Undergraduate Science Education: A New Direction

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Academic science in America is facing hard times. With an oversupply of academic Ph.D. scientists, decreasing funds for basic research, and the breakdown of disciplinary boundaries, it is time to consider new directions for science, both in research universities and in primarily undergraduate institutions.

As a Visiting Scientist (on leave from St. Olaf College) and Molecular Biophysics Program Director at the National Science Foundation, I am acutely aware of funding problems for American academic scientists. In my program, grant proposals are rated on a scale of excellent, very good, good, fair, and poor. In our past review cycle, only 70% of the excellent-rated proposals were funded. The review panel felt strongly that all of the 33 excellent-rated proposals, out of a total of 96 proposals, should be funded. It was only by cutting budgets that we were able to fund 23 proposals from our limited program budget. Among those excellent proposals not funded, were proposals from established world-class researchers and highly-trained bright young investigators. In some cases, not funding their proposals meant that they no longer had any research support. This will force some established investigators into early retirement, and cut short the research careers of some promising new investigators. It was very depressing to talk to these people and tell them that their excellent-ranked proposals will not be funded.

The budget at NSF for basic research by individual scientists has remained essentially flat, and will at best remain level, or may decrease in the next few years. Future prospects for research funding in academic science are not good. Graduate departments in chemistry and other sciences have traditionally trained their students primarily for careers in academic research, and undergraduate science departments have aimed their curricula at preparing students for graduate school. In view of the tight research funding situation and an oversupply of academic scientists, we need to rethink our objectives for undergraduate majors and graduate students in the sciences. There will always be a need for our top students in academic science, but we will need fewer of them. However, in an increasingly science-oriented and technological society we will still have a need for many scientists, but they will need to be trained in different ways to meet that demand.

In an open letter to chemistry faculty,[1] Edward Kostiner, Chairman of the American Chemical Society Committee on Economic and Professional Affairs, said "The overwhelming consensus is that universities provide first-class training in narrow fields of expertise, but that the general education of doctoral students does not adequately prepare them for entering the industrial and government work force. Another perception is that undergraduate chemistry majors are being prepared for graduate study and not for successful careers in industry. The current R&D marketplace requires people with a broad knowledge of chemistry and adequate exposure to related fields such as biology, materials science, chemical engineering, and physics. It seems to me that chemistry faculty have become too parochial in their approach to training students. We should attempt to provide

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all of our students the breadth of knowledge necessary for their success, especially those tools that not only broaden their scientific outlook, but also ensure their continued employability."

The most active and exciting research at the frontiers of science occurs today at the interfaces between disciplines; for example, materials science and biotechnology. Scientific disciplines exist as convenient administrative tools, and persist most strongly in academia. Nature knows no such boundaries. Thus, narrow disciplines can often become a hindrance to scientific discovery and development. Many graduate universities have recognized this and have developed interdisciplinary institutes or programs.

The University of Oregon, in the mid 1960s, developed an innovative Institute of Molecular Biology. This institute brings together faculty from physics, chemistry, biology, neuroscience, and other departments, who have a common interest in molecular biology; these faculty, however, still maintain strong ties with their own departments. A more recent development is the Department of Molecular Biotechnology at the University of Washington. There, Professor Lee Hood has brought together a group of scientists from a wide range of disciplines to work on problems of biotechnology. He has developed a graduate program where students have two mentors in very different disciplines (for example, chemistry and electrical engineering) and learn how to apply the knowledge and language of these two disciplines to a problem in biotechnology.

Undergraduate liberal arts colleges have lagged far behind in the development of interdisciplinary science. One would think that the "liberal arts" nature of these colleges would promote such activities. Instead, most liberal arts undergraduate colleges maintain disciplinary departments; this is particularly true in chemistry. This may be due to a lack of research at the interdisciplinary frontiers of science, and an isolation of these faculty from the interdisciplinary science going on at many universities and in industry. The science faculties in these departments may also be too small to sustain much interdisciplinary interaction. They do a superb job of training students in narrow fields of expertise for graduate school and academic research, but fail to adequately prepare students for today's job market in interdisciplinary science and the new interdisciplinary graduate programs. If they continue in this way, the number of science majors will decline as students become more aware of the limited opportunities in academic science, and as the departments fail to excite students about the interdisciplinary frontiers of science and the many non-traditional alternative careers available in science.

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How do we develop interdisciplinary science programs at undergraduate colleges in the face of tight academic budgets, cutbacks in research funding and the parochial self interest of departments to maintain their administrative structures? The initial steps need to be taken by individual science faculty with the full support of their department chairs and deans.

At St. Olaf College, I helped initiate an interdisciplinary Concentration in Molecular Biology for chemistry and biology majors. This involved designating specific courses already taught in both departments, and involved no extra money. The next step should be the development of interdisciplinary courses and laboratories. I helped develop and team-taught two such laboratory courses[2] with a colleague in the biology department; but later we were told that we could not continue to team-teach these courses unless they had twice the enrollment of a normal course. That would be self-defeating for a laboratory course with limited equipment and facilities. Exceptions need to be made in rigid teaching-load assignments to encourage interdisciplinary teaching, particularly in laboratory-intensive science courses.

True interdisciplinary teaching needs to be interdepartmental. A chemistry department, for example, deludes itself when it thinks that the mere inclusion of biology topics into its chemistry courses is sufficient. Only when a biologist and a chemist come together to teach a common course, do they develop a common language and understanding of each other's discipline. Students learn by example, and when they see faculty from both departments coming together, they realize that science can cross traditional boundaries, and that each discipline can contribute useful ideas and approaches to a common problem.

Other things that undergraduate colleges can do to promote interdisciplinary science may require some extra funding. Interdisciplinary seminar series and visiting scientists, as well as the construction and equipping of interdisciplinary laboratories will probably need to be funded from external sources. New science buildings should have these laboratories independent from specific departments, and faculty offices and research laboratories should be organized in close proximity around interdisciplinary research areas rather than specific disciplines. We need to identify appropriate funding agencies and make a strong argument that this is a novel new approach, particularly at undergraduate colleges, to promote this new approach to science.

Funding agencies need to broaden their perspectives with regard to interdisciplinary science. Many agencies are set up to fund a specific discipline, so when they are approached by co-investigators in different disciplines, they claim the proposal falls outside of their mandate. I recently sent a preproposal for support of an interdisciplinary laboratory program in molecular biology to a foundation that supports chemistry, but which expressed interest in supporting interdisciplinary programs. The foundation director replied that this proposal would not be considered favorably since "past experience indicates that reviewers are likely to view your project as largely a biology effort" (while I was in the chemistry department, my co-investigator was in the biology department). At the NSF, my Molecular Biophysics Program supports investigators in many different departments (physics, chemistry, biology, biochemistry, molecular biology, etc.); the department is irrelevant, we fund the science.

In conclusion, the one thing we should not do is continue teaching science in the same way as we have in the past, despite the success we may have had. In order for science to grow, it needs to develop in new directions. This is particularly true at undergraduate liberal arts colleges. In the past, we have prided ourselves as the major undergraduate source of scientists with Ph.D. degrees. In the future, with an oversupply of such scientists, this distinction will become irrelevant. In order to become relevant, we need to break down the boundaries between the traditional scientific disciplines. If we are to prepare our students successfully for future careers in science, we have to encourage them to become fluent and knowledgeable in at least two different areas. In order to attract the best students, we need to expose them to the exciting things that are happening at the interdisciplinary frontiers and the challenging problems that need to be solved. Large universities are beginning to do this at the undergraduate level, and some are very successful with their greater resources. We also need to make our students aware of the many non-traditional alternative careers in science, and how a broad science education can be excellent preparation for many careers outside of science. We need to redefine a special niche for science education at undergraduate liberal arts colleges.

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In presenting this essay, I would like to initiate further discussion of these ideas. I invite interested readers to respond to me directly (email: hend@stolaf.edu) or through the *CUR Quarterly*. ▼

References

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