



PURM

Perspectives on Undergraduate
Research & Mentoring

Becoming a Researcher: How NSF REU Participation Creates Self-Determined Researchers

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Introduction

Professors and students generally agree that undergraduate research experiences are highly valuable to undergraduates' education and development (Ruth et al., 2025). The responsibilities of undergraduate research assistants (URAs) vary by discipline and principal investigator (PI), but it is common for URAs to be assigned the menial or “grunt” work of research projects (e.g., Luo et al., 2022; Perrella et al., 2020). URAs frequently report leaving research positions because their assigned tasks were unenjoyable (Cooper et al., 2019), even though undergraduates who stay in their research experiences for longer report not only greater benefits (Adedokun et al., 2014; Thiry et al., 2012) but also more chances to contribute meaningfully to research projects (Cooper et al., 2019; Evensen, 2021).

Faculty need URAs to carry out their projects, but when undergraduate research experiences include only repetitive, menial tasks, students do not come away more prepared to conduct research independently. Young scholars often struggle to transition from student to researcher (Golde & Dore, 2001), finding particular difficulty with the aspects of science not typically accessible to young researchers, such as devising high-quality research questions (Lovitts, 2008). Moreover, independent research experience makes students more competitive for limited slots in Ph.D. programs or post-baccalaureate research positions (Mantai & Marrone, 2022).

Thus, there is a need for mentoring programs intentionally designed for students to conduct guided but independent research. These programs should develop students' research skills and knowledge while also fostering autonomous motivation and self-regulation. Autonomy and self-regulation are both powerful predictors of academic success and goal achievement (Deci & Ryan, 2008; Tangney et al., 2004), and research in self-determination theory shows that autonomous motivation improves self-regulation (Legault & Inzlicht, 2013).

In this student perspective, we use a self-determination theoretical framework (Ryan & Deci, 2000) to analyze how the Collaborations in Discipline-Based Education Research (CiDER) program at North Dakota State University (NDSU) successfully uses federal funds to grant undergraduates the agency, self-efficacy, and support needed to complete an independent project. Self-determination theory is based in autonomy, competency, and relatedness. In describing how the CiDER program and its mentors foster these feelings, we draw from interviews with five former students and our personal experiences as program alumni.

First, we describe general information about the program, which was in part provided by former program director Dr. Warren Christensen. We then break the paper into three sections: autonomy, competence, and relatedness. The autonomy section is about who our interviewees were upon entering the program and how they perceived their mentors' deliberate efforts to prioritize their autonomy. In the competency section, we discuss how these efforts built our interviewees' competencies and the influence of these newfound abilities on their journeys as researchers. Our final section, on relatedness, is about the importance of community in REU programs; we argue that prioritizing relatedness is an essential part of building the next generation of researchers. We conclude with thoughts about the importance of research experiences like the ones we had at CiDER, and how other programs can emulate its success.

Overview of the CiDER REU Program

Collaborations in Discipline-Based Education Research, or CiDER, is the REU program run by the Discipline-Based Education Research (DBER) team at NDSU. Not its own department, the DBER group comprises faculty and graduate students across STEM disciplines who research the teaching and learning of undergraduate STEM, and CiDER participants also conduct research on STEM teaching and learning. The team also implements their findings in NDSU classrooms through professional development and institutional change.

CiDER has been running mostly continuously since summer 2014, excluding 2021 and 2024. To date, CiDER has mentored 100 undergraduate students through the ten-week program. Grant funding has been extended until 2027.

The CiDER website describes the program as meant for “any undergraduate interested in exploring the learning and teaching of STEM at the undergraduate level.” Additionally, REU programs like CiDER emphasize training students from backgrounds typically underrepresented in STEM research, whether they be women, ethnic minorities, or students from small home institutions with fewer research opportunities.

Students and projects are chosen through a careful process. DBER-associated faculty who are interested in mentoring an REU student submit a project proposal to the program director. These projects are reviewed and then advertised to applicants, who choose their top three projects upon applying. With funding to sponsor ten students, and thus ten projects, per summer, the program director eliminates projects that were unpopular with applicants. Accepted candidates are then assigned a project and mentor based on their ranked preferences. Students present findings from their project at two venues: 1) an oral presentation to the program students and faculty and 2) a poster presentation at the NDSU Summer Research Symposium.

This perspective focuses on the experiences of the members of the 2023 CiDER cohort, which includes the authors and five interviewees. Including us authors, the 2023 cohort had nine total students instead of the usual ten, and we reached out to the other seven to see if they would like to share their experiences with us for this perspective. Five of our peers agreed to be interviewed; two declined. Because DBER is an interdisciplinary field, our cohort came from a variety of academic backgrounds. Among the authors and interviewees, there were two majors in psychology, two in chemistry, and one each in math, biology, and physics. Entering the program, most students had limited experience with education research. For some (Quinn, Sam), this was their first interaction with research at all; others had been research assistants in a limited capacity (Alex, Blair) or in other fields (Brianna, Taylor). Most students were rising juniors or seniors, though one interviewee had just finished his first year of college. Although NDSU students are not barred from applying and have participated in years past, our cohort was composed entirely of visiting students from institutions across nine US states.

Autonomy

To elicit responses about autonomy, we first asked interviewees about how they chose their projects, about their mentor–mentee relationships, and about their project process. Then, we provided our definition of autonomy—choicefulness and volition (Niemic et al., 2010)—and asked how it relates to their experiences in CiDER.

At the start of the program, mentors and mentees did a structured goal-setting activity in which students articulated what they hoped to learn or accomplish over the summer. Mentors then used these discussions to align student goals with project needs. Blair recalled that,

“The very first stage was more just gauging what I was interested in getting out of the program. So it wasn’t even really about: okay, this is what you’re going to be doing; this is how you’re going to help us find the answers. It was just kind of like, what are you wanting to accomplish here? Where do you see yourself taking this research, and how can we help you build that through doing this project with us?”

Through this exercise, mentors were laying the groundwork for autonomy by listening to students’ goals and desires. Students had a say in how their summer would turn out, instead of it being dictated top-down.

Many students felt heard during the entire summer. Quinn and Taylor both describe how, after an initial period of mentor-led meetings, meetings became more collaborative, with the student presenting work and sharing ideas. Quinn was surprised by the amount of autonomy he was given; after a crash course in the literature, Quinn’s mentor presented the data and asked: “What should we do with this?” After Quinn had a chance to work with the data, he said: “[the project] gradually became more open-ended into what I wanted to see the project become.”

Taylor’s meetings were similarly student-led; he would arrive with updates for his mentor and they would go from there. Taylor observed that for his project, he “couldn’t not be autonomous.” To conduct a thematic analysis of short-form written survey answers, he had to learn and understand the codebook, a codebook he co-developed with his mentor. He had to understand the research question and how his analysis would help answer that question. Over and over, he had to make decisions in which he “couldn’t ask someone else for help, because it had to come from [him]. [He] had to understand everything in the project in order to do the project.”

Every project in our cohort involved qualitative data. The authors’ projects both relied on interview data. Of our interviewees, two used interview data and three used short-form written qualitative data, either surveys or student work. We mention this because these qualitative projects encouraged mentors to provide autonomy to their mentees. It would be a mistake to consider qualitative research easy or unrigorous; that is not what we argue. We argue that these projects afforded students the opportunity to be fully involved, as meaningful contributors, to many important parts of the research process, and that this increased students’ sense of autonomy and purpose.

In Alex’s lab, frequent meetings about qualitative coding with his PI, a graduate student, and another CiDER student felt very collaborative, with a lot of discussion by everyone. Alex’s PI facilitated these meetings, but Alex never felt as if his PI was the boss coming to tell him what to do.

Santiago and Brianna’s meetings were similarly student-led, with Brianna feeling like a trusted contributor to the project. Santiago took the lead on his project, coming to his mentors for advice and feedback. He reflects that his project would likely have been stronger had he more structured

guidance from his mentors. Nevertheless, he is grateful for the autonomy he was given, which allowed him to learn in depth about the research process. Quinn agrees. He reflects that while his mentor's primary objective was the research project, he felt like the program was intentional about making this a space for undergrads. Blair's mentors gave her tools to start doing work on her own and develop agency, but they balanced this freedom with plentiful feedback.

Providing autonomy didn't always play out perfectly at CiDER, though, and the reasons why might be related to students' competencies, which we'll discuss next. Alex was sometimes given choices between tasks he didn't know much about; despite having a say on paper, not understanding the options made this a meaningless choice. Sam came into the program with no experience and a deference to her superiors. She acknowledges that she could have read the literature and come to a meeting with suggestions for the project, but that was not her mindset. Sam's "personal mindset was that this is someone else's project, and [she] doesn't have any experience. [She] should be following someone else's lead on this and doing what will help them the best." Sam's mindset aligns with previous work on REU students inexperienced with a mentorship dynamic. Students often feel unsure about how to interact appropriately with their mentors (Plueger & Wilcox, 2024), further reinforcing the importance of strong mentoring practices that prioritize the student's voice and autonomy.

Despite these blips, the CiDER mentors emphasized student autonomy throughout the summer. Quinn noted that "it would be very easy in a program like this...[to] give the undergrads all the grunt work for the summer and...send them on their merry way," but that's not what they did.

Competence

Self-determination theory suggests that competence is fostered through optimal challenges paired with effectance-promoting feedback (Ryan & Deci, 2000). During the goal-setting meeting at the beginning of the summer, mentors assessed their mentee's abilities and tailored students' research plans according to their background experience and expressed goals. As a result, students were positioned to experience competence through growth in areas they identified as personally significant, such as developing methodological skills, learning how to connect research to practice, or understanding what a research career might entail. For example, Blair and Brianna entered CiDER with the explicit goal of gaining research experience to support their senior theses. In contrast, Quinn and Sam saw CiDER as an opportunity to explore education research and clarify their post-graduation trajectories.

The challenges and feedback that mentors provided developed feelings of competence and self-efficacy in students. In addition to personally tailored research plans, weekly mentor meetings played a central role in fostering participants' sense of competence through ongoing feedback and support. Participants' descriptions of these relationships highlight the importance of mentoring structures that balance guidance and autonomy. Some students worked primarily with graduate students or postdoctoral mentors, while others were mentored by professors or teams that included multiple levels of mentorship. They felt that their contributions were valued and the mentors were invested in their development, rather than solely on project outcomes. Quinn reflected that "it seemed like they intentionally made space for this to be a program for undergrads...It really felt like they spent time mentoring and valuing the feedback that we had."

The program's whole-cohort weekly meetings further contributed to competence development by establishing shared language and exposing students to multiple aspects of the research process. These sessions covered topics such as reading research papers, qualitative and quantitative research methods, and scientific communication. For students with limited research backgrounds, the meetings helped demystify research practices and made the overall process feel more

manageable. For those with more experience, the meetings were less impactful, though still valuable for cohort-building and reinforcing common ground. This variation underscores the importance of layered support structures that allow students to derive competence from different program elements.

Importantly, these experiences of competence also shaped how students engaged with opportunities for autonomy within the program. When expectations and challenges were aligned with students' goals and prior experience, students were better positioned to make sense of choices related to their work. In contrast, as discussed in the autonomy section, autonomy was less meaningful when students had not yet developed the experience or confidence needed to evaluate their options. These findings highlight the relationship between competence and autonomy in shaping students' experiences within CiDER.

All of our interviewees reported having met their goals by the end of the summer, with benefits that extend beyond the program. Three years after the conclusion of CiDER, participants described the experience as influential in shaping their academic and professional trajectories. Several credited CiDER with providing the confidence necessary to pursue graduate studies, complete senior theses, or take on research-adjacent professional roles. Sam shared that “none of grad school would have existed without that CiDER experience.” Sam’s relationship with her CiDER mentor continued beyond the summer, through to her graduate school application, and even now as a second-year PhD student. Similarly, Brianna credits the program for giving her the confidence and professional connections needed to apply to and select a graduate program. At the time of writing, two interviewees are currently enrolled in an education research Ph.D. program and three, including both authors, are conducting education research outside of graduate school—as a lab manager, research assistant, or data analyst.

Even participants whose paths did not shift dramatically emphasized that CiDER affirmed their interests and strengthened their commitment to research and education. Rather than serving as a turning point, the program reaffirmed these students' existing aspirations. Taylor described the experience as clarifying rather than redirecting his goals, noting,

“I don’t think [CiDER] changed the path, but it did affirm that this was the path I needed to be on. It didn’t put me off. I said to myself that this is absolutely what I’m doing in the future. I have to be a scientist, I have to be a researcher, and I have to be an educator.”

Relatedness

The initial focus of this paper was to highlight ways CiDER fostered autonomy and competence, two fundamental components of the CiDER experience. But by analyzing the program through the lens of self-determination theory, we found that relatedness and community highly influenced our experiences in CiDER. Interviewees who attended other REUs shared that a lack of connection there negatively impacted their experiences. One student reflected that in another REU he was unable to talk about the research he was doing with someone in his same position, whereas at NDSU, he shared: “I could talk about the problems that I was having in my research or just in my day-to-day life.”

The chance to talk shop is a great way for budding researchers to get excited about science. Self-determined researchers are not just competent and autonomous, they also share ideas, work collaboratively, and give and receive advice. At CiDER, Sam says she developed a lot of maturity by working with many different people and perspectives.

Relatedness is embedded into research through conferences, workshops, and graduate student cohorts, but undergraduates are often excluded from these spaces. REUs that promote socialization will inspire and embolden their students to pursue research. In this section, we discuss how the CiDER program accomplished this.

The first thing students experienced at NDSU was their shared dormitory. The program director selected suite-style dorms to increase social interaction; he chose room assignments by carefully considering student demographics. Quinn appreciated “being located there with everyone, because otherwise it could have been very isolating.” Brianna felt that the shared living space made informal event planning easier.

Rooms were also shared with a biology REU program, and there were several planned events with this other group. This was done purposefully by the program coordinators to increase the connections between as many people and spaces as possible. This worked well for Alex, who enjoyed that his pool of potential friends had doubled. Santiago appreciated the forced integration with the biology program, noting that without it he would not have interacted with them as much, if at all. In fact, there was a third REU program which was not involved in any shared social plans; Santiago can hardly recall the students from this third program, even though they lived only one floor below him.

Students were also provided with sanctioned social events. Some events were required or strongly encouraged, such as a walking tour of the city and a program barbeque; other events were optional but chaperoned by graduate students or faculty: playing board games, trivia night at a pizzeria, and attending Ribfest, a festival for barbeque ribs.

These orchestrated events did more than just break the ice among students. Many of our interviewees entered the program aiming to establish connections in the academic community and prepare for graduate school. Networking, essentially. These events allowed such networking to happen naturally, particularly for students who may be more reserved or not know the etiquette around talking to Ph.D.s. As Alex pointed out,

“There’s no way as an undergrad I’m going to ask a postdoc to go to a baseball game with me, right? Like, that’s just not going to happen. So having those organized [events] and being able to meet postdocs and talk to them in an organized setting is really cool...I think for me, [it] was like, okay, these people who are in grad school are real people and they’re cool. Maybe that could be me.”

When asked how the memorable moments from the summer influenced their experience in the program, four of our five interviewees mentioned that being around similar peers motivated or inspired them. Blair shared that,

“It’s motivating to be around people who are so passionate about wanting to learn...Being around people like that is what kind of motivates me and makes me feel like, okay, this is something that’s worth investing my time into...I felt excited because y’all were excited.”

Quinn was inspired to work toward what his peers were accomplishing because he saw that everyone else was doing such high-level work; this was a positive influence for him.

Perhaps even more important is that these formal and informal events established trust and self-efficacy. Taylor shared: “Never did I doubt that these people believed in me and believed in the science that I could do. And never did I doubt that I had support from my peers.” He goes on to say that the social events helped solidify this feeling.

Students may feel self-directed when they are capable and have agency, but without someone to support them and someone with whom to share their work, it's easy to lose interest. Also, research is hard. We've discussed ways that mentors can build competence, but there will still be setbacks and frustration. Having a support network of peers with similar experiences might encourage students to stick around, instead of deciding that research isn't for them when they encounter null results, high attrition, or difficult advisors. This is particularly true for the students that REUs are intended to capture: ones from a disadvantaged background with perhaps little knowledge of research and academia.

CiDER was designed to function as a community of practice (Wenger, 1998; Wenger-Trayner & Wenger-Trayner, 2015). In Wenger-Trayner's framework, a community of practice is a group of people who share a concern or passion for something they do and learn how to do it better through regular interactions. Mentor-mentee work agreements drafted at the beginning of the summer laid the foundation for relationships of mutual engagement. The weekly whole-cohort meetings engaged students in joint activities and discussions about research practices, methods, and science communication. Finally, shared living spaces allowed for deeper engagement beyond formal program meetings, encouraging participants to interact with and learn from one another daily.

When considering how to structure an REU program, directors should not forget relatedness. Asked how the formal social events influenced his informal social experience at NDSU, Alex said that while he doesn't have a complete understanding, he does know one thing: "it worked."

Conclusion

CiDER worked for our cohort because our mentors were dedicated to building students' autonomy, competence, and relatedness. Receptive mentors and student-directed projects encouraged autonomy; personalized tasks, frequent feedback, and professional development created competence; social events and a shared living space built community and relatedness.

The program was also successful because mentors tailored the experience to each student. We do not believe a one-size-fits-all approach would have achieved similar levels of success. In fact, the closest thing to this approach—the weekly whole-cohort meetings—were the most controversial element of the program; some students enjoyed them but others considered them dull or unimportant. Students benefited most from their individually designed mentoring plans.

What impressed us the most about the CiDER program were the intentional efforts to build a community for everyone: CiDER students, graduate students, and faculty. The emphasis on relatedness was strong, but its implementation was natural; NDSU DBER community members shared with REU students the activities they enjoy. This grassroots style of community building felt organic and honest. This community motivated CiDER students and made research a collaborative and fun activity. Tremendous effort is required to orchestrate so much socialization, make it feel candid, and then attain student buy-in, but the outcomes are clear: students felt motivated, inspired, and competent working alongside their peers.

Interviewees generally reported positive experiences with CiDER, but we'd like to note that we are missing two voices from our cohort. These students chose not to be interviewed, so our takeaways don't include their opinions. And despite encouraging our interviewees to express all opinions honestly, even negative ones, we can't be certain that students didn't self-censor in our conversations.

NSF REU funding is important because professors need resources (and encouragement) to mentor undergraduates in this type of way. We encourage professors to implement these strategies with their typical URAs, but we don't expect faculty to closely mentor undergraduates with no experience through a rigorous independent research project and build community among the URAs in one semester. Larger projects take priority, classes must be taught, graduate students need advising, and papers need writing. This is precisely why programs like REUs have existed and must continue to exist: to allow for opportunities like these.

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References

- Adedokun, O. A., Parker, L. C., Childress, A., Burgess, W., Adams, R., Agnew, C. R., Leary, J., Knapp, D., Shields, C., Lelievre, S., & Teegarden, D. (2014). Effect of time on perceived gains from an undergraduate research program. *CBE—Life Sciences Education*, 13(1), 139-148. <https://doi.org/10.1187/cbe.13-03-0045>
- Cooper, K. M., Gin, L. E., Akeeh, B., Clark, C. E., Hunter, J. S., Roderick, T. B., Elliott, D. B., Gutierrez, L. A., Mello, R. M., Pfeiffer, L. D., Scott, R. A., Arellano, D., Ramirez, D., Valdez, E. M., Vargas, C., Velarde, K., Zheng, Y., & Brownell, S. E. (2019). Factors that predict life sciences student persistence in undergraduate research experiences. *PLoS one*, 14(8), e0220186. <https://doi.org/10.1371/journal.pone.0220186>
- Deci, E. L., & Ryan, R. M. (2008). Facilitating optimal motivation and psychological well-being across life's domains. *Canadian Psychology*, 49(1), 14–23. <https://doi.org/10.1037/0708-5591.49.1.14>
- Evensen, M. (2021). Undergraduate research: Benefits from extensive involvement as a research assistant. *Perspectives in Undergraduate Research Mentoring*, 10.1.
- Golde, C. M., & Dore, T. M. (2001). At cross purposes: What the experiences of today's doctoral students reveal about doctoral education (www.phd-survey.org). Philadelphia, PA: A report prepared for The Pew Charitable Trusts.
- Legault, L., & Inzlicht, M. (2013). Self-determination, self-regulation, and the brain: Autonomy improves performance by enhancing neuroaffective responsiveness to self-regulation failure. *Journal of Personality and Social Psychology*, 105(1), 123. <https://doi.org/10.1037/a0030426>
- Luo, O. D., Lin, S. H., Grover, S., Sritharan, P., & Hansen, S. (2022). Undergraduate student attitudes and perspectives of the accessibility, supportiveness, and appreciation of research opportunities in the health sciences. *Canadian Journal of Higher Education*, 52(3), 26-41. <https://doi.org/10.47678/cjhe.vi0.189439>
- Lovitts, B. E. (2008). The transition to independent research: Who makes it, who doesn't, and why. *The Journal of Higher Education*, 79(3), 296-325. <https://doi.org/10.1080/00221546.2008.11772100>
- Mantai, L., & Marrone, M. (2022). Identifying skills, qualifications, and attributes expected to do a PhD. *Studies in Higher Education*, 47(11), 2273-2286. <https://doi.org/10.1080/03075079.2022.2061444>
- Niemiec, C. P., Ryan, R. M., & Deci, E. L. (2010). Self-Determination theory and the relation of autonomy to self-regulatory processes and personality development. In R. H. Hoyle (Ed.), *Handbook of Personality and Self-Regulation* (pp. 169–191). Wiley-Blackwell.
- Perrella, A., Dam, H., Martin, L., MacLachlan, J., & Fenton, N. (2020). Between culture and curricula: Exploring student and faculty experiences of undergraduate research and inquiry. *Teaching & Learning Inquiry*, 8(2), 90-113. <https://doi.org/10.20343/teachlearninqu.8.2.7>
- Plueger, J., & Wilcox, B. (2024, July 10-11). *Perspectives from physics graduate students on their experiences in NSF research experiences for undergraduates*. [Paper presentation] 2024 Physics Education Research Conference, Boston, MA, United States. <https://doi.org/10.1119/perc.2024.pr.Plueger>

Ruth, A., Brewis, A., Beresford, M., & Stojanowski, C. M. (2025). Research supervisors and undergraduate students' perceived gains from undergraduate research experiences in the social sciences. *International Journal of Inclusive Education*, 29(10), 1669-1686.

<https://doi.org/10.1080/13603116.2023.2288642>

Ryan, R. M., & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist*, 55(1), 68.

<https://doi.org/10.1037/0003-066X.55.1.68>

Thiry, H., Weston, T. J., Laursen, S. L., & Hunter, A. B. (2012). The benefits of multi-year research experiences: Differences in novice and experienced students' reported gains from undergraduate research. *CBE—Life Sciences Education*, 11(3), 260-272. <https://doi.org/10.1187/cbe.11-11-0098>

Tangney, J. P., Boone, A. L., & Baumeister, R. F. (2018). High self-control predicts good adjustment, less pathology, better grades, and interpersonal success. In *Self-Regulation and Self-Control* (pp. 173-212). Routledge.

Wenger, E. (1998). Communities of practice: Learning as a social system. *Systems Thinker*, 9(5), 2-3.

Wenger-Trayner, E., & Wenger-Trayner, B. (2015, June). *Introduction to Communities of Practice: A brief overview of the concept and its uses*. Wenger-Trayner. <https://www.wenger-trayner.com/introduction-to-communities-of-practice/>