Impact of modern technology on graduate education in animal sciences

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Introductory Comments and Background

I am humbled and honored to receive the L. E. Casida Award, especially because Dr. Casida was my mentor for the Ph.D. I thank the Awards Committee for selecting me as the recipient. I would not be qualified for this prestigious award had it not been for the efforts of my students. I feel this award belongs to them, too. I have been fortunate during my career in academia to have attracted excellent students to my laboratory. It has been a pleasure and intangible benefit to observe the intellectual transformation in logic and reasoning power that occurred during the tenure of their graduate education. As far as I know, all are, or have been, successfully engaged in work related to the livestock industry or the biological and medical sciences. I am proud of their many accomplishments.

My mentoring skills and philosophy basically reflect those acquired by exposure to three individuals, who served as my mentors during my graduate career. I would like to briefly acknowledge these three individuals and their contributions to my mentoring philosophy.

Dr. Ralph Erb served as my major professor for the Master of Science degree. His dedication to science and his work ethic made a lasting impression on me. During my association with Dr. Erb in the late 1950s, he had acquired from Carnation Milk Farms (Carnation, Washington) 25 yr of clinical records on the reproductive characteristics of their Holstein cows. For the years I was in his laboratory as an undergraduate and then his graduate student, he literally spent day and night compiling the data and subjecting it to statistical evaluation using one of those old-fashioned mechanical calculators that would rattle and roll for what seemed like an eternity before providing an answer. His endeavors with those herd records served as an example of how to maximize use of data. From his efforts came some of the first data on factors affecting reproduction in high-producing dairy cows (Morrison and Erb, 1957).

During my junior year at Washington State University, I was hired by Dr. Erb to wash the laboratory glassware for one of his graduate students. This particular student was Jack Gorski. It was Jack who was instrumental in stimulating my interest in the biochemistry of steroid hormones. He did so by letting me become involved in his research project of identifying and quantifying the progestins present in the bovine corpus luteum. No RIA existed for steroids in the late 1950s, so quantification was by paper chromatography and spectrophotometry, laboratory techniques in biochemistry that I found especially intriguing. From Jack, I learned that science could be fun and exciting. Jack indoctrinated me with the philosophy that it was okay to take risks in science by researching problems not being studied by others.

Finally, from Dr. Casida, who served as my mentor for the doctorate degree, I learned the basic elements of the scientific method. He encouraged the development of my thought process, showed me the importance of critical evaluation, and taught me the value of appropriate experimental design and statistical evaluation. His mentoring skills served as a model in terms of how much can be demanded from a student so they realize their potential yet keep them challenged, focused, and enjoying their academic experience.

As a consequence of my exposure to these three individuals, I have tried to impress on my students the following four requirements for success in science:

1. A commitment to the profession that extends beyond 40 h/wk. This is especially important because research on domestic animals encompasses more and more experiments involving molecular biology. As previously stated in *The Eighth Day of Creation*, it is not possible to be successful in science with a 5-d, 8-to-5 work ethic (Judson, 1979).
2. An affiliation with colleagues who are more knowledgeable than you. You must be willing to turn to or collaborate with people who are brighter than you are (Watson, 1993).
3. A willingness to take risks in research.
4. Finding the work to be fun and exciting. In the game of science, the highest goal should not be to win, it should be to win at something really difficult.

Do I feel there have been shortcomings in my approach to graduate training? You bet! Because of the complexity of the problems under study, I regret that

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I had not involved more of my students in interdisciplinary programs that crossed departmental and/or college barriers. Considering the current job market for graduates with advanced degrees, such interdisciplinary programs can increase the students' postgraduate opportunities through exposure to a broader range of experiences (Smith and Tsang, 1995).

In the preceding paragraphs, I have described the traits and teachings of my mentors that served to ultimately define my own philosophy with respect to the mentoring of graduate students and postdoctoral fellows. Science is in a continuous state of flux, regardless of the particular field, and this evolution is driven in large part by technological developments. In what follows, my intent is to address some aspects of technology that I feel are having a detrimental effect on the scholastic abilities of current and future students in the biological sciences. Some of those less desirable effects of technology on our students may be likened to a slow-growing malignancy that will only become apparent by the downturn in quality of research conducted in future years.

Advances in Technology: Good and Bad Aspects for Science

Technological developments in recent years are permitting us to explore the functions of the animal at the molecular level. Most modern scientific instruments are somehow connected to a computer. Currently, a scientist without access to a computer is like a fish out of water. I will be the first to admit that modern instrumentation and computers have permitted us to make significant advances in science that otherwise would be impossible. However, technology is akin to selecting for a given production trait in livestock (i.e., although improvements may be gained in the trait, there is frequently a loss in another trait). Have advances in instrumentation and availability of various laboratory kits actually caused us to focus more on technology at the expense of being more creative and imaginative in science and scholarly activities? Dr. Casida, as meticulous and disciplined as he was in experimentation, actually was very suspicious of the use of new technology in science, especially if he felt it did not contribute to the solution of the problem. On one occasion, when approached to purchase a new digital readout balance for the laboratory he informed me that "some of the best research was conducted using a stick and two strings" (to form a balance). I don't know how far back in the antiquity of documented science this research to which he alluded was conducted, but I have looked for this paper for 40 yr and never found it. Nevertheless, the point he was making, which remains applicable today, is that good research can be conducted without access to fancy equipment.

Impact of Computers on Writing Skills

One aspect of science that has been affected by technology has been the writing skills of our students. A major concern for all educators is the apparent lack of good writing skills among students. This is not just an educational problem; good writing has cultural and economic ramifications as well. Good writing has essentially become a lost art.

According to the report of the National Commission on Writing in America's Schools and Colleges (2003), there is a specific deficiency in the writing skills of high school and college graduates, especially among engineering and science students. Now, more than ever, the major complaint from the business world upon hiring technical graduates has been their poor writing skills. As scientists, we are asked more and more frequently to describe the results of our technical research in written form understandable to the lay public—the same lay public that includes representatives of state and federal legislatures responsible for allocating money for agricultural research. It is obvious that good writing skills are a requisite for success in science.

What are the reasons for the downward trend in writing skills? According to the writing commission, the first reason for poor writing is the lack of writing assignments in our primary and secondary schools. Few high school seniors are ever required to write a research paper or composition that involves honing skills in synthesis and getting to know what the inside of a library looks like. Unfortunately, this deficiency in writing skills is rarely corrected at the university level. The second reason for poor writing skills can be attributed in part to technology, or more specifically, to computers. Computers make it easy to communicate by electronic mail, but e-mail is usually fraught with poor grammar or punctuation and a plethora of slang and abbreviations. I personally believe that computers make it more difficult for some students to synthesize and compose. For some reason, by composing with a computer, it becomes difficult for students to transition from one subject to another.

As educators of future animal scientists, we need to be cognizant of the importance of writing skills and pay extra attention to ensuring that our graduates are able to effectively communicate via the written word. Their survival in the professional world will certainly depend on this skill.

Are Computers Defining the Limits of Recorded Science?

In the futuristic motion picture "The Matrix Reloaded," computers rule the world by making slaves of humans. In essence, are we not already there? And if not in whole, then certainly in part. Computers have essentially defined the beginning of recorded science as of approximately a decade ago. For many students who rely on computers to search the scientific literature, scientific journals online date back only to the early 1990s. Unfortunately, the elegant research conducted and published during the 70 or more years before the 1990s is rarely read and included in reviews. The early

literature is replete with valuable information that may be beneficial to the modern day "researcher." The word research means precisely that—"re-search." However, it is difficult to effectively re-search unless one is cognizant of what work has been done on the subject previously.

Computers and Statistics

Computers have also impacted how data are analyzed statistically. Obviously, some data sets are so huge that data reduction and analysis can only be accomplished by the use of computer programs. However, it has been my experience that few students can interpret the components of even the simplest statistical analyses generated by computers other than by being able to identify the *F*-value and its significance. It is particularly discouraging to find descriptions of statistical analyses in theses and refereed publications consisting of a simple sentence filled with meaningless acronyms such as "Data were analyzed by GLM of the SAS." Such descriptions lead to doubts regarding the significance of the reported data. This is especially true when the experimental design is complex and encompasses a split-plot or factorial arrangement of treatments.

Blind Acceptance of Technology

Relative to the effect of technology on graduate education, there seems to be more of the so-called "tail wagging the dog" syndrome prevalent with current students. The sophisticated and ever-expanding technology available for probing the inner secrets of the cell seems to hold fascination for some students. For example, microarrays have a particular appeal for some. There are some individuals who simply wish to use this technology to visualize which genes light up in a given tissue without really knowing why. There are no hypotheses under test, no ultimate goal in mind. It is imperative for all of us who train the scientists of tomorrow to teach and counsel them about the dangers of letting technology be the master around which the research is conducted. Technology must remain the tool and not the master of experimentation.

The literature now contains numerous examples of research in which cDNA for particular proteins are being transfected into alien host cells. The results from many of these experiments are being accepted outright without question as being representative of gene expression in the donor cell. This technology has the potential of leading to serious erroneous conclusions with regard to the various factors required for normal gene transcription in the donor cell.

Conclusions

In conclusion, as educators, it is essential that we maintain certain time-honored standards in the training of our future scientists. We need to ensure a supply of scholars capable of being effective communicators through the written word. This is essential because science belongs to the public, and their primary source of information about this subject is via the written word. In training our students, who will be future animal/biological scientists, we need to encourage and promote imagination and creativity in research. And as mentors of these future scientists, we need to impress upon them the need to guard against technology becoming the master of their research rather than simply a tool in their experimentation.

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