## Broader Impacts

We identified two key findings related to the implementation and effectiveness of ID4's Broader Impacts activities:

- ID4 has increased outreach and educational activities, using new processes to improve communication about Broader Impacts opportunities.
- Senior personnel questioned the level of visibility and cohesion of ID4 Broader Impacts activities, though existing programs were perceived as successful; many faculty are already engaged in outreach that is not connected with ID4.

### ***ID4 has increased outreach and educational activities, using new processes to improve communication about Broader Impacts opportunities.***

As discussed throughout this report, ID4 leadership recently established four subcommittees, one of which is focused on outreach and education. The inclusion of this committee suggests that leadership is working to increase ID4's **organization and structure related to Broader Impacts activities**, which was an opportunity identified for improvement in the Phase 1 Evaluation Report. As one of the committee's first steps, they developed a new application to solicit and review submissions for ID4 outreach activities. In a recent meeting, ID4 leadership indicated that seven new applications were accepted for funding at the start of 2024, including four outreach activities that had not previously been funded by the Institute. While ID4 is developing new processes for increasing outreach efforts, interviews with senior personnel suggested that there is already **increased outreach occurring across the Institute**. Compared to previous findings, more faculty indicated that they were involved in activities such as summer programs for both K-12 and community college students.

- *On the outreach side of things, summer's a big time for us. We do our REU programs, our undergrad programs, we did a coding summer camp, we did a few coding activities for high school students and middle school students over the summer. Those are probably the biggest things that have happened. (Senior personnel interview)*
- *Then on the Broader Impacts, I think we're also succeeding fairly well on that. We could probably work on having a more cohesive vision for Broader Impacts overall, and I'm hoping that'll come out of the new subcommittee, but we have been meeting our goals. (Senior personnel interview)*
- *So for instance, the summer camp that I wanted to run, [ID4 leadership] was like, "Yeah, sure." I know there was a student in Chicago who had this idea for—I think it was a high school summer camp thing—and the funding was there for that. So I know that whenever anyone has ideas for any kind of outreach, we as the exec board... have always been supportive of those things. (Senior personnel interview)*

**Senior personnel questioned the level of visibility and cohesion of ID4 Broader Impacts activities, though existing programs were perceived as successful; many faculty are already engaged in outreach that is not connected with ID4.**

Similar to the Phase 1 evaluation findings, senior personnel indicated that **Broader Impacts activities**—and specifically K-12 and undergraduate outreach programs—**are concentrated among a small group** of ID4 members and institutions. Senior personnel referred to these efforts as “dispersed” and “a challenge area,” and said that “there could be more visibility within the rest of the Institute.” Findings from interviews suggest that there is a core group within ID4 leading successful outreach activities (e.g., summer programs, research experiences for undergraduates (REUs), coding camps), but that those efforts have remained siloed. Some senior personnel attributed challenges to a lack of engagement and communication from faculty, while others indicated a lack of visibility related to Broader Impacts across ID4.

- *At the kind of K-16 level, our efforts are a little...what's the word I'm looking...dispersed, I guess. We don't have a cohesive, per se, thing going on. But each of the individual programs, to the extent that we've been able to measure it, have been successful. We know our undergrad REU students are applying to grad school or at the end of the REU say they feel more like scientists or are considering careers in science. We don't really have the metrics as much for the coding camps, because that's harder to ask a sixth grader in a year if they want to be a scientist. But yeah, I do think we could be a little more cohesive in our STEM outreach activities, but to the extent that we've measured those, I think we are being successful. (Senior personnel interview)*
- *Even though they're great and they're happening...the people who care a lot about that put a lot of work into it and do it. Nobody else really has a ton of visibility into it. And I'm super glad it happens. But it is something that could be more—there could be sort of more visibility within the rest of the Institute of those activities, I guess. (Senior personnel interview)*
- *[Broader Impacts has] definitely been kind of a challenge area. Again, for the kind of common theme here of a not insignificant number of PIs do not respond to emails or Slacks, period, straight up. So it's fine. But I think it was kind of clear at the virtual site visit, that there's a clear group of core—a minority, really—of core people in the Institute that were either doing outreach or reporting outreach or just trying to do something in a cohesive way. And many others either weren't, or were in that list of people that never respond to requests for these things. Not even to do, just tell us what you're up to and let's connect on these things. (Senior personnel interview)*

- *So it's kind of been hard to get something cohesive because in a sense it's not cohesive. And I've tried with [ID4 leadership] to try and see if there's some guidance or if there's some carrots, sticks, anything that we can use. But it seems like there's not, so I'm not sure about that. (Senior personnel interview)*
- *I had students in my group who were very motivated to create some sort of outreach program. And just because ID4 was a large [Institute] and seemed to have some resources that needed to be utilized, we proposed it to ID4. So we've done this thing where high school students come in and they do maybe three weeks of coursework, high-school level coursework and material topics, and then do about three weeks of some sort of research project. And so the funding has come from ID4, but there are a lot of students involved... (Senior personnel interview)*

Despite the challenges garnering engagement in Broader Impacts activities across ID4, findings from interviews suggest that **some faculty are involved in outreach programs that are not connected to ID4.** For instance, one faculty member described their involvement with a summer program and a local community college, and others shared experiences as part of science clubs and programs in local schools. As mentioned briefly by one senior personnel, there may be interest and value in exploring ways that these external outreach activities can be integrated or expanded through ID4.

- *We've been talking with some community colleges near [our campus] about potentially hosting summer students that wouldn't otherwise be able to do research, so maybe that's something I could broach with [ID4 leadership]. (Senior personnel interview)*
- *I go quite a bit into public school here...to do science days and organizing science activities...not through ID4... Yeah, I'm happy to [connect the work to ID4]. Now, I'd be mostly working with more kids. Yeah. I'm happy to see, I would be very happy to discuss this and see what can be done. (Senior personnel interview)*
- *The closest is I can go talk to high school students. I gave a seminar explaining what we do in the [Institute] and other things that we do as well, how machine learning can help with materials science. That was very well attended. I did a similar outreach to some senior citizens and locally as well because they were very curious how machine learning is going to change their life. And it's all part of the broader picture. It's not specifically funded by HDR, but I did show a bunch of examples from the work in the [Institute] in these discussions. (Senior personnel interview)*



# Findings: Outcomes

We identified three key findings related to the outcomes associated with ID4:

- ID4 members identified collaborative research, publications, and published code as key outcomes of their Institute work.
- Students and senior personnel reported gaining knowledge and skills through ID4, highlighted by interdisciplinary thinking and problem-solving.
- Student ratings of opportunities to build relationships with faculty and learn about career pathways have increased in the last year, while relationships and networking connections remain important outcomes of ID4 involvement for both students and senior personnel.

## Collaborative Products

### ***ID4 members identified collaborative research, publications, and published code as key outcomes of their Institute work.***

For students and senior personnel, developing **collaborative research publications, conference papers, and published code** were the most common responses to questions about outcomes resulting from their ID4 work. Senior personnel described publications between faculty members as well as collaborative products primarily created by students in their research groups. While some faculty described challenges, most expressed a sense that their work with ID4 had led to tangible outcomes.

- *I was already working with [one senior personnel], so that was not so difficult. We had started this new collaboration with [another senior personnel], which is on a kind of weird topic for me. That has really come to fruition and I think the journal paper is going to be submitted soon. It's a little bit of an odd paper for me, but we found a place for it in the civil engineering community, in a really good journal.* (Senior personnel interview)
- *We've had a lot of successes with regard to building this machine learning out... So, applying machine learning techniques to visualization... We've been extremely successful with that. We've been able to create some visual analytics tools that are out there as well. There are several publications that directly stemmed from ID4 as well.* (Senior personnel interview)
- *We were forming collaborations, we're publishing both individual papers and collaborative papers, we're making good progress on the research. So, I think, at least on the research side of things, it started out slow with mostly individual papers, but now we are getting more collaborative papers that kind of make ID4 do things that are beyond the sum of the individual parts, so I think we are meeting that objective.* (Senior personnel interview)

Some senior personnel described **challenges related to the pace and nature of developing collaborative research products** (e.g., finding the right journals, working with students on their writing, reviewing and editing methods/analyses). Others expressed a feeling of pressure to publish, particularly leading up to the July 2023 NSF site visit.

- *In a way, I feel behind. But I don't know, how is it feeling with other members of ID4? I know that there are other sub-teams and sub-roles that are already publishing and getting things out there. In our case, we're just on the first paper, so I think that we're falling a little bit behind. Now, you do understand that the nature of the research takes a different pace, but at the personal level, I*

*feel that at this stage, I should have contributed a little bit more substantial with the actual outcomes and products. But again, it's the nature of research. (Senior personnel interview)*

- *Yeah, well, I don't know. I think on the one hand there has been a... strong request from [ID4 leadership] and the group to really now start publishing. And I think that knowing that the renewal or not renewal [site visit] was coming up, I think that has kind of like, "Ah, this be the end." It has really served as a motivator to now say, "Really, okay, we must produce, we must publish this." I think that has accelerated the work also, whereas when we started, it was maybe a little bit more easygoing. (Senior personnel interview)*
- *I think the [NSF site visit] coming up really served as a kind of trigger to now publish. "I know you've been talking and doing some stuff, but now do all the other work, put it in a format that it can be submitted." So, I think that helped...and my students felt very responsible also. And of course, also, I felt responsible to make this happen. (Senior personnel interview)*
- *And what is tricky is you can't so clearly lay out the future of which of the irons in the fire are going to really turn into awesome success stories... I think at this point, when you're two years in and the cool science is starting—but it takes more than two years to do cool science—I think this just necessarily is one of the more stressful periods of [an Institute]. (Senior personnel interview)*

As previously shown in Figure 6, 100% of students agreed or strongly agreed that ID4 has provided opportunities for them to conduct research that aligns with their interests and/or goals. In open-ended survey responses, students listed products such as software packages, journal publications, and conference papers among the most significant outcomes of their ID4 work. Below are examples of students' responses to the survey question that asked about their most significant outcomes.

- *Two open source software packages, one journal publication and one conference paper. (Student survey)*
- *I've had the opportunity to produce several papers and talks from collaborations with fellow students and faculty. (Student survey)*
- *Writing a truly collaborative manuscript. (Student survey)*

## **Learning and Skill Development**

### ***Students and senior personnel reported gaining knowledge and skills through ID4, highlighted by interdisciplinary thinking and problem-solving.***

In interviews with senior personnel, another commonly cited outcome of ID4 involvement was **deeper interdisciplinary thinking and problem-solving**. Interviewees described building a better understanding of questions and challenges that exist in other domains (e.g., material and/or computer sciences) and identifying ways that they could collaborate to address those challenges in innovative ways. ID4 was credited with generating exposure to new disciplines and ways of thinking for both students and senior personnel that may not have occurred without the Institute.

- *Part of it too is understanding what's in the tool chest and what the big challenges are, and generating foundationally different types of questions and different types of solutions than we might otherwise... (Senior personnel interview)*
- *There's sort of this cross-learning involving hammers and nails basically. But also, hammers and nails is a little bit funny too because it doesn't really talk about the thing that you're trying to build. And so, I think when we bring together new hammers and new nails, it allows us to conceptualize entirely new structures that we can build together. (Senior personnel interview)*

- *The other thing that I have found really cool is, I mean, I don't know, I'm in my mid-forties now. It doesn't seem to be the age that people talk about, okay, learning new tricks, changing their perspective, things like that. But somehow the level of closeness we've had and the way that we've been able to engage with each other and each other's students, it has changed my perspective... [One thing] that I super love that I'm learning just from [another senior personnel] and how you interact with your group is you'll just open up a notebook and write some code and try things. Probably my default instinct would be...to try to lay everything out step by step on that iPad before trying or playing or creating a simulation. And this is something that I've really enjoyed and appreciated. And it's a new challenge for me to try to integrate that into my toolbox. (Senior personnel interview)*
- *[My students] feel very blessed that they can work with all these experts in these other fields. So, I think they recognize that their PhD is a little bit different from the other PhD students in the program who are just working within the domain. I think they feel very blessed. I never really hear them complain. (Senior personnel interview)*

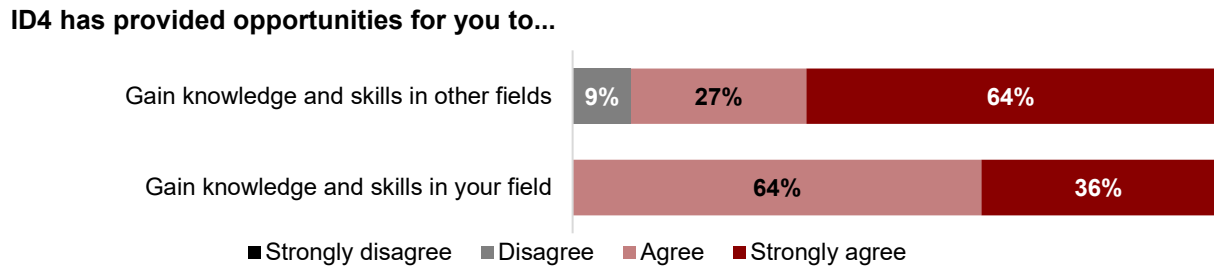
Furthermore, when describing the successes of their ID4 involvement, many senior personnel noted that they had **learned new skills from each other**, both within and outside of formal collaborations.

- *I didn't have actual collaboration with [senior personnel name], but I'm...learning a lot from him about the visualization of data. (Senior personnel interview)*
- *I would say that the focused collaboration has been working really well. We've learned a lot of capability gaps on our side and how to analyze certain mechanisms and, scientifically, it's been great. (Senior personnel interview)*

In survey responses, students' reflections were similar to those of senior personnel, highlighting the development of knowledge and skills acquired through interdisciplinary collaboration. As shown in Figure 7, 100% of students reported that ID4 provided opportunities to gain knowledge and skills in their own field, and 91% reported opportunities to gain knowledge and skills in other fields, which was consistent with 2022 survey data (see Figure 18 in Appendix D for comparisons). Open-ended responses indicated that exposure to other disciplines has **influenced students' research and the scope of their interests**. Below are examples of student responses when asked about the impact and outcomes of their ID4 work.

- *Understanding the current challenges of data and visualization fields. For me, as an experimentalist, it is so exciting to learn about the state-of-the-art techniques in these important fields, rather than just read the quickly outdated information in the articles or the Internet. (Student survey)*
- *The chance to see what goes into operating and participating in an interdisciplinary research institution. As well as showing me how collaborations can be formed between seemingly different disciplines. (Student survey)*
- *I've had the opportunity to develop several research projects within ID4; the research I am currently engaged in will probably inform the direction of my thesis. (Student survey)*
- *As an experimentalist, getting exposure to computational fields of materials science and big models of data analysis outside of my domain are incredibly impactful. (Student survey)*
- *As a member of the domain knowledge of my collaboration, the interaction with machine learning experts has enhanced my ability to use that tool in my daily research. (Student survey)*

Figure 7. Student perceptions of learning opportunities provided by ID4



Source: Winter 2023 student survey (n=22).

## Relationships

***Student ratings of opportunities to build relationships with faculty and learn about career pathways have increased in the last year, while relationships and networking connections remain important outcomes of ID4 involvement for both students and senior personnel.***

When asked about significant outcomes and the impact of their involvement in ID4, students and senior personnel reflected on the **relationships they have built with other ID4 members** and the ways in which their professional networks have grown. In interviews, senior personnel suggested that the cross-disciplinary nature of ID4 encourages mutual teaching and learning, which contributes to strengthening relationships within research groups.

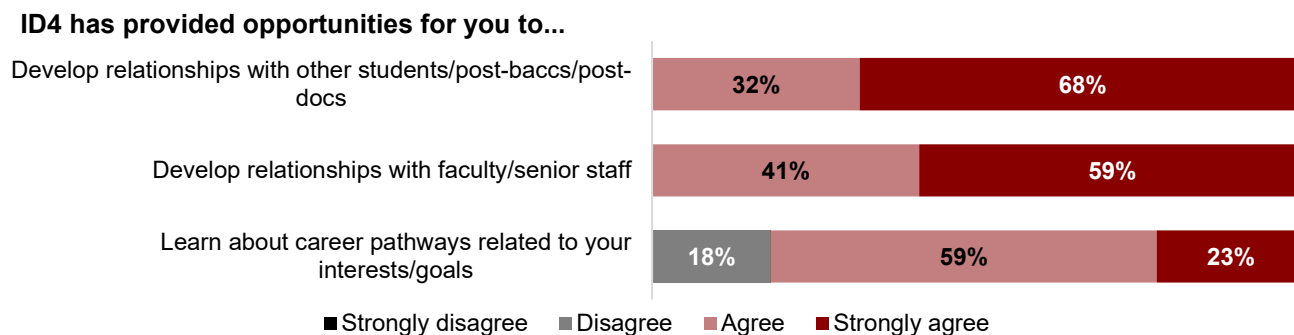
- *I've been in [Institutes]...where I've met new groups of people and you're always like, "Okay, we should collaborate, we should collaborate." I think somehow this time, even without that impetus or pressure, this is just a collaboration I really enjoy and look forward to and I'm excited about. (Senior personnel interview)*
- *Through all these activities, [students] have found, not necessarily as the first kind of goal, but they have found people that they like working with and that can actually contribute also to their research in a meaningful way. (Senior personnel interview)*

ID4 was described as a **valuable resource for expanding professional networks** for faculty, and even more so for students who are considering career paths and making decisions about where to direct their research agendas in the future. One senior personnel described ID4 as *"training the next generation,"* adding that:

*Our grad students and our post-docs are going on to good positions after they—I mean, we're only two years in, but we already have 10 grad students and post-docs who have come through ID4, and they're going on and doing good things, they're getting good positions, so I think we are succeeding in training our next generation.*

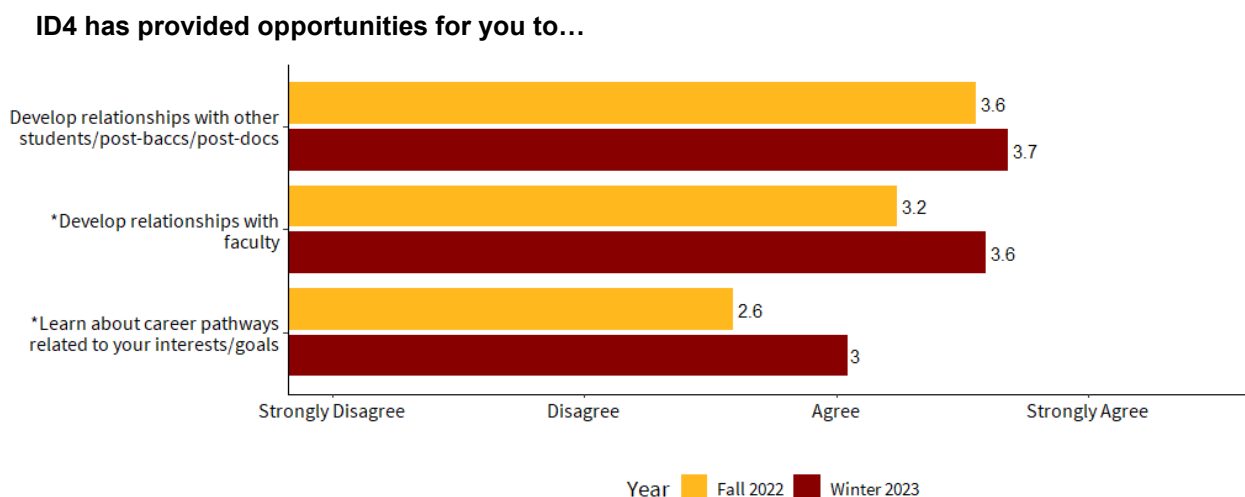
As shown in Figure 8, students indicated that ID4 has provided opportunities to develop relationships with other students and faculty, and to learn more about career pathways related to their interests. Figure 9 shows the same items, using mean ratings to compare results from the Winter 2023 student survey with results from the Fall 2022 survey. T-tests show that students' **ratings about opportunities to develop relationships with faculty and learn about career pathways were significantly higher in 2023 survey responses** ( $p < .05$ , indicated with an asterisk in Figure 9).

**Figure 8. Student perceptions of opportunities provided by ID4 to build relationships and learn about career pathways**



Source: Winter 2023 student survey (n=22).

**Figure 9. Students' mean ratings of opportunities provided by ID4 to build relationships and learn about career pathways, comparing Fall 2022 and Winter 2023 survey data**



Source: Winter 2023 student survey (n=22); Fall 2022 student survey (n=29).

In open-ended survey responses, students reported that ID4 has been **beneficial in facilitating professional connections**, exemplified in the comments below.

- *[ID4] opened up new research directions and passions. The experience helped me land my post-doc job.* (Student survey)
- *The success, excitement, and networking opportunities within ID4 projects have influenced what I'd like my future work to be focused on.* (Student survey)
- *The impact on my academic goals cannot be overstated. Being able to expand my network and collaborate with people outside my discipline at other universities has enabled a lot of personal growth, a broader network, new research opportunities and future directions.* (Student survey)
- *[My ID4 collaborations] have helped me identify fields and roles I may want to work in once I graduate. They have provided introductions to people who have those roles or work in those fields.* (Student survey)



## Findings: Diversity, Equity, & Inclusion

We identified four key findings related to diversity, equity, and inclusion in ID4:

- Students and senior personnel see diversity as a strength of the Institute but suggested that there is an opportunity to increase visibility and evidence of ID4's commitment to diversity.
- Senior personnel pointed to the accessibility of ID4 for students, as well as outreach activities, as examples of ID4's equity efforts.
- Students perceive ID4 as equitable, and gender-based differences in student satisfaction with ID4 that were found in the Fall 2022 survey are no longer present.
- ID4 provides an open and inclusive culture, highlighted by leadership's ability to foster a welcoming environment among students and faculty.

### Diversity

#### ***Students and senior personnel see diversity as a strength of the Institute but suggested that there is an opportunity to increase visibility and evidence of ID4's commitment to diversity.***

Similar to the Phase 1 evaluation, senior personnel described **diversity as a strength of the Institute**, noting the intentionality behind bringing together a diverse team across a range of characteristics (e.g., race, gender, career level). Senior personnel shared in the belief that ID4 leadership and senior personnel are committed to diversity, equity, and inclusion (DEI). However, perceptions varied about the extent to which the combination of a diverse team of faculty and valuing DEI had led to recruiting and funding a diverse group of students in the Institute.

- *I know there were a lot of conversations just even thinking about diversity in lots of different ways... So, these were explicit even when we were writing the grant proposals. And that still exists now in our structure. I don't know of any explicit thing where we are specifically trying to encourage people to recruit a diverse set of people in ID4. But I do think that that initial and intentional selection of who will be on the team just naturally means that that happens. There are people on the team who care about diversity, equity, and inclusion. (Senior personnel interview)*
- *I think I've been part of, and I'm part of a bunch of different programs and centers. By far, I think, this one has been the one that has been most proactive in addressing and working around [DEI]. (Senior personnel interview)*
- *Looking at [ID4 leadership], there has been a focus [on DEI]. There have been, people have been paying quite a bit of attention to Broader Impacts activities, and also the team itself. It's a very nice feature that the team is so diverse. (Senior personnel interview)*

As shown in Figure 10, student perceptions generally align with senior personnel, as 100% of survey respondents agreed or strongly agreed that diversity is valued within ID4, and 91% agreed or strongly agreed that they are satisfied with the level of diversity in the Institute. These findings align with positive perceptions reported in the Fall 2022 survey (see Figure 19 in Appendix D for comparison data).

**Figure 10. Student perceptions of diversity in ID4**



Source: Winter 2023 student survey (n=21).

Along with positive perceptions of diversity, however, faculty and students expressed **interest in more communication and visibility related to diversity efforts** as well as more evidence of the Institute’s diversity.

- *I haven't seen the data for students, but certainly on the PI side, both science and other dimensions of diversity are really exceptional, I think from what I've seen. Yeah, I'd be curious to see the data for the student side and maybe there's sort of opportunities to be more intentional there, if there's flexible funds for fellowships for students to help build that as well. (Senior personnel interview)*
- *Yeah, I'm sure there are gaps. I'm positive that in a sample size of ID4, there will be people who won't value diversity, equity, inclusion the way we would want them to. I don't know how to explicitly track that or identify that unless there is an explicit issue. But then you also don't want to wait until there's an issue to handle things like that either. The reason why I'm giving massive pause, because I actually don't even know the ratio of... I think it's there, but I don't remember ever really analyzing how many females are a part of ID4, or people who identify as female, or how many people of color. It's there because we have to track it. But I've never really seen an analysis of that. (Senior personnel interview)*
- *In terms of the presence of underrepresented communities, I think ID4 is doing a good job. However, I think that activities that foster the active participation of these communities within ID4 are needed. (Student survey)*
- *I'm sure ID4 is going through different efforts to expand the diversity and inclusion in the institute but, regardless of the success rate of these efforts, maybe it would be helpful to inform the general ID4 body, even those outside of faculty positions/community, on these efforts. Because I think these topics are mainly only addressed unintentionally through these surveys rather than being a consistently communicated effort within the institute. (Student survey)*

## Equity

**Senior personnel pointed to the accessibility of ID4 for students, as well as outreach activities, as examples of ID4’s equity efforts.**

When asked about the ways in which ID4 activities and leadership exhibited equity, many senior personnel cited the **accessibility of ID4**, including the ease of communication with leadership via Slack and the availability of funding to travel for in-person meetings. Perceptions of the extent to which faculty consider equity in student recruitment were mixed. Some faculty noted that the post-baccalaureate fellowship, which was intended to bring in students from communities underrepresented in STEM—as detailed in the Phase 1 Evaluation Report—has encountered logistical

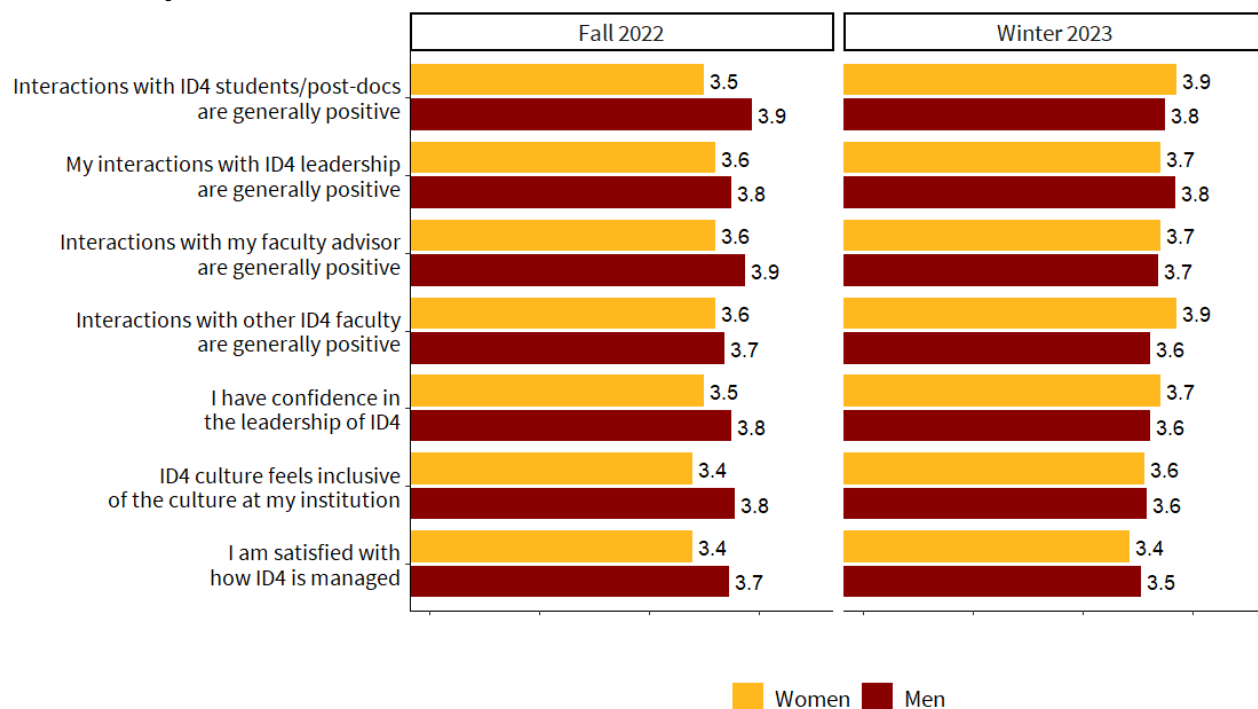
challenges and institutional roadblocks. Other faculty were more focused on equity efforts for students who are already part of ID4. As one senior personnel explained, “*I feel like our job at ID4 is more to create an environment where students are successful regardless of their background. And we'll take whatever students faculty throw at us.*” The quotes below provide additional examples of the ways that senior personnel perceive equity as a commitment for the Institute.

- *I think the specific funding that I got...for this summer research experience for community college students, I think was one very clear demonstration of that. These are majority minority institutions, and everyone that was part of the team was from an underrepresented group in science, at least as defined by NSF. So that was quite good. And I think providing students the travel funding to come to these meetings either from the PI or, I'm sure if you asked, central funds could do that. I think those are things, and I think people in general have the same access to the same science, the same scientists, the same science. I think that's also pretty clear.* (Senior personnel interview)
- *I know also when we had the post-bacc program, when we were recruiting post-baccs, we were explicitly trying to make sure that we are recruiting from communities that generally have low access to higher education. And so there are things that we naturally do.* (Senior personnel interview)
- *So at least within ID4, I think we've done a decent job with equity. Again, we're big on transparency and making everything open to everybody. If we're having a workshop, we ask everybody to apply. If there's a seminar, we want everybody to participate. So we try to make sure that everybody has access to all of the ID4 resources.* (Senior personnel interview)

***Students perceive ID4 as equitable, and gender-based differences in student satisfaction with ID4 that were found in the Fall 2022 survey are no longer present.***

In the Fall 2022 student survey, students who identified as women provided lower ratings on multiple items related to satisfaction with ID4 (e.g., confidence in leadership, interactions with faculty and other students) when compared to men. This year, no significant differences ( $p > .05$ ) were found for means of the same survey items based on gender, and tests of aggregate means for survey constructs (e.g., leadership, outcomes, collaboration, student support) also showed **no significant differences based on gender**. Figure 11 shows those items with side-by-side mean ratings from the Fall 2022 survey and the Winter 2023 survey. The figure shows that ratings remain high for men and women, while mean ratings among women have increased on all except one item.

**Figure 11. Students' mean ratings of satisfaction with ID4, by gender, in the Fall 2022 and Winter 2023 student surveys**

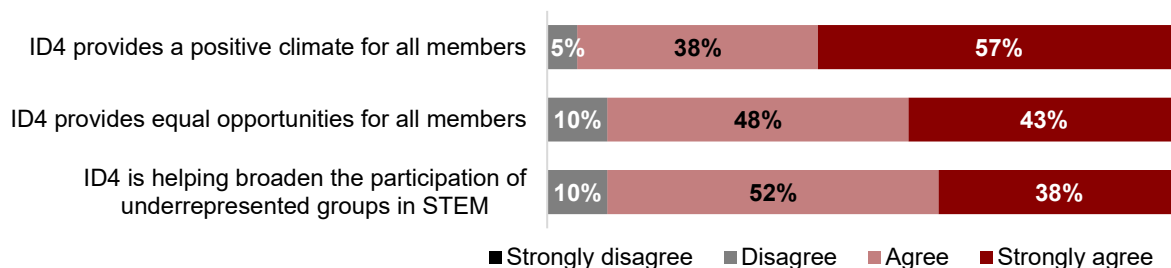


Source: Winter 2023 student survey (men = 13, women = 7) and Fall 2022 survey (men = 16, women = 10).

In open-ended survey responses, students described ID4 as **open and accessible to all students** and did not indicate any differences in ID4 experiences based on backgrounds and identities (e.g., race, gender, sexual orientation, disability status). Examples of their responses are below. As shown in Figure 12, survey responses suggest general agreement among students that ID4 provides a positive climate, provides equal opportunities, and is helping broaden participation in STEM among underrepresented populations. These findings align with positive perceptions reported in the Fall 2022 survey (see Figure 19 in Appendix D for comparison data).

- *As a disabled man, I have not noticed any differences [in ID4 experiences].* (Student survey)
- *I feel that everyone, regardless of background, is having a similar experience.* (Student survey)
- *ID4 is an inclusive community, there is no discrimination here. Everyone is welcome, I believe that we have a significant portion of participants from traditionally underrepresented groups in natural sciences.* (Student survey)

**Figure 12. Student perceptions of equity in ID4**



Source: Winter 2023 student survey (n=21).

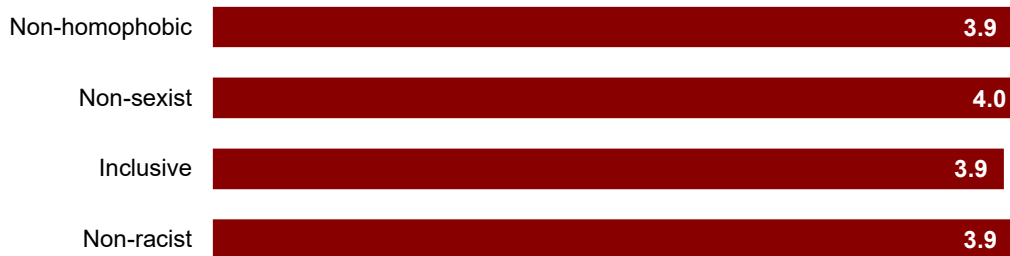
## Inclusion

### ***ID4 provides an open and inclusive culture, highlighted by leadership's ability to foster a welcoming environment among students and faculty.***

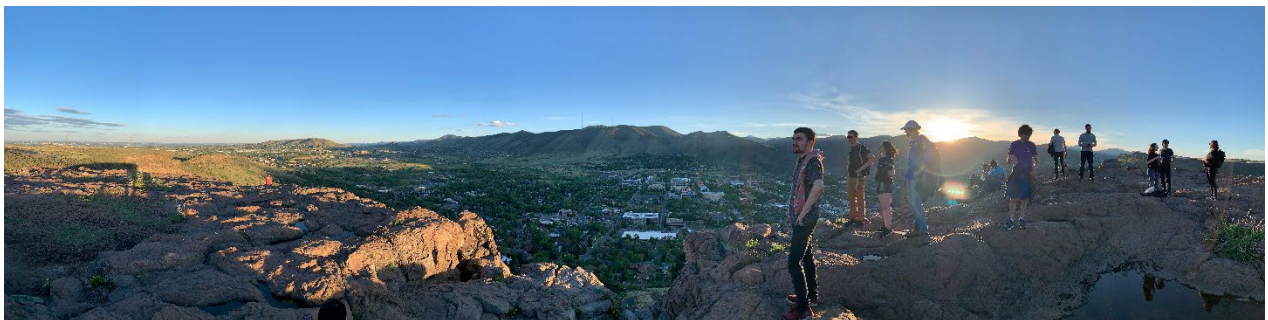
Similar to findings from the Phase 1 evaluation, senior personnel and students believe that ID4 provides a **welcoming and inclusive environment**. When asked about inclusivity in the Institute, senior personnel most often referenced ID4 leadership and the Director's positivity, openness, and encouragement. Both students and senior personnel noted that ID4 meetings/events feel welcoming and inclusive, as exemplified in the quotes below. Additionally, as shown in Figure 13, students provided **positive ratings of ID4's culture** across a range of characteristics.

- *The first thing that actually comes to mind here is actually [the ID4 Director]. So I think [the Director] is really, really good about just supporting all the students that talk at the Zoom meetings. There's always a very positive question. The talks of course have enormous range of greatness, let's say, but [the Director] does a really good job, I think, of making everyone feel like they're contributing a really important thing to the mission. So as an individual, I think he's really done an amazing job at that.* (Senior personnel interview)
- *[The Director] is wonderful I think at bringing positivity but also really encouraging everyone. It comes out really nicely I think, in the in-person meetings where they've got mechanisms to shuffle people into small groups and really encourage students to talk with students, but also to faculty to reduce barriers to speaking with someone that you might not know. I think all the mechanisms that they put in place for those in-person meetings were great at creating that sense of belonging and support.* (Senior personnel interview)
- *The atmosphere of the events/meetings feels very welcoming.* (Student survey)

**Figure 13. Students' mean ratings of characteristics of ID4's culture (on a scale of 1-4)**



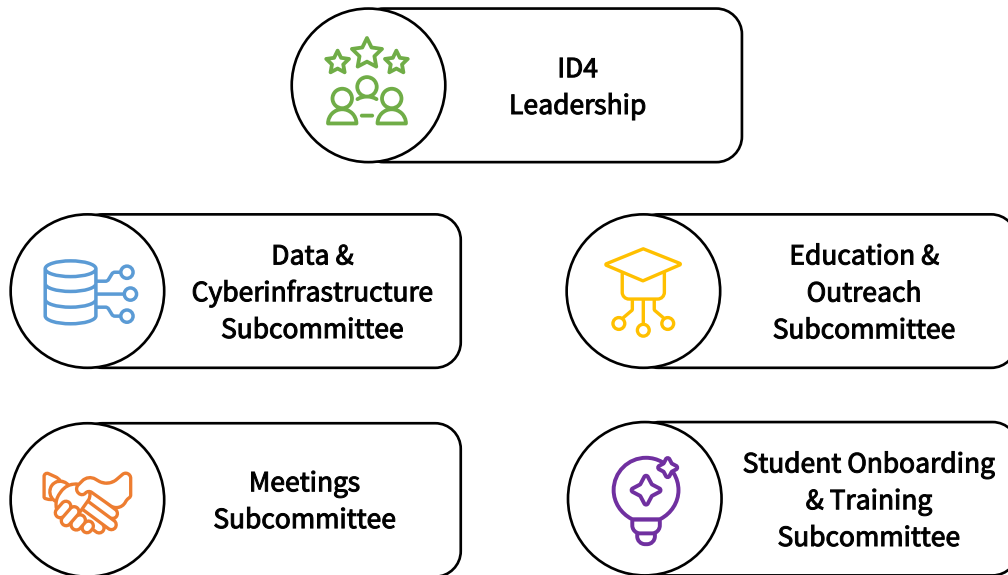
Source: Winter 2023 student survey (n=22).



# Considerations






As described throughout this report and accompanying brief on the ID4 student experience (see Appendix E), Phase 2 of the external evaluation highlighted various successes and opportunities related to the Institute’s implementation, effectiveness, outcomes, and DEI in the 2023-2024 academic year. The following considerations build on the areas of focus that were identified in the Phase 1 evaluation, highlighting the progress that was made toward each of these recommendations in Phase 2 and providing additional action steps, based on recent data, to continue leveraging opportunities in these areas in Phase 3. Some of these considerations arose in the previous evaluation report and were reinforced by recent data as ongoing needs across the Institute, while others are new ideas that have become relevant in the Institute’s current stage of evolution.

To enhance the feasibility and practicality of implementing these considerations, specific attention was given to the target audience. While all of these action steps will require guidance and input from ID4 leadership (i.e., Director, Co-Directors, Research Manager), some are directly relevant to one or more of ID4’s student and faculty subcommittees. To support ID4’s distributed leadership structure, each consideration is accompanied by a suggested primary audience to lead the conceptualization and implementation process. The icons used to indicate the primary audience for each consideration are shown below:



**Phase 1 Recommendation A:**

**Continue to cultivate and communicate the importance of ID4’s collaborative culture.**

Progress & Accomplishments in Phase 2	Relevant Considerations for Phase 3
<p>Over the past year, most ID4 collaborations have transformed from brainstorming to “working mode.” ID4 leadership has made intentional efforts to connect with Institute faculty and support research collaborations as they evolve, and new processes were developed for students and faculty to engage in leadership activities. Examples of progress in Phase 2 toward Phase 1 recommendations include the following:</p> <ul style="list-style-type: none"> <li>• Establishment of the Meetings Subcommittee and the Student Onboarding &amp; Training Subcommittee</li> <li>• Individual check-ins with faculty conducted by the ID4 Director to gauge progress and address ongoing concerns and challenges</li> <li>• Establishment of the ID4 Excellence Award and stipend, which rewards students for significant contributions to ID4 research and community building</li> </ul>	<p>Findings from Phase 2 suggest that cross-Institute connections have progressed through various in-person and virtual channels, though the ongoing challenges of virtual collaboration underscored the importance of full-Institute meetings and other in-person opportunities. The primary challenge with collaborative work for both senior personnel and students was finding time and resources to learn “different discipline languages” while managing multiple tasks. Students also experienced difficulties identifying research questions that benefitted all members of cross-disciplinary teams, developing strategies for effective communication, and deepening understanding of each group’s domain and research problems. Examples of ways that collaborations may be further supported and expanded in Phase 3 include the following:</p> <p> <b>A1 – Continue individual check-ins with senior personnel</b> by the ID4 Director to discuss research progress and any logistical concerns (e.g., faculty sabbatical, student schedules, funding), and <b>consider check-ins with collaborative student teams</b> to support research momentum, alignment with Institute priorities, and resolution of student concerns</p> <p> <b>A2 – Organize additional student-focused events to support engagement, networking, and career development</b> among students in ID4, such as structured discussions or mentoring opportunities for new students to learn from those with more ID4 experience, informal “coffee hours” for students to build community, social events for VPRTT fellows in ID4, and career development events/resources informed by ID4 faculty</p> <p> <b>A3 – Continue providing regular opportunities and resources for in-person interactions</b> among ID4 members, with particular emphasis on biannual full-Institute meetings and other timely in-person events to onboard and engage new students soon after they join ID4</p> <p> <b>A4 – Develop a repository of cross-disciplinary resources</b> to support ID4 members learning about other domains and terminology, as well as strategies for publishing joint papers in ID4, and <b>consider organizing related educational events</b> for students (e.g., discussions hosted by ID4 labs, student-focused workshops or tutorials)</p> <p> <b>A5 – Create a database and process for updating documentation of current ID4 students/faculty</b> and areas of expertise, as well as collaborative teams and research projects, made available to all ID4 members</p>

**Phase 1 Recommendation B:**




**Make the implicit more explicit: clarify ID4’s roles, processes, and values.**

Progress & Accomplishments in Phase 2	Relevant Considerations for Phase 3
<p>Over the past year, ID4 leadership has taken steps toward clarifying roles and opportunities within ID4, as well as Institute-wide processes and values. Slack, email, and the ID4 website have been used more consistently to communicate information and updates to the ID4 community. Additionally, the Institute’s direction and structure were documented and presented more explicitly through the July 2023 NSF site visit, the April 2024 full-Institute meeting, and the August 2024 annual report. Examples of progress in Phase 2 toward Phase 1 recommendations include the following:</p> <ul style="list-style-type: none"> <li>• Identification of priority areas for ID4 subcommittees with clear objectives and expectations for membership</li> <li>• Establishment of Data &amp; Cyberinfrastructure Subcommittee</li> <li>• Development of an online repository for ID4 publications and code, along with a spreadsheet to collect updates/new entries from students and faculty</li> <li>• Summary of April 2024 full-Institute meeting shared via email and Slack, including key opportunities and available resources</li> <li>• Identification of criteria for measuring “convergence success” in ID4, as documented in the NSF annual report</li> </ul>	<p>Findings from Phase 2 suggest that the steps taken by ID4 leadership over the past year to make the Institute’s roles, processes, and values more explicit have been effective. Still, data from ID4 faculty and students highlight opportunities to sustain and expand these efforts in order to bring enhanced clarity to aspects of the Institute such as collective research priorities and measures of success, the role of ID4 students’ advisors, protocols for industry collaborations, and Institute efforts related to diversity, equity, and inclusion. Examples of ways that this may be accomplished in Phase 3 include the following:</p> <p><b>B1 – Continue to discuss and share ID4’s primary research priorities and measures of success</b> with both faculty and students, along with processes to document and monitor individual contributions and collective progress (i.e., a tracking system for each of the convergence success activities)</p> <p><b>B2 – Share with faculty the importance of the advisor’s role</b> in supporting new ID4 students establishing initial collaborations (e.g., making introductions to other ID4 faculty/students and existing projects, generating ideas for an initial collaborative project), and <b>identify expectations for and communication pathways with VPRTT fellows’ advisors</b> who are not directly involved in ID4 to help them support their students’ engagement in the Institute (e.g., alerting them about upcoming ID4 meetings to promote conversations with their students about potential collaborative research topics)</p> <p><b>B3 – Develop plans and protocols for industry collaborations</b> that reflect the realities of the industry context, such as the importance of client feedback/utility and information security, especially as industry relations become increasingly critical for pilot testing and disseminating ID4 research and products</p> <p><b>B4 – Increase communication and visibility of ID4’s efforts and values related to diversity, equity, and inclusion (DEI)</b>, such as publicizing data about the diversity of ID4 members, discussing the importance of DEI in ID4 more regularly, sharing with all members about Institute efforts to promote DEI internally (e.g., student recruitment) and externally (e.g., outreach), and clarifying how outreach activities at participating institutions support ID4’s DEI goals</p>



**Phase 1 Recommendation C:**

**Leverage resources to support coordinated processes and engagement around Broader Impacts activities.**

Progress & Accomplishments in Phase 2	Relevant Considerations for Phase 3
<p>Over the past year, ID4 has established new processes and structures to build engagement in Broader Impacts activities, with a particular focus on processes for community outreach funding and engagement. With increased communication and coordination around Broader Impacts activities, the Institute supported several successful workshops and educational programs that involved a range of ID4 faculty, students, and institutions. Examples of progress in Phase 2 toward Phase 1 recommendations include the following:</p> <ul style="list-style-type: none"> <li>• Establishment of the Education &amp; Outreach Subcommittee</li> <li>• Presentation from the Education &amp; Outreach Subcommittee at the April 2024 full-Institute meeting</li> <li>• Development of an application process for ID4 outreach activities that promoted the availability of funding for outreach across the Institute</li> <li>• Organization of multiple ID4-funded workshops, events, and educational programs across participating institutions including research experiences, community college student mentoring, and K-12 outreach</li> </ul>	<p>Findings from Phase 2 suggest that some students and faculty are highly involved and engaged in ID4 through their contributions to Broader Impacts activities. However, most students and faculty see opportunities for increased and more widespread involvement in Broader Impacts activities, as well as more visibility of ID4-funded activities that are ongoing and successful. Students expressed an interest in more direct communication about ID4’s Broader Impacts progress and goals, and some faculty and students described involvement in related outreach activities at their own institutions that were not formally or intentionally connected to ID4. Examples of ways that Broader Impacts may be further prioritized across the Institute in Phase 3 include:</p> <p> <b>C1 – Continue to gather information about community education and outreach activities that are already being implemented</b> in ID4 institutions and by ID4 faculty/students, leveraging opportunities to expand the reach and scope of activities that are formally affiliated with ID4</p> <p> <b>C2 – Dedicate time during full-Institute meetings and other ID4 gatherings to share, celebrate, and promote Broader Impacts work</b>, with regular invitations to all members of the ID4 community (e.g., new students, VPRTT fellows, senior faculty) to become involved in Broader Impacts activities and subcommittees</p> <p> <b>C3 – Organize seminars dedicated to Broader Impacts activities</b> that provide opportunities for ID4 members to learn about current initiatives and opportunities, share successes and challenges from recent events/efforts, find collaborators or solicit input for upcoming events/efforts, and expand ID4 outreach and education models to additional institutions and communities</p>

## References

McDowell, E., Acree, J., Boyce, A. S., & Rorrer, A. K. (2023). *Harnessing the Data Revolution (HDR) Institute for Data-Driven Dynamical Design (ID4): Phase 1 Evaluation Report*. Utah Education Policy Center.

Saldaña, J. (2013). *The Coding Manual for Qualitative Research* (2<sup>nd</sup> ed.). Thousand Oaks, CA: Sage Publications, Inc.

# Appendices

## Appendix A: Full List of Evaluation Questions (Phases 1-5)

Evaluation Questions	Phase 1 (July 2022- May 2023)	Phase 2 (February 2023-2024)	Phase 3 (February 2024-2025)	Phase 4 (February 2025-2026)	Phase 5 (February 2026-2027)
<b>Program Theory:</b> What is the program logic and theory behind ID4? To what extent do program affiliates’ visions align with each other? To what extent do DEI concerns show up in the program theory and individual affiliates’ views and goals? How did the program logic and theory evolve throughout the Institute?	✓				✓
<b>Implementation:</b> How and to what extent are ID4 activities being implemented on schedule and as planned, both within and across participating institutions? To what extent has implementation been sensitive and attentive to the various cultural complexities of the multiple institutions?	✓	✓	✓	✓	✓
<b>DEI:</b> How and in what ways are ID4 leaders attending to diversity, equity, and inclusion (DEI) for participants, in activities, and across the Institute as a whole? What opportunities and barriers exist?	✓	✓	✓	✓	✓
<b>Effectiveness:</b> Are key components of ID4 (e.g., K-12 and community college research experiences, Post-Baccalaureate Internship Program, mentorship network, Student Leadership Council, HDR Visiting Fellows Program, product/software development, dissemination, management) operating effectively, both in person and virtually, within and across participating institutions? What is working well and for whom? Are participants from different backgrounds/identities having different experiences? How might effectiveness be improved?	✓	✓	✓	✓	✓
<b>Outcomes:</b> What outcomes are associated with participation in ID4? How do experiences differ by participant backgrounds/identities? To what extent has the Institute reached its goals?		✓	✓	✓	✓
<b>Sustainability:</b> How and to what extent are products of ID4 being disseminated to and utilized by the broader scientific community? How is the Institute engaging and collaborating with other funded institutes? To what extent has leadership identified funding streams and processes to maintain ID4 research, activities, and collaborations?			✓	✓	✓

## Appendix B: Evaluation Framework

This evaluation framework outlines the indicators, data sources, and data collection methods for each area of the evaluation.

Evaluation Questions	Indicators	Data Sources	Data Collection Methods
<p><b>Program Theory:</b> What is the program logic and theory behind ID4? To what extent do program affiliates’ visions align with each other? To what extent do DEI concerns show up in the program theory and individual affiliates’ views and goals? How did the program logic and theory evolve throughout the Institute?</p>	<ul style="list-style-type: none"> <li>• Information from documents describing the logic and theory behind the Institute</li> <li>• Information from interviews with senior personnel regarding program theory</li> <li>• Senior personnel members’ statements about role of DEI in program theory (from interviews)</li> <li>• Evaluators’ perceptions of alignment between senior personnel members’ articulations of program theory and DEI</li> </ul>	<ul style="list-style-type: none"> <li>• Institute senior personnel</li> <li>• Institute documents</li> </ul>	<ul style="list-style-type: none"> <li>• Interviews</li> <li>• Document review</li> </ul>
<p><b>Implementation:</b> How and to what extent are ID4 activities being implemented on schedule and as planned, both within and across participating institutions? To what extent has implementation been sensitive and attentive to the various cultural complexities of the multiple institutions?</p>	<ul style="list-style-type: none"> <li>• #/type/frequency of Institute meetings, events, and workshops</li> <li>• #/demographics of participants in K-12 and community college research experiences, Post-Baccalaureate Internship Program, mentorship network, Student Leadership Council, and HDR Visiting Fellows Program, including education level and institutional affiliation</li> <li>• Status of new software developed</li> <li>• Progress and plan for benchmarking and database development</li> <li>• Culturally responsive practices employed (i.e., variations in programming to align with different institutional cultures)</li> </ul>	<ul style="list-style-type: none"> <li>• Institute senior personnel</li> <li>• Student Leadership Council members</li> <li>• External Advisory Board members</li> <li>• Participating students, scholars, post-docs, and Fellows</li> <li>• Institute documents and artifacts</li> </ul>	<ul style="list-style-type: none"> <li>• Surveys</li> <li>• Interviews</li> <li>• Focus groups</li> <li>• Observations</li> <li>• Document/artifact review</li> </ul>
<p><b>DEI:</b> How and in what ways are ID4 leaders attending to diversity, equity, and inclusion (DEI) for participants, in activities, and across the Institute as a whole? What opportunities and barriers exist?</p>	<ul style="list-style-type: none"> <li>• Perceptions of the Institute’s climate among senior personnel and participants</li> <li>• Alignment between participant demographics and Institute faculty demographics (i.e., at least 69% from underrepresented groups in STEM)</li> <li>• Satisfaction with activities specifically related to DEI, such as diversity training for mentors</li> <li>• #/type of opportunities identified for improvement in DEI</li> <li>• #/type of barriers identified related to DEI</li> </ul>	<ul style="list-style-type: none"> <li>• Institute senior personnel</li> <li>• Student Leadership Council members</li> <li>• External Advisory Board members</li> <li>• Participating students, scholars, post-docs, and Fellows</li> <li>• Institute documents</li> </ul>	<ul style="list-style-type: none"> <li>• Surveys</li> <li>• Interviews</li> <li>• Focus groups</li> <li>• Document review</li> </ul>

<p><b>Effectiveness:</b> Are key components of ID4 (e.g., K-12 and community college research experiences, Post-Baccalaureate Internship Program, mentorship network, Student Leadership Council, HDR Visiting Fellows Program, product/software development, dissemination, management) operating effectively, both in person and virtually, within and across participating institutions? What is working well and for whom? Are participants from different backgrounds/identities having different experiences? How might effectiveness be improved?</p>	<ul style="list-style-type: none"> <li>• Satisfaction of participants in K-12 and community college research experiences, Post-Baccalaureate Internship Program, mentorship network, Student Leadership Council, and HDR Visiting Fellows Program, both within and across institutions</li> <li>• Usefulness of Institute components/activities for participants within and across institutions</li> <li>• Effectiveness of product/software development processes</li> <li>• Nature and effectiveness of dissemination efforts</li> <li>• Management: <ul style="list-style-type: none"> <li>○ Confidence in executive board</li> <li>○ Organization/division of responsibilities</li> <li>○ Senior personnel understanding of roles</li> <li>○ Nature and extent of communication among Institute participants, within and across institutions</li> </ul> </li> <li>• #/type of opportunities identified to improve effectiveness of Institute activities, processes, and/or management</li> <li>• Differences in opportunities, satisfaction, usefulness, and perceptions of management across participants from different backgrounds/identities</li> </ul>	<ul style="list-style-type: none"> <li>• Institute senior personnel</li> <li>• Student Leadership Council members</li> <li>• External Advisory Board members</li> <li>• Participating students, scholars, post-docs, and Fellows</li> <li>• Institute documents and artifacts</li> </ul>	<ul style="list-style-type: none"> <li>• Surveys</li> <li>• Interviews</li> <li>• Focus groups</li> <li>• Observations</li> <li>• Document/artifact review</li> </ul>
<p><b>Outcomes:</b> What outcomes are associated with participation in ID4? How do experiences differ by participant backgrounds/identities? To what extent has the Institute reached its goals?</p>	<ul style="list-style-type: none"> <li>• STEM research skills developed by Institute participants</li> <li>• Knowledge and pursuit of career paths/opportunities in data and domain sciences by Institute participants</li> <li>• New collaborations and relationships developed through Institute work</li> <li>• Software/products developed through Institute work</li> <li>• Publications and presentations based on Institute work and collaborations</li> <li>• Engagement with the general public around Institute products</li> <li>• Overall reflections on Institute experiences and interest in continued involvement with the Institute</li> <li>• Differences in experiences and outcomes across participants from different backgrounds/identities</li> <li>• Extent to which stated timeline and goals related to software development and training/broadening participation are reached</li> </ul>	<ul style="list-style-type: none"> <li>• Institute senior personnel</li> <li>• Student Leadership Council members</li> <li>• External Advisory Board members</li> <li>• Participating students, scholars, post-docs, and Fellows</li> <li>• Institute documents and artifacts</li> </ul>	<ul style="list-style-type: none"> <li>• Surveys</li> <li>• Interviews</li> <li>• Focus groups</li> <li>• Document/artifact review</li> </ul>
<p><b>Sustainability:</b> How and to what extent are products of ID4 being disseminated to and utilized by the broader scientific community? How is the Institute engaging and collaborating with other funded Institutes? To what extent has leadership identified funding streams and processes to maintain ID4 research, activities, and collaborations?</p>	<ul style="list-style-type: none"> <li>• Progress made in creating databases to be shared publicly</li> <li>• Nature and frequency of collaboration with other funded institutes (e.g., virtual workshops)</li> </ul>	<ul style="list-style-type: none"> <li>• Institute senior personnel</li> <li>• Institute documents and artifacts</li> <li>• Directors of other funded Institutes</li> </ul>	<ul style="list-style-type: none"> <li>• Interviews</li> <li>• Document/artifact review</li> </ul>

## Appendix C: Phase 2 Methods

### Senior Personnel Interviews

The evaluation team worked with ID4 leadership to identify ID4’s senior personnel, who could speak to the implementation and effectiveness of collaborative research groups, ID4 events, outreach activities, and leadership and communication. These 18 individuals included 17 faculty members and scholars from ID4’s 12 sites, as well as the ID4 Research Manager. During the fall of 2023, the evaluation team conducted semi-structured interviews with senior personnel, individually and in groups. Interviews were conducted individually with the Director and Research Manager. The other interviews were organized into groups of two or three faculty who were part of the same collaborative research team, based on information provided by the ID4 Director and Research Manager. If group interviews were not possible due to scheduling challenges, faculty were asked to participate in an individual interview. The interview protocol included questions about the implementation and effectiveness of collaborative research teams and ID4 activities, program outcomes, and the ways that diversity, equity, and inclusion were incorporated into the vision and implementation of ID4. In all, the evaluation team conducted 12 interviews (6 individual, 6 group) involving 14 of the 18 senior personnel, including faculty from 11 different sites.

Interviews were conducted via Zoom, lasted roughly 60 minutes, and were audio recorded and transcribed for analysis. The evaluation team used qualitative data analysis software, ATLAS.ti, to analyze interview data. Interview data were coded using a combination of descriptive and focused coding procedures that aligned with the evaluation questions (Saldaña, 2013). Interview codes were compared and integrated with other data sources to generate findings for this report. Illustrative quotes from these analyses are included across all sections of the findings.

### Student Survey

In the winter of 2023, the evaluation team conducted a survey of students involved in ID4. The student survey was administered via email to undergraduates, post-baccalaureates, master’s students, doctoral students, and post-docs who were identified by ID4 leadership as involved in Institute activities. The survey asked about students’ education level/status (master’s student, PhD student/candidate, post-doc, etc.), their involvement in ID4 events, demographic information, and Likert-type items used to gauge their perceptions of and satisfaction with ID4. Table 2 shows the primary topics addressed by the Likert-type survey items, along with examples from each topic.

**Table 2. Student survey topics and example items**

Survey topic	Example items
Role & contributions to ID4	<ul style="list-style-type: none"><li>• I feel like I am a part of ID4.</li><li>• I have adequate support and training to conduct my ID.</li></ul>
Climate, culture, and leadership of ID4	<ul style="list-style-type: none"><li>• My interactions with my ID4 faculty advisor(s) are generally positive.</li><li>• I am satisfied with how ID4 is managed.</li></ul>
Communication and collaboration	<ul style="list-style-type: none"><li>• If I feel stuck scientifically, I know who to contact or ask for help in ID4.</li><li>• How many strong, moderate, and casual collaborations do you have with other students and faculty in ID4?</li></ul>
Diversity, equity, and inclusion in ID4	<ul style="list-style-type: none"><li>• I believe diversity within ID4 is valued.</li><li>• ID4 provides equal opportunities for all members.</li></ul>
Professional/career development	<ul style="list-style-type: none"><li>• ID4 has provided opportunities to gain knowledge and skills in your field.</li><li>• ID4 has provided opportunities to conduct research that aligns with your interests/goals.</li></ul>

The survey was distributed via email and administered using Qualtrics, an online survey platform. The survey remained open from December 7, 2023 to January 23, 2024 with weekly reminders to participate. A total of 58 students received the survey, and 24 students responded, for a response rate of 41%. Overall, 19 of the 24 responses were from PhD students/candidates, and 17 of the 19 had been in their graduate program for three or more years. Nine different universities were represented. Demographic information for survey respondents is displayed in Table 3. Additional participant information is noted below and in Table 4.

- 10 respondents said they received full funding from ID4, 9 received partial funding, 6 reported not receiving ID4 funding, and 1 did not know whether they received ID4 funding.
- The median number of reported hours spent on ID4 activities during the academic year was 30 hours per week; the median number of hours during the summer was 20 hours per week.
- Two students reported having a disability.

**Table 3. Number of student survey participants by gender and race/ethnicity**

<b>Gender</b>	<b>n</b>	<b>Race/Ethnicity</b>	<b>n</b>
Man (cisgender or transgender)	13	American Indian or Alaska Native	1
Woman (cisgender or transgender)	7	Asian	5
Prefer not to respond	1	Black or African American	2
		Hispanic, Latino, or Spanish	6
		White	12
		Prefer not to respond	1

**Table 4. Number of student survey participants by event attendance and first semester in ID4**

<b>Event attendance</b>	<b>n</b>	<b>First semester in ID4</b>	<b>n</b>
Hybrid site visit planning meeting at School of Mines	15	Fall 2021	15
Virtual site visit review (July 2023)	14	Spring/summer 2022	9
In-person meetings between multiple research groups	14	Fall 2022	3
Other events*	3	Spring/summer 2023	1
Did not attend any events	2	Fall 2023	1
		Don't know	1

\*Other events included: ID4 workshops, ASDE Young Researcher's Conference, Northeastern Conference

Analysis of survey items included the generation and interpretation of descriptive summary statistics to identify common trends in responses across implementation & effectiveness, outcomes, and DEI. When appropriate, means of survey items and constructs (i.e., aggregated items related to leadership, student support, DEI, etc.) from the Fall 2022 student survey (Phase 1) and Winter 2023 student survey (Phase 2) were analyzed using t-tests. Analysis of open-ended responses involved an initial round of thematic coding using evaluation questions to categorize responses. Themes were condensed or elaborated in a second round of coding, and analysis of open-ended responses are included in all sections of the findings. Ultimately, the open-ended survey responses provide dimensionality and depth to our other findings as well as triangulation of results.

### ***Document Review***

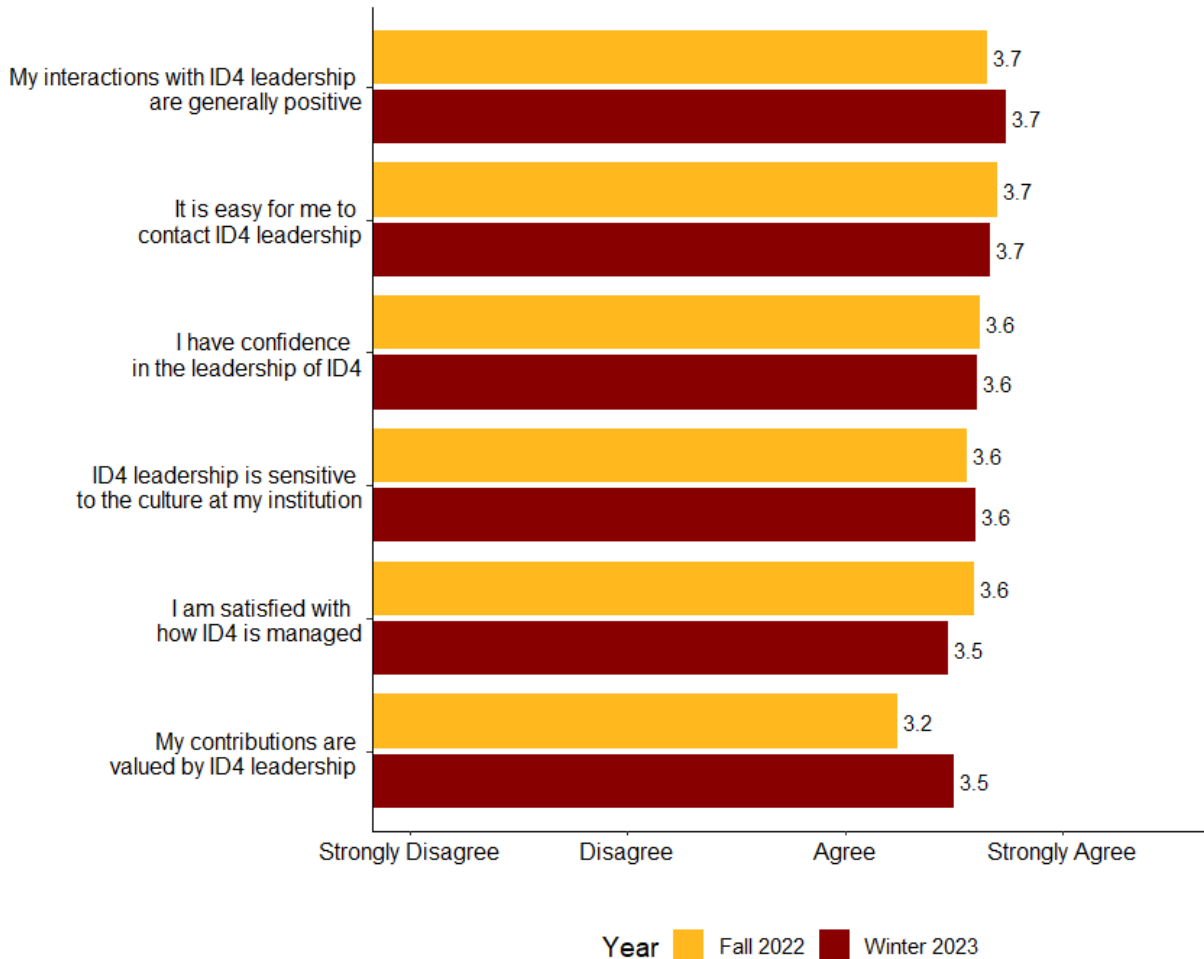
The evaluation team conducted a review of select documents to provide additional context and evidence about the implementation and effectiveness of ID4. Materials that were reviewed included internal notes from meetings with ID4 leadership, notes and materials from ID4 events, [ID4 website](#) content, and ID4 Slack channel communications. Documents were reviewed for relevance to the Phase 2 evaluation questions and were used as a secondary data source in triangulation with interview and student survey data to confirm, elaborate, or further explain findings.



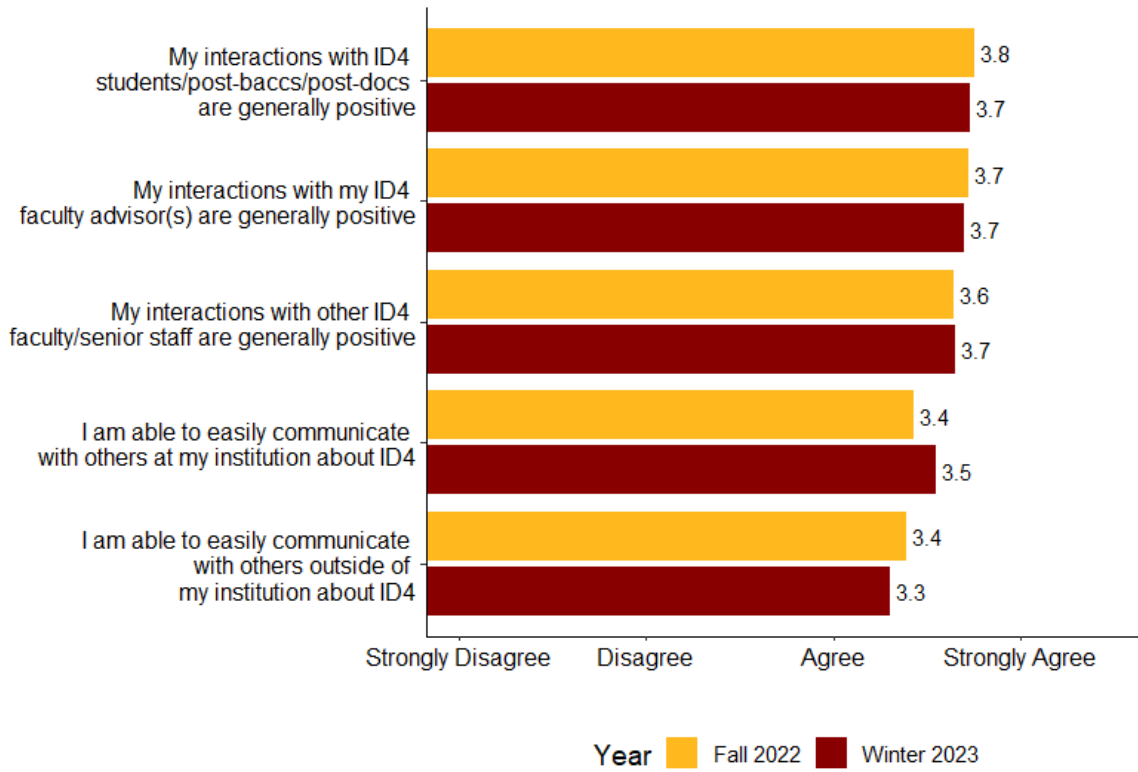
## Appendix D: Comparisons of 2022 and 2023 Student Survey Data

The following figures show comparisons of data from the Fall 2022 and Winter 2023 student surveys. Figures correspond with data from the Winter 2023 survey shown in the main report. For the items in these figures, no significant differences were found between the two time points. Items with significant differences were shown and discussed in the main report.

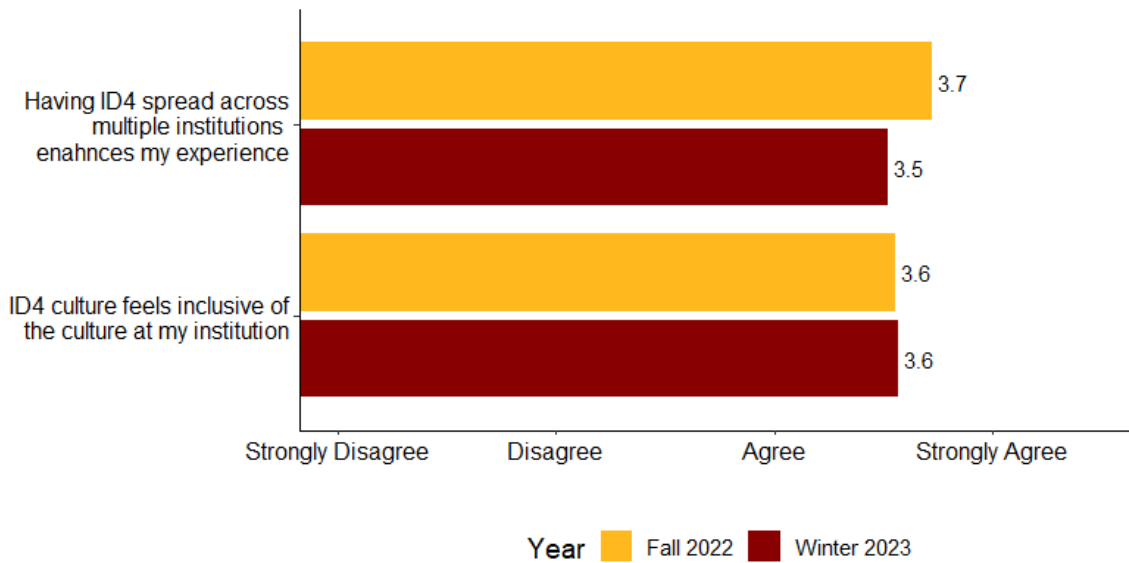
Figure 14. Students' mean ratings of ID4 leadership, comparing Fall 2022 and Winter 2023 survey data



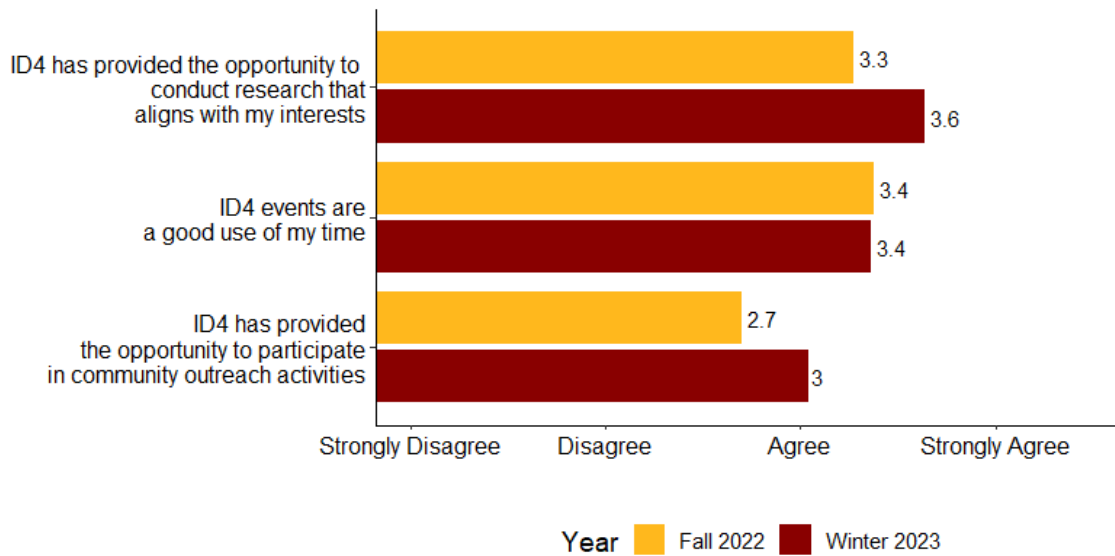
**Figure 15. Students' mean ratings of communication and interactions with others in ID4, comparing Fall 2022 and Winter 2023 survey data**



**Figure 16. Students' mean ratings of ID4's cultural alignment and value involving multiple institutions, comparing Fall 2022 and Winter 2023 survey data**



*Figure 17. Students' mean ratings of opportunities for engagement provided by ID4, comparing Fall 2022 and Winter 2023 survey data*



*Figure 18. Students' mean ratings of learning opportunities provided by ID4, comparing Fall 2022 and Winter 2023 survey data*

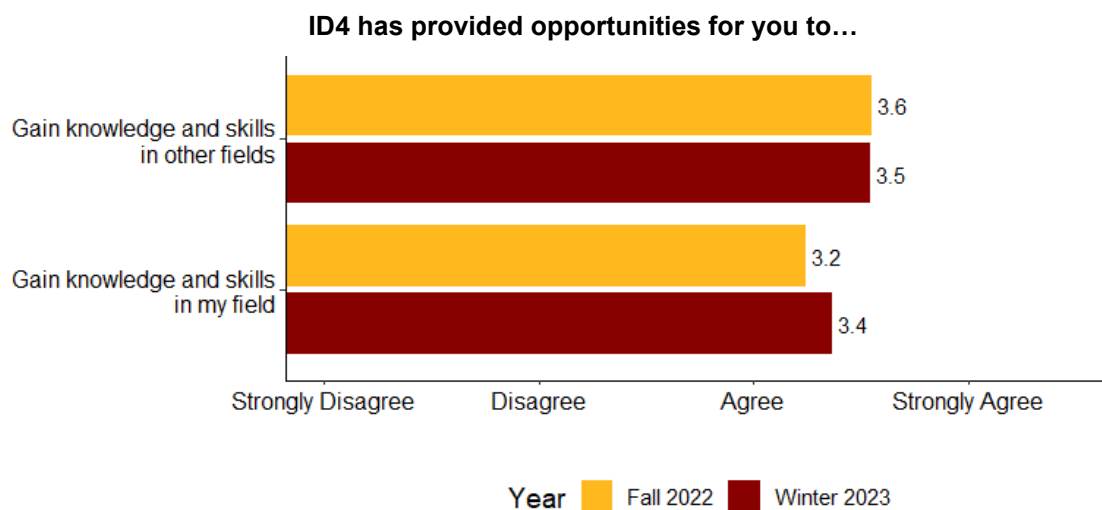
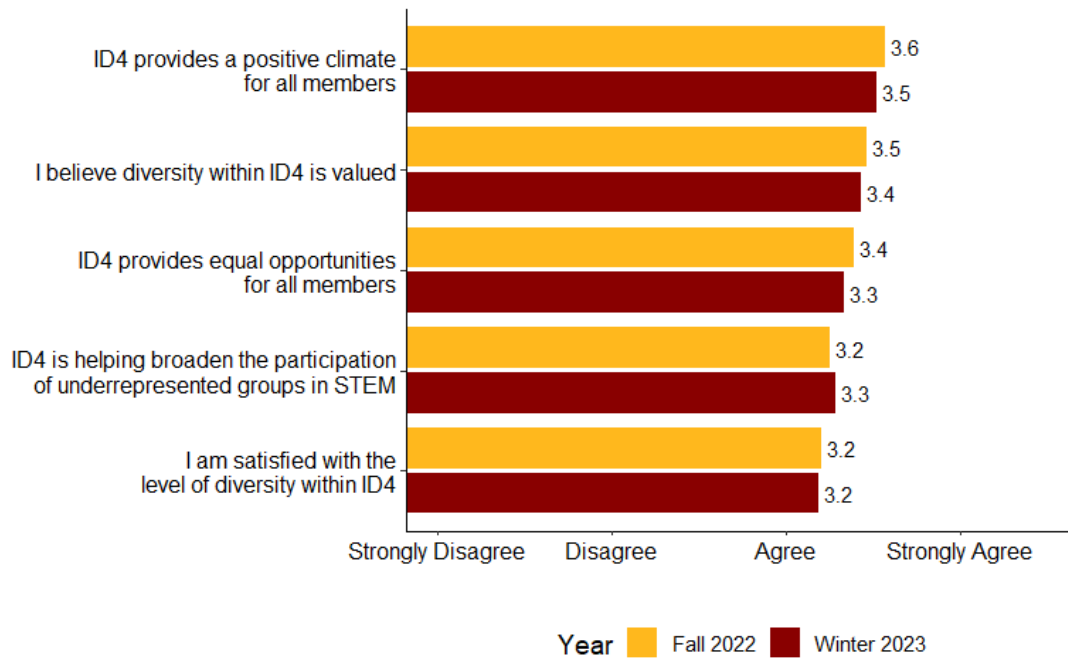


Figure 19. Students' mean ratings of diversity and equity in ID4, comparing Fall 2022 and Winter 2023 survey data



## Appendix E: Brief on the ID4 Student Experience

### *Background & Purpose*

ID4 hosted a three-day, in-person, full-Institute meeting at Harvard University in April 2024, bringing together students and faculty from across the Institute’s 12 participating sites (11 higher education institutions and 1 industry site). ID4 in-person meetings have been held throughout the grant period to build community while furthering existing collaborations and establishing new research directions.

The UEPC evaluation team attended the in-person meeting at Harvard to collect additional data to supplement the main Phase 2 evaluation report. Data for the main report was collected throughout the fall and winter of 2023, and analysis and reporting were completed by February 2024. Given the timing of the in-person meeting and the extent of student attendance, the UEPC team utilized the meeting as an opportunity to collect qualitative data from ID4 graduate students and post-docs, specifically through focus groups. Observations of student presentations and collaborative sessions held during the meeting provided the evaluation team with additional context for the focus group discussions.



As an addendum to the main report, this brief provides additional depth and dimensionality regarding student perceptions of ID4, with a focus on how and to what end students are collaborating with each other and with ID4 faculty members. The brief includes findings related to student collaborations; perceptions of ID4’s student culture and community; diversity, equity, and inclusion; and student outcomes and satisfaction. Additionally, the brief provides insights from two unique student contexts within ID4: a successful post-doc/graduate student collaboration, and the VPRTT Materials Science Graduate Fellowship Program experience.

### *Methods*

On the second and third days of the in-person meeting, the UEPC team conducted six focus groups with ID4 graduate students and post-docs. All students and post-docs who attended the meeting were invited to participate, and ID4 leadership supported the evaluation team with the organization and scheduling of the focus groups. Four of the focus groups were designed to understand students’ general perceptions of and experiences with ID4. These groups were selected by ID4 leadership based on students’ domain of study and advisor, and each group included 5 to 7 participants. A total of 23 students participated in these focus groups. An additional student who was unable to attend their designated focus group participated in a virtual interview with a member of the evaluation team in the week following the meeting. The semi-structured protocol for these focus groups included questions about students’ experiences, sense of support, and satisfaction with various aspects of ID4, as well as challenges, barriers, and feedback related to their experiences.

The other two focus groups centered around unique student contexts within ID4 and were identified in collaboration with ID4 leadership. One group exemplified a successful research collaboration and included a graduate student and post-doc who worked together through ID4. These two individuals also participated in one of the four general student focus groups. The semi-structured protocol for this focus group asked the participants to describe their research project and included questions about the nature of their collaboration, satisfaction and challenges, and the impact of their collaborative work. The second focus group highlighted student experiences as part of the Colorado School of Mines' VPRTT Materials Science Graduate Fellowship Program and included two participants who were involved in ID4 as current fellows. These two individuals did not participate in the other focus groups. The semi-structured protocol for this focus group included questions about the fellows' orientation to and involvement in ID4, satisfaction with the fellowship program, and feedback or support needed to improve the fellowship experience.

All focus groups were conducted in person, lasted approximately 35 minutes, and were audio recorded and transcribed for analysis. The data were analyzed using a combination of inductive and deductive thematic categorization. Themes emerged directly from the data and were further refined and organized based on the Phase 2 evaluation questions. In synthesizing the data and developing this brief, the evaluation team prioritized themes that added depth to key findings in the main report and/or highlighted unique insights from the perspective of ID4 students.

The brief is organized by the following topics, with findings presented as subheadings in each section along with exemplary quotes from focus group participants: Collaboration; Student Culture & Community; Diversity, Equity, & Inclusion (DEI); and Student Outcomes & Satisfaction.

## ***Collaboration***

**Students formed collaborations by way of their faculty advisor's pre-existing connections and through presentations and follow-up discussions at in-person meetings.**

Focus group participants described two primary ways that they have initiated and/or joined research collaborations in ID4. The first is through in-person full-Institute meetings, either by giving or listening to presentations, and then having follow-up conversations based on questions that emerge. Secondly, students described getting involved in pre-existing collaborations via their faculty advisor. Students explained that their advisors introduced them to the work and to their collaborators, offering specific suggestions for how students within those research groups could work together.

- *"I presented [at the last in-person meeting], I came up with the project, and [a faculty member] was looking for some students. So, during the break we started to talk about—we started to work on equations on the board and we started the collaboration."*
- *"Most of the people I've met, it's been facilitated by my advisor, but it's also been just getting to meet people and getting to know them [in person]."*

**Communication, flexibility, and spending time developing a shared understanding of terminology and research problems were key characteristics of successful student collaborations.**

When asked about what makes ID4 collaborations successful, most students felt that communication was the most important factor. For instance, students described the necessity of bridging gaps in domain knowledge and language and the importance of being willing to teach and learn from each other. For many, the collaborative process involved an introductory period for defining terms and

making sure collaborators understood the research problem in the same way. The specifics of meeting types and frequency varied across focus group participants and were coordinated according to what worked best for each collaborative team. Faculty roles in student collaborations varied as well, with some faculty “micro-managing” and driving problem definition and tasks, while others were more flexible and allowed students to lead.

- *“We spent three or four months trying to set a common terminology or clarifying terms. Because for example, for us, a ‘linker’ is one thing, and for the people who graph neural networks, a ‘linker’ is another thing. So I mean, setting the communication, it was very important and it took time. But it was helpful.”*
- *“[The most beneficial thing was] when I spent a week there working with [my collaborator] face-to-face during the week, because during that week he transformed his priorities and I did the same just to make an effort in this specific project. And it was great. I mean, I learned a lot. I believe that he also learned a lot... Basically, we constructed the whole backbone of the whole project in that week...”*
- *“We now do meetings that are just me and the other grad students since we have a longtime collaboration. But at the beginning, [the faculty collaborators] were there every meeting... So we work a lot when we define a project—what I’m going to be looking for and what I’m going to be predicting. And for sure, [the faculty and] everyone was there to make the big decisions... Also it’s very flexible.”*

**Challenges in student collaborations included difficulties identifying problems that benefit multiple students’ research agendas, developing strategies for effective communication, and deepening understanding of each groups’ domain and research problem.**

In some cases, the absence of the factors that led to successful student collaborations underpinned the most prominent challenges described by students, namely limited communication and an unwillingness to take time for in-depth mutual understanding. Students also identified more specific barriers, including finding ways to make their research project beneficial for both parties (e.g., publishable or relevant to a thesis for multiple students) and finding entryways into collaborations when many students and PIs had pre-existing projects ongoing.

- *“I was just in a conversation with [a PI] where I’m like, ‘Can we use these things?’ And he’s like, ‘Yeah, we did that 15 years ago.’ And it would be helpful for my problem, but no one in my group knows how to do it. And it’s like some of the things that we need are fairly old or simple, and so it can’t be a thesis for a computer scientist, but it’s the thing that works. So yeah, there’s been a lot of struggle with that. And then you have to make something that’s interesting for both the computer scientists and material scientists, and that takes a couple of years. That’s really tough.”*
- *“People were pretty resistive to consistent meetings... It was always Slack, and then you’d end up being on Slack for two hours, just going back and forth. So I think that was kind of frustrating. And then not getting a whole lot of involvement from collaborators, ending up doing a lot of the work on my own, doing a lot of the writing on my own, things like that. It’s been frustrating.”*
- *“[At the 2022 meeting in Colorado], I did get to talk to quite a few people about their research and possible overlaps with my research, but at that point, it also did feel like a lot of the collaborations had been pre-established, for a lot of the ones that managed to keep going forward at least.”*

## INSIGHTS FROM A SUCCESSFUL COLLABORATION

As previously noted, ID4 conducted a focus group with two students—a PhD student and a post-doc—to gather a more in-depth understanding of how a successful ID4 collaboration develops and evolves. Analysis of this focus group suggested that pairing a PhD student with a post-doc to collaborate on ID4 research was a successful strategy and may be beneficial more generally across ID4 research groups as it alleviates potential friction when collaborators' individual research agendas do not naturally align. While this collaboration is not necessarily representative of all ID4 collaborations, it may offer strategies or insights that can be applied across the Institute. The excerpt of the focus group below has been condensed and edited for clarity.

### ***Can you describe the collaboration?***

*PhD student:* Essentially, I got some complicated data from a neutron beam line, and I worked with another lab-mate in my group to make a whole bunch of data to try to describe it. And then I reached out to [the post-doc], with her excellent coding skills and plotting capabilities, to help me get a better understanding of this data so that I can have some really cool analysis at the end of my paper that's a little bit more advanced than just plotting things X versus Y.

*Post-doc:* And I am working on DimBridge, which is this wave of bridging dimensional spaces. I am actively looking for people that can use the tool to help generalize it and make sure that the tasks that they have, they can use DimBridge for. So yeah, when [the PhD student] reached out, 'I have data. I'd love to use the tool,' I was excited because it's the first kind of use case for ID4, like 'Hey, I need this for my data that I'm writing a paper on.'

### ***How do you collaborate?***

*PhD student:* Normally I send [post-doc] data and I'm like, "Hey, I don't know if this is going to work. But if you want to try it out..."

*Post-doc:* We can give it a whirl. And then I'll send screenshots and be like, "Look."

*PhD student:* Yes. And then I'll be like, "That's really cool."

*Post-doc:* "Look at this cool shape."

*PhD student:* "Can we color it this way instead?" And then I'll be like, "That's really neat. This tells me this."

*PhD student:* And then also, "This dataset probably isn't the greatest. Here's another one. Can we try this again?" So, it's mostly just those Slack messages of like, "Hey, here's a zip folder for you. It has some set of data in it, and I'd love to see it."

*PhD student:* And then meeting once a week on Zoom usually. At the beginning it was much more like, 'Here is my system and I would like to teach you about what this curve means and how I'm trying to describe this curve. I hope this is interesting to you.'

### ***What has made your collaboration successful?***

*PhD student:* I think on my end, it's very helpful that she is a post-doc with this tool looking for papers with people to use the tool. It's just automatically set up really nicely for success.

*Post-doc:* I guess as a post-doc, I think in part because I'm not working on a thesis, I have a more open agenda for the collaborations. So, I want to write papers and be on papers. But I'm not working towards this main direction. My only time limitation is the different projects that I'm working on. And so yeah, I think that really helps. I had to shift—we had to pause functionality to come up with this use case for the paper. But that's not dominating my weekly agenda, and then I get to go back to the fun stuff I'm building.

*PhD student:* And then on my end, I try to make sure that I have interesting datasets that are nice and clean and easy to read into computers, not just randomly

scattered around in lab notebooks that need to be digitized. And that the datasets are relatively—I guess "clean" is still the word I would use for that—that there's not weird outliers that I'm thinking about the data before I'm sending it to [post-doc] and trying to be like, cool, these are the columns. They're in the right order. Everything's labeled appropriately, and it should just read into the workflow that [the post-doc] already has. So, trying to make sure that it's as low barrier to entry as possible for her so that when I do send over these 8,000 different datasets, it's not like, "Okay, I've got to run this script and that script and then this thing, and then finally it'll get into the visualizer."

*Post-doc:* And that's super helpful because the more data wrangling I have to do, the less time I have for functionality, making sure things are working as they're supposed to be. So yeah, that just really helps with the speed of the collaboration too.



## ***Student Culture & Community***

**Interpersonal connections among ID4 students—primarily through in-person interactions during full-Institute meetings—promoted orientation to ID4, early engagement, and a sense of belonging in the Institute.**

Student focus group data highlighted the important role of interpersonal connections with other ID4 members in developing a sense of belonging in the Institute. These opportunities were most prominent during in-person, full-Institute meetings, and students often cited attendance at full-Institute meetings as a key factor in their initial involvement and orientation to ID4. Students were typically invited to their first ID4 meeting by a faculty member already involved in the Institute (e.g., their advisor); some students were more likely to be invited and able to attend an ID4 meeting if it was being hosted at their university, and then formally joined ID4 after making connections at the meeting. Several students noted that it took time after the first meeting they attended to understand how their research overlaps with the goals of ID4, generate ideas for collaborations, and identify specific students or faculty who they wanted to connect with about potential collaborations. Regardless of status (e.g., graduate student, post-doc, VPRTT fellow) and length of involvement in ID4, there was a shared sense among students that connections with ID4 members—both socially and for research purposes—were associated with engagement in and satisfaction with ID4. Specifically, students explained that in-person interactions allowed them to gain familiarity and rapport with people they saw on the ID4 Slack channel and at future ID4 meetings, feel part of a community, and be more comfortable asking “dummy questions,” all of which was supported by the culture of openness and teaching among ID4 faculty and students. Full-Institute meetings included structured sessions for students to meet and converse with other ID4 members, as well as presentations about ongoing ID4 collaborations that highlighted specific collaboration opportunities and needs. One student mentioned that their in-person connections with ID4 students extended beyond full-Institute meetings and occurred regularly at their home university, providing continued opportunities for learning and relationship development. Overall, it is important to note that this data was collected during a full-Institute meeting from students who were attending the meeting and may not be representative of students who do not typically attend ID4 meetings.

- *“I got involved [in ID4] just after I joined [my advisor’s] lab... It was great that the first meeting was at [my university] so I was able to attend, and in the beginning I was like, ‘Okay, what is ID4?’ But also ID4 was at the beginning [of the grant], so everyone was meeting each other. And from that I started collaborations on projects with groups from ID4, both with experimentalists to synthesize molecules that we predict, but also with computational science groups...”*
- *“I think another thing ID4 did very well is about building the communities. I remember last year we had this Colorado meeting, and we were making slides all together and also having a ski trip afterwards. I think that actually makes me feel that I bonded with a lot of people in this Institute. And also when I came back [to this meeting], I’m seeing familiar faces and I know this is a comfortable environment that I can talk about science.”*
- *“I, fortunately, have a lot of contact with people who are involved with ID4 on campus. We take some of the same classes together, spend a lot of time in lab together. So I think exposure to some of these topics over many, many whiteboard sessions has gradually closed some of the gaps in my knowledge. And different people will teach physics stuff in different ways, so I think gradually my resolution of understanding has increased over time. But I think it’s mostly because people are very friendly and open to talking about these things, so it’s fun to keep working on it.”*

**Students felt less connected to ID4 in the absence of regular opportunities for in-person interaction and a clear sense of their role in contributing to the Institute.**

Some students reported feeling less connected to ID4, and as expected, one reason for this revolved around limited in-person interactions with ID4 members outside of meetings. Other students discussed challenges related to their sense of contribution to ID4, which was sometimes related to specific characteristics of their role, such as graduate teaching assistants who are not paid by the grant or students who are new to the Institute. VPRTT fellows shared this sentiment because their advisors are not part of ID4, as explained in the next section. One student noted that it is particularly difficult to become engaged in the Institute without a sense of structure or having a “well-defined project” when first joining ID4. As noted previously, some students did not face this challenge because they were guided into specific projects and pre-existing collaborations by their advisors who were part of ID4.



- *“There is a community, but then we go back to our schools, and that can be really tricky to maintain the momentum. People get busy or people are oversubscribed and so I think there are these kind of brief times where it’s like, ‘Wow, I love these people. They’re so great.’ And also it’s isolating to be at an institution where you’re on Slack with people and not really seeing them as much.”*
- *“It’s harder, for me, to intellectually see how I can contribute. I do like being around the talks [at the meetings] and hoping that eventually I’ll be able to contribute more. There’s been ways, obviously, I’ve been able to contribute to certain projects, but finding a way to contribute in a bigger way...”*
- *“I, honestly, feel very disconnected from ID4 in a sense that I’m not really paid by the grant... So I still do work for ID4 and I still get the same opportunities, but...it feels like, well, I guess I’m working on this. I like the people at ID4 that I collaborate with. Same time, it’s like, I wish I was also on ID4.”*

## VPRTT FELLOWS AND THE ADVISOR ROLE

As discussed previously, one of the student focus groups included students who are part of the VPRTT Materials Science Graduate Fellowship Program at the Colorado School of Mines. The fellowship aims to foster a community of computational materials science students at Mines who also collaborate with ID4. As stated in the application, the program “supports doctoral candidates who show promise for significant future achievement in materials and/or data science research, and who demonstrate a commitment to advancing diversity, equity, and inclusion in STEM.” Half of the funding for each fellow is provided by ID4 and half is provided by the student’s advisor. Two fellowships are awarded per year, and there are seven current fellows or honorable mentions. It is important to note that only two fellows participated in the focus group, so the data may not be representative of all fellows.

**Overall, the fellows reported having limited involvement and connections with ID4 members, particularly in terms of research collaborations. This was primarily attributed to their advisors not being part of ID4, creating a different context than most other ID4 students with advisors or faculty mentors who are members of ID4.**

The fellows highlighted the importance of their advisor’s role in guiding their decisions about what types of collaborations to pursue and prioritize, particularly given competing demands of the research endeavors needed to complete their degree program, which is overseen by their advisor. For other ID4 students, their advisors are familiar with and supportive of the collaborative opportunities in ID4 because they are part of the Institute themselves. As one fellow explained, *“There definitely is a lot more of a push when you have your advisor [involved in ID4] to get more engaged because it’s like, ‘Hey, should I be trying to make this collaboration? Would my advisor be okay with that?’* This fellow continued with other questions that have been raised due to “conflicting interests” between ID4 and their other research projects, such as, *“How far can I deviate from my current thesis without it being too much of a side project?”* The other fellow shared a lack of certainty about how to pursue an ID4 collaboration without their advisor being involved in the Institute: *“I don’t have open collaborations with anybody in ID4 at the moment, I think partly because my advisor is not officially a part of ID4, and so it becomes a little fuzzy about how that would work.”*

**Both fellows expressed interest in pursuing collaborations within ID4 and being “more involved” in the Institute.**

To do this, they noted the importance of having conversations with their advisors, especially before ID4 meetings, to discuss potential avenues for collaboration that are relevant to their research interests and might align with other ID4 members’ work. As they explained in the quotes below, this would allow them to be more prepared to strategically pursue collaboration opportunities, particularly during full-Institute meetings when there is dedicated time for making these connections.

*“If I would’ve had that meeting with [my advisor] beforehand where I was like, ‘Hey, I know we used to collaborate with these people. Are we planning to do that again?’ and getting kind of a sense of her direction [before the meeting]... I don’t know that she would have to be here to facilitate it, but if we had just talked more beforehand, I think maybe that would’ve been helpful.”*

*“I did talk to my PI very briefly [before the Harvard meeting] about, ‘Okay, what areas might I look for possible collaborations?’ But at least with how I thought of them, I thought more on just my project side rather than, ‘Okay, how well can it mesh with other people’s projects?’ which has probably been a little bit to my detriment... I’m definitely going to try and talk to my PI about, ‘Okay, there’s these people that have presented these ideas, so can we find a way that we could maybe work with them?’ And also another opportunity to get a collaboration, another paper out, always good.”*

**To improve onboarding and general experiences in ID4, students expressed interest in knowing more about who is involved in ID4, participating in student-focused events, having access to resources or events to learn about other domains, and enhancing structures for career and faculty mentorship.**

Focus group participants shared a range of ideas to improve students' onboarding and general experiences as part of ID4. These ideas pertained to four general topics. First, students expressed interest in knowing more about who is involved in ID4, including updates on graduate students who leave the Institute, information about faculty members' areas of expertise, and current collaborative teams within ID4. This would be particularly helpful for new students joining ID4, and may support students' use of Slack, as one student noted that they are hesitant to use the ID4 Slack channel without knowing the people in it. Second, focus group participants noted that it would be helpful to have more opportunities for students to get to know each other through, for example, a student-focused workshop or a peer mentoring program with younger students shadowing older students in their ID4 collaborations. Similarly, VPRTT fellows were interested in an event at Mines to connect with other students in the fellowship program. Third, focus group participants shared ideas about resources (e.g., conceptual repositories), Zoom events (e.g., tutorials, roundtable discussions hosted by ID4 faculty's labs), or in-person events (e.g., student-focused workshops) that specifically support ID4 students in learning about other domains and associated terminology, language, and concepts. This would increase the efficiency of student onboarding into ID4, and casual student-oriented learning events may be "more approachable than a more formal talk," as one student explained. Finally, focus group participants discussed the need for more career and faculty mentorship opportunities within ID4. This might include a structured process for requesting a mentorship session with a particular faculty member, or an informal event like "Behind the CV" where students can hear faculty members openly discuss their career paths, share challenges they have faced, and answer questions.

- *"Something I feel is missing is a way to know who's still in ID4 and who has already graduated, especially among grad students... It'd be good to know every now and then, give an update of who's still around, who's not, whose door we can still knock on."*
- *"I know that the people that are coming [into ID4] now, having this time to just talk and interact with the other students is going to be helpful for sure, both research-wise to find collaborators, but also for help coming up with an event and organizing... I would like to have more... So maybe an event where we focus on the students, like a workshop so you can have everyone there, and both develop skills like career development, but also help more with this integration between the students."*
- *"I feel like I don't have a good base understanding of what sorts of simulations exist... And so I'm like, 'Well, it's really hard for me to know which one would be best suited for my project.' And so my idea [is], well, if we have all of this money for workshops, it might be helpful for the young students to be able to go and just get a base understanding so that when you do go to a workshop like this, you don't have to Google every other word."*
- *"Even...a mentorship session with a specific professor. 'Oh, I want to know more. I am from chemistry, but I'm really interested also in machine learning for physics'... I know that I can go and talk with a professor, but there is no established structure on ID4 to help with that... For some students, it can be a little harder, having this initiative to go. I think that it's important so ID4 needs to show they are there, available to offer help, not just research and money, but we are here to help. So they need to promote that, and provide tools to help the students."*

**Subcommittees and outreach activities have allowed some students to feel more engaged and included in ID4, though updates and opportunities could be shared more widely to encourage more student involvement.**

Several students discussed their involvement in ID4 subcommittees and outreach activities, including an event for community college students, mentorship through a research experience for undergraduates (REU), and a drone camp. These students described developing a strong connection to ID4 through these activities. While ID4 is supportive of student leadership and outreach, there are opportunities to share more Institute-wide updates about current events, progress, and openings in these areas. Some focus group participants were not aware of the ID4 subcommittees or had not received information about the expectations, commitment level, and how to join. Given the positive experiences of those who are involved in ID4 in these ways, students noted the importance of considering how to most accurately and systematically share information about student leadership and outreach activities, such as ensuring that all students are on the ID4 Slack channel and giving presentations about ID4 subcommittees and outreach at full-Institute meetings. This may support more students in feeling involved and engaged in the ID4 community while also expanding the potential for ID4's impact on student leadership development and community outreach.

- *“A lot of my involvement with ID4 has been around outreach in that we did this drone camp and this other little outreach activity, and then also I joined the outreach and education committee. So at least lately, most of my interaction with ID4 has been that committee, which has been kind of good. I've also gotten to know a few people in ID4 better through that committee, namely [two faculty members] and some other people. But yeah, that has also made me feel more included...just being more involved, even just a tiny bit on the organizational side, has made me feel more a part of it.”*
- *“...These presentations that we have in person [at full-Institute meetings], [we should] also have a presentation about outreach that we are doing, just quick updates on events that we did, but also possibilities to like—'Oh, I'm organizing this community college event. Anyone else would like to participate?' I think that people are going to know what is happening inside the committees...but I think the communication to spread the word about what ID4 is doing and why ID4 members are doing it is not that great... Because sometimes I can make people be like, 'Oh, I can do something similar in my university.' Or we can collaborate on something bigger, and spread more nationally. But I think that if people know what's happening, it's going to be much easier to do even more.”*

### ***Diversity, Equity, & Inclusion (DEI)***

**Students generally expressed a sense that ID4 has a welcoming, inclusive, and diverse culture of faculty and students, and that these values are part of the mission of ID4.**

As highlighted in the main report and in previous ID4 evaluation reports, there is a strong sense among students that the culture within the Institute is welcoming, diverse, and inclusive. In focus groups, students discussed the diversity among faculty that has existed since the start of ID4. They also noted that student diversity is dependent upon faculty (i.e., admitting and selecting graduate students and post-docs) and can shift over time as new students become involved, but they felt that faculty have been thoughtful and made intentional efforts to create a diverse and welcoming student community within and across the institutions involved in ID4.

- *“I think that, in general terms, ID4 is doing a good job in diversity, equity, and inclusion. Maybe [we] could be a little bit more explicit, at least in the ID4 community—‘Let’s do this, let’s push forward this specific activity that is aimed for this goal.’ But I believe that in practical terms, of course you always can be better, but we are doing well.”*
- *“The diversity of the actual group, I feel like is much more PI dependent and who they’re hiring into their group. With [my advisor’s] group, I know that we are very cognizant of that and push really hard to have a diverse and welcoming group.”*
- *“Maybe there’s multiple different ways of trying to accomplish [diversity, equity, and inclusion]. So there’s a question of, within the group, is this space inclusive and accessible and welcoming to everybody? And I think that if everybody feels comfortable being honest about their own experience, then you can find out if that’s successful. And then if it’s a great environment, then maybe you don’t need to talk about it. It’s already doing its job. If it’s about outreach and trying to go outside of this group of people, then that’s a different question.”*

**Students suggested that the importance of DEI could be more prominently communicated in ID4 activities and messaging, including making the connections between ID4 outreach and DEI clearer.**

While students perceived the culture within ID4 to be diverse and welcoming, many were less certain about how ID4’s commitments to DEI extend beyond the Institute through community outreach activities and Broader Impacts work. As noted in the main report, ID4 leadership has made efforts to increase outreach activities, including forming a subcommittee that has solicited and received an increasing number of applications for outreach funding through the Institute. In focus groups, however, students indicated that there is still room for greater awareness about these opportunities, and some students expressed a lack of clarity about the purpose and intentionality behind such activities. As one student noted, they participate in outreach through their university but have not previously associated these outreach activities—or DEI in general—with ID4. Others added that more formal presentations about DEI and outreach, particularly at in-person meetings, could provide clarity and increased engagement in those activities and convey the Institute’s commitment to DEI more explicitly.

- *“I would’ve liked to see something about [DEI and outreach] in this meeting [at Harvard]. This meeting has been entirely about research updates and collaborations and nothing about outreach.”*
- *“I think that I am probably just not used to thinking about [DEI] associated with ID4. I think about it more related to my involvements tied to my university... And I don’t know if the outreach that I do with [my university], due to my affiliation with ID4, counts as outreach with this Institute, or... I guess this is just a framing of it. I don’t know what’s associated with what.”*

## ***Student Outcomes & Satisfaction***

**Students reported gaining unique knowledge, skills, and research opportunities through ID4, which were facilitated by tools and collaborative relationships from the Institute.**

When asked about the impact of ID4, focus group participants discussed the value of opportunities to learn about other domains, gain technical and collaborative skills, and broaden their research areas. Several students noted that ID4 has provided them with the tools and, most importantly, access to people with diverse domain expertise who are interested in pursuing and supporting cross-disciplinary work. These experiences and skills were often cited by students as a clear advantage for when they pursue future career opportunities.

- *“On my end, it's just really nice to have these more high-end visualizations in my publications and in things that I'm presenting because I'm realistically probably going to look for a more data science heavy job after I defend [my dissertation] sometime this year. So having the collaborations with [ID4 student name] and showing that I know how to work with other data scientists and showing that I know how to use these types of things is just really helpful for me...”*
- *“I would just say that the Institute has broadened things that we're able to work on, which has been pretty nice... I have been able to pursue problems I don't think I would've been able to without ID4... So I'm pretty satisfied.”*
- *“[My ID4 collaboration] is something I'm proud that I did and it wouldn't have happened were it not for ID4. And now I can have this other supporting pathway of research that I can put in some package for applications in the future, you know? ...So it works towards my broader idea.”*

**Students who were further along in their degree programs expressed interest in additional support from ID4 in identifying connections and career opportunities that would allow them to build on their ID4 research and skillsets.**

A theme that emerged among focus group participants who were further along in their degree program was a need for additional guidance and support in identifying career opportunities that build on the skills and knowledge they have gained through ID4. Students highlighted the unique potential for ID4 graduates to continue contributing to innovative cross-disciplinary work, and they expressed interest in learning about potential career paths and available positions with companies or universities connected to ID4. This could be achieved, in part, with career development sessions or opportunities to connect with ID4 faculty through student-focused workshops, as discussed previously.

- *“After you go through all of that effort to understand what the other side is saying, you read this whole literature that is not your field and then you're about to graduate, and then it's like, ‘What now?’”*
- *“For grad students and post-docs, I feel [ID4] is missing an exit strategy. I don't know if there's ways in which ID4 can also support students or post-docs onto pursuing next steps like a career somewhere else... But I think that given the wide array of people and the big network there is in ID4, maybe there's also opportunity to connect ID4's output, being students, to places in industry beyond ID4... And that would be very, very helpful... Because in the end, we are creating this very specific type of professional... So I think it's a missed opportunity to send them to the right places... It's like all the money put into ID4 just goes to waste because it's not having an impact beyond ID4.”*

## **Conclusion**

Overall, the findings outlined in this brief expand on what was presented in the main report and provide additional depth regarding student perceptions of ID4. In particular, the student focus groups brought to light the nuances of successful ID4 collaborations; factors that support and hinder students' sense of belonging in ID4; and ideas from students to strengthen their general experiences in ID4, understanding of the Institute's DEI priorities, and career pathways beyond ID4. In conjunction with data from the main report, these findings were used to inform considerations for ID4 leadership and subcommittees going into the 2024-2025 academic year (see page 37).