Building upon Existing Research Strengths in Uncertain Times: Analytical Chemistry and ISU

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The chemical sciences have been a research strength at Iowa State University for several decades. Departmental rankings among state institutions and research expenditures are two criteria used to determine this strength. Both the cost and space requirements to start a new chemistry laboratory, as well as competition for existing faculty, are challenges that need to be considered in order to maintain a vibrant chemistry department (as is the case for many others). The challenges of uncertain funding require new and innovative, as well as traditional, approaches to maintain research strengths in a highly competitive environment. Some strategies are proposed herein using an analytical chemistry case example.

Background. The field of chemistry is traditionally divided into five divisions: analytical, biochemistry, inorganic, organic, and physical. Undergraduate chemistry majors usually complete survey courses in each of these areas. Analytical chemistry is a measurement science: the focus of analytical research is to both develop new and improve existing methods of analysis to measure qualitative and quantitative information. A majority of students who earn a B.S. in chemistry in the United States will enter graduate school or industrial employment. Analytical chemists represent the largest group (14.8 percent) of employed members of The American Chemical Society [1]. This highlights the need to maintain a vibrant analytical chemistry faculty.

Analytical chemistry, as a defined scientific field, has a historical foundation dating back to roughly the turn of the 20th Century. Then, it was as an applied field focused on methods of analysis for the steel and iron industries [2]. The discipline thrived through World War II for two primary reasons: measurement needs for the Manhattan Project and petroleum analyses [3]. Analytical chemistry at Iowa State University has strong connections with the Department of Energy's Ames Laboratory, a national laboratory located on the ISU campus, as early as the 1940s. Improved techniques developed by Ames Laboratory and ISU chemists enabled the production of about 2 million pounds of uranium metal ingots, a vital material used by the U.S. military during the war effort [4]. The connection between ISU's analytical chemistry division and Ames Laboratory lasted well beyond WWII. In the intervening decades many universities were shrinking or eliminating their analytical divisions; ISU continued to invest in this research area. In 2004, there were five analytical faculty at ISU and 31 total (tenured or tenure-track) faculty in the department. The analytical division was ranked 5th in nation for analytical chemistry, and was generally recognized internally and externally as a strength [5].

Competitive start-up funds and space requirements for a research group are the most significant challenges to maintaining research strengths in the chemical sciences. The average start-up package for an assistant professor of chemistry for 19 selected universities across the Midwest does not statistically vary by division (Figure 1). The average start-up package across all divisions is roughly $810,000 for an assistant professor, excluding associated costs for renovating space [6]. The average start-up package for a senior faculty member is approximately $1.7 million excluding renovation costs [6]. Many research groups have unique space needs and considerable renovation costs may be associated with hiring a new faculty member.

While the start-up costs in the chemical sciences are high, the average yearly research expenditures in the chemical sciences for 19 selected universities across the Midwest are $18 million per department (Figure 2) [6]. Federal funding represents a majority of the research expenditures as reported for the years 2011-2012. Industrial-funded research expenditures represent about 10 percent of the total.

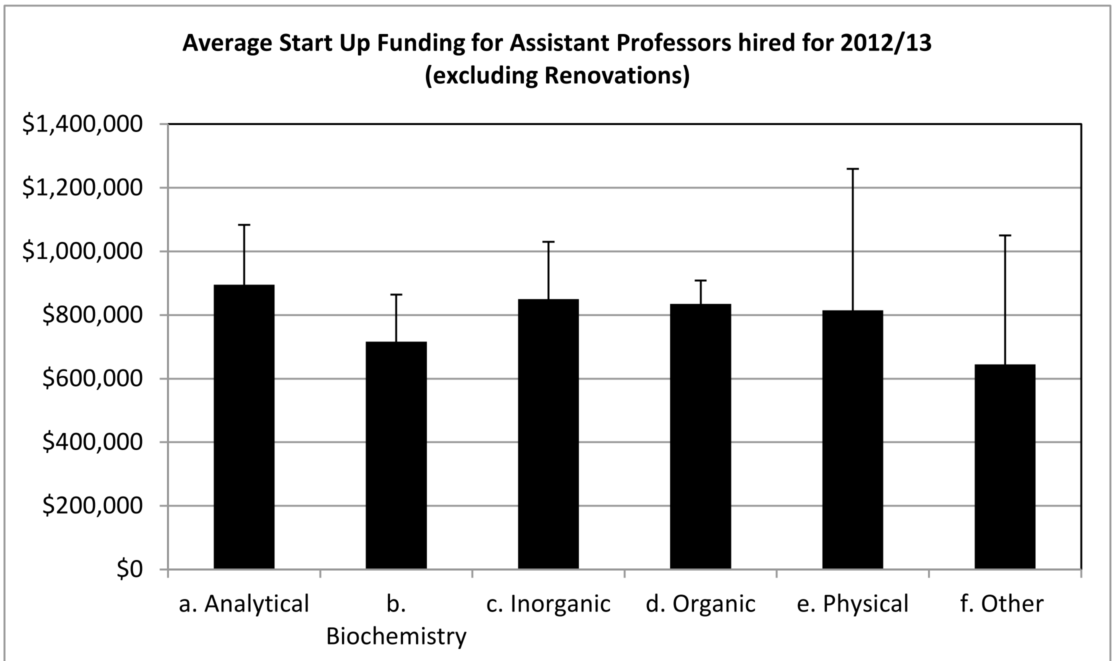

Figure 1. Citation Midwest Chairs 2012-2012 Survey including information from University of Chicago, University of Illinois-Chicago, University of Illinois-Urbana Champaign, Indiana University-Bloomington, Iowa State University, University of Iowa, Michigan State University, University of Michigan-Ann Arbor, University of Minnesota, University of Nebraska-Lincoln, Northwestern University, University of Notre Dame, Ohio State University, Penn State University, University of Pittsburgh, Purdue University, University of Washington, Wayne State University, University of Wisconsin-Madison.

Selected Strategies for Maintaining Research Strengths in Uncertain Times. In times of uncertain state and federal funding for research, maintaining research strengths should include innovation. The following suggested considerations and approaches for maintaining research strengths are not exhaustive. They are presented here in the context of the

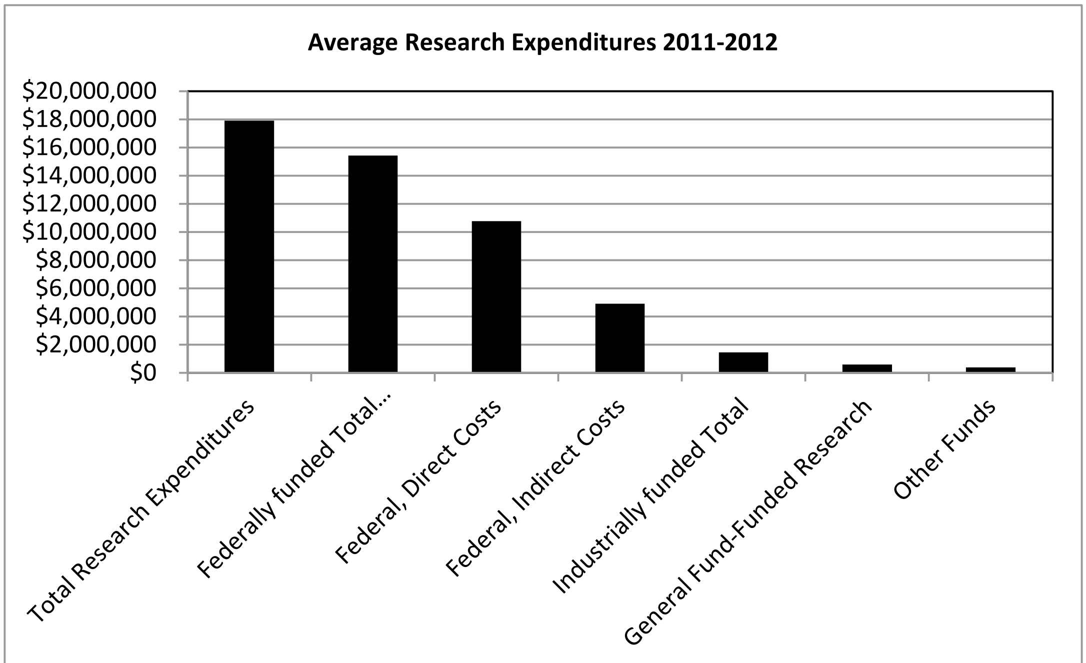

Figure 2. Citation Midwest Chairs 2012-2012 Survey including information from University of Chicago, University of Illinois-Chicago, University of Illinois-Urbana Champaign, Indiana University-Bloomington, Iowa State University, University of Iowa, Michigan State University, University of Michigan-Ann Arbor, University of Minnesota, University of Nebraska-Lincoln, Northwestern University, University of Notre Dame, Ohio State University, Penn State University, University of Pittsburgh, Purdue University, University of Washington, Wayne State University, University of Wisconsin-Madison.

field of analytical chemistry. Most should be applicable to other research fields.

In times when funding sources are increasingly emphasizing the importance of documenting the benefits of funded research projects, strategies to justify the benefit of a scientific project, department or field should be prominently advertised to numerous audiences. To this end, it is useful to define a few examples of fundamental research and technological advancements benefiting society, the scientific endeavor, and the field. Within the field of analytical chemistry, examples are numerous. For example, in the 1970s, Dr. Leland Clark of Yellow Springs Instrument Company developed the Model 23 Glucose Analyzer [7]. This was the first whole-blood glucose meter, and predecessor to blood glucose analyzers used today by millions of diabetics to monitor and manage their disease. The Model 23 Glucose Analyzer, a technological advancement that can't be overstated in importance, measured roughly 16.25 inches by 13 inches by 8.375 inches [8]—it was not a portable unit. Over the ensuing years, numerous measurement advancements were made; today, accurate, portable blood glucose meters fit in the palm on one's hand and some continuously monitor in vivo glucose [9].

On a more local scale, the two main objectives of the Smith research group are: (1) to measure the organization and dynamics of cell membrane components, and (2) to demonstrate Raman spectroscopy analyses of biomass, enzymatic catalysis, and thin films. These objectives are accomplished through a combination of measurements, instruments, and methods development. The instruments being developed focus on improvements to traditional optical microscopy approaches. Optical microscopy is used to image objects that can't be visualized by eye. The spatial resolution, meaning the ability to image increasingly smaller objects, is limited by the diffraction of light. Typical optical microscopy techniques have a limit of a few hundred nanometers. To put this in context, the diameter of a human hair is about 90,000 nanometers, much larger than the diffraction limit. However, many biological and materials samples have important spatial scales of tens of nanometers or less, and these can't be measured with traditional optical microscopy techniques. There are other (e.g., electron) microscopy techniques with a finer spatial resolution. But these techniques don't often allow dynamic information to be measured. One can't measure and obtain information about processes as they happen. The Smith laboratory focuses on developing optical microscopy techniques that get around the diffraction limit of optical microscopy, thus enabling dynamic processes to be measured in smaller and smaller spatial scales [10-11]. This has applications to medicine (e.g., pathology), biology, materials science, and many other fields.

Industrial connections are increasingly seen as an important source of funding and partnership in times when obtaining federal funding for basic research is a growing, unnerving challenge. These connections make particular sense for applied research projects that may offer a shorter-term payoff in the form of developed products or new measurement techniques. In 2013 analytical instrument sales for the top 25 sellers was approximately $32 billion (Figure 3) [12]. Reported values of 4.2-19.5 percent of sales from selected manufacturers have been reinvested in research and development [12]. There is existing evidence for the successful partnership between industry and academic departments with analytical chemistry divisions. For instance, the University of Texas at Arlington partnered with Shimadzu (ranked 5th in instrument sales) to develop the Shimadzu Institute for Research Technologies on the UT Arlington campus. Shimadzu Scientific Instruments donated $7.5 million as a corporate gift and $3 million as an in-kind gift of instrumentation [13]. Named endowments, donated equipment for departmental use, and the use of equipment at remote sites may be beneficial approaches for fields in which analytical measurements are taken.

Since a significant amount of start-up funding in analytical chemistry is devoted to scientific instruments, collaborative hires whereby shared equipment (e.g., nuclear magnetic resonance, mass spectrometers) can be built into a competitive start-up package may be a useful approach. The careful planning of shared university (center) equipment purchases may also alleviate need for a portion of start-up funds for new faculty members, and the entire university community might benefit from the addition of on-site equipment experts. Finally, there is a need to have easy access to shared university (center) equipment that is easy for the community to locate on campus. This may reduce the need for an individual faculty member to possess selected instrumentation, make it easier to find out what is available on campus when negotiating start-up packages, and avoid duplication of instrument purchases across units on campus when multiple units may share instrument time.

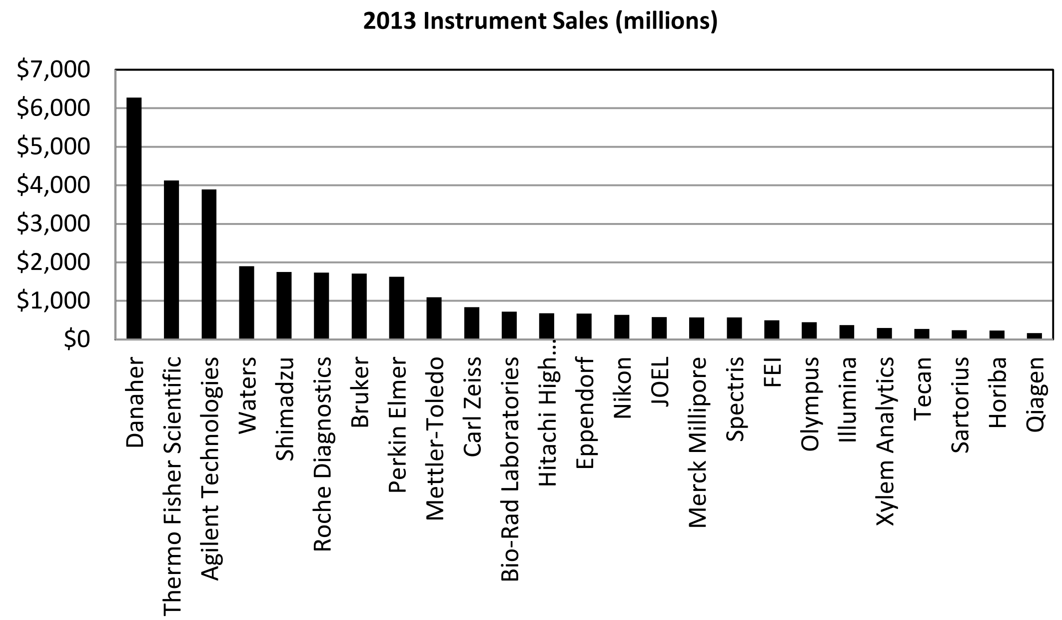

Figure 3. Citation Thayer, A.M. "Top Instrument Firms" *Chemical & Engineering News*, November 18, 2013, 91 (46), 10-14.

Investing in junior faculty members has several benefits. If adding faculty to a department, an $810,000 average start-up package for a junior-level hire makes more economic sense than a $1.7 million offer. Of course, one must expect a longer term payoff that may not be as certain as hiring a senior faculty member. But, there is also a benefit of building loyalty to the university, to provide resources and mentoring that will have a future impact. Part of building loyalty also means investing in the leadership skills of junior faculty through dedicated programs and opportunities, as well as highlighting the appreciation for junior faculty's contributions to the university.

Finally, it is necessary to invest time and money in advertising the unique strengths within and outside one's own organization. Seminars and local conferences have been the traditional route for achieving this. Many funding mechanisms are making a transition to emphasize interdisciplinary teams. Forming well-situated teams requires knowledge of strengths; to be included in these teams, a department's strengths must be commonly known. Highly collaborative fields, such as analytical chemistry, may be an effective route to establishing partnerships both within and outside an organization. For example, as stated by Jonathan Sweedler, the current Editor of *Analytical Chemistry*, "In all processes, whether in engineering, science, or medicine, you need quantitative numbers to optimize the goals [14]." Analytical Chemistry is well suited to make connections in the field of medicine, environmental monitoring, energy, agriculture, basic biological sciences, and engineering. In other words, teams that target all the major federal funding sources.

In closing, existing research strengths at public universities in uncertain times may not remain strengths unless the university invests both time and money to maintain them. This may be accomplished with traditional as well as innovative strategies. Leadership from all levels will be key to successful implementation of these strategies.

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