

Undergraduate students in research

Accommodating undergraduates in the lab is a mutually beneficial relationship

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Participating hands-on in an academic research project can be a fascinating and valuable educational experience for undergraduate students. It not just teaches them additional and transferable skills—such as written and oral communication, critical thinking, or information literacy—but also could be an important factor for deciding on an academic research career. Even if the level of involvement in research projects varies between labs and institutions, students still gain such valuable experience, much more than they gain from the standard laboratory courses that usually perform only pre-tested experiments with expected outcomes. On the other end, the research labs that accommodate undergraduate students also benefit from overall research progress and mentoring experience.

Accommodating undergrads efficiently

Undergraduate students can join research labs at any time during their studies. In our own lab, some have started working on research projects during their first year at college while others were in their last year before graduation. While selecting undergraduate students to join the lab, what matters most is whether they are really interested in practicing science and stay through the whole semester or the academic year, which is of course difficult to know in advance. Their scores do not necessarily indicate their ability in practicing research or conducting hands-on scientific experiments either; good performance in undergraduate school does not necessarily translate into lab performance. The best option therefore is to let them join and see how well they cope.

We have also had students who became increasingly interested in research only after they had a chance to experience it in the lab.

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One factor that we do consider is the amount of time an undergraduate is willing and able to commit to research work in the laboratory. Given the competitive nature of medical school applications, many students, particularly in the USA, tend to be over-committed with other activities and find it hard to dedicate sufficient time for a research project. We typically encourage undergraduates to spend at least 10 h per week in the laboratory, especially when they take research for credits. Other countries and other universities have of course other rules and requirements which may or may not enable part-time work in a lab; students can also work full time for a semester and get credits instead. It very much depends on the local conditions, and the students' workload and requirements and research groups therefore have to show some flexibility to accommodate them.

There is of course always the risk that the arrangement does not work for either side. Students either realize that academic research is not what they are interested in or the student's efforts and work are not satisfactory for the lab. To avoid wasting

time and efforts for both parties, labs could implement a rotation scheme for interested students to spend a brief period working on small projects to gauge their interest in research work and if they get along with the rest of the team. In our own lab, we sometimes have undergrads volunteer for a few months or a semester before they officially join for a longer period or take research for credits. This allows us to see whether the student is a good fit and allows the undergrad to get a feel for the work and our team and decide whether they want to continue. If a student is not interested in the particular research topic, the lab can connect them with other labs that might be a better fit for their interests. Students can also discuss with their mentors the kind of projects they want to work on and whether it has enough hands-on experience to learn new techniques and lab skills.

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Selecting projects that are feasible and instructive

As mentioned above, the work schedule of undergrads in the research lab will depend on their other commitments and classes. It is therefore useful to carefully plan their projects efficiently so they can make progress in learning and performing research and contribute to the overall research effort of

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the lab. For undergraduate researchers, we plan their projects in either of two ways: We carve out specific portions of a larger project that they can work on independently; or we involve them in projects that require a large number of experiments or data sets and therefore considerable manpower.

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Our lab works on DNA nanotechnology, biosensing, and single-molecule biophysics, and we have so far good experience with undergraduate students. We worked with a team of undergrads who collectively contributed to a series of experiments which helped to optimize nucleic-acid detection methods (Chandrasekaran *et al.*, 2019). Other undergrads who worked on single projects also contributed valuable results, such as evaluating the nuclease activity on DNA nanostructures—the student in fact played a major role in gel analysis and is now second author of the resulting paper (Chandrasekaran *et al.*, 2020). In the lab where I did my PhD, we worked on a project that involved purification of a large amount of synthetic DNA strands. We trained several undergrads in the protocols, and they greatly contributed to the collective effort in purifying DNA: The division of labor enabled them to obtain the required amount of pure DNA in less time than if it had been done by two graduate students. We also assign undergrads specific projects that are not dependent on other work in the lab. This helps us make progress on projects that would otherwise lie dormant.

Benefits and advantages for the hosting lab

Faculty also benefits from undergraduate research. Students contribute to the overall research output of the lab, and thereby—directly and indirectly—to publications or finishing the overall research project. Furthermore, it helps the lab or the department to identify those students who have a real knack for and fascination with scientific

research and support them early on to explore their interest and potential; hopefully, they become the next gifted graduate student or postdoc.

Active undergraduate research can help to improve teaching programs which themselves can be a factor to attracting prospective students. Interacting with and instructing students in the lab also enhance teaching practical aspects of topics that are usually only covered in lectures. Graduate students and postdocs can develop their teaching skills, especially in an academic setting (Lukeman, 2013). Teaching lab skills to undergraduate students, helping them plan, execute and analyze their experiments, and monitoring their progress over time is a very useful teaching and mentoring experience. This experience can become very valuable for junior scientists in pursuit of an academic career when they apply for positions both in research and in teaching and it helps them to hone their mentorship skills when they start their own independent research group. Furthermore, training young students is a good opportunity for improving communication skills. In our lab, we have weekly lab meetings where all the members, including the undergraduate students, take turns presenting and discussing their work. Presenting research in a way that is understandable for undergraduates can help to improve language and presentation skills, especially for a general audience.

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Different education experts have discussed various models and approaches to involve undergraduate students in research (Kirk & Hanne, 1991; Canaria *et al.*, 2012), to teach research skills (Danowitz *et al.*, 2016), and how to mentor students in a research laboratory (Beer & Myers, 1995; Lukeman, 2013). These and other articles are a useful resource for any PI interested in developing undergraduate research programs and engaging students as part of a team of scientists.

In conclusion, opening the lab doors for undergraduate students and giving them the opportunity to partake in real research instead of predesigned lab courses are of great benefit for both students and the host lab. Admittedly, the time we invest in training undergraduate students and guiding them through experiments is considerable. But it is this opportunity that gives them a chance to experience research in a realistic setting and inspires them to continue doing science. It also gives us the opportunity to identify those who are genuinely interested in a career in science and guide them along the way. In return, a consistent effort by undergraduate students does help us to advance our research projects; overall, the time we invest into training and mentoring them pays off well. I hope this essay inspires other laboratories to embark on this experiment and give interested undergraduate students the opportunity to get a first-hand experience of how life in a research lab looks like. It clearly is a win-win arrangement for both.

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