



D. W. Armstrong's Mentoring Essay

Because I'm a scientist, I measure things or invent better ways to analyze things in order to model systems or test theory. Thus, I've always felt it was simple to determine if it mattered if one had been born – that is to say quantifying one's existence. This can be the sum a total of three things.

- 1) *If you invent, discover, develop or contribute to something beneficial that wouldn't have occurred by that time without you.*
- 2) *If you influence, teach, mentor or save someone who does #1 above and they wouldn't have done so otherwise.*
- 3) *Your children.*

Most of us have two families, our biological family and our academic family. In fact, there is a website devoted to "academic genealogy" known as Academic Tree in which individual disciplines (e.g., chemistry tree, etree for engineering, cell biology tree, etc.) record ones academic parents and grandparents, as well as academic children (i.e., Ph.D. students, etc.), grandchildren and so forth. The main focus of my academic family is my graduate students. They have come from all "walks of life", most parts of the country/world and have different backgrounds, customs, skills, and levels of education. Of note is that perhaps the majority of my Ph.D. students were the first generation of their family to attend college at any level.

In simplest form, the goal for all my graduate students is for them to be successful, whether they go to industry, academia, a governmental position or become entrepreneurs. Indeed, not to be just successful, but to do and be better than graduates from other universities. Our group currently has this reputation, which greatly benefits new graduates, most of whom have jobs (often multiple offers) well before they graduate. When you do research with graduate students, you are teaching constantly. It is much broader and more time consuming than typical classroom teaching. It often encompasses evenings, weekends and holidays of mostly one on one interactions. Early on, my graduate students learn that there are no jobs for taking tests. You have to be able to do something with what you know, otherwise knowledge is useless.

Typically, new graduate students know little about scientific research nor how to think critically, present their results verbally and in particular how to write a peer reviewed paper. These things must be taught and learned if they are to be successful. I know that I have succeeded when, at some point, they can take the initiative and teach me. On average each of my graduate students will have 8-10 peer reviewed publications by the time they graduate and they have a maximum of five years to do so (four years are preferred – the fastest was three years plus one summer). This requires a good work ethic. In order to be first author, they must write (or attempt to write, with guidance) the paper and be able to successively improve it in response to the volumes of red ink that I judicially place on each draft. After about 10 papers over 5 years, their critical

thinking and writing tends to improve considerably. Additionally, they must make at least 4 presentations at national or international meetings/symposium/conferences. This is over and above any local or regional presentations which don't count except as practice. Thus, by the time they graduate, their C.V.s are far more impressive than others of comparable age and with comparable degrees from other institutions. However, this is getting ahead of the narrative.

We develop and invent the techniques, in my research group, that everyone else will use. Also, we use the techniques that we develop to study interesting problems in the environment, pharmaceutical, biomedical fields, food science and so forth. Initially, everyone must learn to use and maintain instrumentation and to generate data. This is the easy part. More difficult is to know if the data is good (valid, accurate, precise, etc.), why we want to obtain this data, how to interpret it, and whether or not this is the best way to do it. Do we need to use another approach or potentially develop/invent a completely new technique? To make these types of decisions, one must be more broadly educated, have some imagination and be a critical thinker. These things come more slowly, but can be nurtured, especially when it is made clear that this is the expectation and the way towards understanding and research success. While I formulate research projects, by the latter part of their tenure, the Ph.D. student should be coming up with their own viable projects and solutions. That is when you know you have succeeded.

We have weekly research group meetings where two graduate students successively present the background of their projects and their current results. Each student does this, multiple times per year. They can use the blackboard and PowerPoint. No notes are allowed. They are extensively and usually exhaustively questioned during and after their research presentation. Thus, they learn to speak, answer questions, defend their work and learn about possible shortcomings, misunderstandings and/or mistakes. All other students in the group get to learn about a different area of research in which they are not directly involved. Often, they can see an area where they could help or cooperate with the presenting student. If their help or contribution is sufficient enough, they could get to be a 2nd or 3rd author on a subsequent publication. Therefore, the benefits and rewards of helping and cooperative team research become quite obvious. Additionally, everyone who gets a job interview or who does an internship gives a report on it at our group meetings. Everyone is informed about the interview format, the exact questions that were asked, how they were answered and whether or not they could have been better answered. Every group member has probably heard and discussed 6 or more of these before they reach the point where they have their own interviews.

We are asked to provide specific examples of success. Of the hundred or so of my graduates, I don't know of any who were not successful. I could talk about Timothy Ward who is the Associate Dean of Science at Millsaps College, or Jared Anderson who is a popular Professor at Iowa State University and is considered one of the Top 40 young analytical scientists in the world. There is Kimber Barnet at Pfizer who helped develop new life saving drugs. There is Youbing Tang of the Food & Drug administration that makes sure that new drugs are safe and

effective. For every one I mention, I'm leaving out 20 or more who are also successful. I've deliberately not mentioned anyone who graduated in the last eight years since there is a separate list of those included along with their affiliations. They are clearly highly successful as well

My former students keep a running list of all graduates so they can network and have get-togethers every few years, usually at a national or international meeting where I am giving a talk. With perhaps a couple of months' notice, there is a get-together that is a joy for me to see and be a part of. They trade information and stories and the older graduates meet the newer graduates for the first time. Of course, not everyone can come from all over the world, but sooner or later most get to one of these gatherings. Below is a picture from the 2012 "reunion" at the *International Symposium on Chirality* which happened to be in Fort Worth. Others have been in New Jersey, California and in March, another will be at the "Pittsburgh Conference" (the world's largest analytical exhibition and meeting with >20,000 attendees) in Philadelphia.



Research involves developing new knowledge and/or inventing the techniques that lead to discovery and problem solving. Doing this and teaching others to do likewise advances the human condition. Further, and on an individual basis, it can be a great source of enjoyment and satisfaction. Successful researchers often have a seemingly odd combination of ego and humility. It takes both in order to keep driving forward after failures (convinced that they are only temporary) and after success, knowing that it will eventually fade as it is part of an expanding whole and we can never "do it all". But, perhaps someone we taught or influenced will carry on, and in turn influence others. That may be as close as we can come to immortality.