Research With Undergraduates

Amanda Folsom and Sam Payne

TO ADVISE OR NOT TO ADVISE

Advising undergraduate research is not for everyone, but it can be rewarding, both professionally and personally. The stakes for mentoring undergraduate research are high; young talent is precious, and students may be turned off by a bad experience, such as a dull or impossibly difficult project. Working on research with undergraduates is only one of many ways to give back to the community. If you are not confident that this particular activity is a good fit for you at this point in your life and career, or may take too much time away from other professional pursuits and obligations, you could consider smaller-scale alternatives that still allow for meaningful mathematical interactions with students outside of the classroom. If you don't want to include undergraduates in your research, that's perfectly okay. On the other hand, with the right motivation and forethought, there can be benefits for everyone.

SOME POTENTIAL BENEFITS…

…for students. There are undergraduates with talent and drive who can, with suitable guidance, do excellent and worthwhile research. Undergraduate research can also be an opportunity for motivated but underprepared students to break into real mathematics. What doing mathematics research really means can feel mysterious until you do it. A research opportunity as an undergraduate can shed light on many aspects of mathematics that a student won't typically encounter in the classroom, and can be a pivotal experience.

…for advisors. Students sometimes make substantial and meaningful contributions to important projects. It is also often an advisor's market—there are generally many qualified, interested students. There is great satisfaction in seeing talented young mathematicians experience a positive and realistic first taste of research, including the sweet thrill of solving an open problem. It is absolutely possible to learn new things while working with students.

…for junior faculty. Postdocs mentoring undergrads often find that this experience helps them stand out in the pool of tenure track job applicants, and it is a common topic brought up in on-campus interviews. Young faculty applying for grants may also find that including carefully designed projects suitable for collaboration with undergraduates is generally viewed favorably by review panels, especially when the PI has an established track record of successful mentoring.

GUIDING PRINCIPLES AND PITFALLS TO AVOID

Choosing a project. Choose your project with care. Find a topic of genuine mathematical interest that is also accessible. Many different kinds of projects can work, but it's important to be organized and prepared in order to offer meaningful guidance. In some situations, the ideal research may be open-ended and motivated by readily computable examples. Others may call for more specific and narrowly tailored assignments. In any case, students will sense whether or not you are genuinely interested, and also whether or not you already know how to solve the problem. Proceed wisely.

Organization. Plan the structure and schedule that you want to implement, and communicate expectations clearly at the beginning of your program. An effective daily and weekly timetable may be fixed or flexible; consider in advance what will work best for you and your students. Junior faculty especially may need to protect some time for themselves.

Timing. Research projects typically take longer than expected. Do you need to wrap up your project within a certain time frame, and have you set reasonable goals in order for this to happen? Adaptability can be important

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for ensuring that you and your students have a positive experience, even when the unexpected happens.

Struggling students. Intensive research can be immensely frustrating, and sometimes leads to loneliness or isolation. A student working on a solo project over the summer when campus has cleared out and the department is empty is perfect fodder. Group work is not an antidote, but it often helps. Plugging into a program that includes multiple groups with planned activities (colloquia, opportunities to present work, attend conferences, and social events) may increase the chances of a positive overall experience. If different groups have projects that are related enough to be able to have meaningful conversations (and distinct enough that each group feels genuine ownership of their own problem), that's even better. We may joke about machines for turning coffee into theorems, but students are human beings. Stay tuned in to what's going on, and reach out to help when struggles arise. Consider including having a good time as part of your definition of success.

Group dynamics. Even if mathematics is your top priority, human foibles will be part of the experience. Anticipate common hurdles such as impostor syndrome and issues around coauthorship. Interpersonal conflicts quickly steal energy away from the mathematics. Consider partnering with expert professional educators (e.g., from a campus teaching center) who can help with orientation activities at the start of the program, and with communicating effectively about goals and expectations. You may be surprised by what you learn, and how your program benefits, especially when working with larger groups.

Presentation skills. Giving a formal lecture with beamer slides or at the blackboard, making a presentation to the working group, and chatting math over tea are new experiences for most undergraduate researchers. These skills are learnable, and students progress quickly with honest feedback and practical tips from a relaxed, patient, and encouraging mentor. Make sure your students get plenty of practice before they need to present at a conference. And remember that they will look to you as a role model.

Presentation and communication skills are equally valuable for students who decide not to continue in mathematics, or even in academia. Indeed, the ability to communicate quantitative and technical information clearly, confidently, and effectively is needed, valued, and in short supply both in other STEM fields, and also in industry.

Success. A successful or positive undergraduate research program does not necessarily equate to publishing. Having a broad enough definition of success is important so that everyone can walk away with their head held high even if the hoped for results do not pan out. Goals can include having a positive experience and getting a real taste of research, which includes frustration, getting stuck, and some promising directions simply not working out. Students should take away transferrable skills such as the presentation and communication skills mentioned above, as well as reading the research literature, searching the arXiv and MathSciNet®, using LaTeX, and writing for a mathematical audience, regardless of whether any paper gets published.

Not all students who participate in a math research program will continue to study math or stay in academia. This is perfectly OK, and does not mean your program was unsuccessful. Someone having a positive experience with the project and reaching an informed decision that they do not want to go to graduate school in mathematics is a positive outcome. It may be much better for a student to reach this same decision as an undergraduate than after a first research experience in the third or fourth year of a PhD program.

Resources. You may find it helpful to seek and use existing resources, for both your students (e.g., presentation or software guides/templates, including LaTeX, Beamer, Mathematica, etc.) and yourself (e.g., see [1, 2, 3]). Your colleagues might also serve as resources. Students can benefit from the opportunity to meet and discuss with other mathematicians, and will ideally develop a sense of comfort and confidence in doing so.

References

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Amanda Folsom and Sam Payne have personally mentored dozens of undergraduate researchers over the past decade, and founded the Summer Undergraduate Research in Mathematics in Yale (SUMRY) program, which continues to thrive. Both authors also benefited from and enjoyed participating in research programs in mathematics as undergraduates.

Credits

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