The following essay was written on request from Thomas Kent, Dean of the Graduate School. It was printed in a booklet and distributed on 19 February 2002 to each of the 800 faculty members at Utah State University. If you would like a copy of this essay, in booklet form, please contact Bruce Bugbee at bugbee@cc.usu.edu

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On Mentoring

Bruce Bugbee

I am deeply honored to have been nominated by my students and colleagues for the Graduate Mentor award. Few things in life are more satisfying than heartfelt appreciation from students as they complete their degrees and commence their careers. Our development office will forever ask each graduate to remember USU by donating part of their future earnings, but an even better way to enhance the quality of a university is for students to tell teachers and mentors what they have done for them. I hope this essay inspires graduate students and colleagues to nominate the many excellent graduate mentors on campus for this award in future years.

Graduate education at USU makes our campus unique. We compete with many other schools for the best *undergraduate* students in Utah, but only one other public institution (the U of U) has a comprehensive *graduate* program. Graduate education should be at the core of our teaching mission. We need to use our impressive input of external funding not only to generate new knowledge, but to better educate future scientists. The great universities in this country have not forgotten that they do research to educate researchers.

Finding the Scientist within the Student

In preparation for writing this essay, I reread the essays of the previous five recipients of this award (Charles Salzberg, 1996; William Campbell, 1997; Kenneth Brewer, 1998; Fred Provenza, 1999; and Brent Miller, 2000). It is apparent that they all worked hard to identify the unique capabilities of each graduate student. Mentors see talent in its earliest stages - often before the student sees it in themself. The British sculptor Henry Moore said, “The sculpture is within the stone.” My work with graduate students over the past two decades has made me realize that Moore’s insight is a key to mentoring. Mentors see the scientist within the student.

Coaching and Mentoring

I often compare my role in directing a team of graduate students to that of an athletic coach. Both jobs involve identifying young talent and recruiting the best "athletes." Both jobs involve building a sense of team spirit and camaraderie over multiple years. Both jobs require extraordinary patience and a sustained commitment to excellence. Both jobs involve elation - and frustration. Elation when experiments work as planned and our hypotheses are confirmed. Frustration when experiments fail and the hypotheses cannot be answered.

Management versus Mentoring

Our consumer society is replete with books on management. The best managers are thought to be those people who can handle a fast-paced management style and make quick decisions on a wide variety of topics. This approach lead to the popular book title "The One Minute Manager."

Students are rarely inspired by one-minute managers. Students want to work for faculty who care about student development and who continuously challenge them to perform their best.

There are few books on mentoring. Mentoring requires a slow, steady, sustained effort. An analogous mentoring book might be titled "The Ten Year Mentor."

Mentoring by Wandering Around

My laboratory is in the Research Greenhouses. When I started at USU my office was in the middle of campus - more than a kilometer from the lab. After a year, I realized I didn't have the contact with my students that is necessary for optimal productivity and I moved my office to the lab. This move facilitated a management style that has worked well for me. This approach is called MBWA (*Management By Wandering Around)*. I cannot truly get to know my students as people just by opening my office door. Faculty offices can be intimidating. The MBWA strategy involves leaving my office and going to the graduate students' work sites or offices. Our conversations are sometimes technical, and sometimes not. MBWA helps me see, first hand, the difficulties associated with diverse research projects. Frequency of contact is important. When people ask how often we have lab meetings, I sometimes say we have a three minute meeting every hour.

Real Time Feedback

One of the most powerful mentoring skills is the ability to give effective performance feedback. This feedback lets the student know whether their research has been done well or whether they need to improve. Faculty often talk with their students about their research, without directly telling them how they are performing. I try to tell my students how effectively they have performed on a specific task - right at the time it occurs. Being direct and honest with students is a good thing - but it is extremely hard to do.

On Being a Scientist

One of my favorite books on the practice of doing science is "*On Being a Scientist: Responsible Conduct in Research*." This book has helped me show students the importance of being cautious in making conclusions based solely on their own data. I try to help my students see how their work contributes to the larger body of scientific knowledge, but I also want them to understand that the path to knowledge is long and extraordinarily tortuous. A single experiment, or even a dissertation, does not prove a hypothesis.

In my discipline, the classroom definition of "pseudo-replication" usually refers to multiple plants in the same pot. These plants are not sufficiently different to be considered true replicates for statistical analysis. So when *are* replicate treatments sufficiently different? I try to help my students see that "pseudo-replication" can be multiple experiments in the same lab, or multiple measurements using the same technique - even if they are in different labs. Much of what we think we know is really a house of cards based on years of pseudo-replication. Knowledge evolves as people from different backgrounds, in different settings, reach similar conclusions - a long and tortuous path.

I try to help my students see how they can be misled by statistical significance. The best scientists do not make conclusions based solely on numerical analysis. "*On Being a Scientist*" helps students understand when it is ethical to throw out bad data. Separating good from bad data requires an insight that cannot be taught in a classroom. Statistics textbooks say that a data point can be discarded only if it is more than three standard deviations from the mean, yet the data that are apparently good can be misleading, and the outliers can hold the key to new insights. The best scientists know when to trust theory and discard measurements - and when to trust measurements and discard theories.

I try to help my students learn that their success as a scientist will depend not only on their skill in making measurements, but in understanding the theory behind the measurements. Only with this combination can you tell when seemingly bad data are good, and seemingly good data are bad. Louis Pasteur knew the value of keeping "bad data" when he said, "Chance favors the prepared mind."

Contributing to the Infrastructure

Infrastructure usually refers to instrumentation and physical facilities, but I also use it to mean the "corporate culture" of a laboratory group. Teamwork is crucial in research and I want each student to experience its value. This means helping other students when necessary. The sense of teamwork has been facilitated by putting photographs of the students at work on the refrigerator in the lab; and by displaying students' posters in the hallway. Many of the posters have multiple authors, which provides an incentive to contribute to the group effort.

Encouraging contributions to the lab infrastructure must be done carefully. Some students become overly enthusiastic with the team effort and lose their individual focus. Both individual and group efforts are important so encouragement must be customized for each person.

Web Page

In addition to publishing in top quality journals, I have found it highly useful to put summaries of our work on the Web. We have invested much effort to develop and maintain a lab web page that summarizes our research progress (www.usu.edu/cpl). This has been an extremely useful tool for recruiting new graduate students. Students from around the country often contact me about graduate school after they discovered our research through an internet search for "Phytoremediation" or "Hydroponics". For many young students, the web has replaced the library as the primary source of information on who is doing the best research in their field. In addition to photos of the students doing the work and color graphics, the web page includes copies of poster presentations in PDF format, and Power Point presentations.

The web also provides an incentive for students to promptly summarize research results. Presenting papers at national meetings also provides an incentive, but paper and poster presentations at meetings are infrequent. Putting results on the web is inexpensive and can be done in small portions at frequent intervals.

Making a Popular Version of Theses and Dissertations

Theses, bound in their formal black covers, are not widely read, but colleagues are often interested in the details of the research. I have found it useful to make a single-spaced, spiral bound version of each thesis for distribution to colleagues (and parents). The cover is particularly important. It includes a color photograph of the student, and one or two selected graphs, photographs, or color diagrams that concisely summarize the entire thesis. The photograph on the cover personalizes the research and the graphs encourage people to read the details inside. Our research journals now routinely use color photographs on covers and the same approach works to make theses more interesting.

Advocacy

Advisors play a critical role when they serve as advocates for their students. This usually starts early as I look for sources of scholarship funding and guide the students in writing a proposal for the funding. Advocacy includes helping students locate potential employment opportunities as well as writing insightful letters of reference to employers. But it doesn't end there. I want to see them advance in their careers long after they graduate. Keeping in touch with them allows me to be their advocate well after graduation.

Graduate Students as Colleagues

I am always concerned when people joke about getting graduate students to work long hours on menial tasks. These jokes too often reflect a reality of our approach to graduate education - they imply that graduate students are indentured servants rather than colleagues. If we treat graduate students like their time is worth $50 per hour, they will develop the confidence and the efficient work habits necessary to be successful in their first job.

Graduate Students as Mentors

I have found great value in having each graduate student work one-on-one with an undergraduate student. This includes helping the graduate student advertise for a lab assistant through student employment, interview the applicants, make a selection, train their new employee, and effectively utilize the employee's talents. Graduate school is a

good time to develop the leadership skills that will be important in a profession. Aristotle insightfully acknowledged that “Teaching is the highest form of understanding.” Graduate students need the opportunity to teach so they can fully understand.

Two Issues Unique to Graduate Education at Utah State University

1. The 80/20 research / teaching split: Where does graduate education fit in?

Many faculty in the sciences have an 80/20 research / teaching split. However, credit hours for Research and Thesis are not counted in the teaching component, which makes the teaching effort appear much smaller than it really is. Funding from the state legislature is determined by student credit hours (SCH). Funding increases for higher level courses. An undergraduate student in a lower division course has a weighting factor of one. Funding is 6.4 times greater for a Master’s SCH and 15.4 times greater for a Ph.D., so a *single Ph.D. student* enrolled for 9 credit hours of Research and Thesis brings in as many student credit hours as a 3 credit undergraduate *class* with 46 students. A faculty member with 3 graduate students, enrolled in 3 credits of Research and Thesis each semester, can generate as many SCH’s through graduate teaching as with undergraduate lecture classes. Unfortunately, we do not yet attribute the graduate research credits to the faculty member who supervised the research so they don’t show up as part of their teaching effort. A change in this policy would go a long way toward encouraging faculty to increase their effort in graduate education.

2. Funding graduate education - the 12th month

We are all besieged with requests to donate money to charitable causes. Here is a way to make a donation that is matched by the University and the IRS: use your 12th month of salary to fund a graduate student. Lets say the 12th month is worth $5,000 in salary. With 7.3% FICA taxes, 31% federal taxes, and 7% state taxes; only $2750 of this is usable income. For this $2750 contribution one gets $6,900 to fund graduate students. ($5000 in salary plus the $1900 in benefits that would need to be paid on the salary). This may be a larger contribution than many faculty are willing to make, but the point should be clear: for every dollar of salary not taken, $2.50 is made available for graduate education.

Summary

My approach to teaching and mentoring was significantly improved when I woke up one day and realized that you can't teach anybody anything. All real learning occurs when we do things ourselves. The best I can do is to inspire my students to try new things and draw appropriate conclusions from their experiences. Reciting words on test pages does not mean that any learning has occurred. As the famous educator John Dewey said, "We learn what we do."

Footnotes and References

On Being a Scientist: Responsible Conduct in Research. 1995. National Academy Press. Washington, DC. (www.nas.edu).

Blanchard, K. and S. Johnson. 1986. *The One Minute Manager*, 10th ed. Berkley Publishing, NY.

Management by Wandering Around was popularized by a book written by Tom Peters and Robert Waterman in 1982. They concluded that companies that had top managers engaged in interacting with employees were more successful than those with isolated management. They believed this success was due to leadership that spent considerable time outside the executive office. It also allowed for managers to communicate organizational values and management philosophy at a personal level.

Peters, Thomas J. and Robert H. Waterman Jr. 1982. *In Search of Excellence: Lessons From America's Best Run Companies*. Harper and Row, NY.