Council for
Chemical Research
Improving Chemical Innovation Through Collaboration and Advocacy

ACADEMIC LAB

An Overview of Research in Academia

Research is an integral activity in a university, involving faculty, graduate and undergraduate students and support staff. It is primarily a vehicle to educate students and create knowledge. Expectations for faculty engagement in research scale roughly with the institutional emphasis on graduate education. Faculty members at predominantly undergraduate institutions develop research projects primarily to educate students. At large research-intensive universities, tenured and tenure-track faculty are expected to lead and secure funding that can support research programs involving several students and post-docs. There is an increasing pressure for faculty to spin out their discoveries as start-up companies with the view that universities are an engine of economic innovation. The prestige of a university is closely tied to its reputation in research and so the reward structure is closely tied to success in research. As a result, tension between support for excellence in teaching and promotion of research is evident on many campuses. While there is significant variability for the research environments across academic laboratories, there are common elements that are described here.

The Goals of Academic Research

First and foremost, academic research is a means to educate students in the tools and practices of a field, and to introduce them to the research enterprise. At the undergraduate level, students learn basic theoretical and laboratory skills, and develop basic competence in critical thinking and analysis. At the graduate level, students are expected to conduct independent research leading to publications that demonstrate expertise in their discipline. Research projects may be aimed at creating new and fundamental knowledge and/or developing these ideas for practical applications. Academic research also aims to ensure the long-term health and vibrancy of the economy through the workforce it educates and the innovative ideas it generates. State-supported institutions must demonstrate benefits to their regional and state economies.

Reward Structure

Faculty are typically hired on a nine-month basis; additional summer salary may be earned through support from research grants. Many institutions also expect faculty to provide academic-year salary support from their research grants that is consistent with expended effort. Faculty who are successful researchers are rewarded with greater salary increases and prestige (e.g., chaired professorships and more lab space). Typically, faculty are judged on their contributions to research, teaching, and professional service; at research-intensive institutions, research accounts for 50% or more of the expected effort. Tenure is typically granted after six years of successful performance in all three areas. Success is measured by quantity of the output (e.g., students educated, papers published and patents filed) and the quality of the output (e.g., placement of students in academia and industry, journal impact factor and patents licensed).

Less tangible, but no less important, faculty members are rewarded in the context of their work, namely the engagement of students in the generation, dissemination, and application of new knowledge. A career focused on preparing successive generations of students, and the strategies that inculcate their life-long learning and contribution to society, transcends the complex rewards systems that institutions and agencies invoke in assessing faculty.

Budgeting Process and Cost Estimates

Faculty must write research grants to fund their research programs. Research may be funded through federal agencies such as the NSF, NIH, and DoE, state agencies or private foundations (typically much smaller), or through relationships with industry. The largest costs are usually personnel (e.g., students, post-docs, salary support for faculty), followed by materials and supplies, analytical services and equipment use-fees, publication and travel costs; indirect costs (overhead) to the university are defined by government-negotiated rates, typically in the range of 50-80% of direct costs. Certain grants are focused on building infrastructure through major equipment purchases, often shared across multiple research groups or departments. Currently, typical graduate students cost $60K-$100K per year, fully burdened (i.e., stipend, benefits, overhead, and tuition); post-doc costs are typically slightly higher due to higher salaries and the additional cost of benefits. In 2012, NSF awarded 2,000 graduate fellowships, which provide direct support to MS and PhD students in all areas of science and engineering. The current annual cost for a project that includes one full-time student, supplies, and faculty summer support is rarely less than $100K; it can be more if additional personnel (e.g. a post-doc or technician) are required and faculty time during the academic year needs to be supported. Graduate students working toward a PhD require support on one or several contiguous projects for several years.

Key Decision Makers

In selecting research topics the individual faculty member is the key decision maker. He or she chooses projects based on personal curiosity, questions derived from previous work, potential for funding, collaborative opportunities, and response to societal or industrial needs; the ultimate direction of major ongoing research is generally determined by funding availability. The faculty advisor typically defines student research projects. For industrial grants, the University Vice-President of Research is a key decision maker as he or she sets the university guidelines for intellectual property agreements negotiated between the university and industrial research sponsor.

Known Constraints to Collaboration

The single biggest hurdle to collaboration between academia and industry is creating a mutually agreeable intellectual property agreement, which includes ownership of the intellectual property, licensing, and potential royalties. Also of importance in the IP agreement is addressing publication rights and restrictions – academic researchers will want to freely publish all their work, while industrial sponsors may desire to restrict publication for competitive reasons. Other difficulties from the academic side include identifying potential partners and mechanisms for graduate students to engage with industry without disrupting their research project or educational timelines. Additionally, new and inexperienced faculty often need guidance to negotiate the differences in culture between academic and industrial research activities, e.g. expectations, timelines, and the steps needed to convert a good idea into a commercial success.

An Overview of Research in Government Laboratories

Research in the Federal Government is performed to serve the best interests of the public. Each government agency has a defined function and mission, established by Congress, which drive its work. There are several different types of laboratories, including: federal laboratories where researchers are directly employed by the government (e.g. NIST, NIH), government owned-contractor operated (GO-CO, e.g. PNNL in DOE), regulatory agencies (e.g. FDA and EPA), and funding agencies (e.g. NSF). The range of research within the government is very broad, ranging from fundamental science to product development. PhD-level professionals are employed in a variety of roles, including: scientific investigators, research managers, program portfolio managers, regulators, and policy developers/analysts. While there is significant variability for the research environments across the government laboratories, there are common elements that are described here.

The Goals of Government Lab Research

The primary purpose of research in the government is to serve the best interests of the public. If the public benefit of a research program is not clear or distinct, then the government should not perform it. Government has inherent functions, including: providing for national security, establishing a system of weights and measures for the purpose of commerce, providing rigorous testing for assuring the safety of commercial goods, advancing energy policy, etc. Government research should not compete with industry in providing goods and services that commercial ventures supply. Therefore, government research is focused on solving a significant national or global problem (treaty verification, for example), improving our quality of life (e.g. health), or enhancing economic development in the United States. In general, the mission of each government agency is broad and can encompass many different areas over time as national priorities change (e.g. after an election). The research managers in government laboratories are responsible for the effective and efficient use of public dollars as well as being responsive to the priorities of the current Administration and Congress, emerging needs, and, at times, crises (e.g. Deepwater Horizon spill).

Reward Structure

There are two primary tracks of employment for PhDs in the government: research and management. In general, research in government pay is lower than equivalent positions in industry, but can provide increased stability. Each agency has an annual formal review process for staff. Individual researchers are rewarded for their impact on the public through publications, patents, other products, workshops, guidelines, or scientific breakthroughs. Research managers are rewarded for effective management of core capabilities, building significant programs that meet national needs, anticipating needs for the future, or enhancing the reputation of the laboratory. The specific reward structure will vary by laboratory with the primary reward being pay increases and promotions. Specific to GO-CO laboratories, there is an annual evaluation by the stewarding agency. The "grade" awarded determines the percentage of the fee awarded to the operating contractor. Thus, excellent science and technology along with management and operations leads to maximum fee.

Budgeting Process and Cost Estimates

For government agencies, the overall budget comes from an appropriation from Congress (and from the President's request). In general, there is a base budget required for the agency to execute its mission that is often tracked as changes from year to year. Changes to the budget can come from initiatives, which are often new programs to serve a specific purpose (e.g. ARPA-E). Within each agency, funds are either targeted by Congress for a specific purpose or distributed by senior leadership to sub-units of the organization. The research management in most research laboratories strives to balance higher-level programmatic goals with innovative ideas from individual scientists through budget and proposal planning. For GO-CO labs, a significant fraction of the employees are on "soft money" – competitively awarded contracts from primarily (but not solely) government clients. Employees that operate user facilities are typically supported by budget line items. The leadership team works to determine what is available for internal investments; usually near 10% of the annual total budget for a given lab, though this is variable. The average cost for a PhD researcher is also variable, but $250-$350K burdened is a good figure for ballpark estimates.

Key Decision Makers

The level of discretionary budget authority of decision makers within government research varies between agencies. In general, the top level is the Laboratory Director, with several layers of research management (three to four), to the individual researcher level with decreasing levels of authority over resource allocation. Often, there is usually someone in a "project management office" type role (commonly several with different technical scope areas) to coordinate large efforts such as a major initiative or topic. In GO-COs, decisions on the future of the organization, capital investments, etc., are made at the Executive Committee level (this goes by different names at different labs) or those they have empowered. Typically the Management Council is comprised of the Lab Directorate (programmatic and operations), the Associate Laboratory Directors (similar to academic deans or industrial business unit presidents), as well as representatives of the contracting organization.

Known Constraints to Collaboration

Collaboration is strongly encouraged in government research as long as these interactions advance the mission of the government research organization – in fact, government labs will often seek funding from another agency with academic and/or industrial partners. There are guidelines and requirements that come from working with a government agency that can introduce challenges. An example from GO-COs comes from the unique regulatory environment that exists for contracts and subcontracts with government labs. These labs have a set of clauses that "roll-down" from the government and by which they must abide. Government labs also have specific clauses in contracts that define access and control of IP, as well as terms to define royalty rates. There are also limitations and restrictions on how industrial collaborators can fund work and access resources at government labs. Each government agency is unique and will have different challenges for collaboration. For example, a DOE nuclear weapons laboratory will have greater restrictions on access than an open commerce-focused laboratory like NIST.

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INDUSTRIAL LAB

An Overview of Research in Industry

Research in the chemical industry is an integral part of company strategy. As with any highly technical and competitive enterprise, chemical research is viewed as a potential competitive advantage. Researchers typically fall into one of four categories, depending on whether they are in research management or an individual contributor, and whether they work in a central research organization or are embedded within a company business unit. Hence, researchers usually choose between one of these two career ladders, often within the first 5-10 years of their industrial career. While there is significant variability in research environments across various industrial laboratories, there are common elements that are described here.

The Goals of Industrial Research

The primary purpose of industrial research is to create new or improved products and processes for the benefit of society that can generate significant financial return that exceeds the cost of the research. Research expenditures are considered investments that must produce a return that is competitive with the next best alternative. The cost of capital for most chemical companies is on the order of 10% per year. Thus, returns that do not meet this minimum are unlikely to be funded, as they destroy shareholder value. Two long-standing intellectual challenges in industrial research are valuation and prioritization – how can value be assigned to risky research projects, and what portfolio of risks should a business undertake?

In general, it is the job of research management to decide on valuation and prioritization, while individual contributors are focused on delivering against project objectives. Also, central research is responsible for long-term projects, whereas business research is expected to deliver value in the near term. Hence, a manager in central research usually decides on valuation and prioritization of long-term projects, while an individual contributor in a business R&D unit is often heavily engaged in commercialization efforts. Managers are also responsible for hiring decisions and performance calibration. Due to the technical nature of the underlying work, chemical industry research managers almost always hold an advanced degree in the field, such as a PhD.

Reward Structure

Industrial researchers are, on average, the most highly paid chemical research professionals in the United States. In general, research managers command higher salaries and benefits, but they also are subject to greater risk of turnover. Individual contributors are rewarded for individual and team performance on key metrics, such as new product launches, new product sales, patent-advantaged sales, profitability of new sales, and number of patents filed, as well as the creation of new scientific insight and the ability to solve problems. In addition to these metrics, research managers are also measured on the quality of the people they can attract and retain in their organization.

Budgeting Process and Cost Estimates

Budgets are set by company affordability. In some companies, research is a strong function whose budget is set centrally to protect long-term investments. In a distributed model, each individual business R&D team has a budget based on historical and expected performance. Typical research expenditures can range from 1-10% of revenue, depending on the nature of the underlying business quality. For example, a commodity business might have 1% of revenue directed to research, with a heavy focus on process R&D. Advanced specialty materials businesses, such as electronics or biotechnology, might invest closer to 10% of revenue directed mostly toward product research. The typical cost of a fully-loaded PhD employee is on the order of $300k per year in the United States. Research managers are responsible for remaining within their assigned budget.

Key Decision Makers

Research managers have titles such as manager, director, vice president, or chief technology officer. Individual contributors have titles such as specialist, chemist, scientist, or fellow. The title chief scientist is usually held for the highest pointed individual contributor, and is often confused with chief technology officer. They are almost always separate and distinctly different positions. For the purposes of creating a new collaboration, highly ranked research managers with clear delegation of authority are most critical, although respected individual contributors such as corporate fellows also have significant influence.

Collaborative R&D dollars usually flow from central research, although there are exceptions – for example individual business unit-based R&D may also seek collaborators to overcome specific challenges in development projects. Thus, the vice president of central research, if applicable, is a key figure for collaboration outside of the company. Often, the vice president will delegate authority to an external technology leader, although key decisions will almost assuredly be handled at high levels. Central research is also a very comfortable transition for most graduate students, and hence many new researchers begin their industrial careers in such organizations. Business R&D usually requires a higher degree of financial acumen and typically its staff members are recruited from more experienced personnel internally.

Strategic marketers are also important for collaboration. People who hold this title are responsible for commercial aspects of innovation and have significant input in determining which technologies are strategic.

Known Constraints to Collaboration

Since the primary purpose of industrial research is to generate shareholder return, anything that obstructs that objective significantly constrains collaboration. Without question, the single biggest hurdle is intellectual property. Since industry bears the majority of capital and liability risk, the right to practice and the ability to defend new inventions is of paramount importance. Also, there is a vast chasm between the viability of a new business opportunity and the likelihood that it will be funded, which is a subtlety that is often lost on industry outsiders. This can lead to mismatched expectations of value and risk, and is the biggest point of conflict between industry and technology transfer offices. Since royalty and other licensing terms have a disproportionate impact on whether a project proceeds, more companies are insisting that if they pay for research, they own the intellectual property. Caps on royalties, commonly known as "bonanza clauses," are also becoming more common.