

Essential Elements of a Successful Undergraduate Research Career at a PUI

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A third of a century ago I was a graduate student studying nuclear physics at Florida State University. At that time, I was beginning my thesis work at the 10-million-volt tandem Van de Graaff accelerator laboratory and learning how to operate the machine. It was an exciting time because the lab was building a linear accelerator and the Van de Graaff would be used as the injector for it. I was also trying to decide if I wanted to become a research scientist or teaching professor when I graduated. I was having difficulty determining what I should do since I enjoyed both teaching and research and saw them as mutually exclusive. Coincidentally, a young professor from Tennessee Technological University began visiting the lab with his undergraduate students that year. He had obtained a grant from the Department of Energy (DOE) to work with undergraduate students at the lab during the summer months. As it turned out, this young professor who was not much older than me surprisingly did both research and teaching. Over the next few years I got to know John Mateja and his cheerful band of undergraduates from Tennessee Tech, a comprehensive college in Tennessee. They were a good bunch of people who did interesting nuclear physics research. They published their DOE-supported work in top physics journals and presented it at national meetings.

A few years later I graduated and became a new professor at the State University of New York at Geneseo. During my first year there I modeled my research program after John's. My wife Susan, 6 students and I would travel from Geneseo, New York, to Tallahassee, Florida, to do research for ten weeks during the summer. We did this for the next five years. Later we moved our summer research effort to the accelerator lab at the University of Rochester, a mere 30 miles away from Geneseo, and after a few more years we moved across the street to the Laboratory for Laser Energetics and to our own accelerator lab here at Geneseo.

After three decades of performing research with undergraduates, some things have changed. For example, the scale and magnitude of the work is much larger. When I started I had 3 students, one project and a yearly budget of \$1,200. Now, the number of students and the faculty on my grants are approximately 20 to 25 a year and we undertake a half dozen projects with a total funding exceeding \$450,000 (Funded by Department of Energy, and a small amount from the New York State Energy program and College). However, the core values I began with in my early years are the same. From these many years of experience, I believe I have a fairly good perspective of the many aspects of the research endeavor at a liberal arts college. My view points have evolved as I moved from being a new assistant professor, associate professor, professor, chair, research council chair, and associate provost. Currently, I hold the rank of Distinguished Professor of Physics. In this article, I would like to take this opportunity to share with you my insights of being an active research faculty member at a non-doctoral institution.

A Caveat

The comments below are predicated on the belief that you are at an undergraduate institution where you have a teaching load of roughly 12 contact hours a week, lab and lecture prep, grading, online

course development, special projects, committee work and national meeting preparation at least once a year. Roughly speaking, you do not have much time to perform publishable work during the academic year. This means you probably can only do "real" research about 10-15% of the time during any given semester. If you want to perform publishable and fundable research and complete it in a given year, you have to work fulltime with your students during the summer. In order to attract talented*** students to your summer research, you most likely have to pay them so they can feed and house themselves and save for fall tuition. Being at a public liberal arts college, my students do not have the luxury of coming from wealthy families and are required to earn cash in the summers. Very few can afford to do summer research pro bono, so they absolutely need financial support.

Research Boundaries

As many of you know, undergraduate research comes in many flavors. I will not try to enumerate all of them here. However they all share some physical boundaries. Temporally, a project can occur over the period of a semester or tens of years. Spatially, the projects can take place in a basement closet or at a billion dollar national lab. The work may require large expensive equipment costing millions of dollars or require only a couple of old 1960's sodium-iodide detectors you obtained from a decommissioned university facility. The research topics may vary from being specific to your academic pedigree or to something far afield that a student dreamed up during winter break. Research can be funded at the national, state or local college level or done as a pro bono effort. The funding levels can vary from a few kilo bucks to a few mega dollars. It may be done with a group of students and collaborators at the best facilities in the world or with only one student on a lab bench. Whatever the scenario, there are some good practices faculty can follow to improve their academic survival, enhance their careers and grow their funded undergraduate research programs. First, let me separate faculty into 3 categories and discuss how research with undergraduate students affects your career at each stage and makes a positive impact on your students. The three categories are:

- **Category 1:** untenured (newbie)
- **Category 2:** tenured (moving up the ranks), and
- **Category 3:** tenured at the top of your rank (professor, distinguished professor etc.).

Category 1

If you are a member of **Category 1** and a good teacher who enjoys performing research with students, you must always maintain an appropriate research focus if you want to keep your job. Yep, this is serious business. At many non-PhD granting institutions today, it is no longer sufficient to simply be a good or excellent teacher to achieve tenure. You must have a research record. That being said, do not do research that will not advance your career! Be sure to meet the goals of your college or university's tenure review process. Having sat on many department and campus wide tenure review committees as a professor, chair and then associate provost, I can tell you that side-bar research is nice but it does not carry much weight compared to peer-reviewed published work. Funding is great if you can get it. So try to get it. Keep writing proposals even if you get turned down. Faculty who sit on tenure review committees know that it is difficult to write a proposal and even harder to be awarded a grant. It is especially challenging for newcomers. Committee members understand the emotional letdown of being rejected even after receiving proposal grades such as two excellents, a couple of very goods and one good from the funding agency's five-member review board. As I have been both a proposal writer and a

reviewer on national panels, I can tell you from firsthand experience that it is a gut wrenching experience when you are turned down for a grant or if you have to turn down a meritorious proposal because of limited funding. What the tenure review committee does not understand is why you only tried once or did not try at all to obtain a grant. The take home point here is to write proposals. If your proposal is not funded, talk with the program officer at the funding agency and resubmit it with their guidance and suggestions. Believe it or not they want you to succeed.

If you are new to the proposal writing game, propose work in your field, work with collaborators who are respected in your scientific discipline, be an active member of your community and regularly publish and present the work you and your students have done at national meetings. If you are having difficulty obtaining a grant, connect with a researcher at a large institution who has a grant with the option to bring in visiting faculty. Additional funding for visiting faculty is often easy for them to obtain since their research has already been funded based on its scientific merit. Adding a couple of inexpensive undergrads and a faculty member for a few months in the summer is an easy give for funding agency program officers and scores big educational points for them in their year-end report. Be certain to ask up front if your collaborator has funds for you AND for your undergrad students before you agree to do the work. Working with others at a Research 1 (R1) institution might mean you will have to do work they want you to do, as opposed to work you want to do. But, this is okay. The R1 PI is paying and you will most likely get your name and your students' names on a few papers and benefit from being associated with the institution. By working with a large group you can make inroads to funding opportunities and eventually obtain direct funding for yourself and your students.

As for your campus tenure review committee, give them solid reasons to tenure you via your research accomplishments with your students and your collaborators. Do not forget that an administrator who obtained her degree in English does not know much about biophysics, but she knows that a collaboration with Johns-Hopkins University is a "big deal". It is okay to drop those big R1 names at social events especially when talking to administrators. They like to brag about their faculty's scholarly accomplishments with their peers, so give them something to talk about. "Did you notice that Professor X is now a team leader at NASA?" I can tell you that sounds pretty good at a dean's conference. They will also remember what you have done when they are reading your tenure portfolio. Oh yes, and when you do get funding, let the department chair, dean and academic VP know of your successes soon after it occurs. Do not wait until the end-of-the-year report.

As for undergraduate research assistants, try to establish a pipeline that may begin in high school and continue through graduate school to professional life; more about this later. If you are just starting to develop an undergraduate research team, as long as they are staggered by academic year, it is actually better to have more students than less. I often hear faculty say "I can't possibly work with more than two students at a time." Actually, I have found this to be the hard way to do it. Try to work with 4 students simultaneously. Just be sure that you have a competent senior, junior and a couple of sophomores or even perhaps a freshman in the group. As your seniors graduate you will have well-trained assistants for the next year. This will give you the opportunity to hit the ground running in the summer with rising juniors.

Another advantage to building a student pipeline is it will allow you to divest some of the early teaching responsibilities associated with bringing a new student into your research lab to your more experienced senior students. Senior level students who have been involved in your research program for a year or

two can teach the freshman and sophomores the ropes. It is also very beneficial for the upperclassmen to take on this mentoring role. They will learn how to explain their research to others. They will also find holes in their own knowledge and come to you with excellent questions, often initiating deeper discussions. If they do this frequently, they will improve their ability to explain complex scientific concepts well, which is beneficial to them during conference poster sessions and graduate school interviews. By having a senior level student instructing the newbies, you also get to avoid freshman questions like “how do I turn on the framus and what is that blinking thing over there do?” An upperclassman is excellent for this task. It is also less intimidating for a freshman or sophomore who is a bit shy to ask an upperclassman a question rather than the professor. Establishing a healthy pipeline is essential and in the long run it will be helpful to you, your research and your students. The idea with developing a research team is to make certain it results a WIN for your students (i.e., they learn something and they build their resumes) and a WIN for you (i.e. The effort results in work that can be presented at professional society meetings and publishable in peer-reviewed journals).

With regard to administrators at your institution, get in contact with them early in your career and ask them for help, money, support and grant writing assistance. Use the system that is in place at your institution and do it soon and often. If possible get an administrator to send you to Washington DC to talk to an NSF or NIH program officer. Find out what is being funded (and what is not) and go for it.

Category 2

If you are a **Category 2** person in science, you really have achieved academic freedom. No, not that type of academic freedom, but the freedom to do whatever type of research you like with undergraduate students without having to meet tenure expectations. At this point in my career, I sure did my fair share of weird science. It was a hoot and I still do it. This, however, is a dangerous time for you in terms of your research career. If you go too far afield with your work or your projects are too lightweight or sporadic, you may be putting yourself at risk for limited or no future funding. Normally, no self-respecting funding agency or foundation will take you seriously if you drop off the face of the planet for 2 or 3 years and then resurface and submit a \$100k proposal. So, unless you are at an institution that gives you all the internal funding you need for your work, you need to keep in mind that funding is important if you want to pay yourself and students a summer salary, travel to national meetings, purchase equipment, publish your work and perform research at remote facilities or field stations. As my mother was fond of telling me, “You have to put food on the table, clothes on your back, and a roof over your head first,” then you can go do the fun stuff. Obtaining funding, or at least making a good attempt at obtaining funding, means you have to stay active in your field. This will also help with academic promotion and the likelihood of internal support if external funding is not obtained. One of the things I heard often from faculty when I was department chair, chair of the research council, and then as associate provost was that “There just isn’t any funding for my research.” If this is the case, you need to switch gears and take on a more mercenary attitude. Instead of picking research that you want to do, find research that someone is willing to fund you to do and is simultaneously interesting to you. Go after that! This might mean performing research out of your comfort zone with collaborators who are new to you. It might mean doing some pro bono work first and establishing yourself in a different area of your field. Hey, it is an adventure and if you and your students get to do something fun, learn new things and get paid for it, what is the downside? As a tenured faculty member, there is not much to lose if you fail. By trying something new, you are opening up the possibility of funding for a project you may very well end up enjoying. Anyway, some administrator might notice your effort (especially if you

tell them) and help you. But, they will help only if you make a genuine effort to seek outside funding first. As associate provost, I certainly helped faculty who tried.

Category 3

If you are a **Category 3** faculty member who is still an active researcher, like me, you need to think carefully about your research and professional goals as well as personal life. Your remaining academic years are finite. In my case, I am certainly interested in my research and my students. However, I am also concerned about the next generation of faculty and students who will do research at Geneseo. I spend a great deal of time ensuring that faculty on my grant get what they need to do their research and progress. When I can, I mentor and help faculty who are not on my grant. For example, I encourage grant writing and sometimes use discretionary funds to help folks do research unrelated to mine. An active department is a supportive department. Everyone in our department is involved in funded summer research with undergraduates. This past summer we had 9 faculty and 25 funded students working on research. This makes for a community of faculty and students interested in and enthusiastic about research. The community becomes self-supporting after a while and encourages more research, grant writing and extra-research activities beneficial to all the groups. For example, during the summer we have weekly Wednesday night barbecues, ultimate Frisbee Thursdays, and pizza Friday lunches for all the students. These activities are arranged by the faculty and run by the students. I have the BBQ at my home every Wednesday where I supply the burgers, dogs and rolls and the students bring side dishes. They setup, cook and clean and I simply supply the house, grill and front deck. Another faculty member arranges Frisbee on Thursdays using the college's facilities while pizza Friday lunches are at a local Resteraunt that has outside picnic tables. Students pay \$4 each for all the pizza they can eat (and that's a boat load) and I cover the remaining cost. These events build a strong comradery among the faculty and students. It has become our culture.

Funding

If you are fortunate enough to have a grant and you are at a small institution where there is not much administrative research support, you will most likely have to do a lot of paperwork (not fun at all). This seems to be an ever increasing problem and burden at many institutions due to federal and state regulations. Sometimes it is worth it to train a senior student to help you with the administrative work and it gives them the opportunity to see the week-to-week operation of a grant, which may be helpful to them when they become a scientist, faculty member or just an adult. I also have my most senior students review proposals and papers. I certainly had no experience with grantsmanship when I became a faculty member and was shocked at the degree of paperwork required of me. My students will be better prepared.

Responsibility

As a senior faculty member, it should be part of your responsibility to protect young faculty so they can move forward with their undergraduate research effort. When needed, you should alert the administration to their needs and successes and help with their college wide recognition. You should actively promote their work on campus to improve their chances of tenure. You should also make undergraduate research an integral part of the educational experience of the students in your program. Be certain to use the adoption of the Undergraduate Research statement by the APS Council, CUR P/A Division, AAPT, AAS and SPS

(http://www.spsnational.org/governance/statements/2008undergraduate_research.htm) to argue for and justify the development or expansion of an undergraduate research program on your campus when making your case with your administrators.

As for your graduates, keep in touch with them. I have worked with, and still do work, with my graduates on funded research projects. Many of them have been, and continue to be, my collaborators and have helped my students get into graduate schools, helped others obtain jobs and helped still others get into REU programs. Former students can also help you obtain valuable used equipment, run time at their facilities and sometimes grants. Former students that have the financial wherewithal and who own companies may be interested in donating funds to your local foundation which can be used to support a summer fellowship or two. This is especially true, if they themselves had a good experience as an undergraduate.

An Observation

Successful undergraduate research occurs because of the efforts of faculty. Many times these efforts exceed a “normal” work load, by a lot. If the degree of the research is to have depth, reasonable duration and gravitas additional community support is required. That community includes your collaborators, scientific societies, organizations like CUR, faculty, deans, chairs, academic VPs, funding agencies, and enthusiastic students. To believe that high level undergraduate research can be achieved easily without cost and effort is just plain silly. Recently many colleges have jumped on the undergraduate research bandwagon. They often consider a 4 week faculty student effort an in-depth, life-altering, educational experience worthy of being called a research experience. This frankly trivializes the true nature of research. For example the National Science Foundation (NSF) considers a Research Experience for Undergraduates (REU) to be at least a 10 week full-time assistantship performed with research scientists. Inquiry, exploration and investigation takes time, effort, perseverance and long hours of mentoring. It is unlikely that a four week project during a busy academic semester will meet that criteria. For most of us, we became scientists because we sought, and still seek, answers about the wonders of the universe. For those of us who have become professors, we wish to convey that wonder to our students. The universe does not give up her secrets easily and it takes time to learn the craft of science so we can add to our knowledge base. To rush this process so your campus can say you have a capstone 4 week course is foolish. Let’s be sure we keep this in mind as we modify our college curriculum and redefine undergraduate research.

Stephen Padalino is a Distinguished Teaching Professor of Physics at the State University at Geneseo. He was awarded the system wide Chancellors awards for Research Mentoring and Teaching. He has obtained over six million dollars in direct research funding and more than a million in matching equipment funds. He has performed research with more than 200 funded undergraduate research students during the past 30 years. A large fraction of these students now have PhD’s in physics and engineering. All of them have advanced degrees. He has been chair of several departments including the Physics department and was associate provost for 5 years. He is currently collaborating with The Laboratory for Laser Energetics at the University of Rochester, The National Ignition facility at Lawrence Livermore National Laboratory, the National Institute for Standards and Technology, Houghton College, Ohio University and Lawrence Berkeley National Laboratory.