PURM
Perspectives on Undergraduate Research & Mentoring

Employing a Student-Centric Approach to Managing an Undergraduate Research Lab at a PUI

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Introduction

Conducting research at a Primarily Undergraduate Institution (PUI) can be a challenge for faculty and affects a broad spectrum of faculty considerations, including allocation of time in relation to teaching loads, research expectations in relation to promotion and tenure guidelines, and, as Malachowski (2019, p. 42) states, "the relationship between faculty and students." (Dahlberg et al., 2021; Malachowski, 2019; Torrente & Dilek, 2023) Torrente and Dilek (2023) also add challenges associated with faculty conducting research at PUIs keeping pace with and competing (for grants) against faculty in their fields at research universities. At teaching-first institutions, faculty are generally responsible for teaching a full load each semester, leaving little time to focus on research projects during the academic year. Regardless, tenure-track faculty and faculty looking for advancement beyond tenure are still responsible for research or other scholarly work. While faculty at PUIs are at teaching-first institutions, significant pressure remains on them to progress their research. Moreover, that pressure translates as pressure to publish their research via promotion and tenure guidelines (Morrision, et al., 2019; Schimanski & Alperin, 2018; Schultheis et al., 2011). This pressure is exacerbated, as Schultheis et. al. (2011) point out, when there is ambiguity or conflict between how faculty are evaluated with respect to their mentoring undergraduate research.

For example, Schultheis et. al. (2011) cites that while many teaching-centric PUIs specifically address their emphasis on teaching in their mission statements, a failure to recognize the link between undergraduate research and undergraduate education "can lead to devaluing undergraduate research for the purpose of evaluating faculty members," (Schultheis et al., 2011, p. 25). Particularly in the sciences at PUIs, it is typical that the undergraduate research carried out in a faculty mentor's lab is part of the faculty mentor's broader research program. Failure of an institution to judge undergraduate research and products of those projects as part of a faculty mentor's annual review or tenure and promotion applications discounts a major facet of the undergraduate mentor's efforts.

For new faculty members who are just out of graduate school or postdoctoral positions, the transition to conducting research at a PUI can be challenging and disappointing at first. Transitioning from active research groups where research is every group members' priority to a position where new faculty may be lucky to find a few hours per week to focus on research can be discouraging. As Dahlberg et al. (2021) point out, faculty at PUIs generally make the largest strides and progress in their research during summers, when course loads are minimal to naught.

To advance my own research at my PUI, I have found success in moving from a project-focused approach in my lab to a student-centric approach with the work. Instead of building up the work in

my lab based around the project(s) being conducted in the lab, I build up the projects in my lab based around the student researchers working in the lab. As a result, the lab's goals and objectives are aligned with the mission statement of my PUI. Moreover, working with a student-centric approach aligns the lab's goals with tenure and promotion requirements involving undergraduate (UG) research at my PUI.

This paper outlines the approach I take towards mentoring UG research at a PUI. This is not the only approach to mentoring UG research and may not be suitable for everyone, but it has been successful in my case, so I share the details of this approach here. The approach presented here is quite similar to the "Ten Salient Practices of Undergraduate Research Mentors," as outlined by Shanahan et al. (2015). Those practices can briefly be summarized as pre-planning, setting clear and scaffolded expectations, instruction in technical skills, personal investment in students, building a research community, one-on-one mentoring, developing student ownership of their projects and providing opportunities for professional development, peer mentoring and communicating results. These practices had been previously presented by the Council on Undergraduate Research (CUR) (Kinkead & Blockus, 2012). They continue to be supported by CUR (Blockus, 2024), professional societies within my own field (American Physical Society and American Association of Physcis Teachers, 2025; Joint Task Force on Undergraduate Physics Programs, 2016), and additional literature (Allocco et al., 2022; Walkington et al., 2020; Walkington & Rushton, 2019). In applying these ten salient practices, the student-centered approach to mentoring undergraduate research at a PUI prioritizes UG research students, keeping their needs and goals at the forefront of the mentor's mind.

This paper is written from the perspective of mentoring UG research in the sciences at a PUI, but topics and approaches presented may be of interest to those mentoring UG research beyond the sciences. I will use examples from mentoring my own UG research students that are discipline specific to illustrate the diversity in student projects and interests that result from using a student-centric approach to mentoring UG research. I have tried to make such particulars accessible to readers outside of my field and the sciences.

Student-Centric Considerations for Building an Undergraduate Research Program

When approached by a prospective UG research student, I try to consider the following: What do they wish do gain from their research experience in my lab? What do I— and my lab in general— have to offer them to help them achieve those goals?

In answering those two questions, I determine not only whether a prospective student will be a good fit for my lab, but whether I (and my lab) will be a good fit for them and can help them to achieve their goals. The answers to those questions will revolve around the different aspects of research I can offer them at the time (Fig. 1): Do I have—or can I find—a project that would meet their needs? Will the subject matter and background information necessary to conduct the research help them enhance their educations? Are there methods and skills the student would like to learn that I can give them experience with through their research experience? Are there other student or faculty collaborators that I have or can establish to help enhance the student's research experience? And finally, if my lab does not have the infrastructure to support a prospective student's research project, are there means of gaining funding to do so?

Taking on a new undergraduate research student is a process. An introductory, one-on-one meeting is a helpful first step in this process. This creates an opportunity for the student to tour the lab and learn the types of research being carried out by other students in the lab. This also gives a student an understanding of what will be expected of them.

The earlier UG students become involved in research, the greater the potential benefit. This is because early involvement in UG research translates to increased time for involvement in conducting UG research. Thiry et al. (2012) found that multi-year research experiences benefitted UG students both intellectually (via improved skills and understanding) and behaviorally (via improved confidence and recognition of the temperament necessary to conduct science as a career). As a result, I often have these introductory meetings with students still working through their lower-division curriculum. In my experience, it generally takes a student a minimum of one semester to learn the basic background information necessary to begin applying themselves towards conducting legitimate research. Kitutu et al. (2016) have demonstrated the benefits of students conducting research early in their programs.

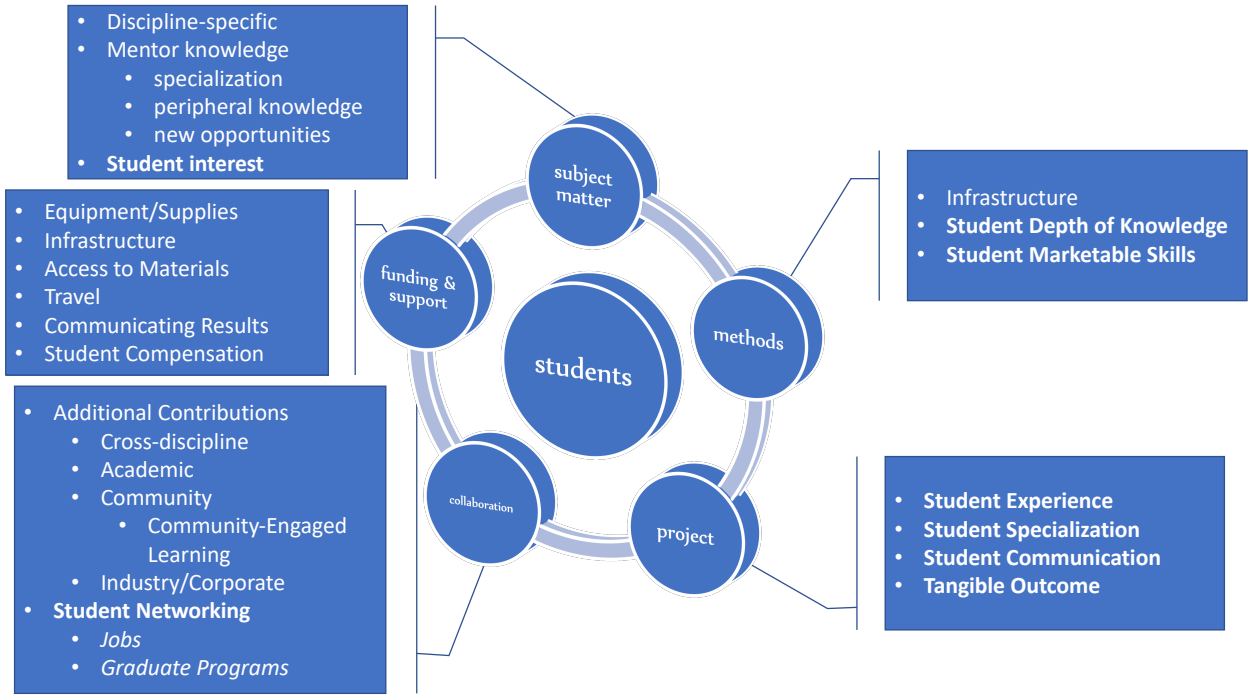

Figure 1. *Considerations when building research projects around the student-centered approach.*

The introductory meeting and lab tour also creates an opportunity for students to learn what they can expect from their research mentor. The mentor-mentee relationship has been shown to be critical in the UG research experience and so should not be taken lightly when taking on a new research student (Craney, et al., 2011; Russell et al., 2007). Just as a new UG research student needs to make a commitment to doing research in the lab, their mentor also needs to make a commitment to support, train and teach that student how to effectively conduct research within their specific discipline. In a cross-disciplinary study by Craney et. al., of 314 UG research students polled after completing their research experience the overwhelming majority (79%) stated that their mentor "provided needed instruction/direction," (2011, p. 103).

Expectations for UG researchers can be further reinforced by sharing an undergraduate research contract or syllabus with students at the initial meeting. Pfund, Branchaw and Handelsman (2014) give good examples of an Undergraduate Mentee Contract and a list of Expectations for Undergraduate Mentees in their manual *Entering Mentoring*. Completing a mentoring contract at that initial meeting would be premature, because students have not had adequate opportunity to consider and assess possible research projects. I instead share my list of expectations with

prospective undergrad research students via my Undergraduate Research in Physics course syllabus. There a detailed list of expectations includes Lab Safety, Time Commitment, Laboratory Performance, Completeness of a Laboratory Notebook, Ethical Research and Communication of Scientific Results.

That introductory meeting is in fact an informal interview. During that meeting, the mentor learns what the student is looking to gain from their research experience. Taking a student-centric approach to mentoring UG research projects means that the mentor needs to find a project that will suit the student's needs. Often, an existing project will meet a student's needs, and it is not necessary to create a novel project. One of the benefits of managing an undergraduate research lab at a PUI is that there always seems to be more work that needs to be done, and opportunities are often available to meet a diverse set of students' needs and goals.

The principal considerations when taking on an UG research student involve the subject matter, methods and skills to be learned and applied towards the project, how the individual project will be housed under and contribute to the larger scope of the lab, what possible collaborations might be leveraged to supplement and improve the UG student research experience, and what funding may be needed or available to support the project.

Subject Matter

That introductory meeting gives the mentor an opportunity to assess the prospective student's interests and educational status (Adedokun, et al., 2012; Lopatto, Undergraduate Research Experiences Support Science Career Decisions and Active Learning, 2007). With respect to the latter, the mentor must assess whether the student has had prerequisite courses that would support the research, or if they will need to be mentored in that subject matter before being able to conduct meaningful research. Alternatively, students can use elective courses to fill in content they lack while working in the lab.

Methods

The mentor can use the introductory meeting to assess the student's educational and career goals and determine whether the lab has the infrastructure to train them in marketable skills that will help them achieve those goals. In my own lab, those skills can draw from computational modeling and simulations, designing and building optical systems, computer interfacing and instrumentation, general experimental design, image processing and data analysis, and sterile tissue culture methods.

My Biophotonics Lab conducts multi-disciplinary research and pulls students from across the sciences. In general, we use computational modeling and holographic and scatter imaging methods to study cancers at the cellular level. Our studies involve a combination of therapeutic, biochemical and mechanobiological considerations.

Therefore, if a biology major approaches me about conducting research in my lab, I need to consider if there are important biological questions that can use their background to be answered. While managing tissue culture for the lab would be good experience for many biology majors—and would be a natural fit based upon subject matter, as compared to a physics major—I cannot simply restrict a biology major's work to overseeing tissue culture for the lab. They still need to be simultaneously conducting a research project that will give them experience in experimental design, methods and analysis. Both the skills of managing tissue culture for a lab and conducting independent research will help that student in advancing their education and career beyond their UG degree. A good deal of pre-planning—the first salient practice discussed by Shanahan, et. al. (2015)—is involved in on-boarding a new UG research student within my PUI research group.

When a physics major approaches me about conducting research in my lab, one of the first things I need to assess is whether they are interested in hands-on applications using physical devices or using computation and simulations to conduct their investigations. I have built an undergraduate research lab that uses computational modeling to lead optical design of novel benchtop imaging systems. Depending upon the student's response to whether they are interested in physical applications or computational work, I then need to consider what possible projects I can offer them to meet those needs and interests.

In the end, whatever project a student works on, it should give them tangible skills that go beyond general research experience (Bauer & Bennett, 2003; Craney, et al., 2011; Harsh, et al., 2011; Linn, et al., 2015; Russell, et al., 2007). Craney et. al. (2011) found that long-term achievement was associated with students who had an undergraduate research experience, while Russell et al. (2007) measured an increase in confidence in and understanding of research in a poll of 4500 undergraduate students. When applying to jobs or graduate schools after leaving my lab, my students should be able to draw from specific experience in those interviews. Perhaps they can detail how they learned how to use a specific programming language; that they know how to use specific computer software to automate experimental devices and collect data or images; that they have learned techniques specific to building optical systems; that they have learned sterile tissue culture techniques. Whatever project they work on will have to be conducive to their learning and gaining experience in those specific skills aligned with their educations and in which they have expressed an interest.

Projects

By the conclusion of that initial meeting and lab tour, I try to have an idea of a couple of possible projects that might fit the student's needs and interests. I then generally try to send the student off with some homework to do over the next week or two related to the project(s) that I am considering for them. This homework is generally either some cursory research to conduct—more of an informal investigation—or a paper to read. I let them know what project(s) I am considering might be a good fit for them and that the research or paper(s) I am sending them off with are related to those project(s). This way they have some time to reflect upon the research we have discussed, look more deeply into the subject matter and decide whether my lab will be a good fit for them. Before a prospective undergraduate research student leaves that initial meeting, I like to schedule a follow up meeting where we can talk in more depth about the possible project(s) after they have had some time for consideration. This also gives them a hard deadline by which to have competed the research or paper I have sent them away with.

We want our undergraduate researchers to leave the lab with a final product, having completed a research project. This relates back to the discussion by Shanahan et al. (2015) regarding clear, well-scaffolded expectations and ideally student ownership of their project and opportunities to share their results (salient practices 2, 7 and 10, respectively). At the undergraduate level, this does not necessarily mean that they have completed data analysis and a publication. Those results are ideal, but given the time undergraduates can commit to conducting research—both in the immediate and long-term time scales—this is not always possible.

Instead, the focus should be on creating a project based upon the individual student's needs and interests that are an incremental contribution to a larger project within the lab. For example, one student's project could be to complete some computer simulations to help guide the design of a benchtop imaging system. In my lab, the students who model, build and program imaging systems are rarely the students that collect and analyze cell images. Often, one student spends their time building, automating and calibrating an imaging system and then graduates before the overall project is completed. When an incoming UG research student who has needs and interests related to

the remaining work joins the lab, their project would then be to conduct the actual experiment, collect and analyze the resulting data. In that example, there are multiple incremental, complementary yet independent UG research projects that need to be carried out for the overall project to be completed—computational modeling, building, calibrating and automating the optical system, conducting imaging experiments and analyzing the results.

Collaboration

Between the initial and follow up meetings, the mentor has time to further consider projects that would support the prospective student's needs and interests. This is a good time for the mentor to consider whether they have current or prospective collaborators, community engagement opportunities or internships that can be leveraged to help enhance the student's research experience. This is an especially important consideration when conducting multidisciplinary research and taking on an undergraduate research student from outside of one's own department. Student collaborations with faculty at other institutions or industry partners establish relationships that could lead to opportunities after graduation, such as acceptance into a graduate program at the collaborator's institution or being offered a job with an industry partner. Collaboration helps to build community within the research group (Shanahan et al.'s (2015) salient practice 5) and provide possible professional development opportunities (Shanahan et al.'s (2015) salient practice 8). Collaboration in general has been shown by Craney et al. (2011) to increase undergraduate researchers' interests in pursuing advanced degrees or careers in the field.

Funding

The time between those initial meetings with prospective research students can be used to assess the lab's infrastructure in relation to the possible project(s). The mentor can consider whether the lab has the equipment and supplies necessary to conduct that research or funds to support the prospective researcher via a stipend. If the mentor does not have funding to support some or all of these needs, they have the opportunity to look for means to do so. Funding is not always required for a given UG research project, but it can always help. For example, UG travel to communicate project results often requires financial support. Funding avenues for supporting undergraduate research at PUIs will be addressed in more detail in a latter section (Funding to Support Undergraduate Research at PUIs).

There is not always a fit between a prospective student and the lab. The faculty member may not have the expertise to mentor a student in the skills they are interested in learning. The student may not be interested in the different kinds of projects in which the faculty member has expertise. A student may not have the time to commit to conducting undergraduate research in the lab—this can be in the immediate sense, in the long-term, or both.

The mentor may not have sufficient time to dedicate to an additional UG research student. Taking on additional UG research students impacts the mentor's availability for current students working in the lab. Taking on an UG research student and not giving them sufficient time and guidance can cause more harm than good. Limeri et al. (2019) would classify this as absenteeism, and possibly a lack of psychological support or even unequal treatment among UG researchers. Mentor absenteeism can result in students leaving their UG program without the skills and experience they hoped to gain, because mentor guidance was lacking. Not only does this leave students with a bad UG research experience, but it also has the potential to hinder a student's prospects for jobs or graduate programs. Souring a student's research experience can have long lasting repercussions on their overall career and job satisfaction, as discussed by Limeri et al. (2019). If a mentor does not have sufficient time for an additional UG student, it is better to not take on the student and encourage them to seek out an alternate mentor.

Undergraduate Research Timeline

Conducting research can be a long, arduous process with many setbacks and disappointments. But for those who enjoy conducting research, the successes more than compensate for the failures. This is a difficult lesson for UG students to learn. Cooper, et al. (2020) discuss the importance of "normalizing failure" in research, where failure is to be expected in research but also strengthens UG researchers by providing the opportunity to develop perseverance in research. Constant guidance and mentorship can help students stem the tides of conducting research and see their work through to a positive achievement and contribution (Russell, et al., 2007). This requires frequent communication between the mentor, individual UG researcher, and the research group as a whole (Craney, et al., 2011).

To help students stay on course, this frequent communication can be broken down into different timescales (Fig. 2). Furthermore, an Individual Development Plan is a good means of pre-planning (Shanahan et al. (2015) salient practice 1) and keeping students on pace with their respective projects. Pfund, Branchaw, and Handelsman (2014) give good examples of Individual Development Plans for Undergraduate Researchers in their manual *Entering Mentoring*. In those examples, students track goals for the different time-scales (immediate, long-term, etc.) along with the skills and activities that will help achieve those goals. Providing such structure to the UG research experience was found by Brown et al., (2016) to increase student proficiency in research.

Immediate Timescale

Immediate and constant mentorship is required, with meetings between the mentor and student or group on a regular basis. I prefer to alternate between individual and group meetings every other week (Fig. 2, inlay). This way each student gets individual guidance and attention, but the group is aware of everyone's individual contributions and progress.

During weekly, individual research meetings, the faculty mentor can monitor individual UG research students' progress and instruct them in skills, methods or tools that they will need to apply to their project. Finally, at the conclusion of the individual research meeting the faculty mentor can send students away with clear and achievable tasks to be completed before their next individual meeting.

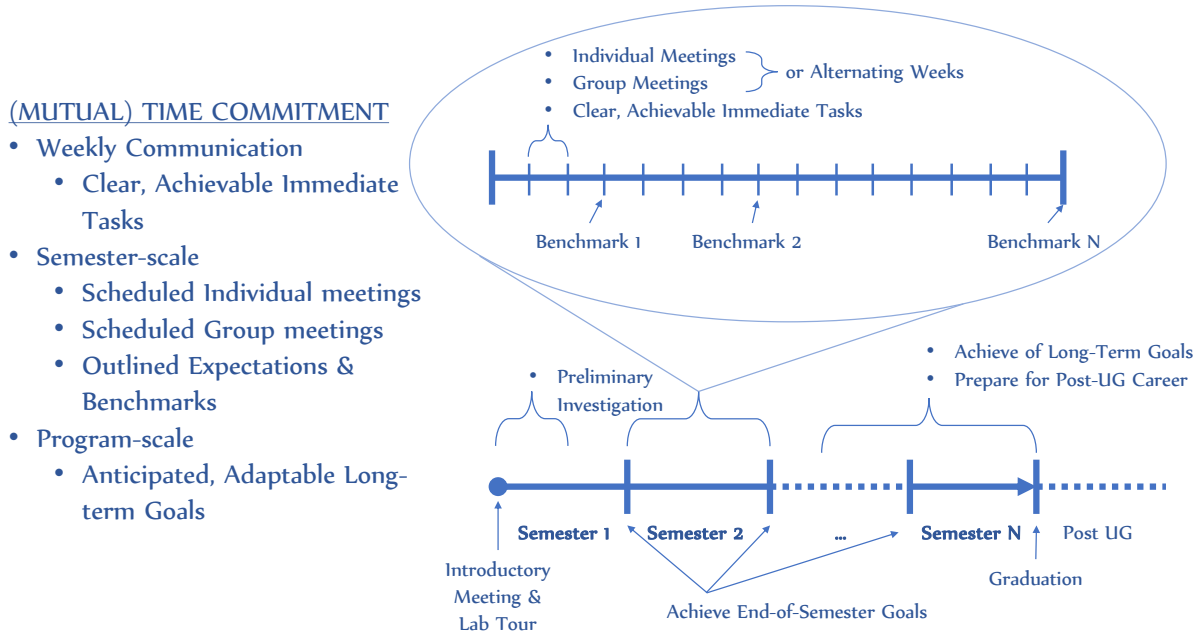

Figure 2. *Scheduling and Timelines for Managing UG Research Projects at a PUI.*

During group meetings, each UG research student gives an informal update on their progress. When individual UG researchers complete a particular benchmark, they can give a more formal research presentation to the group. This serves as a low-stakes introduction to communicating scientific results. When a university or regional research conference is approaching, the entire group can practice giving their presentations during group meetings. Group meetings also afford the opportunity to give mini-lessons on background material that students will need to know based upon the lab's specialization.

Short-term Timescale

On the scale of individual semesters (or terms), the faculty mentor should outline for each student—and the group as a whole—expectations and benchmarks for the semester (Brown, et al., 2016; Lopatto, 2003; Seeling & Choudhary, 2016). These expectations and benchmarks can be given at both the individual and group scales and often will refer back to or modify students' Individual Development Plans. Expectations and benchmarks give an UG research student short-term and intermediate goals to strive for and can help maintain their focus. Having intermediate goals on this time scale helps UG researchers recognize that there are longer-term benchmarks that they are working towards and that setbacks or failures in the short-term do not indicate failure overall but are merely hurdles that need to be overcome. These setbacks and failures are often the greatest learning experiences because something new or critical has been learned that wasn't anticipated in the original experimental design.

Long-term Timescale

Finally, UG research students should be aware of their long-term project goals. Using a student-centric approach to UG research, these long-term goals should align with the individual students' needs, interests and educational and career goals beyond graduation. Defining long-term research goals helps to create cohesion between students' fine-scale tasks throughout their research experience.

Towards the end of a student's UG education, it's beneficial for them to compile some final, capstone-like summary of their work. This generally comes during their final semester and can be either formal or informal, in the form of a written document or presentation. The key to this summative work is to give students an opportunity to demonstrate their successes and for the mentor to give some final feedback on their work (Lopatto, 2003). This summative work also can serve as a resource for current or incoming UG researchers who will be working on complementary projects.

While students are approaching the end of their UG programs and research, they will also be looking ahead towards their post-graduation careers. Those plans will typically involve attending graduate school or seeking work in the field. Either way, their job and/or graduate school applications will be based largely on the tangible skills they have applied in their research. Ideally, the faculty mentor should be available as a resource for their UG research students with this process. After all, the student-centered approach to mentoring UG research at a PUI emphasizes student outcomes. The ultimate student outcome will be their placement after graduation. Beyond helping students learn the skills that will make them marketable and competitive applicants post-graduation, the faculty mentor can also mentor students as they seek out and submit those applications. In a way, the application process is the final "soft skill" that UG research students learn via their research experience.

Building a Complementary and Supportive Network of Undergraduate Researchers

The primary goal of the UG research lab at a PUI is to provide undergraduate students tangible skills and experience that will benefit them in their careers beyond their UG experience. However, there is the growing trend of PUIs pressuring faculty to conduct meaningful, relevant research and publish their results. (Johnson, et al., 2015; Dahlberg, et al., 2021; Malachowski, 2019; Morales, et al., 2017; Torrente & Dilek, 2023) This pressure is generally provided via tenure and promotion requirements that can be imparted at the departmental, college, division or university levels.

Using the student-centric approach to UG research at a PUI by breaking down individual student research into complementary projects that fit individual students' needs and interests allows the lab to progress while fostering successful UG research. In this fashion, each student contributes to the overall lab's progress while pursuing their individual goals and interests. The work of the lab—and specifically the faculty mentor— is judged on the integral over individual student contributions, on advancing the overall project.

The benefits of this approach are not found on the individual student level or by the mentor alone. Integrating individual student projects into the lab's overall research umbrella also provides benefits to the research group. It is important that UG researchers are responsible for their individual contributions and take ownership of their projects (Shanahan et al.'s salient practice 7), but working in a siloed context does not help morale or provide students with an overall context for their work (Cooper, et al., 2020; Craney, et al., 2011; Shanahan, et al., 2015). While student projects are individual, with individual goals and tasks, their work contributes to the lab's progress and in turn to each other's UG research projects and progress. Cooper et al. (2020) discuss the importance of reinforcing to UG researchers how their individual projects contribute to the lab as a whole. This gives a point of reference for students to collaborate and share their findings and work with each other. In turn, this provides individual UG researchers a sense of belonging and importance to the larger group (Shanahan et al.'s (2015) salient practice 5) (Russell, et al., 2007). Collaboration among labmates was shown by Cooper et al., (2020) to be of particular benefit among UGs suffering from depression.

Senior student researchers in the lab can gain experience in training incoming students (Shanahan et al.'s (2015) salient practice 9), which further helps to solidify the concepts and skills they have been learning in the lab. Establishing relationships based upon training and collaboration between students also helps to foster a sense of community within the research lab (Craney, et al., 2011; Coooper, et al., 2020)

Student collaborations across the larger project can be in real-time or asynchronous, in the same lab or between collaborators' labs, at the same university or between universities. The timing and distribution of these student collaborations will ultimately depend upon the windows of opportunity for individual UG student research projects. Student projects can be carried out simultaneously, such as a pair of students simultaneously building and programming an imaging system. Individual undergraduate student research projects can also be carried out in series, such as a previous member of the lab building the optical system, followed by a later student automating the system. In the former scenario, the students can collaborate closely and in real time. In the latter, the collaboration is indirect, where the students depend on each other's previous or pending contributions to the overall project. Indirect collaborations of this sort can be as simple as the incoming student relying on the graduating student's lab notebook, presentations and other records. In either case, the faculty mentor is the overarching factor that unites these projects and helps to establish this relationship between the student collaborators.

Funding to Support Undergraduate Research at PUIs

Funding is critical for running an effective UG research lab in the sciences, even if a faculty mentor's field of research doesn't include equipment or supply costs. At the least, a faculty mentor should strive to send their UG research students to give presentations at professional conferences—more will be said in the next section about the importance of developing communication skills in UG researchers. National and international conferences have obvious expenses, but regional conferences also have expenses. Sending students to present their work at a professional conference includes the expenses of registration fees, travel, room and board.

Funding conference travel is a challenge at a PUI. Even though national agencies sponsor external funding programs specific to PUIs, these grants are highly competitive. Generally speaking, faculty at PUIs cannot rely regularly upon large external grants from federal agencies (e.g., NSF, NIH).

Internal Funding

Fortunately, many PUIs that are invested in UG research as part of their mission statements will have internal funding mechanisms to help alleviate the burden of costs associated with managing an UG research lab (Moore & Felten, 2018; Webber, et al., 2013). Petrella and Jung (2008) cite the benefits of the UG experience reaching beyond the individual student or faculty mentor, ultimately benefitting the university itself. The benefits of promoting UG research experiences motivate internal funding mechanisms. Internal funding opportunities vary between PUIs, but they can come from any of the departmental, college, division or university budgets (Table 1). Foundation (donor) grants are another avenue for funding UG research programs.

Table 1. *Examples of Internal and External Funding Resources Available for Conducting UG Research at PUIs.*

EXAMPLES OF INTERNAL FUNDING RESOURCES	
Source	Approximate Dollar Amounts
Undergraduate Research Office	$1,000 - $2,500
Student Poster Grants	$85 - $100
Student Travel Grants	$1,000 - $2,000
Large Faculty Research Grants	$10,000 - $30,000
Small Faculty Research Grants	$2,000 - $5,000
Foundation Grants	$100 - $5,000
Student Development Grants	$500
University Funds supporting UG Research (managed by Provost's Office)	$2,000 - $5,000
College Funds supporting UG Research (managed by Dean's Office)	$2,000 - $5,000
Department Funds supporting UG Research (managed by Department Chair)	$100 - $500

** Approximate dollar amounts for internal sources are based on the author's experience.*

EXAMPLES OF EXTERNAL FUNDING RESOURCES
Government Agency Research Grants (e.g., NSF, NIH, DoE, DARPA)
Regional Academy of Science, Arts & Letters
State University System UG Research Grants
State Initiatives

Industry Partnerships
Professional Societies--Student Scholarships
Professional Societies--Student Travel Grants
Government Agency Scholarship Grants (e.g., NSF S-STEM grants, NASA Space Grant, NIH URISE grants)
Private Granting Institutions (e.g., Howard Hughes Medical Institute, Gates Foundation)

Internal grants can vary in size, ranging from under $100—which could cover the cost of printing a poster to present at a conference—to tens of thousands of dollars that can be drawn from over one or more years. Often, internal grant proposals need to be submitted by UG research students. Student proposals give faculty the opportunity to mentor their UG research students in preparing and applying for funding—another important "soft skill" for students to learn. Applying for (and receiving) a student grant is an accomplishment that students can highlight in their CVs and can add to their competitiveness when applying for graduate programs and/or jobs.

The key to finding internal funding opportunities is maintaining communication with different institutional offices. Offices of Undergraduate Research, Offices of Teaching and Learning, Faculty Senates, Dean's and Provost's Offices are all different entities on PUI campuses that might typically offer funding to support UG research projects. Some student governments even offer small student research grants.

External Funding

Researchers are generally aware of the larger external funding sources such as the NIH or NSF, however there are additional national funding sources to target, such as DoD, DoE, or DARPA. Within the larger government agencies, there are scholarship grants available that also provide research funding to support their recipients, such as the NSF S-STEM program and NASA Space Grant. At the state level, there are often state-driven initiatives and regional academies of science that provide research funding to higher education institutions.

Industry partnerships or private granting institutions, such as the Howard Hughes Medical Institute, the Gates Foundation, or the M.J. Murdock Charitable Trust, are other sources of potential funding for an UG research lab at a PUI. Finally, professional societies often have larger student scholarships and smaller travel grants to help support UG research.

While the granting agencies listed here focus predominantly on funding scientific research, organizations dedicated to funding work in other disciplines also exist, such as the National Endowment for the Humanities and the Rockefeller Foundation.

Table 1 outlines many of the typical internal (along with typical dollar amounts) and external funding resources available to PUIs.

Integrating Soft Skills into the Undergraduate Research Experience

This section will take a closer look at the importance of helping UG researchers develop soft skills in relation to their projects. The student-centric approach to mentoring UG research has the long-term in mind—with the ultimate goal of the UG research experience being the development and advancement of the students' educations and careers. Recent reports support the positive effects of UG research on career readiness (American Physical Society and American Association of Physcis Teachers, 2025; MacDonald, et al., 2024; Mekolochick, 2023).

For a student, successfully reaching the end of their research project is important. However, without the ability to defend their work and explain their contributions to the work, a graduating UG will not be as competitive when applying for graduate programs or jobs. When interviewing for graduate schools or professional positions, a student who has been mentored in developing soft skills via their research experience can demonstrate their competence and mastery of these skills (Lopatto, 2003; Lopatto, 2007).

Soft skills are often associated with communicating research results. In a Survey of Undergraduate Research Experiences (Lopatto, 2003; Lopatto, 2007), student presentations were identified by faculty mentors and UG researchers as a critical aspect for the UG research experience. Publications, and more often, poster or oral presentations are the main vehicles for practicing and establishing these soft skills. An oral presentation gives UG students a forum to compose and present a coherent and concise summary of their research, whereas a poster presentation gives them the opportunity to thoroughly engage with the audience and to address a wide array of audience questions with respect to their research project. The former is a more formal presentation, whereas the later provides opportunity to engage more thoroughly in one-on-one discussions of the work.

Preparing a student grant proposal as an UG researcher is another vehicle for learning soft skills. In preparing a student proposal, students do not explain their research results, but instead explain how they will carry out their proposed research project. If a publication or presentation is analogous to a graduate dissertation at the UG level, then an UG grant proposal can be considered analogous to a qualifying exam at the graduate level.

Not all UG students will have the opportunity to compose an UG grant application for their project. However, composing a Research Project Outline and Science Abstract, such as presented in Pfund, Branchaw, and Handelsman (2014) provides a similar opportunity for UG students to detail their prospective projects in advance of their work. Providing a thorough account of the project's hypothesis, goals, tests, possible challenges and anticipated outcomes and reporting mechanisms prior to embarking on the project will help guide and inform the students' efforts during their work.

Giving multiple presentations is an effective means of developing communication skills in UG researchers. We look now at different venues for scaffolding in UG research presentations as a means of developing communication skills, beginning with some examples of informal, low-stakes forums and working up through more professional, high-stakes forums.

Low-stakes Forums

Many students enter the research group insecure in their content knowledge and are therefore initially tentative in presenting their research. This is to be expected— UGs are there to learn how to conduct authentic research and to expect otherwise would be naïve. Recognizing this, having students give oral presentations via group meetings is an effective means of introducing UG researchers to communicating their projects. This creates a low-stakes, friendly environment for UGs to practice presenting their research.

Undergraduate research students in my group are expected to give a formal research update to the rest of the group once per semester. Scheduling more senior members of the lab to present earlier in the semester provides a model for junior members of the lab to follow. This also helps to establish the cordial, low-stakes environment of the group meeting and the associated presentations. Finally, this also provides a personal, relaxed environment for the faculty mentor to help guide their students and correct student misconceptions regarding their respective research. In my experience, student group presentations provide some of the richest mentoring opportunities available.

Mid-Stakes Forums

As students progress in their individual research projects, becoming more competent and comfortable with their contributions, the mentor can scaffold in higher-stakes opportunities to present their research (Fig. 3). The rate at which these opportunities intensify will be individual. Some students might be prepared after their initial group presentation, while others might need to go through additional iterations of their group presentations before being comfortable presenting their work in larger environments.

Figure 3. *Scaffolding Communication Skills for UG Researchers via Presenting Their Research.*

Transitional or intermediate-stakes environments for UG students to present their research typically include university or institution-wide showcases or symposiums. There, students present their work to other students and members of the university community. This is a good platform for UG researchers to present their work to people outside of the comforts of their research group. These venues are medium-stakes in that university communities at PUIs are generally supportive of UG research. Members of the general community in attendance also tend to provide a sympathetic audience as peripheral members of the university community—such as donors, alumni, family and friends of UG presenters.

High-stakes Forums

As UG research students approach graduation and the end of their respective projects, opportunities to give research presentations at more high-stakes venues will present themselves. These opportunities can still be on campus—such as formal research presentations from graduating seniors within the department—or away from campus for the first time—such as a regional professional conference or the Undergraduate Research Day at the Capitol.

Finally, the most competent and advanced UG researchers are well served by having the opportunity to present their research at national (or even international) conferences. This is the highest-stakes setting for UGs to communicate their research results. The high-stakes nature of this venue is two-fold. First, UG research students will be presenting their research to experts in the field and so will need to provide a detailed and accurate explanation of their work. There, UG researchers will have to account for nuances of their research that might otherwise go unchallenged in lower- and mid-stakes forums. Second, they will likely be presenting their research to prospective employers or faculty from graduate programs they have or will be applying to. The impression they make at these high-stakes

events can be formative in advancing their careers. The goal of scaffolding in research presentations with increasing intensity is to thoroughly prepare UG research students for these formal presentations that will often serve as informal interviews.

Conclusion

Undergraduate research students greatly benefit from the student-centric approach towards UG research. By making students the center of the research lab's focus, students are trained in tangible, marketable skills that align with their individual educational and career goals and make them competitive when applying for professional jobs or graduate programs. The student-centered approach is a holistic approach to fostering and growing UG research via considering subject matter, methods and skills, project goals and outcomes, collaborations and funding in the context of how each will benefit individual UG research students. The infrastructure of the UG research lab is therefore built up around UG research students, as opposed to merely filling projects with students.

Faculty can also benefit from adopting the student-centered approach to UG research. Managing an UG research program at a PUI is full of challenges. In particular, faculty are challenged with the demands of earning promotion and tenure. Chief amongst these considerations are often research and scholarship. Taking a student-centric approach to conducting UG research at a PUI frames the lab's research in the context of the PUI's mission statement, aligning the lab's expectations and timelines with those of the PUI. This will generally include the PUI's tenure and promotion requirements for directing UG research.

The ideas and practices represented in Shanahan et al. (2015) help foster an effective UG research experience. Balster et al. (2010) demonstrate how these practices can be further reinforced by having students participate in an *Entering Research* course that introduces UG students to various aspects of research including selecting a mentor, the role of UG researchers and connecting research to their educational programs.

Similarly, faculty mentors reading this article who would like the experience of a more in-depth training in mentoring can participate in mentoring seminars or workshops, which have been shown repeatedly by the Wisconsin Center for Education Research to improve the UG research experience and outcomes (Butz, et al., 2018; Lee, et al., 2015; Pfund, et al., 2006; Sorkness, et al., 2017). Mentoring workshops may be provided by PUIs, often via their Center for Teaching and Learning, Office of Undergraduate Research, or the like. Alternatively, mentoring workshops can be facilitated by external groups such as the Center for Improvement of Mentored Experiences in Research out of the University of Wisconsin-Madison (Center for the Improvement of Mentored Experiences in Reesearch, 2024) or the National Research Mentoring Network (National Research Mentoring Network, 2024). Finally, faculty mentors who don't have access to such workshops or resources can improve their mentoring practices by working through the *Entering Mentoring* workbook on their own (Pfund, et al., 2014).

Ultimately, the primary products produced by an UG research lab at a PUI are the research students graduating out of the lab. The goal of the UG research lab at a PUI should therefore be to give students an authentic research experience that provides tangible and marketable skills. Taking the student-centric approach to managing an UG research lab at a PUI helps in achieving this primary goal while maintaining consistent research aligned with the PUI's mission statement and dedication to providing quality UG educations.

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