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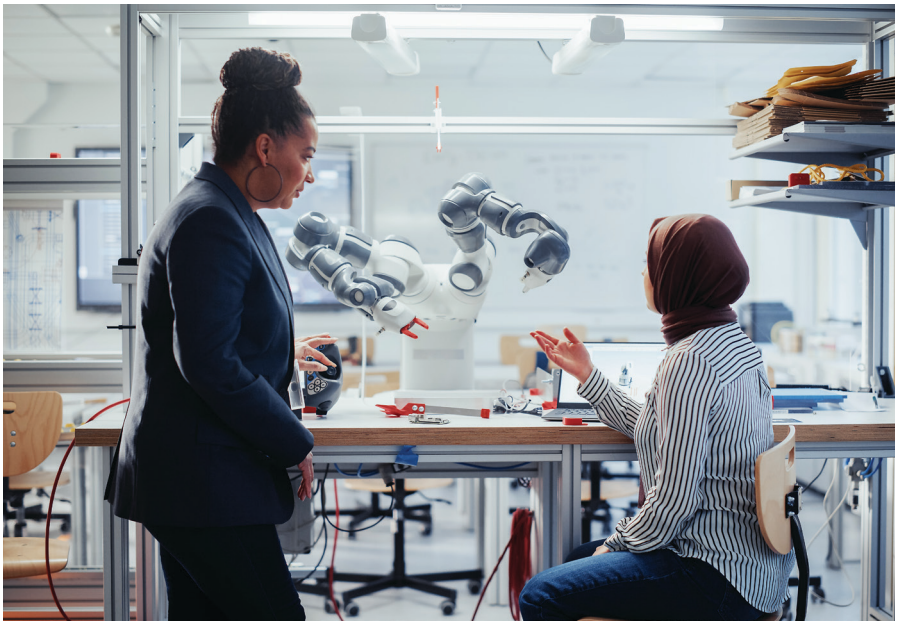
Education

Research Experiences for Undergraduates Are Necessary for an Equitable Research Community

Encouraging the expansion of undergraduate research programs.

Everyone deserves a chance in science. But the paths available can vary for reasons unrelated to merit. For example, suppose a student wants to apply for Ph.D. programs in programming language theory. It turns out their undergraduate institution does not do programming language theory. As a result, they lack the research experience sometimes required for entry into Ph.D. programs. One option could be to apply for a master's degree, which would both let them specialize in courses relevant to programming language theory while also building up research experience. This is a great option, except that many programs can be prohibitively expensive—often the first year salary of a new graduate. This is inequity.



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We see research internships for undergraduates as a necessary part of any solution to equity in computing education. The kind of internships we have in mind are intensive, mentored 8–12 week computer science research programs. In the U.S., programs of this type are funded by the National Science Foundation's (NSF's) Research Experiences for Undergraduates (REU) program. Many other countries have similar programs—see the accompanying sidebar for links to programs in Canada, Germany, India, Korea, Nigeria, and the U.K. In this column, we use the term REU to refer to any program of this type. REUs are available to students outside your institution. They provide accommodation, travel, and stipends while preparing students for Ph.D. programs. They are a key intervention for students who cannot afford continuing education through a master's degree.[6]

Efforts to improve equity in graduate education tend to focus on improving retention and recruitment. For example, many schools offer funding and/or organize social activities for underrepresented students—such as a Latine happy hour. The logic is that these activities build community and increase the chance that underrepresented students graduate. Generally, retention efforts are about helping students feel comfortable and providing clearer paths to graduation. Though these efforts are important, we feel that more time and money should be

spent on talent-development activities, such as research internships.

In 2022, just 233 (1.6%) of the 16,725 students enrolled in computer science in the U.S. and Canada were Black or African American according to 2022 Computing Research Association (CRA) Taulbee Survey data.[7] Let's say we invest in retention activities to improve the graduation rate of these students. If they are successful, such retention activities will boost graduation rates by one or two Black Ph.D. students nationally per year. But what if we invest in recruitment activities like research internships? Recruiting just 20 more of the 1,004 Black or African American computer science bachelor's graduates[7] will have much more impact on the diversity of our research and faculty. We know there is interest amongst these students. Data from the CRA shows that students often express interest in research but lack opportunity to explore those interests.[4] Moreover, it is not obvious from the data that our community suffers from a retention problem. Black students graduate from computer science Ph.D. programs at essentially the same rate as the overall Ph.D. population.[7]

Training the next generation of researchers is our collective responsibility. It is our view that PIs should recruit students through REU programs in addition to traditional means. Traditionally, PIs recruit undergrads who show promise in their courses or through personal connections. This traditional approach cannot be as thoughtful and systematic about selection and recruitment as an REU program can be. As a bonus, it is our experience that students in REU programs are on average more skilled and motivated than students we recruit through other means. This creates a path toward the equitable research community we want.

Running a REU Effectively

Co-author of this column Joey Velez-Ginorio directs Research Experiences for undergraduates in Programming Languages (REPL) at the University of Pennsylvania, a new program that had its first cohort last year. Column co-author Joshua Sunshine co-directs Research Experiences for Undergraduates in Software Engineering (REUSE) at Carnegie Mellon University, and has since 2016. While we have argued for the necessity of REUs, we should also say that it is not trivial to run an REU effectively.[3,6] Effective REUs require attention to details which we focus on for the rest of this column.

Recruitment and selection. An REU cannot increase diversity without enrolling marginalized students. An REU cannot recruit and select students like an undergraduate or Ph.D. program. The same process will yield the same non-diverse results. REUSE cultivates relationships with minority-serving technology groups around the country. We don't just recruit at the small handful of historically black colleges and universities (HBCUs) and Hispanic-serving institutions (HSIs) that are targeted by every program. There are many minority students at other colleges. For example, there are approximately six times as many black students at the public Georgia State University than at premier HBCU Spellman. REUSE does not rank and select the top students. Instead, for each student, we ask, "Is this a student for whom the CMU REUSE is likely to be a positive, transformational experience?" We consider each student for whom the answer to this question is "yes" to be eligible for the program. There are many more eligible students than we can admit. We then assemble a diverse and interesting cohort from these eligible applicants. Following these steps has allowed us to recruit cohorts with 10 times the share of underrepresented minorities as are enrolled in CS undergraduate programs overall.

Shifting culture. Running an effective REU can catalyze significant cultural shifts. Faculty were at first very afraid that the students we selected would be unable to engage in our research. We have successfully shifted the faculty mentality over time so they now focus on student-centric outcomes such as learning and preparation for graduate school. We worked with faculty on the details of their projects to make sure they were accessible to a broad swath of students. The positive outcomes from our student projects have convinced our faculty to buy into our admissions model. That said, we still have to work with faculty and graduate students every year to continue to disseminate our mentoring philosophy. Thankfully, we no longer have to bear that work alone. The faculty who have mentored for years are our biggest evangelists.

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Mentoring. Well-run REUs are mentored experiences. In our programs at Penn and Carnegie Mellon, each student is matched with at least one faculty mentor and at least one graduate student mentor. The personalized guidance that mentors can provide is particularly valuable for marginalized individuals who may face unique challenges in their journey. For example, marginalized individuals are more likely to misattribute the normal setbacks of research to their own abilities.[1] Mentors can help students reinterpret these setbacks by exposing their students to their own setbacks and suggesting paths forward.[5] Marginalized individuals may also feel like they do not belong in the computing research community. Mentors can help students see themselves as scholars who can contribute to computer science. Mentors can provide insights, advice, and strategies to help mentees overcome obstacles, build confidence, and seize opportunities they might not have otherwise considered.[2]

Funding. In the U.S., the NSF generously funds undergraduate research through its REU program. However, REU site awards only fund 10 students per program and do not support international or undocumented students. Philanthropists and corporate funders with DEI or outreach goals are essential to filling in these gaps. If you work at a company that is interested in advancing equity in computing, consider funding an REU.

Evaluation. Effective service must be evaluated. How otherwise would you know if what you're doing is effective? For NSF REUs the CRA's Center for Evaluating Research Pipelines (CERP) offers a free external evaluator, which we use at Penn and CMU. They organize surveys with REU students before and after the REU to measure whether the students feel they're receiving adequate mentorship and adequate training among other things. But in addition to these external evaluations, it is important to seek feedback directly from students during the REU. At Penn, we make sure to schedule private check-ins with each student individually to get a sense for how things are going for them and how we can pivot to improve their experience. Sometimes students are content, other times they become discontent with their research project or mentorship dynamic. These are often problems you can fix, but not if you do not meet with students who do not realize these problems have solutions. Over time, the feedback you collect can also help restructure the program itself. For example, at Penn we are trying out a new mini-course to teach our students. Student and teacher feedback helped us realize the pacing was too slow. The virtuous cycle of evaluation and iterative refinement allow REU programs to continually improve and adapt to changing student needs.

Conclusion

Students need opportunities to join our science. There are only two NSF REUs available that focus on programming language theory or software engineering. They are REPL and REUSE, the programs we run at Penn and CMU. This clearly cannot suffice, especially so for international students, who are barred from NSF REUs. We urge faculty and students to start REUs and industry leaders to fund them. C

Programs in Canada, Germany, India, Korea, Nigeria, and the U.K.

Government-sponsored undergraduate research programs exist all over the world. They share many features—they aim to introduce undergraduates to research, they are full-time intensive experiences, and they are hosted at universities. However, the names and details of the programs vary. Some programs from countries around the world include:

- **Canada: Undergraduate Student Research Awards (USRA) https://bit.ly/4c3T3Ha**
- **China: Summer Undergraduate Research Program (SUGRP) https://bit.ly/4eEIJqO**
- **Germany: Research Internships in Science and Engineering (RISE) https://bit.ly/3VtAc0Y**
- **India: Summer Undergraduate Research Exposure (SURE) https://bit.ly/3KNPN6E**
- **South Korea: UST Research Internship https://bit.ly/3VPYTWZ**
- **UK: Undergraduate Research Opportunities Programme (URO) https://bit.ly/3z3eUzE**

References

1. Aguilar, L., Walton, G., and Wieman, C. Psychological insights for improved physics teaching. *Physics Today 67*, 5 (2014), 5.
2. Alvarado, C. et al. The role of mentoring in a dual-mentored scalable CS research program. In *Proceedings of the 52nd ACM Technical Symp. on Computer Science Education* (2021).
3. Alvarado, C. et al. Scaling and adapting a program for early undergraduate research in computing. In *Proceedings of the 53rd ACM Technical Symp. on Computer Science Education-Volume 1* (2022).
4. Bizot, B. First generation college students significantly less likely to have had an REU. *Computing Research News* (2015); https://bit.ly/3VMGcDi.
5. Cohen, G.L. et al. Reducing the racial achievement gap: A social-psychological intervention. *Science 313*, 5791 (2006).
6. National Academies of Sciences, Engineering, and Medicine. Undergraduate research experiences for STEM students: Successes, challenges, and opportunities (2017).
7. Zweben, S. and Bizot, B. CRA Taulbee survey. *Computing Research News* (2022); https://bit.ly/3xf45dw.

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