Best Practices for Expanding Pathways to Undergraduate CS Research

Christine Alvarado, *University of California, San Diego*
Michael Hilton, *Carnegie Mellon University*
Amy J. Ko, *University of Washington, Seattle*
Lori Pollock, *University of Delaware*
Kelly Shaw, *Williams College*
Neil Spring, *University of Maryland*

Summary

This report is a concise guide for academic leaders and interested faculty in CS to support and expand pathways for undergraduates to engage in research. The report explains the benefits of supporting undergraduate research, highlights critical decisions in creating pathways, and shares many best practices for scaling undergraduate research in ways that are mutually beneficial to faculty and students.

1. Introduction

Since 2006, North American universities and colleges have been facing a surge in undergraduate CS course and program enrollments due to the increase in CS majors, minors, interdisciplinary CS+X programs, and other majors requiring computing and data analysis skills [2]. At the same time, while PhD enrollments have also been growing, the percentage of new PhD students who are North American residents continues to shrink, down to 39% in 2018/2019 [1].

The increase in the North American undergraduate CS student populations, while posing many challenges, provides an opportunity to both grow and diversify the pool of students from the United States who pursue a PhD and a research career. Engaging more undergraduates in research is an important step toward this goal [3, 4].

Yet, establishing and scaling undergraduate research opportunities is no simple task. This report will enumerate the benefits of expanding pathways, identify specific challenges, highlight key decisions in addressing these challenges, and recommend best practices. Our hope is that this guide can help leaders frame and structure undergraduate research opportunities, helping them systematically devise plans, carefully select resources, and anticipate challenges.

2. Benefits of Undergraduate Research

While there are many obvious benefits to students—learning about research, mentorship to pursue doctoral studies, and even meeting practical needs, like part-time jobs—there are also concrete benefits to faculty and departments:

- When done well, undergraduate research can strengthen and accelerate existing research activities.
- Undergraduates can bring new perspectives, ideas, and technologies to research labs, potentially enriching department culture.
- If coordinated well, doctoral students can learn invaluable mentoring and collaboration skills.
- Some undergraduates may become viable prospective Ph.D. students, especially for areas without large pools of prospects.

When coordinated well, these can all amplify each other, strengthening the overall culture and community of a department.

3. Challenges in Research Participation

Achieving the benefits above poses some challenges, each deserving careful consideration.

Time to Mentor

Undergraduates are by definition beginners in research, not disciplinary experts. Thus, excellent mentorship of undergraduate research can require significant mentoring commitment, energy and time. Undergraduates may require more structured research tasks and more frequent check-ins, particularly early on, so that research does not become overwhelming and take a backseat to the demands of their much more structured coursework. These needs can result in significantly more time and energy from their mentors. Moreover, undergraduates require a different mentoring focus. Mentors must spend more time teaching the basics of how to approach open-ended problems, rather than focusing mainly on the research questions themselves.

Project Scope

Compared to PhD students and masters students, undergraduate researchers typically make slower progress, have a more constrained time to contribute and have more competing demands on their time. Thus, a well-scoped project is critical to their success and learning, even more so than with doctoral students.

Tensions with Tenure and Promotion

Despite the rewards of mentoring undergraduates in research, faculty who are evaluated primarily on their research success are strongly obligated to their own research scholarship, and may feel that mentoring undergraduates in research slows them down. Indeed, it can take longer for undergraduate research to result in publications, if it does at all. Others face the challenge that their institution values undergraduate research as "teaching" and not "research".

The Cost of Creating Pathways

At most universities, there is no clear path for undergraduates to get involved in research. Interested undergrads are forced to reach out directly to faculty, and often struggle to convince faculty to invest the time to mentor them. Creating explicit pathways for participation, despite their advantages to faculty and students alike, takes additional time to facilitate.

Managing Scale of Demand

There are typically many more undergraduates interested in participating in research than there are faculty in a given department. To reach even a fraction of the students interested, faculty may need to be able to mentor many undergraduates at once.

Achieving Equity and Diversity

Many traditional research structures and practices are biased, favoring students with specific backgrounds, cultures and comfort levels. These biased structures lead to the exclusion of women of all races (and particularly Black, Latina and Native American women), students with disabilities, and all students from racially minoritized groups. When access to research opportunities is not intentionally designed to be inclusive and transparent, undergraduate research programs risk further excluding students in these groups, worsening the diversity of computer science.

Student Compensation

Students have many competing demands on their time, and many responsibilities to fulfill. Most students cannot afford to take any opportunities that would delay their graduation. Only very privileged students can afford to work as a volunteer, and some students might not be able to take a relatively low-paying research stipend over a higher-paying summer job. Experiences designed without these constraints in mind are likely to exclude large groups of students, privileging those with wealth, and therefore free time.

4. Best Practices for Inclusive, Scalable Pathways

We examined several structured and less-formal research programs across the United States, identifying best practices for addressing the above challenges. We summarize how each best practice addresses the challenges listed above in the table below, and then provide more information on each best practice.

Challenge	**Associated Best Practices**
Time to Mentor	Expand Mentoring Structures, Lower Cost to Faculty
Project Scope	Lower Costs to Faculty, Expand Mentoring Structures
Tensions with Tenure and Promotion	Increase Benefits to Faculty, Lower Costs to Faculty
Cost of Creating Pathways	Lower the Barrier to Entry, Lower Costs to Faculty
Managing Scale	Expand Mentoring Structures
Achieving Equity and Diversity	Offer Student Incentives, Lower the Barrier to Entry, Expand Mentoring Structures
Student Compensation	Offer Student Incentives, Celebrate Research

Table 1: Summary of challenges to scaling undergraduate research with associated best practices to address each challenge.

Offer Student Incentives

While there are many benefits to students for undergraduate research, most students cannot afford to work for free. Organizations that want to increase the number and diversity of undergraduates participating in research should compensate students, so that everyone interested has a viable opportunity to engage. Compensation can include:

- **Pay**. Typical stipends range from $15-$20/hour; funding can come from NSF Research Experience for Undergraduate (REU) supplements on existing grants, building REU support into new grants, applying for an REU Site grant, or other sources of support, such as diversity funds.
- **Academic credits**, particularly those that count towards major requirements, such as honors thesis requirements or electives. Some universities even have research credit as graduation requirements.

In addition to money and/or credit (but not instead of), there are many other benefits that can attract prospective students to research:

- Having a mentor, which can create pathways to graduate school.
- A title (e.g. "Research Scholar"), which can support job searches.
- Opportunities to network with researchers and other peers.
- The opportunity to participate in academic conferences.
- Skill development beyond that available in courses.
- Communication and collaboration skills that will help them in job interviews.
- A graduation distinction (e.g. graduation with honors) and awards.

Lower the Barrier to Entry

It can be challenging for students, especially early undergraduates, to find research opportunities. Having to stand out in an upper division course or go door-to-door to faculty looking for opportunities can dissuade qualified students from pursuing research opportunities.

- **Centralize recruiting.** Rather than requiring each faculty member to create their own recruiting and selection processes, create unit-wide processes, making it easier for students to understand how to apply and for faculty to identify interested students.
- **Promote clear pathways to research.** Create resources and hold training sessions to help all students learn how to find and obtain research opportunities.

Increase Benefits to Faculty

While there are many advantages to faculty's participation in undergraduate research, faculty must perceive the work as rewarding, personally and professionally. Some best practices include:

- **Promotion incentives**. Explicitly count engaging with undergraduates in research in promotion, as research, teaching, and/or service.
- **Train faculty as mentors.** Many faculty struggle with mentoring in general, and desire support. Offer training to faculty for mentoring both doctoral and undergraduate students, increasing the overall quality of advising for all students.
- **Celebrate faculty who successfully mentor undergraduates in research.** Such faculty can be mentors to other faculty, and demonstrate how engaging undergraduates can accelerate research productivity.

Lower Cost to Faculty

In addition to increasing benefits to faculty, some best practices can lower perceived cost:

- **Fund positions.** Offer stipends to students, and possibly faculty for successfully including undergraduates in research.
- **Provide fundraising templates.** Offer a simple template for requesting REU Supplements on existing NSF grants can streamline fundraising efforts.

- **Create research courses.** By creating a research course, undergraduates will learn the basics of research at scale, and be better prepared to engage in research with faculty. Many materials exist to structure such courses, such as the book Entering Research.

Expand Mentoring Structures

Outstanding and supportive mentoring is the key to undergraduates' experiences in research. Yet, this task does not have to fall solely on the faculty member (and in fact it usually works better when it does not). Here, we present several structures that can help undergraduates get the mentoring they need.

- **Train graduate students as mentors.** Graduate students can often be even more effective as mentors than faculty as they are closer to the students in age and experience, often have more intimate knowledge of the software systems that undergrads might struggle with, and have more time to spend with undergraduates.
- **Train undergraduates as peer mentors.** Undergraduates who have engaged in research for a year can be excellent mentors to their more junior peers, offloading much of basic instruction and logistics to students.
- **Use a multiple-mentor structure.** It can be helpful to provide undergraduate students with more than one mentor. For example, one mentor might provide detailed technical guidance, while another can help students contextualize their work and develop their communication skills. This structure can both reduce the workload on a single mentor and provide another place for students to voice their concerns.

There are many resources for structuring mentoring, including from CRA-WP, the University of Georgia, and the Center for the Improvement of Mentored Experiences in Research.

Celebrate Undergraduate Research

Regularly celebrating undergraduate research success can raise the profile of undergraduate research, attract new undergraduates to research projects and help students find role models. Departments can celebrate undergraduate research in many ways, including hosting poster sessions, giving research awards internally, nominating students for external research awards (and then celebrating students who are nominated and/or receive the awards), and posting research highlights on their social media/department pages.

5. Tracking Success

Any good process needs outcome monitoring, and undergraduate research is no exception. Some metrics to consider include:

- **Proportion of students engaged in research.** Tracking this annually can help monitor for access issues. Some universities may already track this centrally.
- **Diversity of students engaged.** Monitor diversity in gender, race, ethnicity, citizenship, and socioeconomic status to ensure that opportunities are going to students that reflect the broader diversity of campus. These outcomes will predict the future diversity of prospective graduate students and faculty.
- **Proportion of students authoring papers.** This lagging indicator can reveal the extent to which undergraduates are successfully participating in projects, meaningfully contributing, and being recognized for their contributions. This can also help identify students to highlight when communicating to prospective students, alumni, and supporters.

Best practices include assigning staff to gather and report this data annually, and integrating these practices into centralized processes.

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