UNDERGRADUATE RESEARCH IN CHEMICAL ENGINEERING: BENEFITS AND BEST PRACTICES

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INTRODUCTION

What sparked your interest in becoming a faculty member? Did you have the opportunity to perform undergraduate research? Did you watch the evolution of student peers as they grew in confidence, experience, and presentation skills while they performed undergraduate research? Maybe you were challenged as a graduate student when assigned to mentor an undergraduate researcher. These varied experiences lead to questions for many of today's faculty: what are the best practices in mentoring undergraduate researchers?

The positive effects of undergraduate research are what inspires many chemical engineering undergraduates to attend graduate school. In fact, in a 2021 survey of the editorial board of this journal most respondents pointed to their undergraduate research experience as a motivating factor in that decision.[1] The opportunity to participate in the generation of knowledge or the application of new technology might be what sparks the desire to pursue an advanced degree. The experience of working on a team to analyze and solve a real problem and the development of the skills to communicate discoveries to others are excellent preparations for graduate school. The excitement of an experiment and the satisfaction of seeing results can confirm that a career that includes chemical engineering research is the right path to follow. Yet without an undergraduate research mentor, none of this can happen in an effective manner.

Just a few decades ago, including undergraduates in faculty research projects was an uncommon occurrence limited mostly to students in small honors programs. The 1998 Boyer Commission report offered recommendations on rethinking undergraduate education with a focus on inquiry-based learning.[2] Undergraduate research experiences are now considered High Impact Practices (HIP) [3] and are broadly used in many institutions of higher education to improve recruiting and mentoring. The overall benefits in improving recruiting and retention are also shown to more strongly affect women and underrepresented minorities.[4-7] Thus, university-level attention to promoting and supporting undergraduate research has expanded significantly. The Council on Undergraduate Research (CUR) now has 700 institutional members.[8] A CUR analysis of The College Report by the National Survey of Student Engagement (NSSE) reports that 20.3% of students across baccalaureate, masters, and doctoral institutions indicate that they have performed research.[9] This has increased both the number of students working on research projects and the level of intellectual engagement that those students are afforded in that work. For example, the Wikipedia® page on "Lists of Undergraduate Research Journals" notes the number that have been founded since 2000.[10] Many institutions now include undergraduate research and its outcomes (presentations, journal articles, etc.) as part of the metrics for their strategic plans (e.g., University of British Columbia and University of Alabama).[11, 12]

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As undergraduate research participation has expanded, the approaches and desired outcomes have also continued to expand. The classic approach toward undergraduate research was to pair an undergraduate student with a graduate student or post-doctoral mentor and have them work side-by-side on a research problem. In this way the undergraduate learned by engaging with the mentor. Some of the shortcomings of this approach include the time requirement for the one-on-one mentoring and that the student only learned what the mentor covered. In an effort to employ the concept of discovery-based learning, some fields have developed research courses for first-year students to help improve retention. In this type of course, often called a CURE (course-based undergraduate research experience), the students are mentored as a group on research methods while simultaneously conducting research under the instructor's guidance.[13] Another approach is to group-mentor students into the research process so that they are both more prepared for the subsequent laboratory experience and less reliant on the support from their mentor.[14, 15] These research methods courses are often similar to graduate research methods courses and are designed to guide undergraduates through the process of developing their interest and finding a mentor. They also include literature searches, reading scholarly literature, delivering presentations, the scientific method, research ethics, proposal writing (for REU applications), patents, copyrights, and research notebooks.[16-18] This approach has the benefit of helping overcome the activation barrier to finding a research mentor but also jump starting the student's preparation to be quickly successful in the lab. While the most common mechanism is still probably the classical approach, even this has undergone evolution. More and more, the students are required to attend additional workshops on literature searching and citation management software in addition to working under a laboratory mentor.[19]

While the benefits of undergraduate research are known for the students and the institution, there are still unresolved questions associated with the goals and approaches that are currently used. For example, as demand for undergraduate research grows, is an individual mentorship model sustainable given the need for the faculty mentor to perform all of the training?[20, 21] In addition, numerous questions remain regarding the expected student skill set:

- What skills do students need to participate in undergraduate research?
- How do these skills differ by discipline?
- Where in the curriculum do students develop these skills?[21]
- What are the skills that we expect students to have when they complete undergraduate research?

Summer REUs and graduate level introduction to research courses suggest some answers, but could there be others?

Benefits to faculty supporting undergraduate researchers are largely unexplored, and faculty efforts in mentoring undergraduate research are usually not significantly recognized by institutions.[22] Faculty motivation for mentoring undergraduate research is still a growing area of study.[22-25] While undergraduate research may be widely recognized as a high-impact practice in higher education, pressures on new faculty can make them hesitant to pursue the potentially time-consuming mentorship of undergraduate researchers. The objective of this article is to inspire and equip chemical engineering faculty with current best practices to engage undergraduates in their laboratories and research programs both to enrich the educational experience of the students and to enhance faculty research productivity.

BENEFITS OF UNDERGRADUATE RESEARCH

The benefits of undergraduate research to students have been well studied over the past 25 years.[4, 26-28] Documented benefits can be divided into three categories, as shown in Table 1, including intellectual development, professional development, and personal development. Of course, the degree to which any of those benefits are achieved depends on the nature of the project, the environment in which it is performed, the depth of involvement that it offers, and the time and ability of the mentor. If students are treated as laboratory assistants rather than researchers, the intellectual benefits will be lacking. Studies suggest that there is room for improvement on integrating undergraduates in data interpretation and research design to better prepare them as scientists.[26] Opportunities to develop professional skills are inherently present in a cooperative research setting, but intentional inclusion of undergraduates in group meetings to discuss results and next steps builds both their interpersonal skills and their identity as researchers. The traits listed for personal development necessitate long-term engagement in a project, so inviting students to begin research early in their academic careers is best for them. Early engagement also increases their opportunity to contribute meaningfully to the faculty mentor's work.

TABLE 1
Benefits of Undergraduate Research for Students

Intellectual Development	Professional Development	Personal Development
Critical thinking	Teamwork	Perseverance
Scholarly Reading and Writing	Time Management	Independence
Scientific Knowledge and Skills	Communication	Informed Career Choice

Although the benefits of participating in undergraduate research apply to all students, they are particularly important for students from groups underrepresented in STEM disciplines.[4-7] While the deeper level of engagement with faculty and peers in a scholarly pursuit has been shown to increase retention and persistence to degree completion for all students, those individuals from minority groups show additional increases. Thus, undergraduate research is an important means toward increasing the diversity of the chemical engineering workforce, and ultimately the professoriate as well.

While the advantages afforded students are clear, advantages to the faculty mentors are not as well documented. Studies of faculty attitudes and perspectives on undergraduate research indicate that some faculty consider it an altruistic pursuit.[24, 29] Still, with adequate planning on the part of the mentor, undergraduate researchers can be productive members of a research team. Obviously, they provide an extra set of hands in a laboratory to assist with data collection. With training they can become experts on particular instruments or experimental techniques, and, if started early, can provide that support for several years. They can assist with data analysis, perform literature reviews, and act as a sounding board to work out research ideas. Eventually, they can even help with publications, drafting sections of papers or formatting figures. Clearly, at primarily undergraduate institutions, the students are expected to perform all of this and more, again requiring additional faculty mentoring.

Even though most institutions still lack significant specific incentives for working with undergraduate researchers, successful mentorship of the outstanding students that chemical engineering programs attract can lead to special recognition for faculty members. When students win awards, their mentors are usually noticed, especially if the awards are associated with faculty research projects. Opportunities for such awards for chemical engineering students range from such national honors as the Goldwater Scholarship and NSF Graduate Research Fellowship and poster awards at the AIChE annual and regional meetings, to department, college, or university undergraduate research day awards. Including these awards on the department website and social media also leads to recruitment of the next generation of student researchers. Beyond formal recognition, seeing a student succeed provides gratification and meaning that enhances the faculty experience.

Institutional incentives may be lacking, but institutional support for undergraduate research is growing, with many universities establishing undergraduate research offices with deans, directors, or assistant provosts to run these offices. CUR reports at least 250 institutions with membership in its Undergraduate Research Program Directors (URPD) Division.[30] If these offices exist, they should be a well-used resource by the faculty mentor. They may offer seminars for faculty or students, summer programs, and competitive opportunities for student stipends or travel funding. As a faculty member, there is no need to develop policies and procedures if these are already established at the institutional level.

The level of faculty reliance on and responsibility for undergraduate researchers varies significantly by the type of institution. If a large graduate program is in place, then graduate students will often provide the primary research support. Training graduate students to mentor undergraduate researchers can increase capacity for including undergraduates in faculty research programs. This also serves as professional development for these graduate students because, as graduates with advanced degrees, they will be expected to be mentors in their companies or institutions. For chemical engineering faculty at mid-tier institutions with small graduate programs, undergraduate researchers might be essential to building a productive research program. Finally, at an undergraduate-only institution, the one-on-one mentoring associated with undergraduate research may be a part of the institutional mission. Not unlike teaching a class, both advanced and detailed preparation are key to efficient progress and effective outcomes for faculty and students.

In addition to different levels of reliance on undergraduate students at different types of institutions, the type of institution may also affect other methods of mentoring. A large research institution may allow for group undergraduate safety training together with pre-scheduled department-wide graduate student safety training. At an undergraduate institution, safety training may require an email from the faculty to the university's safety office. In this situation, communicate with others in the department. One faculty member may take the lead on safety while another takes the lead on literature searches. While a large research institution typically has large research groups for each faculty with standard group meetings, at a smaller institution it may be desirable to have group meetings that include all of the undergraduates in the department or across several departments. Again, have one faculty take the lead on scheduling while others perform different tasks. As noted above, the type of institution will also likely affect who does the direct day-to-day mentoring.

Efforts to address non-traditional students and students from marginalized backgrounds need to be focused. Don't rely just on word of mouth for students to learn about research opportunities. Even a meeting in the evening might exclude some students. Instead, reach all of the students by taking a class period from a sophomore class (for example) and have interested faculty spend five minutes talking about their research. Then make any interest forms readily available. Perhaps make it a class assignment for all students to talk briefly with two faculty about their research (be sure to get the faculty's buy-in first). In addition, have current undergraduate researchers from underrepresented groups serve as role models and relate their experiences. For non-traditional students, consider the time commitment associated with undergraduate research (usually three hours per week per course credit). Instead of being in the lab, can they contribute from home by performing data analysis, literature summaries, or computational modeling from their residences? Lastly, make it worth their time.

BEST PRACTICES FOR MENTORSHIP OF UNDERGRADUATES

In chemical engineering and other STEM disciplines, undergraduate projects usually fall within the research program of the faculty mentor, who benefits from additional assistance to collect data for grant proposals and papers. At a research university, this might simply be extra help for lab productivity; for an undergraduate institution, this might be the critical mentoring that is the hallmark of the school. Benefits to students and faculty are best realized through a strong, active relationship, requiring mentor time commitment. Best practices for effective mentoring include: [31]

- Planning projects tailored to student experience and constraints
- Setting clear expectations to meet mentor, student, and institutional goals
- Teaching technical skills, research methods, and disciplinary norms
- Teaching safety procedures and providing a safe learning environment
- Supporting professional development by one-on-one interaction
- Fostering a community of faculty mentors and student researchers

On an individual basis these practices can be inefficient and perhaps seem untenable for a tenure-track faculty member. Below, we discuss two pathways for student guidance. The first includes tips for streamlining the classic one-on-one individual mentorship to benefit all parties. Next, we discuss a classroom-based mechanism to prepare students for research with the advantage of multiple subsequent mentors.

One-on-One Mentorship

Effective planning of a project before the student begins work is crucial to a positive experience for both the student and the mentor. The greatest productivity is likely to be achieved if the project is outlined prior to engaging a student to do it. This enables the faculty member to set clear expectations regarding workload and schedule so that desired research outcomes can be met, and to clarify necessary training and what academic background the student will need. In short, a job description with expected qualifications will set the stage for student recruitment. If a graduate student is also working on the project, solicit their input. Use this as a tool for mentoring them into developing suitable projects. Consider allowing the graduate student to write a draft of the research description. In that description take into account the constraints of undergraduate course schedules, which probably limit work time to about ten hours per week (verify these expectations with the course catalog and department policies) and recognize that those hours come in predefined blocks. Make sure that some time overlaps with the graduate student availability if applicable. In addition, some institutions do not allow undergraduates to have individual electronic or key access to laboratories, so make sure someone will be available to let the students into the lab and to stay nearby to maintain safety protocols. While the total duration of a project will probably extend for several terms, it might help to outline it on a semester basis to match the rhythm of undergraduate life. Questions to consider in scoping the project are listed in Table 2.

Before choosing a student, recruit broadly. Start with discussing the project in any courses you teach. Can you physically post the advertisement somewhere in the department or send to an undergraduate listserv? Consider advertising in other departments (chemistry, mechanical engineering, biological engineering, etc.), depending on the project. In choosing students, faculty should meet with potential undergraduate researchers to discuss not just the project itself but also the long-term goals of the student and the expectations of the faculty member. Student involvement in coursework and extracurricular activities might place constraints on their schedule that make the project a poor fit. The student might be looking for a short-term commitment, while the faculty member knows that multiple terms or years will be necessary to reap returns on their investment in the student. Other considerations include whether the student is doing the project for pay, for academic credit (follow the course catalog and department policies), or on a volunteer basis (for liability reasons, not allowed at some institutions). Once a student is identified, a contract that establishes expectations for both interactions and delivered outcomes increases the likelihood for research productivity.[32] The contract should include the considerations in Table 2. Many example contracts can be found online, and some universities provide them for their faculty.[33, 34]

The intentionality with which a project is designed and a student is identified should continue into the mentoring relationship. Regular meetings between the mentor and student should be scheduled and honored. These meetings should include research updates and planning, but should also allow time for developing research skills, such as searching for and reading scholarly papers or maintaining a lab notebook. Be on the lookout for seminars sponsored by the library, honors college, or undergraduate research office that cover literature search skills, citation management software, REU proposals, presentations, etc. If writing is part of the expectations, timely and regular feedback should be provided. Finally, the faculty mentor should be willing to offer personalized academic and professional advising as the student progresses and makes decisions on their next career steps. Many students perform undergraduate research as a step toward graduate school. Recognize early on that these students will come to you as their research mentor to write letters of recommendation. Use the contract built from Table 2 to connect expectations and outcomes with what you will write in a reference letter. Make notes of student performance along the way to provide authentic anecdotes in your letters.

Even within the research project, how the student contributes may vary. To provide a broad and enriching experience, it may be desirable to have the student essentially "shadow" their graduate or post-doctoral mentor. In this way the student can learn different aspects of the project along with different synthesis techniques, analysis techniques, and instruments. The student essentially sees the project from beginning to end, though at the expense of depth in most of the areas. In contrast, another approach has the student become an "expert" on just one synthesis technique, analysis, or instrument. All the other students might make samples and pass them on to the expert. In this way the student becomes adept and consistent with the technique and really learns one area in depth at the expense of broader laboratory exposure. This approach may also lead to error minimization and consistency of analysis because the measurements are done by just one person. Also consider whether the work is crucial to the overall research program or is perhaps an interesting side project. A side project may be more suitable for letting the student do the research from start to finish. Also consider letting the undergraduate student start working on the "next step" of the project. Once they know all the techniques, they may be able to move the project forward and start getting the data for the next proposal. Finally, if you

TABLE 2
Questions to Consider in Planning an Undergraduate Research Project

The Project
- Give a brief description of the project and its objective(s).
- Is there a broader research project that the undergraduate project is part of?
- What is the research question that the student will investigate?
- What are the specific tasks that the student will undertake?
- What should the student accomplish/deliver?

The Student/Preparation
- What level of student is most appropriate?
- What knowledge, skills, and goals should the student possess?
- Do you have some background reading material to provide?
- What training will the student need? (safety, instrumentation, data management, etc.)
- Who will do the training?

The Schedule
- How long should the project take if the student works 5-10 hours per week?
- How will the work schedule be managed?
- Will the student coordinate work with another grad student/post-doc/undergrad?
- How often will you meet with the student?
- What should the student bring to those meetings?

Other Considerations
- Will there be group meetings that the student can participate in?
- Is there an upcoming conference or symposium where the student can plan to present work?
- Will the student be included in the publication process?
- What professional attributes can you help the student to develop?
- What will you do if the student is not making satisfactory progress?

need data analysis or coding, the students may be able to do that without even coming into the laboratory. None of these techniques is inherently better than the other. The faculty mentor's choice may come down to their experience and the interests of their students.

Other considerations include providing opportunities for the student to engage in research meetings and participate in discussions. At first, students might hesitate to present results before a group, but doing so is a vital part of their scholarly development. Attending group meetings where more senior undergraduate researchers present their work can demonstrate expectations and lower anxieties. Look for venues to feature the student's work, whether it be on-campus forums or regional and national meetings, such as the AIChE regional or national student conferences. Even if the student finished up in the lab during the previous semester, make sure that both you and the student reap the full benefit of the work by reviewing and editing their conference abstracts. Be aware that your letter of recommendation might be crucial to the student's winning of awards or fellowships and their admission to graduate programs, and pay attention to specific incidents that you might use to strengthen your letter. Enjoy the relationship and remember why you chose to be a chemical engineering educator. In addition, when you look for competent undergraduates to bring into your research group as graduate students, remember that one of your colleagues likely spent time mentoring those students.

Group or Course-Based Preparation

Individual mentorship may be necessary for undergraduates to develop scientific knowledge in a particular research program and technical skill in an experimental technique, but other scholarly research skills can be instilled in a classroom setting through an undergraduate level research methods course. The goal of such a course is to provide a group mentoring experience to undergraduates that covers the broad aspects of research. It also helps to overcome the "hidden curriculum" of how a student finds a mentor and a project. This prepares the student for success in the subsequent undergraduate research experience in the laboratory with their individual research advisors/mentors. These courses are broadly offered (with slightly different objectives) in the social sciences,[35-37] and they are starting to become more widely available in formal and natural sciences and engineering.[13, 38, 39] Similarly, topics to improve the research experience are also being incorporated into summer research experiences for undergraduates (REUs).[40] Secondary goals for these courses may include increasing the number of submissions and admissions to graduate schools, NSF REU applications, undergraduate research funding applications (e.g., McNair Scholars), and undergraduate research conference presentations (National Council on Undergraduate Research or Posters on the Hill). Many institutions have added these outcomes as specific goals in their strategic plan.[41, 42]

Formal Research Methods Courses. Documented examples include both one-semester three-credit courses [14] and two-semester one-credit courses.[15] The course may be offered through the university honors program, the college honors program, or a specific department. An example for larger research groups is a one-credit journal club course in which both undergraduates and graduates in a research group produce literature reviews, increasing the group's productivity.[43] In smaller programs, broadly cross-listing a course in multiple departments/colleges can help ensure a sustainable student enrollment. Tailor the course number to meet suitable requirements of the department or honors programs. To increase student and faculty productivity, set the prerequisites to allow students to enroll early in their program (second semester first-year or first semester second-year). Early engagement in research enables longevity in a research project, and undergraduate students can develop the expertise necessary for meaningful research products.

Class schedule and course assignments for a one-semester three-credit course developed and taught by one of the authors are available.[44, 45] The course was taught once as an engineering honors elective, and then expanded in the next offering to serve as a general honors elective. Planned lectures fell into several categories: (1) finding your research interest and finding a mentor, (2) reading the literature, (3) scientific methods and developing a hypothesis/research plan, (4) research ethics, (5) graduate school familiarity and applications, (6) research presentations, and (7) professional research skills. Course assignments that reinforced the skills/concepts with each topic are also outlined in the literature.[44] The approach of this course is similar to research methods courses broadly available for graduate students.[16-18] However, the different level of the courses (undergraduate versus graduate) merits some differences in the courses. For example, undergraduate research classes can preferentially focus on finding mentors, funding opportunities for undergraduates, and specific example papers from undergraduate research journals.

It should be noted that the research methods course-based preparation here differs from what is now termed a Course-Based Undergraduate Research Experience (CURE).[13] A CURE is an experiential learning course centered on a particular research problem. Similar to what is discussed here, students do develop scholarly skills. The difference is that the focus is obtaining results in a topical collaborative project with a single mentor designed to last one semester. In general, the biological sciences are the leaders in the development and offering of CURE courses. Development of CUREs on chemical engineering topics and dissemination of the results are both valuable and interesting, but it is beyond the scope of this article.

Initial offerings of this course-based research preparation approach have resulted in strong outcomes. All students found research mentors in positions ranging from volunteer, to for credit, to paid researcher. Successful proposals for REUs or other undergraduate research funding were also submitted. Specific benefits from this course were also compared to broad benefits from a survey on a CURE offering. Despite the significant difference in delivery, the benefits from this research methods course compared very similarly to the CURE survey in appropriate areas.[14] Thus, if a department or other unit seeks to make a significant increase in the number of students performing undergraduate research, the approach of this course provides a tool to efficiently group-mentor students and more appropriately prepare them for the subsequent in-laboratory experience.

An Informal Approach. Depending on the departmental situation and curricular constraints, developing a new course may not be an option. Still, the benefits of the course described above are attainable through a less formal mechanism. For several years, three faculty in one of the authors' departments have run weekly meetings with undergraduate researchers. Early in the year, the faculty divide the responsibilities of discussing topics that support development of student research skills, similar to the content of the formal course discussed above. Later, the focus shifts toward student presentations, either of papers the faculty choose from the literature or of the students' own research results. Students receive feedback on their presentation skills and advice for improvement. This format allows for timely addressing student needs like preparation for conference, symposium presentations, or defenses of honors or senior theses. The informal nature allows for accommodating schedule constraints; in a week with a large project due or several tests, the meeting can be skipped. While attendance and participation are entirely voluntary, we have observed that students are deeply engaged, with an attendance of 20-30 students most weeks. Some of those students are active researchers, and others are just exploring opportunities to get involved. Perhaps surprisingly, there are always volunteers to present in the next meeting when needed. These gatherings have been foundational to the undergraduate research culture in the department and have offered a satisfying collaborative teacher-scholar experience for the faculty involved. Other outcomes have been several AIChE poster awards every year and several students per year moving on to highly ranked graduate programs.

TIME-SAVING TIPS FOR MENTORS

Regardless of the mechanism by which a student starts undergraduate research, a faculty mentor can establish their own practice and culture to save themselves time in the long term. Here are a few recommendations:[46]

Design a Straightforward Project with Clear Goals and Timelines. Consider the undergraduate educational experience and that the best results for both the student and professor in extended projects come when assignments are clearly defined and outlined, including intermediate deliverables. By its nature, research is an open-ended project, which can be a special challenge for undergraduates. Quality results are far more likely to result when students can see the plan.

Sign a Student-Mentor Contract Each Term to Establish Expectations. This was discussed above and should be revisited periodically as your expectations change. As you become more adept at obtaining valuable results with undergraduate researchers, you may develop some flexibility that allows you to tailor those expectations.

Develop Standard Training Resources to Avoid Repeat Work. Each student starts anew, but that doesn't mean the mentor has to start over. Save time with the following practices:

- Have a streamlined process for on-boarding, including background reading materials, safety training, and laboratory access
- Maintain well-written protocols to facilitate experimental training
- Establish standards for record-keeping throughout your research group
- Provide a template or earlier versions of posters

If your university will allow you to use its learning management system (LMS) to create a site for your research group, this offers an easy and efficient repository for resources to accomplish the four points above. A well-organized shared drive can accomplish the same, with the advantage that others can add materials such as posters, papers, and protocols. Especially since the COVID-19 shutdown, the LMS is often the primary mechanism by which undergraduate students engage in communication regarding their education, so using such a familiar platform might encourage their participation and lower their activation barrier towards participation.

Foster Research Communities, Especially for Training on Scholarly Procedures. Even in departments where the course-based research preparation mechanism does not exist, undergraduate research training can be provided in a group environment. Engage with other faculty who work with undergraduate researchers in the department or college to form a community of practice surrounding the undergraduate research training efforts. When possible, divide the training workload by developing seminars on literature searches, poster preparation, abstract writing, etc. As students develop an identity as undergraduate researchers, they will likely be eager to attend. Let the institutional safety office decide the necessary training and then provide it (encourage asynchronous delivery of these courses to allow students flexibility in completing them).

Enforce a Protocol for Requesting Letters of Recommendation.[47] Set expectations for timely requests and mandate that the students provide information to assist in preparing letters. Consider these requirements part of the students' professional development and communicate to them that the process will result in stronger letters.

Start Students Early and Retain Them. Not surprisingly, faculty are often skeptical about what a first-year student can contribute to a research program. Rather than expecting significant contributions from those early students, take a long-term approach and let the first year serve as exposure to research and some intentional and specific laboratory skill development. Remember, very few graduate students are instantly productive. Then, as students develop deeper knowledge through their coursework, their ability to contribute intellectually will grow, and the synergy between the research project and other learning that yields the benefits of undergraduate research discussed above can be realized.

CONCLUDING REMARKS

While undergraduate research mentorship does require faculty time and attention, it need not come at the cost of faculty research productivity and can even enhance it. As a practice that sits at the intersection of the teaching and scholarly efforts in the career of a chemical engineering faculty member, mentoring undergraduate researchers has the potential to be a very gratifying and fruitful pursuit.

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