Deciphering Importance from Information

Introduction

I am quite honored to be invited to present this lecture. Unlike many of the students who were trained by Sheridan Simon in physics, I am able to say that Sheridan actually influenced my interest in biology. This came about in the following way: Sheridan and Rose asked me to be the caretaker for their apartment while they were away during the summer of my sophomore year. In July, I was directly confronted with mammalian biology when I realized that their female cat (whimsically named Grimsley) was pregnant. Late on a Saturday night, I witnessed her giving birth to a litter of kittens. Following their maturation and growth was fascinating, particularly when all the kittens would run en masse across the floor like the Seventh Cavalry. Now that I study the molecular aspects of developmental biology, I remember observing those kittens as part of the spark that kindled my interest.

It was my good fortune to be a student at Guilford, as I managed to get a pretty decent education. I was then fortunate enough to eventually obtain a faculty position at Tulane University, engaged in both research and teaching. The fact that I have become a faculty member points out the importance of having "faith in the future." It is this faith that helps us train our students to be successful in the next generation. Therefore, my talk tonight will concern what I learned at Guilford that it important for the future: It is necessary to seek the answers to questions in order to decipher importance from information. My professors at Guilford taught me how to ask good questions, as a part of learning how to learn. I have been able to use this important concept of asking questions continually during my career. However, training students in the process of asking questions may be a talent that is becoming lost in the information age. If we are to have faith in the future, then teaching our students the ability to ask questions and seek answers is an essential means of preserving that faith.

What I learned at Guilford College

At Guilford College, I completed a degree in Biology and Physics. What aided me in completing the required work was the feeling that I was directing my own course of study and pursuing my own interests. Rather than experiencing learning as a prescribed set of courses to complete, or a given amount of information that should be mastered, I was taught that learning required me to ask questions and find answers. This lesson in learning continues to be important to me in all the diverse aspects of my life.

As most students at Guilford will tell you, asking questions and then looking for the answers is an interesting and demanding way to learn. It can be very demanding in that the student will have to overcome hurdles that are not present to other students who simply memorize the class notes and repeat the information on the exam. Demands are made as well upon the teacher, because there are critical points at which it may be necessary to inject some assistance to help a floundering student. Judging these points accurately not only enables students to continue to learn, but separates the teacher from the lecturer. Fortunately, from my training at Guilford, assisted by Sheridan, Rex Adelberger, and Frank Keegan, I found that asking questions was the manner in which I wanted to continue my education. Therefore, it seemed natural that I should proceed on to graduate school. Combining my interests in biology and physics, I was accepted at Penn State in the Biophysics program.

I arrived at Penn State just at the time when the Biophysics program was in the midst of a change, becoming the Molecular Biology program. Although at first I was a bit concerned that I had made an error, it turned out that I was fortunate with the timing of my admission to graduate school, because I was growing up right along with the new field of molecular biology. It was a terrific and exciting way to learn, witnessing progress happen at a dizzying pace. I can remember being eager for the next issue of a given journal to arrive, in order to find out what clever new ideas had been tested. It was truly a time when questions were being asked and answered using methods that had never been available.

An additional novel experience for me at Penn State was that I was in a "big science" situation, in a huge laboratory that had all the equipment necessary to perform experiments similar to what was being written about in the journals that we fought over. This was a new situation for me, because although Guilford College has labs, it doesn't have anything like these labs. I couldn't believe that such a situation existed. I was naive and young, and actually said to someone that I was amazed that people were paid to work in research labs. The reality of the situation was that I was able to follow my own instincts, devise questions, and learn their answers in order to know things that no one else knew before me. It is the ultimate satisfaction that comes from being able to seek the answers to the questions; the feeling of knowing what no one else knew until that time. The majority of investigators will tell you that this is the real payment that comes from the long hours of laboratory research.

Although graduate school was a delightful time with the excitement of an emerging discipline and unfettered ideas, I had to face the fact that one cannot remain a graduate student forever. (It could be said that I have tried.) I moved upward on the career path to a post-doctoral position at the University of Rochester, and then to a second post-doctoral position at the University of Rochester Medical Center. In each of these positions, I learned more about the nature of my career choice, and a great deal about the reality of this choice. I knew that I would continue to ask questions in order to drive my research forward, but I also found that I had to define a single area of investigation for these studies. In making this decision, some of the important aspects of finding the answers to interesting questions play a large role.

I decided to study a model organism, the dwarf mouse, which contains a genetic mutation which has a profound effect on body size, as shown below.

Figure of dwarf mice.

In this photograph of a "dwarf" mouse and a sibling normal mouse at about 6 months of age, it is easy to note that there is a tremendous effect; the dwarf mouse is only about one-quarter the size of the normal. Dwarf animals lack the hormone that is responsible for normal growth. It turns out that human patients can be afflicted with similar syndromes, which are more politely termed short stature. Dwarfism is beyond the normal range of size variation, and has been found to lie in mutation of the genetic information encoded in the DNA. My research interest is therefore rather simple, for I want to determine the exact genetic change in the DNA that causes dwarfism in this type of mouse.

The important aspect for this talk is the fact that the changes in the genes of the animal can be seen from outward appearance. Given all the mouse litters that have been observed over the years, someone saw that an obvious and really interesting change had occurred. Someone was led to ask “Why are these mice so different?” In fact, the field of mouse genetics has been founded on repeated questioning of observations of differences that indicate importance. Some of these “mouse fanciers” who breed these animals have been interested in changes affecting coat color rather than size, while others were involved with tail features, not color. In combination, a tremendous amount of information about mouse genetics and mutations is available, and can be used as the foundation of others who ask questions about why these changes exist.

Now, I want to point out that I am appreciative that someone else has done much of this analysis of mouse variation. I surely do not want to spend my life in that particular pursuit, although to many of these fanciers it was an enjoyable hobby. I have chosen to spend my life in pursuit of the exact details of just one of the mutations found in mice, by finding the genes that may be responsible for these defects, and attempting to decode the precise cause of dwarfism. As an example, let me point out that there are actually two different kinds of dwarf mice that have arisen independently, and are known not to contain the same genetic problem. Both dwarf types appear nearly the same in reduced size and weight, but the specific cause underlying one dwarf mouse mutation has already been determined. In these dwarf mice, of the entire sequence of all the genes in the mouse, which is roughly one billion “letters,” the mutation involves only a single letter change. Thus, normal growth of the animal is disrupted by a truly one in a billion occurrence, which has multiple consequences for the animal.

Repeatedly, in molecular genetic analysis, it can be seen that single changes have dramatic consequences. For example, analysis of cystic fibrosis has led to the finding that some forms of the disease are the result of a single "letter" disruption of a gene. Here again, a debilitating syndrome is due to a one in a billion occurrence. These are minute changes, but we can see these changes, and we can study these changes, because they have a similar effect: they are important alterations of one critical piece of information. No one knew beforehand that such seemingly small changes would have such deleterious effects, but by asking questions and finding the answers, the reality of the importance of each bit of information becomes apparent. I am able to work with, to understand, to comprehend, the idea of how important one bit of information is against the billion other bits of information. These single changes are important, and stand out against a background of all the other information that is present in the entire organism.

Remember, I really like looking at these long sequences of DNA to find these one in a billion changes. There is massive amount of information and data that is now available to that must be sorted by using a strategy that I use as a molecular biologist investigating this dwarf mutation. To me, a logic exists that I can use to try and scratch out from clues here and there. Out of all the billion bits of mouse DNA letters, I have to use logic and questions to attempt to find the one that I want. I do this work because I believe that the logic exists, and I want to be a part of finding out what some little portion of that logic is. This strategy is not really new, but must be adhered to rigidly in order to avoid false conclusions. That's the important topic for this lecture: interest in a subject leads to asking questions and seeking answers, even though the answers are buried in piles of extraneous information. My interest in answering a seemingly simple question has led to use all of the means at my disposal in order to find that answer. In doing so, I have to gather all of the available information, devise ways to sieve through pertinent data, and attempt to formulate the question in the most exact wording possible. Finally, with the goal of finding an answer, I have also found a career that will last a lifetime.

How my research influences my teaching

In the midst of all of this research-oriented career development, I was fortunate to obtain a position at Tulane University as an Assistant Professor in the Department of Cell and Molecular Biology. I was hired to establish a functioning research laboratory, and to teach a senior biochemistry course that would be of my own design. Although I would not choose biochemistry as the course I most wanted to teach, I felt that the opportunity to initiate my own course would allow me to make the material more interesting than in my previous experiences. However, one object that I had to deal with was how to develop an entire course that would provide adequate coverage in one semester, given that most textbooks of biochemistry have an average of 1200 pages.

The idea that first appealed to me was to find a means to cram all of the information directly into the students heads. After all, with all the power of multimedia technology available to me, I could certainly lecture rapidly enough to cover all of this material. Using videotapes and CD-ROMs as a means of presenting all of this information to the students would surely be a wonderful course, wouldn't it?

However, I began to think about how to develop this course using the process which I employ as a researcher. It seems to me that my job could then be summed up in one sentence: teaching students how to learn how to find out what is important vs. what is unimportant. Given the privilege of teaching 85 bright young students about cellular biochemistry, how am I supposed to go about it? Start with the history of the subject, or start with the most topical information in order to be current? It is indeed difficult to decide on the best pathway, particularly because of the fact that it had taken me a long time to understand the distinction between information and learning.

For example, teaching in science is often discussed in a different vein from teaching in other areas. When I first envisioned my senior biochemistry course, I set it aside from the routine of research, in part based on statements such as the "amount of information" that the students must learn, and the overall concept that what fuels research is somehow different from that which fuels teachers. However, the methodology of science - hypothesis, thesis, and synthesis - works to guide educators in any area to kindle the excitement of learning for their students. Thought of as questions and answers, the process can endow students with the ability to learn “how to learn” rather than simply regurgitating the material.

It is very important for biologists to adopt this mode of thinking, because so much of biology is a purely informational science. Currently, huge amounts of data and results are being gathered by various means and need to be critically examined for their biological importance. All three billion nucleotides of the human genome will be determined by the year 2005 (if not sooner); this is enough information for at least 27 volumes of the encyclopedia. Biology lacks the mathematical foundations of other scientific areas simply because the systems under study are so complicated, yet this complexity provides more empirical and quantitative data that must be processed and analyzed. If you are a student in biology today, you must be prepared to deal with all of this data, and the future with even more information. After all, sequencing one complete human genome will lead to the sequencing of other human genomes to allow the elucidation of the causes of diseases that are genetically determined. The result is that we will have multiple sets of the 27 volumes of data, which must be compared letter by letter for differences. By analogy, imagine that you are given the task of comparing all of the books in the New York Public Library in order to find the one typographical error that exists in only one of the books. However, if you are driven by the importance of the task, perhaps because the missing letter causes a disease that exists in your family, then the challenge becomes significant.

The realities of today’s academic world

For today’s student, more so than in the past, seeking answers to questions may be the only means possible for avoiding an information overdose. So, how do we teach this idea, communicate it to our students so that it becomes an innate skill to help them navigate this maze. What I believe is that we must remember how we act as intellectual investigators and then transfer that invigorating feeling to our students. Given that all of us really are “active seekers of knowledge,” then we should be able to pass on the excitement of this activity to our students and have it become their concern. Although this will not ensure that all students will receive higher grades or even passing grades, I believe that it does allow for each student to better achieve or realize their potential, rather than targeting a particular type of student. It also provides for faith in the future.

Encouraging this type of learning may be best exemplified is in the way that students question grading on an examination. If a student feels that their answer is correct although marked wrong, then I tell them that they must show me from the textbook why this is so. This leads to the most creative use of the textbook that I have ever seen. It is amazing the depths that students will plumb in order to find the most subtle nuance that vindicates their answer. Figure legends, appendices, any piece of written material in any text is considered fair game for justifying their answer. The desire, interest and vigor with which students search for exam mistakes should actually be their passion for learning the material in the first place.

Beyond scoring every answer as wrong, how can this fervor for finding the right answer be taught in the classroom? I have asked myself the related question: How did this feeling get instilled in me by my teachers? What drives me in my academic endeavors is the idea of knowing for my own interests. I think that we must teach our students that the real motivation for learning comes not from the fear of a test or homework deadline, but simply from curiosity in its purest form. This may be the most universal means of igniting student interests, whether in science, literature, arts, or any other field. Because I want to find the one altered letter in a mouse’s genetic code, then I will work to do this, through all hours of the night, regardless of my nutritional status, because I want to know something that no one else knows. On the other hand, if someone told me do this project in order to receive a grade, I probably wouldn’t have any passion for the work. A great deal of the difference comes from whether it is my work or assigned work. A student who wants to know something will find an answer, regardless of the impediments in the way; a student told to memorize tables will end up bored and listless.

I think that it is vital to utilize the talents that make the best researchers in order to develop the best students. I was influenced at Guilford College by the lectures on physics by Richard Feynmann. Although a Nobel Prize winner, Feynmann still lectured in introductory physics classes. His courses have been published as a text, but show photos of the live lectures, which included playful items such as bongo drums as a tool to teach physics. Feynmann's approach must have been a terrific learning experience, demonstrating that someone who has the ability to distill information and ask powerful questions was able to work with students just beginning on the same path. In part, I have to believe that this was tremendously appealing to Feynmann's view of the future for his discipline. As another example, consider Harold Urey, a Nobel Prize winning chemist at the University of Chicago. I saw a terrific picture of Urey as a lecturer in front of a classroom of 200 freshman chemistry students. Although Urey probably did not use the bongo drums, there mere fact of having a Nobel prize winning scientist ignite the curiosity of beginning students demonstrates a tremendously positive interaction between teaching and research.

Now, ask whether the interaction of teaching and research is happening today in the classroom. It is not, I would venture, and this is a trend that needs to be reversed. However, this is very difficult because of the specialization that we face over and over again today. Too often, what we hear is "that person is only doing research" or "that person is only doing teaching" with the implication that one cannot function in both ways at the same time. With that separatism, although great progress is occurring in research, what is also occurring is that the discipline required in research to evaluate vast amounts of information is not being transferred to the classroom. Teaching becomes poorer for it, because the separation of laboratory and classroom devalues both. A biology student should not be required to know the genetic code without being able to identify DNA in the lab. Research suffers when students are prepared only for memorizing texts, and not for evaluating experimental procedures. In this way, rather than being a part of the call for new means of teaching for its own sake, which is a worthwhile endeavor, I would like to call for the remembrance of how research and teaching need to interact. Together, the two combine to produce the means to decipher the importance out of all of the information that we possess.

How do teaching and research interact?

Note well, that I think of these as methods more for how I approach the classroom, rather than as some sort of manual for all teachers. Everyone has their own classroom, just as everyone has their own type of office, and it is not that any one style is best. In fact, it is just the opposite: exposure to many different styles makes a greater number of opportunities for the students' experience.

It is important in teaching, as in research, that concepts must be understood in their simplest form. For the student, this makes the whole appear more manageable and bite-sized. We can all understand simple concepts. In fact, the most important ideas are typically communicated rather simply. Einstein is known for $E = mc^2$. Those five letters and symbols make this complex and beautiful theory become much more manageable and understandable. In molecular genetics, the foundation of much of what we study comes from a classic paper. It is contains only about 250 words, which is incredibly short compared to most subsequent papers, but it is insightful and direct. In another field, Thomas Jefferson only needed one page for the Declaration of Independence (although he employed small margins). Over and over, simple, direct and effective thinking often contains great meaning.

Simplicity allows students to enter into the problem in an immediate way. It does not imply that students are completely ready to tackle the problem, but it allows the student to have a stake in its solution. As the student develops a more sophisticated view of the situation, they will be come aware of the simplicity that they started with, and understand its use as a tool. But they must get their start, and it will not come from the idea that everything is too complicated to learn.

Modern means of information using the computer should not be considered as monolithic and unfailing. This is an important concept that is part of teaching the simplicity of great ideas. Computers don't give answers, they give information. We need to stress that the important point is to develop your ideas and present them. It shouldn't matter if the medium is videotape, typewriter, chisel, lecture, or performance art, as long as the ideas are presented. This is actually may assist in teaching, because we can now pawn off routine, repetitive tasks on the computer, and dwell on the importance of the material. A real distinction can be gained when we compare what is needed to survive vs. what is needed to prosper in the information-rich society. Survival means being able to "keep up" with the changing times, and not become swamped in the mire. Prosperity means being able to employ the changes for your own benefit, curiosity, or interests. You literally now have command of the situation, and can find out the answer to any question you ask. This is the point where you are asking the really important question.

And so, the means to liberate the student from information overload is to teach the ability to ask a question first, and then go and find out the answer. Again and again, people habitually cruise the Internet and randomly collect information, essentially without any criteria or design. However, if the teacher can change the reason for information collection, and give the cruiser a purpose of answering a question, e-mail proficiency often can become the most useful of assets, allowing the assembly of very complete and informative answers.

It is important to remember that the internet only started 10 years ago, and it was devised a research network. This may be the best example of the interaction of research and teaching that will ever exist. Without the internet and all of its connections, research in many fields would not progress at the pace that has become customary. Given the information resources of the internet, it is understandable that the uses of this network for teaching would also develop. If we apply the critical evaluative judgment of the use of the internet for teaching that we use for research, students can be made aware of the fact that information itself is not the goal. The real development of the future will be the means to distill and refine the volumes of information that electronic communication provides.

To come full circle, when I left Guilford, I was cast adrift in a sea of information, and could only find my bearings by asking the questions that led to the importance of the information. As a researcher, I was able to comprehend the information around me by asking questions, in a precise way, that led to specific answers. Now, as a teacher dealing with deciphering that mass of information so that students can learn, I have to continue to use the skills that were taught to me at Guilford College, and pass on to my students the ability to seek answers to questions.

Teaching today involves a massive amount of information, and so teachers must teach strategies of dealing with this information. We have access to everything we need, and yet we fall short so often. We must teach strategies that lead students to ask questions, and then teach them how to find the answers hidden in all this information. Incisive work is often concise work, is often the work that needs no explanation, yet needs years of following up to trace all the ideas that are spawned by it. This is the challenge - by asking good questions, we can integrate what we have learned with the entire body of information. The really important point is to ask the really important question. This process is what we all are doing in our own work, as academics, and so the idea is fundamental to all intellectual pursuits.

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