AC 2007-627: NEW FACULTY, UNDERGRADUATES, AND INDUSTRY CONTRACTS: OBSERVATIONS AND LESSONS LEARNED FROM ENGINEERING PROFESSORS

James Squire, Virginia Military Institute

Dr. James Squire is an Assistant Professor of Electrical Engineering at the Virginia Military Institute. He received a B.S. in Electrical Engineering from the United States Military Academy in West Point, NY and served in the army as a Military Intelligence officer during Desert Storm. Although his PhD is in electrical engineering, he completed his doctoral work in a biomedical engineering laboratory at MIT and has interests in analog and digital instrumentation, signal processing, biomechanics, patent litigation, and cardiology. At VMI he teaches analog circuitry, continuous time and discrete time signal processing, and advises a variety of independent study projects.

Charles Bott, Virginia Military Institute

Dr. Charles B. Bott is an Assistant Professor in the Department of Civil and Environmental Engineering at the Virginia Military Institute in Lexington, Virginia and an Adjunct Professor in the Department of Civil and Environmental Engineering at Virginia Tech. His research and consulting activities focus on nutrient removal in both domestic and industrial wastewater treatment applications. Charles also specializes in the treatment of unique chemical constituents in industrial wastewater applications by both physical-chemical and biological processes. Prior to joining the faculty at VMI, Charles was an Environmental Engineer with Parsons Engineering Science and Adjunct Professor in the Department of Civil and Environmental Engineering at Virginia Tech. He was awarded the WEF Harrison-Prescott-Eddy Medal for a paper published with Dr. Nancy G. Love in Water Environment Research in 2002. Charles received a B.S. in Civil Engineering from VMI, a M.S.E. in Environmental Engineering from the Johns Hopkins University, and a Ph.D. in Civil and Environmental Engineering from Virginia Tech.

Matthew Hyre, Virginia Military Institute

Dr. Matt Hyre is an Associate Professor of Mechanical Engineering at the Virginia Military Institute. He received a B.S. in Mechanical Engineering from the United States Military Academy at West Point, NY. He completed his Ph.D. work at MIT in the areas of computational modeling and multiphase flows. He has over 10 years industrial experience in the modeling of environmental technologies and manufacturing processes. His current interests include numerical analysis, virtual reality modeling for industrial processes, monte carlo methods in numerical radiation modeling, computational modeling of viscoelastic materials, and biological thermofluids. At VMI he teaches energy conversion, computational modeling and virtual design, biothermal fluid mechanics, aerodyanmics, and advises a variety of independent study projects.

New Faculty, Undergraduates, and Industry Contracts: Observations and Lessons Learned from Civil, Electrical, and Mechanical Engineering Professors

Abstract

Most new faculty have little experience managing contracts, and most have minimal experience advising undergraduates conducting research. Combining these two roles leads to both synergistic and antagonistic opportunities/challenges often not obvious at the outset. In this paper, relatively new (3-6 years) authors from civil, electrical, and mechanical engineering departments describe their observations on this topic based upon over 30 different contracts, specifically:

- 3 types of research contracts, and the benefits and difficulties with each.
- 6 tips for success in choosing and writing suitable contracts
- 3 tips for success in choosing suitable students
- 3 tips for success in conducting projects
- examples and analysis of projects that went well
- examples and analysis of projects that went poorly
- things the authors wish they had known in their first year

As an example, using both specific examples and inductive generalizations, the suitability of federally-funded and industry (including traditional industry, consulting firms and municipalities)-funded contract sources are analyzed. Each of these funding sources is evaluated for undergraduate research suitability with respect to typical timelines, funding agency's criticality of success, the undergraduate's class year, and the professor's time before tenure review.

I. Introduction

Ph.D. granting universities have long expected their faculty to conduct an active research program, however in the past two decades an increasing emphasis has been reported in the amount of emphasis undergraduate-only engineering schools are placing on their faculty to build research programs.[1] While some studies have questioned whether this has a negative impact upon the teaching experience, especially of technical subjects[2,3,4], it will likely continue to increase as administrators seek to improve faculty productivity and university income[5], and states enact measures to encourage this.[6] The past two decades have also seen a concomitant increase in the desire from university administration through federal granting agencies for engineering faculty members to develop active learning strategies to teach undergraduates, a practice recommended by numerous recent studies. [7,8,9].

Given a limited amount of time and pressure to actively involve undergraduates and conduct research, it is commonly assumed that new faculty intuitively understand the need to combine the teaching and research domains. While that is true, it is not obvious how do this effectively, and this paper conveys the best practices learned by three faculty members representing civil/environmental, mechanical, and electrical/biomedical engineering with a combined 18 years experience and 30 grants/contracts that involved undergraduates.

All Research Contracts Are NOT Equally Suitable for Undergrad Research

Research contracts can be broadly grouped by the funding agency: the federal government (e.g. National Science Foundation) and industry. "Industry" in this sense includes both private industry and private consulting work where the clients are typically consulting engineering firms or municipalities. Each funding agency presents its own unique challenges for the new professor seeking to employ undergraduate researchers:

- Federal Government: Difficult to obtain grant funding (often approve less than 10% of applications), many requests for proposals require substantial initial pilot study work to be completed, often for large, multi-year contracts that do not give undergraduates with only a semester or two an ability to appreciate the entire project in context, often for basic-science research that do not give undergraduates an opportunity to get a feel for applied engineering design and development
- Industry: Want short-term results so often not tolerant of learning curves. They seek to hire an "expert consultant" to solve the problem immediately since otherwise would assign the problem to an employee to solve. Usually not tolerant of a null finding; if a direct solution to the problem is not found, they expect/require alternative approaches to be pursued that may be outside a specific undergraduate area of study. The authors have empirically found these challenges are less problematic than the limitations of the other two funding sources, and we recommend that undergraduate research topics be funded primarily from industry contracts.

Why One Should Use Undergraduates for Industry Contracts?

- Research is expected for tenure, as is the use of active learning techniques for undergraduate education; combining both is an obvious way to punch both tickets while earning funding dollars. However, this is not the only reason to use undergraduates for industry contracts..
- Undergraduates are a "force multiplier" if you are in an undergraduate engineering college and do not have access to graduate students.
- Use of undergraduate students can help the new professor with managing the contract itself. Most professors with consulting experience have experienced the "consulting project that will not die" syndrome that occurs when unforeseen problems require a change in the work done which the client then leverages to keep requesting incrementally more work be done before payment. Making it known that the work involves undergraduates with a definite semester schedule can end these incremental changes and allow the professor to reframe additional desired work in the context of a new contract for the following semester.

Undergraduates vs. Graduate Students

The use of undergraduates for industry research is not a panacea, and presents the new professor with challenges not generally seen when employing strictly graduate students.

- The most obvious problem is that since they have less academic training, undergraduates require more supervision than graduate students. Although it might be expected they have less motivation than graduate students since only a class grade rather than their entire degree is dependent on the quality of the work, the authors have found the process of self-selection for this optional research activity results in a very self-motivated student group.

- A less obvious problem is with the new professor rather than the student: most new professors have either no experience being undergraduate research advisors, or little if they advised some as a graduate student. This can lead to inappropriate expectations. Graduate students are usually more independent and thus require less management experience on the part of the advisor.
- The high turnover rate from graduation means continuous loss of "institutional knowledge" with undergraduates. Professors typically have only at the outside maximum 5 semesters of work from undergraduates starting in their first sophomore semester, and the first semester is usually spent substantially in training. In some cases, this time is substantially reduced if classes taught during the junior year are necessary to inform the student prior to commencing a project. It is therefore imperative to establish a steady pipeline of undergraduates in which the more senior ones train the newest members to minimize the time the professor must spend teaching young undergraduates basic research skills (including laboratory, writing, and administrative skills).

II. Tips for Developing Appropriate Research Contracts

It is clear that some industry sponsors/contracts are more appropriate than others for undergraduate research projects. Sponsors should have an appreciation and understanding that the work will be completed by undergraduate students, they should value the educational component of the work, and they should have expectations fully in accordance with that of the research advisor. Contracts should have a duration of approximately one year or less and should result in publishable data. The following general guidelines are suggested:

- Provide projects that are small enough in scope and content that the work can be completed during a summer and academic year. This might be a specific phase of a much larger project, but regardless, the student must be exposed to the full scope of his or her own project.
- Ensure that students are exposed to the profession through applied projects, the importance of which can easily be demonstrated by the value provided to the industry.
- Pay the undergraduate a nominal stipend for both summer and semester work so that the perceived value of their work is enhanced. Provide credit towards graduation requirements.
- Ensure that projects emphasizing laboratory experimentation are combined with field trips, onsite meetings with industry representatives, and/or field exercises.
- Use groups of no more than 2 students for any given project task.
- Ensure that each project leads to at least one publishable paper (conference or journal) and a 20-30 minute presentation. Ensure that each student presents his/her work in at least one state-level or national meeting of a professional engineering organization or other comparable venue.

Tips for Developing and Maintaining Industry Contacts

Industry contacts can be quite difficult to make and develop to a point where a research contract follows. The authors concluded that it is much easier when the faculty member has already established contacts as a result of prior employment in a consulting or industry position. In at least one engineering discipline, the types of experimental work often being conducted is that which the consulting firm or industry would likely have done themselves in-house 10 years ago, but have since decided that outsourcing this work would be more effective. Several suggestions to develop and maintain contacts involve:

- Attend conferences and technical meetings where potential contacts are likely to be present.
- Serve on professional committees with potential contacts.
- Present yourself as someone who understands the applied nature of the problems experienced by industry contacts.
- The most important thing to "market" is your ability to do experimental or modeling-based investigations for a fraction of the cost compared to the private sector. However, it is critical to be as upfront as possible about the compromises that come with using undergraduates to conduct the project.
- Attempt to get involved in a larger project where you provide a service that cannot easily be offered by the private sector.
- Present and publish work that has an immediate interest and application for potential contacts. Send them a copy of the presentation or paper and indicate that you would be willing to do something similar for them in the future.
- Do a really good job on the first contract to establish a good first impression and a good reputation. Deliver more than promised and more quickly than expected in the first contract.

Tips for Selecting an Appropriate Project

Project success is not company critical. There needs to be an understanding on the part of the sponsor of the value provided to the project by the professor being involved and the low-to-zero cost of accompanying student time. The sponsor should be interested in not only the accomplishment and outcome of project, but they should also recognize and value the educational component. Sponsors may be able to favorably publicize their funding of an undergraduate project that encompasses the education of new engineers. The project should be in the advisor's area of competency with minimal requirements for new tools and instrumentation. The project might be one where the advisor could do all of the work (not including long-term experimentation or data collection) him/herself over a long weekend.

Proposals to conduct research should not be submitted blindly. In general, the scope of a project should be well defined through telephone and email correspondence such that the final proposal or scope of work is somewhat perfunctory in nature. Costs, financial and other administrative matters, and schedule should be addressed well ahead of the final proposal.

Tips for Managing Administrative Issues

In most cases, a good approach is for the advisor to act as a project manager leading a team of project engineers on the project. The students should be paid a nominal stipend from the project so that their perceived contribution to the project is valued. Students should be exposed to the financial and contracting issues associated with the project, because this experience is probably just as valuable as the technical aspects. Other administrative issues include:

- Indirect Costs: Most university offices of sponsored programs (OSP) require payment of indirect costs. In some cases, potential project sponsors are not willing to pay the high rates now commonplace. The sponsor may be willing to pay indirect costs towards the Principal Investigator's stipend but not student stipends and other direct costs. The authors have found that the best solution is for the sponsor to contact the OSP, and specifically state that they will not fund the project unless the indirect cost rate is reduced to some value (email correspondence is sufficient). In most cases, the OSP is willing to accept the sponsor's terms versus declining the grant. The objective of the faculty member should be to discretely help the project sponsor to send this notice.
- Student Credit and Stipends: In some cases, there is hesitation associated with providing students both a stipend and academic credit towards graduation requirements. The author's opinion on this matter is that the nominal stipend demonstrates to the student their value to the project, while the academic credit recognizes their achievements with respect to enhancing engineering capability and skills. In the Civil Engineering Department, the policy is that only 3 credits of independent research can count towards required technical electives for graduation requirements. Any additional credit can influence student GPA, but it does not count towards other mandatory technical electives and courses. The principal investigator must also decide whether lump sum or hourly student payments are appropriate. One author routinely provides hourly labor payment, while another prefers lump sum stipends. Lump sum amounts paid are approximately $750-$1,500 for a semester and $3,000-$4,000 for summer work.
- Supplies and Travel: The contract should include sufficient budget for supplies and travel costs. The authors have found that this cost is often significantly underestimated during the budgeting process.
- Professional Liability: In cases where the project has immediate engineering design implications, the professional liability of the principal investigator can be a significant concern for the sponsoring organization, the university, the OSP, and the professor. In most cases, the OSP holds general liability insurance, but there is no professional liability and no Errors and Omissions insurance. In some cases, it may necessary to forgo the project due to liability concerns. Otherwise, one mechanism is for the professor and OSP to indicate that they accept no professional liability, and the indemnification for the project as a result of negligence, errors, and omissions is limited to the value of the contract. This may or may not be acceptable to the sponsoring agency.

Tips for Publishing Work and Intellectual Property

Each project should lead to at least one publishable paper (conference or journal) and a 20-30 minute presentation. The student should present his/her work at a state-level or national meeting of a professional engineering organization or other comparable venue. Limitations to publication include project confidentiality or intellectual property concerns, commonly associated with industry contracts. The project advisor should start very early in the project to discuss publication and the value for the student to present their work in a professional venue. Often though discussion, it is possible extract from the sponsor exactly what portions of the project should remain confidential and what parts could be published or presented. Again, the student's involvement in and understanding of contract confidentiality requirements provides an important lesson for future employment and graduate school. In some cases, the sponsor may be interested in publicizing that they have funded an undergraduate research project. At this level, it is also important to recognize that conference papers and posters may better benefit the student than a journal publication. Furthermore, visibility of the undergraduate research program at conferences may enhance the potential for future work with other industrial sponsors.

Two Examples: Good and Bad Contracts

Good

An industrial sponsor funded a project to evaluate the potential for a biological wastewater treatment process that they market to accomplish a new objective (i.e. biological phosphorus removal). In this case, the experimental work required to do this evaluation could not be accomplished by the sponsor themselves, and there was really no way to accomplish the project objectives by contracting to the private sector. In addition, the treatment plant of interest was located within 45 minutes of the university, and sampling time was a critical factor. The industrial sponsor was also looking for an independent third party to perform the evaluation and to publish the results to increase the value of their future marketing claims about their process. The scope of work was negotiated by the sponsor and the professor, and the final proposal was submitted without significant problems or delays. The experimental work was conducted during the summer, and a final report was submitted that was beyond the expectations of the sponsor. Abstracts were also quickly submitted for conference publications. For the specific treatment plant investigated, the experimental data were somewhat ambiguous as a result of factors beyond our control, but the sponsor asked us to continue our work with evaluations at other similar sites on the east coast (which required travel to those respective plants).

Bad

A project that a professor had been involved during previous employment as a consulting engineer had changed hands and was currently being managed by a different consulting firm and a completely different group of engineers. On request from the client, the professor was given a lump sum contract by the consulting firm to assist with the project because of his involvement over the last few years. It was clear the budget would not be spent, because the new firm was not involving the professor in ongoing work associated with the project. As a result, the professor proposed three beneficial tasks that could be completed with the help of undergraduate students and would result in the expenditure of the full contract amount. Through negotiation of the scope of work, one of the more research-oriented tasks that would have been quite appropriate for undergraduate student involvement was eliminated. The scope of another appropriate task was modified to be a relatively minor fraction of the project, and the primary project task evolved to become a standard field sampling and laboratory analysis exercise with no significant research question to be answered or controlled by the professor and students. The primary project task was negotiated to a point where it could have been completed more effectively by a contract analytical laboratory and the consulting firm itself. The work was completed, but it was clear to all parties that the task was not appropriate for undergraduate student or university involvement. The consulting firm's expectations were not met. Fortunately, the outcome of the relatively minor research-oriented task was relatively successful, and the consulting firm may eventually implement systems based on that work.

III. Tips for developing a successful research group

Whether the research contract comes from industry or is governmentally funding, finding suitable students to conduct the research is a task which takes a great deal of preparation and patience. Generally, the three biggest challenges in the creation of a successful undergraduate research project team are:

1. *Continual loss of critical skills*
   Frequently only those students who are close to graduation possess the engineering skills and background to be of much help. Their project expertise is lost after one or two semesters of work

2. *Inability to identify undergraduates with an aptitude for research*
   It can be difficult to identify quality undergraduates who will thrive in the unstructured environment of independent research

3. *Lack of large blocks of uninterrupted time with students*
   Undergraduate engineering students tend to be heavily loaded with classes which leave them much less time to work on research projects than a typical graduate student

Tips for Developing Project Continuity

Perhaps the most critical task in creating a successful undergraduate research program is developing skill set continuity. This is nearly impossible if one tries to incorporate only those students who come to the project with the background needed to immediately make a positive impact. The key is to build a core group of students whose talents span the range from senior level students to those that have only a rudimentary understanding of engineering concepts. Inevitably, the older and more experienced students end up mentoring those who have just joined the project. This transfers much of the initial introductory project training from the professor to the senior project leadership. It also ensures that as the seniors graduate, there is a pool of younger students to step in to fill the talent void.

Another method for ensuring skill continuity is by embedding research project tasks within engineering classes. For example, the creation of an elective course in computational modeling which is offered during the fall of the senior year creates a whole pool of students capable of taking on tasks that involve FEM or CFD modeling. More rudimentary skills (experimental measurements, data acquisition, programming with structured languages or packages such as Matlab, etc.), can be included much earlier in the curriculum. This method has the added benefit of bringing industrial engineering projects into the classroom. This benefits all the students whether they decide to conduct research at some later date or not.

Tips for Identifying Undergraduate Students with an Aptitude for Research

Creating a good mix of students in an undergraduate research group requires “pipelining.” It is imperative that relationships are established with students as early as their freshman year. The most obvious way to make initial contacts with freshmen and sophomores is through classroom interaction. "Cherry picking" the most gifted students or those who are able to learn and operate independently is the most reliable way to create a good pool of talented lower level students. References from other faculty who have identified younger students that have the ability to function well in a research environment also serves as a great mechanism to create a short list of research candidates.

Often times, however, engineering professors have little or no contact with the freshmen or even sophomore students. An alternative means of introducing students to research projects is to have a forum where they are able to learn about different research opportunities. Having students currently in the research group introduce the projects has proven to be a very effective recruiting method. Rather than "cherry picking," the use of forums or alternative techniques aimed at presenting research opportunities to a wide range of students relies on self-selection. This is a less reliable means of developing a consistent talent base. Generally, younger students are not aware of the skills required in a research environment. Additionally, it is very common for freshmen and sophomores to overestimate their abilities and/or underestimate the time and effort research projects require. Unfortunately, the same can be true of higher level undergraduate students as well.

The other problem that can accompany "self-selected" students is that they may have motives which have little to do with a desire to conduct research. The two most common motives are money and the hope of an easy "A." Since there will inevitably be students who are more interested in a grade or money than the research, the project must be structured and implemented in such a way that these students can thrive…or fail.

One method of reducing the number of students who take on research in search of a "free ride" or to make some quick money is to have them sign a contract outlining their responsibilities and expectations. The contract should outline the hours expected to be worked, the work schedule, and the project goals and deadlines. It should also make it clear that the student must be self-motivated and contact the advisor as necessary for guidance. Additionally, the student should understand it will not be the professor's duty to prod the cadet along with specific demands, assignments, quizzes, or exams. Violation of the contract should result in the student being dropped from the course, or simply dismissed from the project (if work is being done for pay). In the hectic world of undergraduate research projects, there is little room for students who are working for a minimal grade or to earn a little spending money. Keeping these students on the project can result in a great deal of frustration to the professor and the other team members.

Tips for Creating a Research Environment

One of the most vexing problems when using undergraduates for research is their lack of large time blocks. Their day is inevitably splintered by classes, extra-curricular activities, and athletics. When a student decides to join the research team, either for pay or for credit, it is very important that large blocks of time are identified that can be used for the project. If at all possible, some portion of this time should overlap with other students on the project so that the student can serve be mentored by the more senior project members. Additionally, part of this time should overlap with the supervising professor so that the student's progress can be continually monitored and any outstanding issues can be resolved on a daily basis. The time set aside by the student should not be particularly flexible. In general, the hours should be set and altered only at the approval of the professor. This prevents a continual pushing back of deadlines and goals throughout the semester.

Another issue that affects the environment and work schedule of the team is the mix of students who are working for pay and those who are working for credit. Pay and credit projects both have their positives and negatives. These include:

Students Working for Pay

Positives

1. Students generally feel a greater sense of project ownership
2. Students approach the project in a manner similar to a "real" engineering job
3. Students who enjoy the work, and who are paid for it, are often a project's best advertising

Negatives

1. It can be very difficult to hold students accountable to project goals if their interest in the project wanes
2. Classroom work often takes priority over work for pay
3. Student motivation can cycle with external events that have nothing to do with the project (i.e., you will find a high degree of motivation on work for pay projects in the weeks leading up to spring break)

Students Working for Credit

Positives

1. Students understand that poor performance is reflected in a bad grade. There are both positive and negative reinforcement mechanisms built into the grading process.
2. Working for credit generally creates more free time for the student since it replaces a technical elective.
3. Having a "class" which is associated with the project will often automatically create a time slot with overlap time for the professor and the student.

Negatives

1. The student does not feel a sense of ownership or responsibility to any funding agency or company.
2. Students often look at independent research projects as an easy "A" which will not require much work.
3. It may not be possible to simply "fire" a student who is underperforming or negatively affecting the project.

Generally, credit based projects are more successful for lower level students. Once a student demonstrates a genuine interest in the project and has learned skills that make him/her a valuable resource, pay based work is more appropriate. Additionally, pay based projects are usually very successful when conducted over the summer months when students have more time and the competing priority of other classroom work is eliminated.

Two Examples: Success and Failure

Success

A very successful undergraduate student experience started when the student was a first semester sophomore. The student was referred to the project by a professor who identified him as having a real gift for engineering with an unusual amount of intellectual maturity for a young student ("cherry picked"). For one semester, the student worked for credit learning computational modeling and CAD skills. The seniors on the team quickly brought him up to speed and by the end of his sophomore year, he was the project expert on geometric creation and mesh generation on a glass forming contract. In subsequent years, he went on to take an internship at the funding company and completed several more semesters as a paid researcher. He has published several papers and presented his work at international conferences in England and France. He will continue his work in computational heat transfer as he pursues a graduate degree.

Failure

An unsuccessful experience with undergraduate research began with a student asking to join a research time on a work for pay basis during his last year. Since he was a very good student and had already taken most of his engineering classes, he was immediately given critical tasks for the completion of a project which had a very aggressive schedule and hard deadlines. The student did quite well until he had earned enough money for his spring break trip. During the last 6 weeks of the semester, it was very difficult to get any meaningful work out the student. Having come to the project late in his student career, he felt little responsibility to the sponsor. Since he did not need the research in order to graduate, it quickly fell to the bottom of the priority list. In the end, he was dropped from the project. This left the professor the task of completing the remaining work and meeting the project deadlines. It also left negative impressions on several of the younger researchers.

IV. Things the authors wish they had known in their first year

Although each from different engineering disciplines, the three authors have identical lists of things they wish they had known before their first semester teaching and conducting research.

Undergraduates major in engineering because they want to solve problems in society, not in textbooks. They therefore respond better when involved in engineering research, especially in the context of funded contracts. This is also true for their advisors!

Industry offers a better source of contracts than many federal sources. It is typically easier to obtain industry contracts, their scope of work is more appropriate for undergraduate involvement because they have a shorter timeline and are more design-and-build oriented, and once a relationship is established, companies can provide a steady pipeline of contracts for future student work.

Pay students from an external grant at the first possible opportunity to build confidence, interest, and ownership on the part of the student. The amount of pay is not important – even a negligible amount gets a good response. Tell the student their pay is coming from an outside source, and share the financial and project management details of the contract. Let them meet the specific people who are paying them to do this work and have them give some small presentation to them at an early time: the students will quickly learn that they must take full personal responsibility for the quality of their work.

It takes both the right type of industry contract and the right undergraduate(s) to make the research experience work. If either isn't appropriate, the experience is miserable for the student, granting agency, and advisor. It can be difficult for a new professor to turn down a potential contract or a student that requests to be involved in a project but it is far more difficult to manage an inherently poor match into a successful outcome. Spend as much time in the early stages learning about the project and student(s) as necessary to be sure.

The right industry contract with the right student(s) at once punches the tenure categories for teaching, undergraduate development, and research, and more fundamentally yield rich personal opportunities for the student and professor. It is truly these experiences that make the profession worthwhile.

Bibliography

1. Page Smith, "Killing the Spirit: Higher Education in America", Viking Penguin Publishing, NY,1990.

2. Paul Ramsden and Ingrid Moses, "Associations Between Research and Teaching in Australian Higher Education", *J. of Higher Education*, 23(3), 273-295, 2000.

3. Angela Brew, and David Boud, "Teching and Research: Establishing the Vital Link with Learning", *J. Higher Education*, vol 29(3), 261-273, 1995.

4. John Hattie and H.W. Marsh, "The Relationship between Research and Teaching: A Meta-Analysis", *Review of Educational Research*, vol 66(4), 507-542, 1996.

5. J. Mingle, "Faculty work and the cost/quality/ access collision", *Trusteeship*, October, 11-16, 1993.

6. Edward R. Hines and J.Russell Higham, "State Higher Education Appropriations, 1996-1997", State Higher Education Executive Officers, Denver, 1997.

7. Richard M. Felder, Donald R. Woods, James E. Stice, and Armando Rugarcia, "The Future of Engineering Education", *Chem Eng. Education*, vol 34(1), 26-39, 2000.

8. W.J. McKeachie, "Teaching Tips: Strategies, Research, and Theory for College and University Teachers", 10th edn., Houghton Mifflin, Boston, 1999.

9. P. Wankat and F.S. Oreovicz, "Teaching Engineering", McGraw-Hill, New York, 1993.