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Guerrilla Puzzling: a Model for Research

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Guerrilla Puzzling: a Model for Research

Nature is full of intriguing puzzles for researchers to solve. The jigsaw pieces don't come in a box, with the number of pieces listed and a picture of the solution on the lid. To solve any of nature's puzzles, researchers need to find the pieces before trying to place them in the puzzle.

There are two main settings for puzzle solving in higher education: graduate programs, with professors and both graduate and postdoctoral students; and predominantly undergraduate institutions, with professors and students. Research programs at large universities are well-oiled puzzle-solving machines. Graduate students there work long, hard hours in the laboratory, under the supervision of postdocs and professors. Students at predominantly undergraduate institutions, on the other hand, can rarely devote more than 10 hours a week to research during the academic year, what with course work; extracurricular activities, like sports; jobs; and other commitments.

Nonetheless, government agencies like the National Institutes of Health and the National Science Foundation have allocated special funds exclusively for research at undergraduate institutions. Very few people would argue against the pedagogical advantages of undergraduates' conducting research. But can undergraduate institutions contribute enough to the solution of nature's puzzles to justify those federal programs? Or are they a waste of the taxpayers' money?

The Research Corporation and four other private foundations tried to answer that question, surveying 136 undergraduate institutions and nearly 3,000 faculty members; that study resulted in a book called Academic Excellence: The Role of Research in the Physical Sciences at Undergraduate Institutions (Research Corporation, 2000). The foundations found that researchers at undergraduate institutions publish less than do their colleagues in graduate programs, but they are just as cost-effective in terms of grant dollars spent per publication.

That is the good news. The bad news is that less than one-third of the publications produced by teachers at undergraduate institutions had even a single undergraduate co-author. It seems that many of those professors do not involve their students in research in a significant way.

How can professors make sure that their research contributes valuable pieces to the puzzle they are working on, while including undergraduates? That is, how can they achieve both their research and pedagogical goals?

It is important that professors at undergraduate institutions try to complement, rather than compete with, their peers at research universities. One way to do that is to set up a smaller version of a graduate research group, with undergraduates; possibly a postdoc or two, or a research assistant; and a professor working on a puzzle or part of a puzzle that scholars at research universities are not studying.

That approach is fairly common at highly selective liberal-arts colleges. For example, one of my colleagues studies firefly luciferase -- the protein that produces the firefly's light -- with the help of three research assistants, one full time and two part time. Undergraduates participate in the lab work and, with the professor and postdoc or research assistant, publish in excellent, peer-reviewed journals.

Such small research groups usually work well, uncovering useful information and giving students good training for graduate school. But they are expensive to operate because permanent employees require a salary, health insurance, and other benefits: The salary and benefits for one postdoc typically amount to $60,000 or more per year, whereas a research group using just undergraduates can survive on less than $30,000 a year.

I prefer a second, less-common model, which I call a "guerrilla puzzling" operation.

When I described graduate research programs as efficient puzzle-solving machines, I did not mention their one large drawback: They generally involve many graduate and postdoc students, who need to publish papers to get jobs. Thus the stakes are high, and the programs have to be large, typically requiring grants of at least $500,000 and lasting three to six years. In many ways, they resemble a complex military campaign.

In contrast, undergraduate projects can be more like guerrilla attacks. They can concentrate on one aspect of a puzzle and be done in one or two summers; the average grant for such a project is less than $25,000. If they do not produce results, they might make the professor less likely to get future grants, but they do not harm the undergraduates' chances of finding employment or getting into graduate or medical school. Therefore the professor can take more risks.

For example, I have three undergraduates trying to make a fluorescent mutation of a nonfluorescent protein. If our experiment works, we will have a great paper. If it doesn't, the students will have gained valuable research experience. No professor would assign to a graduate student a project that might produce no results after several years of work, leaving the student basically unemployable.

Effective guerrilla puzzlers usually follow one of three approaches.

* **They find a new puzzle and work on the borders or the corners.** By starting to work on a problem while many of the big groups are still trying to get grants, researchers at undergraduate institutions can choose which pieces to look for. That has two advantages: You can hunt for the pieces that are easiest to find, and other scholars often use your pieces to locate subsequent parts of the puzzle, which gives your undergraduates a broad audience and, eventually, many citations in other papers.

The difficulty is that you need to have a good grasp of the field and a thorough knowledge of its literature to identify new puzzles. You also have to be able to start a research program quickly and to realize when a problem is no longer worth investigating -- perhaps because all the easy pieces have been found, or the pieces are so numerous that there are no easy solutions, or interest in the puzzle has waned.

I have been extremely lucky in my own research. In a 1995 seminar at my institution, I heard Douglas Prasher talk about his work on green fluorescent protein in jellyfish, a field in its infancy. Prasher -- then at the Woods Hole Oceanographic Institution -- could not have imagined how useful the protein, at the time the only one known to fluoresce, would become in medical and biological imaging.

The talk was interesting over all, but what was most important to me was that Prasher ended with his thoughts on where the field was heading, and a review of the problems yet to be overcome. I realized immediately that I had the research tools and training to solve one of them, identifying what in the protein's structure was responsible for its fluorescence.

* **They identify a puzzle in which new areas, with distinctive pictures, are continually appearing.** Some problems can be solved and set aside, but with others, each apparent solution leads to new mysteries.

I have stayed with the same puzzle since 1995 because the protein I work on can be used to do a variety of amazing things, like seeing how a mouse thinks and following individual cancer cells in live mice. New questions -- such as how to create brighter and differently colored mutants -- are always being asked about the protein, and my undergraduates and I can answer them. So although I now share the field with many chemists from high-powered research universities, I avoid competing directly with them by looking for puzzle pieces in a new area.

* **They look for colorful, distinctive pieces.** Often the last parts of a puzzle are vast expanses of sky, water, or other areas that are fairly uniform. Those sections are difficult to complete, and they are not very exciting to undergraduate researchers, sources of grants, or the general public. Colorful pieces are quicker to find, easier to put into place once they are found, and more likely to be interesting.

Before I got involved in studying green fluorescent protein, I spent a decade studying cow flatulence -- a surprisingly important topic. Each year about 50 million tons of methane escapes into the troposphere, significantly contributing to the greenhouse effect; a large portion of the methane comes from our bovine friends. The last step of methane production is catalyzed by a nickel-containing enzyme, which was the focus of my research.

It became harder and harder to get new results, and to interest journals in publishing them. I finally decided that all the interesting pieces in that smelly puzzle had been found. Years later I found out that I had been wrong: Another scholar published the crystal structure of the nickel-containing enzyme, and a new batch of important questions emerged.

Someone else working on cow flatulence had found something interesting while working on the puzzle's sky. Was it a bird? A plane? Suddenly there was more left to the puzzle than just sky. The puzzle has become so interesting again that I now have two students working on it.

The guerrilla model I have described should be considered by faculty members at predominantly undergraduate institutions. It is cost-efficient, its time span is appropriate for undergraduate participants, and it can produce significant results. It is a great way to get students involved in research at an early stage in their academic careers.

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By Marc Zimmer

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