
Early Research

An Alternative for Scientific Formation

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Research, like any other activity, is learned by doing. Unfortunately, our current educational system tries to develop scientists through courses where students are basically taught to solve problems that are often foreign and therefore irrelevant to them and to carry out instructions for which the principles are often unknown.

“How” and “why”, the two questions asked continually by scientists, are buried under mountains of papers describing experiments, procedures, guidelines, summaries, etc. Nothing could be further from the truth of what research really is. Although the scientific attitude is really an attitude toward life and is present everywhere, it is in the laboratory, which is specially designed for research, where an activity like chemistry finds the best environment for its development. There we can find the social and academic machinery, oriented toward the acquisition of knowledge where the young student can participate in a unique process: to learn how scientific research is done—by scientists. With this idea in mind, we started a program that acquainted young students with the research being done in our Inorganic Chemistry Laboratory, in the College of Chemistry of the Universidad Nacional Autónoma de México (UNAM), almost six years ago. The intention was clear: to develop scientists through scientific research.

In the beginning we did not have any blueprints or background information to guide us in our purpose. The rules and forms, which will be discussed later in this paper, were adopted by our group after pondering our goals and the means we had to achieve them. In 1984, J. F. Bunnett published the description and results of a similar program that he supervised (1). Taking into account his results and our own experiences, for an undergraduate research program to be successful today, we must pay special attention to the following aspects:

1. *Time* dedicated to the research.
2. *Subject* of study and research.
3. *Commitment* to the research.
4. *Formality* given to the research.

Time

Research has to be thoroughly enjoyable. Few activities are so when submitted to a tight schedule. In our program neither a tight schedule nor a minimum amount of work hours is required. The students choose the amount of time they want to dedicate to the project. This flexibility implies that the student will not have his or her research interfering with his or her academic, social, and cultural activities. Also he or she will have access to the lab, equipment, and substances all day long. Even though this freedom may cause a few problems, in our experience it has never been a serious drawback. Frequently, work in a chemistry lab requires a minimum amount of work hours, for example, the time to assemble the equipment, carry out the reaction, separate certain products, and put the equipment back in place. In these cases, it is the student who decides when he or she will have enough time to carry out the experiment. A surprising result is that the students decide to spend a considerable

part of their vacations, often all of them, working on their project. In fact, semester breaks are the most productive periods in our lab, when the students crowd around the vacuum lines.

Our program invites students to do research, not to fulfill requirements. Because of the nature of their work and the time they spend on it, they may need to work at it for a long period, often years. Inevitably their daily work produces the undergraduate thesis and social service required in Mexico to obtain a degree. In brief:

- We do not demand schedules or minimum work hours.
- Students create their own schedules choosing their own vacation periods.
- The most productive period is always during vacations.

Given the characteristics of the curriculum in the UNAM, where students usually do not begin research work until the end of their studies (after the ninth semester), from the second semester on, our students dedicate more and more time to their research projects. In the beginning, with just a few hours a week, their productivity is relatively low, but their attitude toward work is different. Little by little, fears and doubts disappear, and questions and initiatives arise. Simplistic explanations begin to be doubted, and scientists are becoming formed. In the last year, they are not only a group of able and expert professionals, but also a group of good friends.

The Subject of Study (The Theme)

For a student to agree to spend many hours on his or her research project, it must be, at least, interesting, appealing, and important to him or her. At the same time, the suggested project must be feasible from the advisor's point of view.

Our group is formed by five staff members and the respective students. Our main research is focussed on platinum-group metal derivatives with sulfur and fluorine containing ligands. In our program the students have the choice of selecting an individual subject from the main research in which the group is working. To carry out the main research as a group, it is necessary to study various subjects of different complexity whose examination calls for different aptitudes and even different personalities. The newer students in the group start out with assignments that are relatively simple but, we insist, fundamental for the overall development of the research project.

For this reason, the results obtained in any of the projects are of high quality and importance from a scientific point of view. Chemistry is still far from being nurtured with paper and pencil. Sometimes a project that seems relatively simple on paper turns out not to be so in the laboratory. Instead of the lovely crystals we were expecting, we end up with a disgusting oily gum. After a reasonable number of attempts, the student is convinced that the approach followed is incorrect. The situation is not pleasant, but the student goes to the lab to do research, not to get a good grade or to pass an exam. Therefore it is not a depressing failure. On the contrary, these are invaluable occasions not only to go over the

chemistry involved and come up with an explanation of the facts, but also to discuss such subjects as establishment of a hypothesis, the significance of negative evidence, or the role of experimentation in science. The student lives the scientific method, he or she does not just read about it. Nevertheless, in some cases, changing course is unavoidable, and so is changing the research topic, but nothing is lost and much has been learned. As a result of structuring a research group as described, the communication level between its members is very high. The newer students may discuss doubts or problems with their contemporaries, more advanced students, or supervisors. They are all equally interested in what these students are doing and in whatever advances or obstacles develop, because much of the group's future work depends on their results.

A weekly activity is to gather the whole group to share experiences, mainly dealing with chemistry, but sometimes with other subjects as well.

Chemistry, as any other science, has a language of its own with its colloquial forms, tones, and accents. It is a language we must learn, and, as with any other language, listening stimulates talking. Of course repeating does not mean understanding, but it is indispensable for communication and for explanations.

In summary:

- The individual theme is part of a global research project.
- The individual theme must lead to original results.
- The individual theme may be modified.
- The individual theme helps students to communicate academically.

The Commitment

An indispensable requirement to participate in this program is that the priority in the student's life must be his or her major field. He or she must be a good student, dedicating whatever time is required to his or her studies.

In our experience with this type of scientific formation, the students' only commitment has been to themselves. It is often an extraordinarily solid one. It is hard to establish clearly what it is that motivates the student to commit him- or herself so seriously to a research project. No doubt it is a mixture of circumstances that are different for each person. Many of the students that worked with us while completing their studies decided to continue with postgraduate studies. This reflects their individual commitments to scientific work. We also think it proves, as we expected, the possibility of forming scientists by getting young students excited about research.

In conclusion:

- The priority in the student's life must be his or her major field.
- The student's commitment is to him- or herself.
- The commitment leads him or her to postgraduate studies.

Formality

There is no reason for serious subjects to be boring nor for formal ones to be solemn. Thanks to the students, the laboratory develops a pleasant atmosphere where, during coffee breaks away from the laboratory, results are discussed in the same way that parties are organized. Students are also responsible for presenting their results in seminars held at the Graduate Division of the College of Chemistry, in national and international congresses, and through scientific articles. In general, very few undergraduate students have the chance to discuss the results of their research projects and, unfortunately, even less chance of doing so as the students in our program group have done.

Our students have participated in more than 20 research seminars, 15 presentations at national and six at international chemistry congresses, and seven articles have been published or accepted in national and international scientific journals (2-8).

The richness of this experience is invaluable. It is true that the feeling before one of these events is close to panic, but afterward what remains is a feeling of confidence. All the papers are the result of teamwork. The students and advisors are directly involved, but we insist that the oral presentation be done by the student, no matter how advanced they are in their major field. This is a useful practice because, among other reasons, the students get into the habit of presenting their work each time with more clarity, order, and even elegance. In the end they are convinced that their research is not completed until they have discussed it and have excited their colleagues with their findings. Something similar happens with papers for publication. In general, it is the student who has all the information and who, along with his or her advisor, prepares the manuscript with its tables, drawings, etc. They know that in these cases the examination of their work will be more rigorous and its acceptance more gratifying.

In brief:

- Presentation of results in seminars and congresses.
- Publication of results in scientific journals.
- The speakers are students.

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