

## **AC 2007-1269: PERFORMING ENGINEERING RESEARCH AT NON-PH.D. GRANTING INSTITUTIONS**

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# Performing Engineering Research at Non-Ph.D. Granting Institutions

## Abstract

Research is becoming increasingly important at liberal arts colleges and masters universities. However, performing research at a non-Ph.D. granting institution has unique challenges when compared to a larger research oriented university. Faculty are expected to publish research articles with high teaching loads, limited lab space and equipment, and no graduate student assistants. This paper provides advice for new tenure-track faculty on how to effectively perform research at smaller institutions. In compiling the list of tips presented in this paper, we have not only relied on our experience as new faculty members but also received advice from more experienced faculty that represent several different disciplines of engineering.

The paper presents tips in several key areas: choosing the right research project, managing time effectively, supervising undergraduate research, finding collaborators, obtaining resources, and publishing results. One key tip that is pervasive throughout this paper is understanding the tenure requirements in your department at your institution.

## 1. Introduction

Research expectations have been constantly increasing at teaching colleges and universities where the primary focus is on teaching. This includes liberal arts colleges, comprehensive schools, and universities that have a Master's program but do not offer doctorate degrees. Research has several benefits to teaching oriented institutions. First, faculty members must stay current in their field. This makes faculty members more knowledgeable and as a result, more effective teachers. Having faculty members that perform research opens up opportunities to students. They can assist faculty in research, learn about cutting edge developments from talks by faculty or their contacts, and have meaningful discussions about contemporary issues in their engineering discipline. Lastly, publishing research papers and presenting work at conferences improves the visibility of the institution.

This paper describes tips and strategies for new faculty members performing research at a non-Ph.D. granting institutions. These tips were based on our own experiences and gathered from talking to other faculty members, representing a variety of engineering disciplines. Some faculty members are relatively new, starting in the last couple years. Others are untenured but nearing their tenure review. Finally, we talked to more experienced tenured faculty, some of which are chairs who are involved in reviewing tenure cases.

Our first piece of advice is to carefully pick a research topic and projects to work on. For example, it may be difficult to find undergraduate students with sufficient background to participate in a project that is too theoretical. On the other hand, if the research is too experimental, the need to obtain funds for adequate equipment and laboratory space may make certain experiments impossible. You also need to think of the looming tenure review and likely avoid projects that require significant learning and/or infrastructure development. Tips on selecting a research topic are presented in Section 3.

Faculty members have other responsibilities beyond research. Improving time management skills to juggle these duties is essential. We discuss techniques to choose your other responsibilities such as teaching, university and professional service to further your research. For instance, it may be possible to teach a senior level elective course related to your research topic. In such a class, students can be asked to pursue research oriented projects or produce tools to help the instructor in his or her scholarly activities. Time management tips are discussed in Section 4.

One of the main difficulties in performing research at smaller institutions is the lack of graduate assistants. Involving undergraduate students in research can be a tremendous asset in your research program as well as an excellent learning experience for the students. However, we have found that the success rate of undergraduate research projects varies widely. In section 5, we discuss how to define research problems that are approachable by undergraduate students and present additional tips on how to effectively work with students to further your research and their education. It is also possible to get assistance by collaborating with other researchers at your school, other schools, or in industry. Section 6 outlines tips for finding and working with collaborators.

Many new faculty members, fresh with a Ph.D. from a research university, are surprised at some of the challenges encountered at a teaching oriented school. Lab space and equipment you took for granted while you were at graduate school may not be available. It may be necessary to obtain resources in order to perform your research. Strategies for procuring resources are presented in Section 7. Another concern of new faculty is where to publish conference papers and journal articles. Tips on publishing are covered in Section 8.

## **2. Related Work**

Other papers that present tips about performing research at predominantly undergraduate institutions include the work by Engelken<sup>4</sup>. He discusses strategies for successful research with a focus on avoiding or coping with some of the economic and political obstacles encountered by new faculty at teaching institutions.

Howerton<sup>7</sup> presents case studies of three undergraduate research projects at Metropolitan State College of Denver describing the lessons learned from these projects. He stresses that undergraduate research is an extremely worthwhile experience for both the faculty and the student and encourages them to try it at least once.

The paper by Schuster and Birdsong<sup>10</sup> describe the challenges and rewards of establishing an undergraduate research program in a primarily undergraduate institution. They give details on best practices when starting an undergraduate research group including the choice of a project, funding, organization and management, and project documentation.

Hernandez<sup>6</sup> describes how a course with low enrollment provides a unique opportunity to effectively combine teaching and research into a research oriented undergraduate course. He presents a case study on his special topics class on digital image processing. The paper provides

a detailed account of the course which could be a great starting point for a faculty member interested in teaching a similar class.

Hardin and Hodges<sup>5</sup> compare the tenure requirements at large research oriented universities and small teaching oriented institutions. They stress that it is essential for the new engineering educator to understand both the written and the unwritten tenure requirements by reading all of the available material as well as talking to department heads and other faculty members.

Brent and Felder<sup>2</sup> suggest the use of a mentor program for new faculty members to help them deal with problems in research, teaching, and time management, and eliminate the feeling of isolation that is common during the first few years in a new academic position. The authors quote data from a study in Boice<sup>1</sup> that shows that in order to get off to a good start in research, it is necessary to become efficient in time management including limiting the time spent preparing for teaching and scheduling regular time for research and networking.

Colbeck<sup>3</sup> describes how different faculty members devoted time to research. Her paper looks at professors in both research and teaching oriented institutions. She finds that the faculty surveyed in her study spent more time on teaching than on research. Colbeck also notices that the production of research was somewhat constricted by the narrow definition of what some institutions considered as “acceptable” scholarship.

The book by Wankat<sup>11</sup> is a great resource for new engineering educators. It concentrates on the development of time management skills in new faculty and discusses effective and efficient techniques for teaching, scholarship, and service. Reis<sup>9</sup> addresses his book mainly to graduate students and postdoctoral researchers preparing for academic career. However, the last chapter of the book is dedicated to the first years in an academic position and includes advice on time management, teaching, research, professional responsibility, and tenure.

### **3. Choosing Research Projects**

Choosing a research topic that will be successful at an undergraduate institution is a critical step when creating your research program. The tips below assume that the faculty member is interested in a successful research program as well as a successful tenure review. The tenure track process, among other things, places some time restrictions on when research needs to be completed.

#### **Tip 1: Continue in an area closely related to what you already know.**

In the four to six year period you have before your tenure review, there is typically not enough time to completely change your research topic from what you have been previously working on. Focus on areas that are closely related to what your field of expertise. Changing research topics is difficult at a non-Ph.D. granting institution unless you have a colleague already experienced in the field you want to explore.

**Tip 2: Have two to four related projects so you can always make forward progress.**

All of the people we talked to work on multiple research projects which are in different phases. This allows them to always make progress in at least one project. Some projects may have to be put on hold for a variety of reasons: research requires large blocks of time, waiting for feedback on a submitted paper, waiting for students to finish experiments, waiting for a particular piece of equipment that will not arrive for another month, etc. Also, some projects may not work out at all and produce negative results which cannot be published. It is a good idea to have another project to fall back on.

While the people we talked to do worked on multiple research projects, their projects were related to the same main research topic. Here are some examples of research projects that can be split into related subprojects and general tips on working with multiple projects from the faculty members we talked to:

- While obtaining experimental results in lab, work on a similar problem using computer modeling. (To generalize, work on experimental and theoretical questions related to the same problem.)
- While obtaining/processing data for one project, set up the infrastructure for the next project.
- Work with different collaborators on each project, taking advantage of the knowledge base of each collaborator.
- Reserve projects (or a portion thereof) that can be done by undergraduate students in the future.
- Work on larger problems during the summer and tackle smaller problems during the academic year.

One way to increase your research visibility and/or publication count, without affecting quality and consuming much time, is to extend your research to related applications. Often an algorithm used to solve one engineering problem can be modified or extended to fit another application.

**Tip 3: Do not be too risky in your research.**

Tenure review committees expect a new faculty member to show an evidence of continuous scholarship throughout the pre-tenure years. You will be expected to show research results from the time when you start your appointment to when the final tenure review occurs (pay attention in advance to when the tenure file is due during that final year). Do not invest significant time in research that will not produce publishable work. For instance, it is risky to spend your first four years developing infrastructure and then hope that you publish several papers just before you go up to tenure.

It is also risky to explore a research problem where you are unsure of the success. However, this is the nature of most research problems. If possible, run shorter simplified feasibility studies that can determine if the project is likely to succeed or fail. Often, it is possible to present feasibility studies at workshops.

#### **Tip 4: Understand the limitations of a teaching institution.**

Teaching institutions have smaller research budgets and more limited infrastructure than research universities. You need to keep this in mind when selecting a project. For instance, there may not be an adequate lab space or equipment to conduct your experiments. If your project requires extensive experimentation, you should be prepared to spend many hours in the lab without significant assistance from others. For computational modeling and simulation projects, there may not be a pool of computers to run your simulation on.

In many cases it is possible to address these constraints (see Section 7 for tips on obtaining resources). However, it is important to keep in perspective the amount of time to obtain and set up resources. In addition, you also need a backup plan in case you are unable to secure resources for a project.

#### **Tip 5: Understand the factors used to judge scholarship.**

Almost everyone we talked to enjoys research and would be involved in research even if it was not part of the tenure requirements. However, almost everyone said that the tenure requirements affected how they performed their research.

Different institutions have varying tenure requirements with respect to scholarship. Virtually all institutions, even predominantly undergraduate institutions, have a publication requirement. It is important to get a sense of the requirements with respect to quality and quantity so you do not spend time on activities that will not count. Some institutions do not define how many publications are needed for tenure. In this case, talk to other faculty who arrived at the same time as you or a few years earlier (especially if they have just completed a mid-tenure review) and compare notes. Be careful with advice from more experienced faculty as they may have had different tenure requirements when they received tenure. Of course, faculty that serve on the rank and tenure committee can potentially be a good source of information.

It is also important to understand to what extent the following factors contribute to scholarship if at all: publishing pedagogical papers, synthesis or review papers, setting up labs for research and teaching, writing grant applications, developing software, exploring different research areas, performing research that is unsuccessful, and involving undergraduate students in research.

### **4. Time Management**

One of the most difficult challenges to conducting research at a smaller institution is finding the time for it. This section presents tips on how to manage the time required for teaching, research, and service.

#### **Tip 1: Spend summers doing almost exclusively research.**

Virtually all of the people we talked to used the summer to concentrate on research. Unlike the academic year, summer is free of classes and other departmental commitments. We recommend

taking this step further and not spend any time on preparing for classes until a couple of weeks before the upcoming school year.

**Tip 2: Reserve summers for the more time consuming tasks.**

Spend the summer doing the tasks that take a lot of time such as performing experiments, writing code, and analyzing data. Finding time to do these tasks can be difficult during the school year. One possible strategy is to perform the research in the summer, write up the results in the fall, and plan/prepare for the next summer in the spring.

**Tip 3: Plan research into your schedule during the school year.**

Some faculty at our institution reserve a block of time (typically a half or full day) to concentrate on research. Many do not permit meetings to be scheduled during this block. Unless research is scheduled, it is difficult to find time given the other responsibilities of an academic position. Another technique is to note some paper deadlines during the school year. For added motivation, one author places the call for papers on her wall behind her monitor forcing her to see them each day. Teaching has constant deadlines: Thursday morning's lecture must be ready before Thursday. By assigning deadlines to your research, you are more likely to concentrate on both. Lastly, it is important to follow your schedule. If you reserve Wednesday for research, then Thursday morning's lecture needs to be done Tuesday night.

**Tip 4: Stay engaged if you cannot find the time to do research.**

It may be difficult to find time for research, especially during the first year or two in an academic position when one is teaching several courses for the first time. In this event, you should still try to keep current of the latest developments in your field by browsing journals and conference proceedings, discussing research with colleagues, attending seminars and professional meetings, and reviewing papers.

**Tip 5: Look into reducing your teaching load to increase research time.**

Some institutions offer a mini-sabbatical for faculty in the middle of the pre-tenure years allowing the faculty to fully engage in research for a term without other responsibilities. Even if your institution does not officially have this policy, it never hurts to ask. If you can get paid via alternative sources, you may be able to get an unpaid leave of absence. Getting an entire term off may be unrealistic, but getting a one course release may be more reasonable. Also, try to minimize the number of new course preparations you have. Early on, try to limit the number of course preparations to one per term. Later on, once you have taught several different courses, try to have a few terms where you have no new course preparations. Lastly, be careful that any deviations from the normal teaching load may be accompanied with increased expectation in research when your tenure file is reviewed.

## 5. Undergraduate Research

The authors believe that research experience should be treated as an important part of undergraduate education, similarly to how the design experience is regarded. It is especially advantageous to students who plan to apply to graduate school. Contributing to research projects, working on open-ended problems, and presenting work at conferences are often unforgettable and extremely enriching experiences for an undergraduate student. Participating in an undergraduate research program triggers students' curiosity about the world beyond the classroom, enhances their understanding of the subject, and deepens their feeling of involvement and achievement in the field of electrical and computer engineering. These are undeniable benefits of undergraduate research, but how can we ensure that a faculty member can benefit from this experience as much as a student?

### **Tip 1: Carefully select a project for undergraduate research.**

Supervising undergraduate research students will force you to stay involved in the research thorough the quarter. However, some faculty members we talked to admitted that they often feel that the time spent helping undergraduate students to get started on a research project could have been spent more productively if they were doing the research themselves. Our advice is to select the undergraduate project carefully. Successful undergraduate projects are short (can be completed in one or two terms), well-defined, and have a small learning curve for the student. Such project could be based on a small self-contained problem that the professor has had no time to explore. It could also be a smaller piece of a larger project.

The project topic should be interesting for undergraduate students. They should be able to understand the big picture of the work and appreciate the final results. Students need to be excited about the project in order to feel motivated to work on it. Similarly, application oriented projects may be a good fit for undergraduate work. The project should mimic the research experience and should not engage the student in busy work that requires no thought.

The faculty member should have reasonable expectations from the student. For example, one should not expect a student to be a major contributor to a paper submission due at the end of the quarter. Also, students vary in ability and motivation. Do not get discouraged from supervising undergraduate research projects based on one bad experience.

### **Tip 2: Encouraging undergraduate students to participate in research.**

To encourage a student to participate in undergraduate research during an academic year, faculty member can give him/her credit for independent studies or a directed research course. Some students desire a last-minute research experience to strengthen their application to a graduate school. In this case, they may be even willing to volunteer their time for a research project. A faculty member interested in recruiting undergraduate research students should also talk with his/her chair or dean. There are often donors who give small sums of money to the department or college that could be used for student salaries.



Research projects can also be incorporated into a class, especially a senior level elective. For example, a final project in a class could lead to the development of a software tool that can be used for research or an execution of an experiment needed to complete a research project. A student may also write a paper on a particular topic of interest to the instructor and thus help the faculty member locate resources and learn about a new topic.

To recruit the best students, advertise the above options in courses, on the departmental website and by sharing research results through posters and seminars.

**Tip 3: Find the best students early on.**

It is a good idea to attract undergraduate students when they are in their junior or even sophomore year. By the time they are seniors, they will be more likely to contribute to the project than somebody who has just started.

**Tip 4: Mentoring undergraduate research students.**

Undergraduate students need lots of patience and careful guidance. Their research tasks should be clearly defined (preferably written down) and discussed in weekly meetings. If there is more than one student working on a project, it is advised to hold both weekly group meetings and weekly one-on-one meetings. Meetings should be used to discuss past progress, next steps of the project, and also to remind the students what the big picture of the research is. In addition, the faculty should provide time when students can ask questions outside of the arranged meeting times. Students can also write periodic progress reports; their understanding of the project is strengthened if they can write about it.

## **6. Collaboration**

One of the main challenges of doing research at a non-Ph.D. institution is the lack of graduate students to assist in your research. Most of the work needs to be done by the professor. Finding collaborators can tremendously improve your research quality and efficiency.

**Tip 1: Continue to work with people you did your graduate studies with.**

Depending on your relationship with your graduate advisor, you may elect to continue working with him or her in some fashion. You may find it helpful to work with fellow graduate students, especially those who are in similar positions at other universities. One advantage of continuing such work is that they already know you and are generally more forgiving if you run into time management issues. On the other hand, they may have the same expectations as when you were in graduate school which may lead to friction. Be sure your collaborators are aware of your other responsibilities.

**Tip 2: Find contacts at nearby research institutions.**

If possible, look for contacts at research universities located near your institution that may result in a collaboration effort. One advantage of collaboration with a faculty member at a research

institution is the potential of sharing resources: lab space and equipment, research seminars, meetings with research faculty, etc. You may also get assistance from graduate students; for example, they may be able to mentor undergraduate research students from your institution.

Another avenue is to do apply for a grant together. Grants that contain collaborative efforts are generally viewed favorably. It also opens the door for money that is not typically available for non-Ph.D. granting institutions due to lack of research experience and graduate students.

**Tip 3: Spend the summer doing research via an internship.**

Research labs (either government based or in industry) are another good source of collaboration. The best way to get started is via an internship. Besides getting paid, it forces you to concentrate on research without worrying about the other responsibilities. If the internship goes well, you may decide to continue collaboration efforts during the school year. Depending on your university policy, it may be possible to extend an internship into the following term by taking an unpaid leave of absence.

Even if you have no desire to do an internship, it is a good idea to reach out to local industry – maybe giving a talk on your research. In return, they can give an industry perspective on the most pressing open research problems, something that is often missing at many technical conferences and papers. Industry contacts can also positively affect your whole department by organizing interesting seminars for students, donating lab equipment, or sponsoring student scholarships.

**Tip 4: Attend technical conferences and network with attendees.**

Perhaps the best people to collaborate with are those working on similar problems to what you are exploring. To meet these people, attend technical conferences in your subject. Take advantage of breaks and social activities to network with other attendees.

**Tip 5: Understand how collaborative efforts will be viewed by your institution.**

Before embarking on a collaborative project, it is important to be aware of how the project will be viewed when you go up for tenure. For instance, you may be viewed in a negative light if most or all of your publications were written with your former advisor as a co-author. The tenure committee may want to see original work produced on your own. If all of your projects are collaborative, they also might want evidence that you are a primary contributor for some of the papers and that you are not merely riding the coattails of other researchers. Another potential source of friction is if two colleagues at the same institution do all of their research work together. Policies vary widely by institution and department so it is important that you are aware of any potential consequences.

## **7. Obtaining Resources**

Resources for research work are usually very scarce in primarily undergraduate institutions.

### **Tip 1: Negotiate your start-up package.**

It is important to negotiate an appropriate start-up package. Items to ask for include funds for equipment, books, travel to conferences and collaborators, student salaries, summer support, and lighter teaching load during the first couple of years.

### **Tip 2: Keep asking for resources.**

There are often sources of internal funds in the college that can be used to further your research work. Educate yourself about available resources and keep asking your administrators for reasonable support especially after you had a successful review or a paper accepted for publication. Remember that they all want you to succeed in establishing your research program.

### **Tip 3: Write grant proposals.**

Writing a grant proposal takes an enormous amount of time. Some faculty members discovered that in the time it would take to write an external grant, they could have already had accomplished a fair amount of research. This is true, however, for one of the authors of this paper writing a grant proposal is often a very good exercise because it forces her to write down ideas about the research, summarize results, do a thorough literature search, establish a research plan, and generally become more organized about a particular research project.

If a faculty member decides to write a grant proposal, it is advised to start with smaller grants which are likely to be less competitive. Once you are successful with several smaller grants, it is time to apply for more competitive grants that provide a larger sum of money.

If you have collaborators in a larger institution, it is a good idea to apply for a grant together. A faculty member in an undergraduate institution can be a co-PI on a joint grant. One institution can also subcontract the work to the other institution.

There are some grant opportunities that are targeted at undergraduate research or at research in an undergraduate institution (such as the National Science Foundation Research in Undergraduate Institutions (RUI) Program<sup>8</sup>). Educate yourself about these opportunities and take full advantage of them.

### **Tip 4: Collaborate with other departments in your institution.**

Learn what equipment is available in other departments in your college. You may be able to use that equipment or at least get data needed for your research. Talk to faculty in other departments to see if you could establish a collaboration to share research resources such as a lab space.

## **8. Publishing Your Research**

Sharing research results with the professional community is essential to furthering one's career. Since writing papers takes a lot of time, it is important to make the right choices and submit the articles to the right venues.

**Tip 1: Establish a balance between conference and journal publications.**

Conference papers are easier to write because they are usually shorter and they have a definite deadline. Conferences are also a great place to learn about the latest developments in the field and to network and establish collaborations. However, if your institution requires journal papers for tenure, it is in your best interest to carve out some time to write them. Understand what the tenure expectations are in your institution and make sure that you have a balance in the type of publications.

**Tip 2: Selecting the right venue for publishing research.**

Again, it is important to understand the expectations in your department, college, and institution regarding the type of journal and conference publications. If the requirements are not very strict, there are several choices that you may have to make. First of all, in general, peer-reviewed publications are valued higher than non peer-reviewed articles. With limited time during which we can do research, it is wise to avoid producing a large number of non peer-reviewed publications. However, some non peer-reviewed publications are more recognized than others, for example a book chapter or an invited presentation at a professional meeting.

In addition, there are many peer-reviewed conferences and journals to choose from. Some of them are top-tier and recognized to be the leading conference or journal in the field. Others are smaller publications, more subject-specific. A faculty member has to choose wisely where to send his/her work. Since conferences have usually a shorter turn-around time, it is common for faculty members to submit their work to the best or the largest conference in their field and if the paper is rejected, submit it to a smaller conference or a symposium. It is a good approach; however, one has to be careful to maintain a consistent record of publications (that is having a similar number of articles every year).

Journal articles take more time to write and their review process may take a year or even longer. Taking into account how little time faculty in smaller universities have for research, it is wise to consider not only the quality of the journal but also how long the review process will take. It is common for top journals to take much longer to review a paper than for some smaller, field-specific publications.

It is also important to match the type of a journal or conference with the type of research a faculty member is doing. In some fields, experimental or application oriented research is not accepted by all journals.

Note that it is very difficult for a researcher from a smaller university with a high teaching load to join a program committee of a large conference or become an editor of a top-tier journal. Smaller venues such as workshops, symposia, or lesser known journals may often offer unique opportunities for leadership, networking, and collaboration.

### **Tip 3: Do not get discouraged.**

It is very important not to get discouraged if your paper gets rejected. Concentrate on improving the paper, follow the advice of the reviewers, reconsider the venue where you are trying to publish your article and submit it again.

### **Tip 4: Write something every day.**

One of the faculty members we interviewed mentioned that “slow progress is better than no progress”. Try to write something every day or two.

## **9. Conclusion**

Recently research has taken more central role at primarily undergraduate institutions and is now a required part of tenure review at many non-Ph.D. granting colleges and universities. We address this paper to new engineering educators faced with the challenge of performing research with limited resources (lack of graduate students, insufficient time due to high teaching loads, and inadequate equipment funds and lab space). To help new faculty cope with these challenges, we have provided tips on how to choose research projects that are appropriate for an undergraduate institution, how to wisely allocate time for research and teaching, how to take advantage of undergraduate research and collaboration opportunities, how to obtain resources for research, and how to be successful in publishing research results. A general advice that repeats through the different sections of this paper is to make sure that the faculty member understands what is expected from him/her in terms of scholarship by the department, college, and the university. For example, in a particular institution, writing grant proposals may not be required to receive tenure while involvement in an undergraduate research may be necessary. Since many of the recommendations listed in the paper require a certain level of self-discipline and a constant re-evaluation of one’s goals and achievements, we also suggest starting each academic year with a plan and a list of goals and evaluating the progress at the end of each term.

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