ChE views and opinions

COMMON MISCONCEPTIONS CONCERNING GRADUATE SCHOOL

J. L. DUDA
Pennsylvania State University
University Park, PA 16802

* * * * * * * * * * * *

Twenty-five years ago, I started graduate school at the University of Delaware. Looking back on that time, I can see that I was a typical graduate student in that I was both excited and terrified, confident and anxious, sure of success one day and afraid of failure the next. I did, however, harbor certain basic misconceptions about the experiences which lay ahead of me. In talking to our graduate students here at Penn State, I found that those same misconceptions are still common, and this insight prompted me to give the following introductory address to our incoming graduate students.

* * * * * * * * * * * *

LIKE YOU TODAY, I was also entering graduate school twenty-five years ago. My mind was also filled with questions and concerns. It was also cluttered with certain misconceptions, which are still popular today. I would like to look back on that time with you and try to tell you how my views on graduate school have changed.

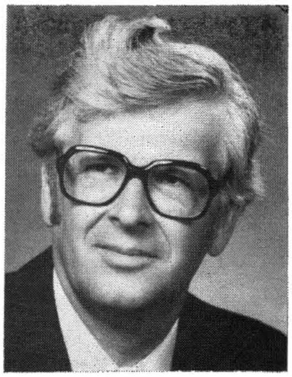
The first misconception I had was that graduate school would be a continuation of my experience as an undergraduate.

This was probably my greatest misconception. First of all, graduate courses and undergraduate courses are, in general, somewhat different. You are an elite group since we only accept one out of every fifteen applicants to our graduate program. Consequently, there is no doubt in our minds that you can perform well in graduate courses since your ability in chemical engineering courses has been demonstrated by your undergraduate record. Therefore, graduate courses tend to be more relaxed, with less emphasis on evaluation and certainly no hint of being a weeding-out process. We feel that you are in these courses because you want to learn, and therefore our main emphasis is on enhancing your technical expertise. You are now engineers, not just high school graduates.

The key to graduate research is problem solving, not the acquisition of specific information. You will learn to solve problems by actually performing this task under the direction of an expert . . .

The main difference between undergraduate and graduate education is related to the research aspect of graduate studies. Very few of our graduate students fail to receive their graduate degree because of their performance in courses. The main hurdle is the ability to do independent research. Up to now, in my opinion, your educational experiences have been somewhat artificial. You have studied in order to pass exams which cover very specific and limited areas. In the past, you worked certain problems on examinations. You knew there was an answer. You also knew you had enough data to reach that answer. Conducting research in graduate school, on the other hand, does not involve an artificial environment. You will be working on problems where no one knows the answer, and the problem itself might not even be clear. Graduate research is similar to an apprenticeship. You will be working directly with an expert and will learn by doing and observing how this expert approaches problems. The key to graduate research is problem solving, not the acquisition of specific information. You will learn how to solve problems by actually performing this task under the direction of an expert, not by studying the philosophy or idealized approach to problem solving.

What happened to me may also happen to some of you. I slowly began to realize that research was unlike anything that I had been exposed to previously. There is a natural tendency to exaggerate the difference and come to the counter-misconception that research has nothing to do with your undergraduate work. This is not true either.



J. L. Duda is Professor and Head of the Department of Chemical Engineering at The Pennsylvania State University. He received his BS in chemical engineering at Case Institute of Technology and his MS and PhD at the University of Delaware. He joined the staff at Penn State in 1971 after eight years in research with The Dow Chemical Company.

Research is a natural extension of your learning career to date, but it is also more than that. You have been learning and obtaining information from teachers, textbooks, and independent study in libraries. But what do you do when the knowledge you desire is not available in any book or article, or when no individual exists who knows the answer? Research in the physical sciences and engineering is the process of learning by asking nature questions. In a sense, nature becomes your ultimate teacher. When you design experiments, you are really formulating your questions for nature. Unlike your previous teachers, nature does not anticipate your question. You will get a direct and honest answer to your question as it was formulated. If you are misled or have difficulties, it will not be because nature failed to answer your question. It will be due to your failure in formulating the question or in interpreting the results. The best researchers are the ones who ask what appear to be very simple questions and receive earth-shaking replies.

At this point, one might ask how theory fits into all this if the basis of research is asking nature questions through experimentation. As J. Willard Gibbs said, "The purpose of theory is to find that viewpoint from which experimental observations appear to fit the simplest pattern." You want to determine this pattern so that you can generalize your experimental observations and minimize the number of experiments that have to be conducted.

My second misconception concerning graduate school was that the choice of a research topic was one of the most important decisions of my life since it would determine what area I would work in for the rest of my career.

New graduate students continually forget that the main purpose of research at the graduate level is to learn how to do research and to solve problems. The acquisition of knowledge in a particular area is of secondary importance. If you have learned how to do research in area A, it is a relatively minor step to acquire the facts and background needed to conduct research in area B. Consequently, when choosing a research topic, your main concern should not be whether you like the research area, but whether this particular research project and the director of this research have the best chance of teaching you how to conduct research.

My third misconception was that my research work would follow the idealized method of scientific inquiry which involves a literature search, development of a theory, design of the experiments, and interpretation of results that tested the theory.

One quickly learns that research is often more like a random walk than an idealized textbook approach. The young researcher is often quite upset when discovering this fact. At first it is difficult to accept this basic truth. It is much easier to arrive at one of the following conclusions:

. . . when choosing a research topic, your main concern should not be whether you like the research area, but whether this particular research project and the director of this research have the best chance of teaching you how to conduct research.

- **My thesis advisor is incompetent.**
- **My research topic is a real lemon; I don't know how anyone talked me into doing this.**
- **My research has nothing to do with what I have learned in the classroom.**
- **No one else has problems like me; my project is unique in its difficulty.**

What the young researcher fails to realize is that the way research results are presented in a paper or a seminar has nothing to do with the process that was followed in obtaining those results. Research cannot be planned like many other human endeavors. It is, in fact, a form of art. If you knew beforehand what your results were going to be and the path you would have to take to obtain them, it simply would not be research.

No matter how badly things are going, or how tortuous your route, you should always maintain a clear idea of your objective.

One frustration which all faculty members face is that many funding organizations also do not realize this. As a graduate student, you must be careful not to confuse the formal presentation of results in papers or seminars with the actual process. A related misconception is that the results you obtain in research should be in proportion to the time and effort you have spent. The most difficult aspect of research is that you do not usually see a steady progression of results. Instead, results come in bursts or surges. It takes tremendous tenacity to hang in there and keep plugging away when you are not aware of any progress.

Many young researchers also feel that their problem is so complex that it really cannot be explained to anyone else in a reasonable period of time. No matter how badly things are going, or how tortuous your route, you should always maintain a clear idea of your objective. If you cannot give a clear overview of your research project in a few short sentences, you have a good indication that part of your problem is your inability to keep things clearly defined in your own mind.

My fourth misconception was that the study of chemical engineering had nothing to do with human values, ethics, morals, etc.

When I started my graduate studies, I considered science to be ethically or morally neutral. However, as Bronowski has pointed out, this is confusing the results or findings of science with the activity of conducting science. There is no question that the results of your research will be ethically neutral; however, at the center of scientific inquiry is the standard that facts or truth, not dogma, must dominate your research. By conducting research, you will be training yourself to avoid and resist every form of persuasion but the facts. The most difficult part will be to avoid deceiving yourself. In everyone's career, there comes a time when experimental observations are inconsistent with a pet theory. It will be a true test of your maturity as a researcher to unbiasedly look at the facts and to determine if the experimental observations are consistent or inconsistent with the theory, independent of your personal feelings. As T. H. Huxley said, "The great tragedy of science is the slaying of a beautiful theory by an ugly fact." There is a natural tendency to formulate vague theories which cannot be proven wrong, but all good theories will eventually lead to their own demise since they will finally predict something which is inconsistent with experimental observation.

Science does not have a Hippocratic oath or any other professionally induced ethical rule. However, you can be untruthful and still be a successful doctor or lawyer. This is not a viable possibility for the scientific researcher. As you develop into a good researcher, you will develop the capability of making judgments based solely on the facts. I feel this training can have a very significant positive influence on the moral and ethical aspect of your life since it tends to minimize self-deception and rationalization.

My fifth and final misconception was that graduate study was all hard work and the rewards would come later when I had an interesting job and was making a lot of money.

After I received my advanced degrees, I realized that some of the best years of my life were those I spent in graduate school. I found that the pleasure and sense of accomplishment that came with learning and creating far outweighed the other pleasures in life. As graduate students, you are among the fortunate few who will not have to spend all of your time for the next few years working to meet the material needs of your life. Until this century, the great majority of people had to spend 100% of their time just to feed their bodies. A few privileged individuals, such as the Brahmins, Mandarins, aristocrats, etc. had the opportunity to simultaneously feed their bodies and their minds. We have made great advances, but today most people still spend a major part of their lives working to fill their material needs. No matter how difficult you find the days ahead, I am confident that you will look back on these years and be grateful that you had this opportunity to devote all of your effort to learning and creating.

If you are very lucky, you might, after much hard work, devotion, and frustration, be fortunate enough to be the first person to see one of those patterns to which Gibbs referred. That will be the most rewarding time of your graduate studies, not the moment you receive a piece of paper which declares that you have now earned a specific degree or that first pay check. □