SCIENCE EDUCATION FOR NEW CIVIC ENGAGEMENTS AND RESPONSIBILITIES

Reinventing Myself as a Professor: The Catalytic Role of SENCER

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Rutgers University

A SENCER BACKGROUNDER

HARRISBURG UNIVERSITY OF SCIENCE AND TECHNOLOGY

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A SENCER BACKGROUNDER FOR DISCUSSION AT SSI 2005

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Dr. McGuire has been an active participant in the SENCER project (Science Education for the New Civic Engagements and Responsibilities). He first participated as an advanced team member at the 200 SENCER Summer Institute. He brought Rutgers teams to SSI 2003 and SSI 2004. In 2004 he become a core faculty member and was appointed a SENCER Senior Associate at The National Center for Science and Civic Engagement at Harrisburg University of Science and Technology. He has been active in regional SENCER symposia and the NJ SENCER group.

Introduction

David Burns takes great relish in describing his first impression of me at the 2002 SENCER Summer Institute as a "burned–out, middle aged professor." According to him, I was both bewildered and cynical. Over time, however, I became a "true believer" and now I get to be sort of a "poster child" for SENCER. I wish that I could write that David was guilty of exaggeration and that he had no idea what he was talking about. However, he pretty much had me figured out.

I agreed to write this SENCER Backgrounder to describe the types of things that I have done at Rutgers University in bringing SENCER ideals to courses for majors in Genetics and Life Sciences. This paper is most decidedly ***not*** a "how-to" narrative. My progress toward changing the curriculum should be viewed as a type of "Drunkard's walk." That is, although the averaged path might make a statistically straight line, the actually path veers right and left with (at times) very little forward progress. In order to understand what I am trying to accomplish, I am inviting you to take a journey through my own career as a teacher, scientist and a student.

My University

Rutgers University is a large Research-1 University. On the New Brunswick campus we enroll more than 28,000 undergraduate students. "Life Sciences" at Rutgers are divided across several administrative units. Within the Faculty of Arts and Sciences (FAS) is a Division of Life Sciences (DLS). DLS is further subdivided into three specialized departments: Genetics, Molecular Biology and Biochemistry, and Cell Biology and Neuroscience, each offering its own baccalaureate degree. The DLS also offers a generalized BA degree in Biological Sciences. As of 2005, there were 1,100 undergraduate majors within the DLS; the Department of Genetics had 110 of those majors. The Department of Genetics is a small department with 13 full time faculty members. Genetics has an additional 5 faculty members with part of their line within the department and the rest of their line in a research institute. All faculty members are expected to do both research and teaching despite the differences in line weight.

The Department of Genetics is committed to high-quality, innovative undergraduate teaching. As a department, we have made many of the curricular changes such as those being discussed at SENCER and by others. Many educators suggest that teaching and research must become more tightly aligned (Boyer Commission Report, 1998; Brew 2001; Jenkins et al 2003, NRC 1999). At Rutgers University all genetics majors are expected to complete a 3-credit laboratory in their junior year. This is an interactive introduction to research where students carry out a supervised original research project. In their senior year, all majors conduct two semesters of research (12 credits) in an active lab. Students discuss their project with other seniors in a two-semester senior research seminar. The final report is written as a scientific paper suitable for publication in a journal such as *Cell* or *Genetics*. All students pursuing departmental honors, as well as any graduating senior who wishes to do so, present their research as a platform talk at a senior symposium. Every major in the department now has the research opportunities formerly available only to selected honor students. A minimum of 17 out of 42 credits (40%) of the required biology/genetic courses are entirely research based.

The Department of Genetics is also required to teach a number of service courses. All students in life sciences are required to take Genetics 380, as are many students in applied science fields. As such, we teach five large courses per year of introductory genetics to more than 800 students. We also teach a computer-based genetics laboratory each semester to 240 students. Faculty members are expected to be adequate-to-good teachers, but promotion and merit raises depend mostly on grants and publications.

My Teaching Reputation

I was already one of the best teachers in the Division of Life Sciences (at least according to the end-of-the-course assessment forms). During my 25-plus years at Rutgers, I had developed several new courses, including a very popular course for non-majors called *Genetics, Law and Social Policy*. This course actually did teach science "through" social issues. I had been introduced to this concept as a TA at the University of Illinois in the 1970's. There I was involved in Biology 101 under the leadership of George Kieffer. That course was a forerunner of SENCER. We taught biology to 900 non-majors through social issues. At Rutgers, my section of *Genetics* was acknowledged to be the most "rigorous" of the seven sections being taught at Rutgers at that time. I have many of my old exams from the early 1980's so I can document that my course had moved significantly from memorization to problem-based learning.

Despite the work I put into *Genetics,* year after year I generated a predictable grade distribution with about 10-12% A's and a good number of F's and D's. This was acceptable to my University since we have to justify assigning too many A's. As a large, loud, male professor who doesn't always smile, I've heard anecdotally that I scared the heck out of many of my students. Many were afraid of coming to my office hours. This only reinforced my perceived role (and the role of the *Genetics* course) as a "gatekeeper" whose job was to prevent the "unqualified" from getting into medical school. I really saw no way to reach the lower 50% of the class (C and below) who seemed immune to my teaching style. I was at a teaching plateau. Then came SENCER.

SENCER 2002

Monica Devanas (who has often been embarrassed at being called one of the "mothers of

SENCER" for her pioneering work teaching biology "through" HIV/AIDS) applied to take a full team to the SENCER Summer Institute in 2002. That application failed, but she was allowed to select one advanced team member to participate. She asked me to attend and I accepted. I really had no idea what I was getting into. Neither the published material nor the SENCER website gave me a real feel for SENCER. What I did understand from these sources did not seem to be applicable either to courses for majors (where my teaching efforts had to be concentrated) or for the large classes that we have to teach at Rutgers. I hoped that my four days in San Jose were not going to be a waste of time, but I had no particular expectations.

My first surprise at SENCER was my exceptional homeroom. The homeroom teachers were David Burns and Bill Bennett. In my group, among others, were Kristen Kulinowski (Executive Director for Education and Public Policy at the federally-funded Center for Biological & Environmental Nanotechnology (CBEN) at Rice University; Kristen subsequently authored a backgrounder and the SENCER course she developed after attending SSI 2002 and 2004 has been selected as a model), Sherryl Broverman (Duke University, who recently received an NSF grant to support her HIV/AIDS and Africa work), Greg Van Doren (Heritage College, who subsequent to SSI 2002 has become an NSF award recipient), and Steven J. Bachofer, (St. Mary's College of California, whose work on brownfields has been recognized as a SENCER Model course). It was during the dual homeroom periods (we didn't have team time) that we tried to make sense out of the flood of information that was coming our way. While I enjoyed many of the daily presentations (especially Jose Mestre's interactive presentations in the plenary sessions), I was constantly reminded that I didn't have the luxury of teaching non-majors courses. Further, I was convinced that none of this "stuff" would work with the large courses (150+) that I had to teach at Rutgers.

Eventually I became angry. I saw many exciting ways of teaching, but I could not see any way of fitting them into my courses. I kept searching, however, for something that might work. One session in particular made a real impression. This was Laurie Fathe's workshop, "Active Learning Techniques in Large Classes." For the first time I realized that it might be possible to engage my *Genetics* class. I further enjoyed a session by Robert L. DeHaan (National Research Council) called, "Issues in Undergraduate STEM Education—Perspectives from the National Research Council**."** In this session, I was exposed to a series of books and reports by the NRC and others. As a research scientist, I tend not to read educational material, so these texts were new to me. Of particular merit was the book by Angelo and Cross (1993), Classroom Assessment Techniques.

So after 120 hours of "educational bootcamp" at SENCER, I flew back to New Jersey tired and confused but willing to try to integrate at least one thing into my large genetics course. I had only three weeks to make the change.

One Tiny Step.

I had taught genetics courses for 22 years and believed that I had a good understanding of student progress in learning genetics. I didn't want to make any radical changes, so I cautiously adopted two items for Fall 2002. These tiny steps were: "Current Events" and "One minute-papers."

In the past, I had occasionally mentioned a current event in the course of a lecture. Now I was determined to discuss genetics outside of the required course content. I wanted the students to realize that genetic issues were a part of their lives. Every class started with a current event. I spent no more than five minutes on this. The current event did not have to relate to that day's lecture. I merely indicated where in the course the event might fit. ("You remember when we discussed...” or, “In three weeks we will talk about...”). I generally used examples from human genetics. However, as time went on, many students asked me to include more examples of animal-oriented topics.

I ended every class with a single one-minute assessment of that day’s lecture topics. This was the one assessment technique from Angelo and Cross that thought I could easily fit into my course. The questions varied in a non-systematic way. I introduced this assessment mainly to get feedback on how the current events were received. Students were expected to complete this assignment every day and completion was worth 10% of the final grade.

In the one-minute assessment, the students responded to a single open-ended question at the end of each class. (“What was the most interesting thing you learned today?” or “What was the muddiest point in today’s lecture?”) These short assessments gave me instant feedback on my lecture and were invaluable in tracking student understanding. I discovered, for example, that students could get lost in places where I didn’t know there were places. This was actually the first time in more than 20 years of teaching where I had information on student understanding *before* I gave the first quiz or exam. My knowledge that students did not understand some important point meant that I was obligated to deal with their problems. I addressed the most important questions and concerns either at the start of the next class or on my course website. Many students commented to my teaching assistants that they felt that I was talking directly to them whenever I would respond to their concerns. Incidentally, the students often used the in-class assessments to comment on that day’s current event or to request more information on current event topics (my original purpose). It was somewhat sobering to realize that even biology majors did not actually see the relevance of genetics to their “real life”. The genetics course was something to “get through” on the way to their ultimate goals (a good grade, medical school, etc). The disconnection between scientific work and their everyday life was disconcerting to me. It reinforced the idea that teaching science through "capacious social issues" was an approach that our science majors need—perhaps even more than our non-science majors do.

The performance of the 2002 cohort of genetics students differed only slightly from previous students on the first midterm. There appeared to be more A students and fewer F students, but the trend was not strong. By the second midterm, however, it became apparent that many more students were performing at the A level and fewer students were failing the course. This trend persisted through the comprehensive final exam. Large parts of my final exam are reused each year. The 2002 students scored significantly higher on the final exam than the 2001 students. Engaging the students as I did, even at a modest level, raised overall achievement. This was particularly noticeable in the large increase in the number of A and C students and the very large drop in the number of D and F students.

Another benefit of the SENCER approach to engaging students was that it engaged me; this was "professorial engagement" rather than student engagement. Changing the professor was not really discussed at the 2002 SENCER Institute, though it appears to be an underlying theme of the project. I worked very hard at teaching that semester after SSI 2002, particularly in responding to the student assessments. Suddenly, I discovered a new area at the end of that teaching plateau: a place at which I hoped I could begin to climb to new heights. I could see ways to make improvements in many other courses. For the students, achievement and retention of information was extremely good. I believe that the overall improvement in student learning in introductory genetics was an interaction between direct student engagement and my own increased enjoyment of teaching.

How did the students react to this new approach? To quote David Burns (2005) in the end of the year assessments, they were "markedly less positive than they had been in his 'traditional' rendition of the course." Some students objected to having to come to class or having to stay until the end of class to do the assessment. Another part of the problem has to do with Rutgers' evaluation/assessment form. If I had to take five minutes to clear up a mistaken idea, I must not have done a very good job teaching it in the first place. As I lectured less, I had expected the students to read more. Even the minuscule shift I had made to help the students become active learners instead of passive note takers was seen as a threat to a class style with which they had become comfortable. I found myself in the awkward situation of having to choose between higher teaching evaluations or better student learning. I opted for the latter.

Genetic Analysis I and II

In the summer of 2003, I was offered the opportunity to develop a two-semester sequence in genetics to be offered to our genetics majors. This would be a smaller course (50 students) than *Genetics* and would have significantly more resources. I decided to make this course, as much as possible, a SENCER course.

Except for the current event and the end of class assessment, however, I was not sure what changes this might take. I took my cue from laboratory independent study.

The best teaching that I ever do is in my lab. This is a one-on-one tutorial with students learning to do research. I introduce students to important lab techniques with the intention that they soon become independent of my direct supervision. I assess their progress nearly daily. I don't let them proceed until they have mastered fundamental techniques. It would be ridiculous to teach them how to do PCR (Polymerase Chain Reaction) until they were comfortable using a micropipeter. In the lab, I give them papers to read and then discuss those papers with them. I want them to become highly independent, but encourage them to ask me, or others in the lab, if there is something that they don't understand. The purpose of the independent study is to learn about research and master the skills to be a researcher. Although each student will get to the final goals by an idiosyncratic pathway, their ultimate grade is expected to be an A.

Rutgers is a highly selective University. We expect all students to be able to succeed in the lab if they are motivated. I decided that we should have the same expectations in our courses. Since the Genetics Department is a research-oriented department, I ultimately wanted to put together a genetics course modeled loosely on independent study. This is an ongoing process.

Genetic Analysis I and II (GA I and GA II) have very ambitious goals. The major in genetics at Rutgers is designed to prepare a student for a career in research. As previously stated, GA I and GA II are taught from a research perspective as we believe that students ultimately will need to be able to apply basic genetic knowledge to their own research. Since this course is the "feeder" course for advanced genetics courses, there was no question that students needed to learn basic genetics. On the other hand, I had the very comfortable situation that students only had to be "as good as" the better students in the large *Genetics* class to be adequately prepared for upper-level courses. It was not my intent to "cover" more material in GA I and GA II, but rather to work for deeper understanding of genetics. How?

One obvious goal was to help the students connect academic knowledge with future laboratory applications. Equally important was the aim to connect academic knowledge and research with current social issues. Science majors often view courses simply as impediments (as in things standing between them and their longer term goal: their future careers). Courses are "roadblocks" or "hurdles" which must be overcome (ideally with an "A") to reach their ultimate goal. Converting a roadblock into a "building block" is the challenge we face.

Making and reinforcing the connection between what is being learned with current issues is invaluable in promoting learning. It helps knowledge "stick." When information is important to understanding "real life," the students are more willing to master the material and retain it past the testing date. In addition to current issues, I began using many historical examples. This included reading classic papers (Mendel, Hershey and Chase, Meselson and Stahl) and organizing class discussions around historically-situated factors ("How did the availability of relatively cheap isotopes after World War II advance molecular biology?"). At other times, I introduced documentation on the historical misuse of genetics (e.g., forced sterilization and eugenics) to further political aims. These latter examples always seem a bit ludicrous or quaint and antique to my students. However, when I raised similar issues from today's newspapers, the students began to realize and understand the potential impact from the misuse of science.

Finally, I "humanized" the pursuit of knowledge. That is, I found ways for students to experience the day-to-day activities that go on within genetics laboratories. My students were fascinated with the process of turning theory and design into actual experiments. One of the hardest ideas for students to comprehend is that scientists actually have to work very hard and spend a lot of time doing very tedious experiments.

Current Events

As in Genetics 380, I started each class in GA I and GA II with a current event relevant to genetics. For each event, I explained the scientific and societal issues. This worked well in my larger genetics class and works equally well in a smaller class. ("I never realized that genetics had such a role to play in real life" is a now a familiar refrain to me.) As before, I emphasized where the ideas from the current event fit within the course. You never know when a current event will "grab" them. Just recently, several students became extremely interested in the identification of a gene that seems to govern the switch between white meat and dark meat in turkeys. On the other hand, anything involving red hair always generates interest!

For me, the sobering lesson about current events is that even highly motivated students pursuing courses in their major have a very difficult time connecting college work to the real world. Academia, from the student's perspective, truly is an ivory tower.

Active Learning in Lectures

Even in a small class it is initially difficult to get class participation. Students are still worried about "looking stupid." Some ideas for getting student participation did not work. For example, following a suggestion by Laurie Fathe, I asked multiple-choice questions within a lecture and students could respond by holding up a piece of colored paper. Several students told me that they were afraid to show the wrong answer so they looked around the room and then held up the same color as the majority.

Eventually, I began to ask for feedback <u>during</u> the lecture. That is, I asked for a written response to a question immediately after completing a topic. We then discussed their answers and discussed any misunderstandings. I also asked for short written summaries of the previous lecture. These written questions were collected and read (not graded). Over time the students realized that I was serious about their learning and they began to ask questions about the material. An added benefit of requiring writing samples is that I obtained feedback from students who were unwilling to speak out in class. In the second year of teaching Genetic Analysis, I incorporated in-class problems (analysis of data) that were passed out and collected immediately after a topic was discussed. I found ways to listen to, as well as see, the students' concerns and misunderstandings.

One of the most successful ways of encouraging discussion came about as a fluke. I have to present a lot of my lectures on PowerPoint slides. (Classroom design is another issue SENCER might want to look at.) I generally get to the classroom early and set up the LCD projector. This means that there is a fairly uncomfortable period during which some students are taking their seats and waiting to for me to start. During this time, however, they tend to avoid looking at me. One day, I posted a picture of me doing beekeeping as a "placeholder" for the PowerPoint slides. The students immediately began asking questions about the slide: "Was the person in the bee suit you?" and "Where do you do beekeeping?" and "Could the bees sting you through the coverall?" Other students expressed their fear of bees and wanted to know about allergies to bee stings. Once class started, the students were noticeably more involved in that day's discussion. That day, the one-minute assessment slide had a picture of me in a coracle (a Welsh boat that I constructed in England) as well as the usual question. This prompted more discussion and the students asked for more photographs (so far they have seen me at Stonehenge, doing woodworking, at my pond in Pennsylvania, and on a two-masted schooner in San Diego). The students have opened up ever since I became more of a real (and perhaps even an interesting) person. I have continued to use this approach in both GAI and II and in a different course *Behavioral and Neural Genetics*.

Active Learning in Recitation

With a small class I also taught the recitation section. I decided to make recitation a place where students had to apply their knowledge to laboratory situations and/or problem solving. For example, one week the students were divided into four groups and assigned *Drosophila*, *C. elegans* (nematodes), Mouse or Zebrafish as model systems. Their task was to breed a line that was homozygous for a dominant mutation. This is not a trivial problem. The students needed to take into account Mendelian principles, probability, and biology. I also required them to account for the amount of time required to breed their line and cost of such work. (Interestingly, some students were reluctant to spend even artificial money on the project.) The students worked on this problem almost the entire class period. In another recitation periods, students were given data and asked to analyze it, or they were asked to design an experiment. I was available for consultations on specific scientific facts, but I otherwise circulated around the room and assessed the reasoning (sometimes even critical thinking) within the groups.

This approach to recitation was initially quite difficult for the students. Over time they realized that I would give them hints, but that I was not going to rescue them when they got stuck. Most groups eventually came to some answer. Students realized that they could actually apply the material that they had learned. These tasks also reinforced the notion that the textbook and the class notes were resources containing valuable clues to solving complex problems. By listening instead of talking, I could assess the level of student understanding. I then used this understanding to modify my lectures and assessment techniques. As the semester progressed and as we moved into Genetic Analysis II, I found that I could require deeper levels of understanding from my students and give them more challenging problems. Within biology we often tell our students that it is critical to "know your organism." That is, you need to understand something about the biology, ecology and social organization of any experimental subject. Obviously, in teaching, it is equally important to know your students.

Assessment of Learning Gains

Testing: My first test in Genetic Analysis I was an in-class, closed-book test. There were 17 equally weighted questions and the students had to answer ten of them. The results were mixed. Some students did extremely well, while others did extremely poorly. It became obvious that some students had studied for this test in the traditional manner; that is they had essentially memorized assigned chapters in the book. Another student told me that she was sure that she could have done better if she only had had more time. I decided that I was not interested in measuring either memorization skills or speed. If these students had been in my lab, I would have demanded that they learn the material before they proceeded to the next topic. I decided to do the same thing here.

I returned their tests and told the class they had one week to retake the test (all 17 questions) as an open-book test. Furthermore, the retake would be a major part of their grade. I very carefully explained that the goal of Genetic Analysis was that they learn genetics, not that they merely get through a test. I also stated that doing a mediocre test was understandable, but that a similar performance on the retest was not acceptable. I emphasized that I expected every one of them to do extremely well. After they got over their surprise, most students did, in fact, master all 17 questions. This was not because the test was now open-book (these were problems not easily answered by looking things up). The key breakthrough was that the students came to realize that the material was not going to disappear just because the test was over. My demand that they learn the material and my willingness to review their mistakes, and the unprecedented opportunity (to them) to retake a test, emphasized my commitment to their learning. I have subsequently abandoned the hourly exam approach and replaced these exams with graded weekly assignments. The structure of widely-spaced periodic tests encourages the idea that learning only is about getting through tests, not that it is an ongoing process.

Ongoing assessments: I continually assess the student's understanding of genetics. At the end of every class I ask for a one-minute assessment of the day's material. As previously mentioned I also ask questions during a lecture and ask for written responses. I read all of their written material and respond to the most important questions. My response might be in class (if easily presented) or on the website if the response requires additional, detailed explanation. Since I believe that it is critical that students keep up to date, I now require weekly assignments. Occasionally I ask extremely difficult extra credit questions. These weekly assignments require integrating material from two or more lectures. Essay questions need to be well-organized, contain the appropriate vocabulary, and be grammatically correct. Students are permitted to work in groups but they are required to say with whom they worked. The products of these assignments are graded. Material that the class understands poorly is gone over again (in class or on the course website). Students who appear to extremely "lost" are given extra help and are asked to redo the assignment. Assignment grades are recorded on the re-graded work.

I require a final exam as the capstone (my students might say "millstone") experience in the course. The final exam is an extremely long, detailed and comprehensive take-home test. It has multiple-choice questions, problems, and essays. This is the most difficult test that I have ever given in an introductory genetics course. For multiple-choice questions, students not only have to give me the right answer (one that they might have found by looking in the book or consulting class notes), but they also have to explain in some detail why the other answers were wrong. This last step requires a much deeper understanding of genetics. The problems are detailed and require analyses of experimental data. Essays require integrating concepts and information from several different areas of genetics. Despite the difficulty of these tasks, most of the students have done extremely well, missing only trivial points. In the first year, the final grade distribution for GA I was 14 A's, 2B's, 2C's and a D. In the second year the final grade distribution was 18 A's, 10B's, 3C's and 2 D's.

Two students from GA I did not continue the sequence with GA II (a C and a D student). The remaining 17 students were highly motivated. In GA II, students criticized the wording in some problems in population genetics. I had used some of these problems for more than 15 years without ever hearing a complaint from my students. I realized that my GA II students were now comfortable with the complex material and could see and experience (sense) the ambiguities that come when you "know too much." That is, they could see how to interpret a statement or a question in several different ways.

My students have become more engaged in their own learning. One student asked for class time to set up the chat room feature on WEBCT. This way they could share knowledge and help each other solve the problem sets. I had suggested this several times, but now they, themselves, saw the value of working together and organized to do so. My "worst" remaining student from

GA I scheduled weekly appointments with me. She believed that my approach was a good one and that there was no reason that she could not learn the material. After her shaky start, I am happy to report that each week her understanding of genetics increased.

GA II was team-taught. I have turned the course over to three other faculty members. Dr. Howard Passmore (SSI 2004) was the first to follow me. After the first class, he was telling other faculty members how good these students were, that they were intelligent and motivated and were involved in class discussions. His impression was that these were good students, but that some of them would have washed out in our traditional genetics class. By my efforts to demonstrate that there is clear connection between knowledge and the ways in which that knowledge can be used in laboratories, medicine, and in addressing larger issues, the students became engaged in their own learning. Two other faculty teaching the advanced course also expressed their enjoyment of the students. Interestingly, although these faculty members at first wanted to give a traditional in-class exam, they were convinced by the students to go with the open book exam.

In Spring 2005, I did not lecture in GAII. However, I supervised a new faculty member. He started out using the traditional approach, but he soon realized the weekly assignment approach vs. the hourly exam approach was much better for boosting student achievement. The students also convinced him to use an open-book format. That faculty member is now involved with SENCER through regional meetings.

Behavioral and Neural Genetics

I have taught *Behavioral and Neural Genetics* as a discussion course for 20 years. *Behavioral and Neural Genetics* (BANG) is a small class and I get to know the students quite well.

In this class, students must read and discuss 26 original papers. In addition, they take written examinations and write a paper critically reviewing some area of behavioral and neural genetics.

The paper assignment in my course is a complete learning experience. Students need to select their references and submit an annotated bibliography. They then write a rough draft, which I severely edit. Later they submit a final copy. This is often the first major paper that many of them write in college. In many ways, BANG was already an active learning class, however, I attempted to SENCERize the class this last semester.

In BANG, I have one major goal: to get students to read and critically analyze scientific papers in the area of behavioral and neural genetics. The topics follow a loose historical chronology, but the actual papers are not that important.

As in all classes I now teach, I started with a current event and end with an in-class assessment. In BANG, I used the current event as a springboard to discussion. Most often, I presented the current event and then displayed excerpts from the actual publication on which it was based. At other times, I based class group work on current events. For example, one of the very first current events concerned Harvard President Lawrence Summer's comment about how women might be "biologically inferior in math". I presented as a "past event," former Rutgers' President Francis Lawrence's comments suggesting that genetics accounted for the performance by blacks on SAT tests. Later in the course and recalling these "current events," I spent several group work sessions having the students design a study in which they had to describe all the variables that would need to be controlled before you could infer that phenotypic differences in math ability were, in fact, due to biological differences. (You have to suspend ethics rules for such a demonstration.) Another time, I followed up a current event about identical twins separated at birth by randomly pairing up the class with their long lost "identical twin." The students listed all of the amazing behavioral similarities they "shared" with their new-found twin. Reports of isolating genes for schizophrenia in mice were followed up with a lively class discussion of what a schizophrenic mouse might actually look like (e.g., do they hear squeaks that aren't really there?). In the latter part of the course, I assigned the actual papers cited in the current events to the class to read. Students compared reporter's comments with actual data.

BANG is a class where being prepared for class is crucial. To reinforce this, therefore, each class started with a short quiz (two multiple choice questions) on the preparatory reading assigned for that day. The quiz was open-book, but students had only three minutes to do the quiz, so it was almost impossible to do well without having already prepared for class. Immediately after the quiz, we discussed the answers. My lecture time was limited to describing basic techniques and answering questions that arose from the in-class assessments, not covering un-read reading assignments.

Nearly every class ended with ten minutes for group work. The students were given some large question that they had to answer with appropriate citations from the assigned papers. I encouraged presentation of data, not opinions. These group notes were collected and graded.

My main goal was to have students who could critically read original scientific research. As such, my hourly and final exams were open-book, take-home papers in which students had to read and interpret one or more current research papers. Students who did poorly on the exam were required to retake the exam. For the retake, they were encouraged to work in groups.

The final in-class question for the semester was, "Has this course changed your view of science?" Almost uniformly the students agreed that it was essential to read the entire paper (not just the abstract), that the reportage of scientific findings needed to be taken with a grain of salt, and that they could not rely on a self-described “authority.” Rather they had to use their knowledge of genetics to evaluate the design, the execution and the data and conclusions of any scientific study. In sum, the students learned to think critically and they learned the value of critical thinking.

Observations on Three Years of SENCER

SENCER has changed my teaching in many ways. Perhaps the biggest change, and one with which I am still grappling, is that I now know that most students are neither stupid, nor lazy, nor unprepared. Such attitudes about students are wrong and insulting to the students; unfortunately we often fall back on these characterizations to explain why our “brilliant teaching methods” fail to produce brilliant scholars. For many years, in *Genetics*, I was continually disappointed in the results for the first midterm when my teaching efforts resulted in a predictable grade distribution. Nothing I did was able to reach most students and *Genetics* remained a course where I separated students into neat categories. This began to change after I started doing frequent assessments and listening to the “voice” of every student. All the students, not just the exceptionally good ones, were able to get my attention. That is, they became individuals.

When I maintained an active research lab I was an expert in genetic individual differences. One of the classic papers in the field of individual differences is by Robert Tryon (1934). In that paper, Tryon commented that if you trained naive animals to a criterion, individual differences in learning ability existed only in the middle of the training procedure. Before you start training, the animals knew nothing (they were equally untrained). At the end of the training, all of the animals would have learned the procedure (they were equally trained). Only in the middle of training would individual differences be manifest. These differences would have to do with motivation, ability, intelligence, learning strategy, etc.

If true for mice, is this not possibly true of students and the rest of us as well? I certainly do not mean to suggest that students are equivalent to rats and mice, nor that learning genetics is equivalent to learning a maze. However, the "learning curves" within a class should follow pretty much the same pattern. Traditional widely-spaced tests are designed to maximize individual differences (i.e., obtain a grade distribution), not, finally, to measure learning.

Rutgers University is a very select University. Thirty-six percent (36%) of our students were in the top 10% of their graduating class and seventy-five percent (75%) were in the top quarter. Any student unable to do the course work in science would have probably changed their major long before I saw them in *Genetics* or *Genetic Analysis*. My students are a highly selected group of students, motivated to study science, and would have completed courses in introductory biology, chemistry, physics and calculus. I can reasonably expect that every single one of the students has the capacity to get an A in my courses. Could I not set clear learning goals (a criterion) that every student could reach? Once I started to teach under that basic premise, that I could, my job no longer became an exercise in sorting the students into categories, but rather my job became to help each student learn. Unlike naive mice and a maze, my students enter my class with different skill sets (as shown by pretests). Consequently, at the start of the course they will already show wide individual differences. Students may reach the final goals by different pathways and at different rates. However, by offering many different approaches to learning and by aiming for all students to excel, I am offering all students the chance to achieve excellent results.

I have never been a great believer in the concept of "general intelligence" of fixed traits. I see no reason why a C student in one class cannot excel in another class. My disbelief in general intelligence started with my personal experience and has been reinforced throughout my career as a behavior geneticist. As an undergraduate, I did fairly poorly. I was the best student from a mediocre rural high school and was admitted to the honors program at Ohio State University. OSU was overwhelming. I sat in several classes that had more students than my entire high school. I worked extremely hard, but my grades did not reflect this. It got so bad that, after two years, I decided to give up biology and go to law school. I decided to complete my major in genetics, however, since I wanted to graduate on time and the law schools thought that my GPA was fine given the difficult science curriculum that I was completing. Furthermore, I liked genetics and decided that, now that I was headed for law school and not a career in genetics, I could actually enjoy the genetics courses for a few semesters before I became a lawyer. I believed that I would get the A, B or C in these courses that I always got. Of course, once I stopped pursuing the grades and went after knowledge, my grades immediately went up. I can tell this story as a sort of "triumph through adversity" story. However, I can also see this as a sort of cautionary note. If I had found the right professor or the right courses, I might have reached this learning oasis much more rapidly.

What does it means to believe that your students are capable? First, students are often incredulous that we want them to do well. They are all to used to the "look to your left, look to your right, only one of you will be here at the end of the semester ..." weed-out courses. If you, as a teacher, state that you expect every student to do well, you need to follow up this statement with exercises and assessments that continually reinforce that you are interested in their learning and not merely in generating a grade distribution. I often use the one-minute assessments. But I use them mostly so that I can subsequently use class time to clear up areas of confusion. My emphasis on group work, frequent assignments, and the chance to redo substandard work isn't simply a strategy for getting the students to do more work. Rather, it means, that it is nearly impossible for students to "destroy" their "final" grade in the middle of the course. Even the current events and the frequent references to real life examples are meant not just to make class more interesting, but to reinforce the idea that one academic course is just a small part of the overall and ongoing story of their lives. The course is not a hurdle to get through and forget.

My colleagues Kathy Scott (SSI 2004) in her course, Moving Bodies, and Jeannette Haviland-Jones (SSI 2003) in her course Adolescent Psychology, have both expressed how much difference it has made to their students that "student learning" rather than "student sorting" is now the focus of the their course. More of their students excel. As compared to students in previous years, overall achievement is significantly boosted. Higher achievement is reflected in higher grades, but these grades are not a result of "grade inflation" (to use an economic term out of context). Rather, they are a clear result of overcoming "teaching deflation."

Finally, better teaching has transformed the students' perception of me. I have had several students express their gratitude for the amount of work that I put into the course. They realize that I want them to succeed and that I am not the judgmental and fearsome gatekeeper standing between them and their ultimate goals.

Some Lessons for Introducing SENCER-Style Teaching

I originally said that this paper was not going to be a "how-to" narrative. However, in appreciation for your reading what I have had to say, I would like to offer a few suggestions for adapting SENCER courses for majors. These suggestions are ones that the members of my two Rutgers teams that have participated at the SENCER Summer Institute and I have found to be useful in our various courses. Since this is a teaching paper, I will call these "lessons."

Lesson 1: Start as small as possible. I started with a commitment to a current event and a one-minute paper. All subsequent modifications of my courses have arisen from those two minor changes. My colleague Dan Ogilvie (SSI 2004) started modifying his course Principles of Personality Psychology with a few extra credit assignments. He will introduce more interactive exercises next year. As a general guideline, do not ask your students to do anything with which you are not comfortable. I really enjoy reading the one-minute assessments. On the other hand, at this point in my life, I would not like to moderate an on-line chat room, although many people find this to be useful. No teaching innovation is worth it if it makes you uncomfortable. You also need exercises and assessments that your students are willing to do and I suggest that completion of such exercises and assessments be made part of their overall grade.

Lesson 2: Acknowledge that our goals and the students' goals may be very different. We all want students who are committed to lives of scholarly excellence and who are willing to do independent work to achieve personal satisfaction. On a more concrete level we have goals and objectives that our students must meet to successfully complete our course. However, 95% to 100% of our undergraduates are most concerned with getting a good grade. In order for a student to reach their goal of a high grade, you need to make it essential that they have to pass though your goals. For example, I consider it essential that students read the assigned material before they come to class. Since I believe that being prepared for class is valuable, I quiz the students at the start of every class so that the high grades go to those who meet my expectations. My colleague, Dr. Jeannette Haviland-Jones (SSI 2003) not only starts each class in *Adolescent Psychology* with a quiz, but also assigns group work (graded) based on that day's reading and lecture.   Groups with unprepared students do very poorly and the more prepared students eventually demand that everyone in the group pull his/her weight. In *Genetic Analysis* each topic builds on the previous topic. In order to get a good grade in the class, it is essential that students demonstrate mastery of each topic in the weekly assignments. Students who cannot do the assignments are tutored and allowed to redo the assignment. At no time are students allowed to "move on" after a poor performance. By fulfilling my goals, students are able to get to their goal of a good grade—and with gratifying incidence, they become very interested in what the course is all about, as well.

Lesson 3: We must be serious about the interconnectedness of knowledge. We seldom teach the connections of our discipline with and to other disciplines. From personal observation, many biology faculty members pay lip service to such connectedness, but seldom address it in their courses. The biological sciences major has been around long time. Every student majoring in biology has to take courses in introductory biology, organic and inorganic chemistry, physics and calculus. Such a curriculum is required for the MCAT test and is generally required by graduate schools. If you ask an individual faculty member, he or she will assure you that each course is essential for understanding all of biology. However, it you then quiz them as to the relevance of any one topic (say calculus), you get a very vague answer about why such a course is critical or, you might be treated to a single example from a science career that might span 25 years or more. I often have students state that they "Will never need organic chemistry" or that they "Can't see the relevance of physics." I contend that much of this problem is that we not only fail to place biology into a societal context, but that we also fail to place biology into a scientific context. Biology at least recognizes the relevance of chemistry and physics. Physics, however, seldom requires either chemistry or biology for its majors. If we, as faculty, fail discuss the connections between disciplines, why should students be expected to view their scientific endeavor as more than a series of disconnected facts?

As previously stated, the one-minute questions let me hear the voices of all students for the first time. Ideas that I take for granted are not apparent to my students. For example, when discussing the use of radioactive or heavy isotopes in molecular biology, some students were quite puzzled about how we could incorporate such isotopes into the cell. We had already discussed how the reactors used in the Manhattan project (history) had been turned to peacetime use. We had briefly discussed how physicists and engineers could make isotopes. The students were quite puzzled by how those isotopes get into the cell. ("Just how did you get radioactive food?"). At one point I said, "You ask a chemist to make a simple food or nutritional supplement. Meselson and Stahl, for example used radioactive ammonium ions (NH_4^+) as the source of nitrogen for DNA." The students looked astounded. Finally one of them asked, "Can chemists actually make new substances?" These students are all aware of chemistry. All of my students have completed a full year of inorganic chemistry and are either in, or have completed, organic chemistry. These chemistry courses include labs. Despite this, many students failed to understand that chemistry was a vital science that went far beyond the "canned labs" that both bore and terrorize my students. Since that incident, I take the time to point out where one would need to consult with a chemist or a physicist to take the next step in any experimental procedure. I realized that I was successful when one of my more outspoken students wrote, "So you're saying I just need to suck it up and actually learn organic chemistry?" While I appreciated the insight, I wish that the chemistry department would make a greater effort to teach chemistry as if it were connected to the other sciences.

I remember my own undergraduate years and the struggle to get through physics. At that time the connection between physics and biology seemed even more tenuous than the connection between chemistry and biology. Only occasionally could I find even the remotest connection between biology and physics. For example, I had already learned about radioactive isotopes as molecular and cellular labels, so I was quite interested in those. On the other hand, bridges were of no interest to me. My only concern for bridges was that they did not fall down when I was traveling over them. Physics was something to get through and I took the physics course (as opposed to learned physics) without enthusiasm. Several years later in graduate school, I read the book *"On Growth and Form"* by Darcy Thompson. In that book Thompson showed that quadruped skeletons were classic examples of cantilever bridges. As such, the larger the organism, the higher had to be the abutments (pelvis and shoulders) to support the weight. I was astounded. I only wished that some physics professor had taken the time to learn that information and to incorporate it into a SENCER-style course for biology majors. There are, of course, many places where physics is essential for understanding biology (Why do elephants have large ears? Why can a fly land on the ceiling? Why can't a spider be 10 stories tall?), but you would never know it from a typical introductory physics course. As with chemistry, I continually reinforce where physics is essential for a deeper understanding of genetics.

The lesson is: *If we don't point out connections, our students may not learn them*. As experts we have constructed a framework of knowledge where nearly everything fits. Students, on the other hand, see this knowledge as a collection of disconnected facts. This view of knowledge is only reinforced by the proliferation of multiple-choice tests. Success on multiple choice tests requires a capacious short-term memory, but seldom requires actually understanding of the material. I remember an ill-fated attempt to reform general biology at my university. There were a number of proponents of the "12,000 fact" model of general biology. Under this model we were to develop a list of the 12,000 facts that every biologist "had to know". These facts could then be put on the computer and the students could take multiple-choice tests until they had mastered the list. Unfortunately many of our students would have been quite happy with such an approach. ("Just tell me what I need to know"). We would have told the students exactly what "we wanted" and most of them would have then would have memorized enough of the facts to get the best grade. A month later very few of those important facts would have been retained. By the next year, our colleagues would have complained that the students didn't seem to know much about biology and so therefore we obviously had "not covered the material". In fact, we would have covered the material and the students might have performed quite successfully in the course. However, if our goal was long-term retention of knowledge, computer-based multiple choice tests would not speak to that goal. If our goal is learning, our courses must be designed to facilitate learning. One pathway to life-long learning is to model how specific information may fit into the overall framework of their lives.

Lesson 4: Don't cover all the material. When I speak about the changes I have made in my teaching, I am often asked how I manage to "cover all the material." I am actually never sure what that phrase—"cover all the material"—means. There is no consensus of what students need to know (i.e., all the material) in genetics. If I talked with my colleagues, I would be lucky to get a consensus on the five most important areas of genetics. If "all the material" means the contents of a textbook, then what does it mean for me to be a teacher? I have never believed that any textbook had to be the authority in a course.

On the other hand, I do still worry that I might be doing my students a disservice. I have had to adopt the mantra that it is *"Not the amount of material that I cover, it is the amount of information and learning that is retained that is important."* Otherwise, I might sabotage my own teaching. For example, in a class I might "budget" ten minutes for an in-class exercise that ultimately takes the students 20 minutes to complete. I sometimes worry about how I can make up the ten minutes. I have to remind myself that true learning seldom occurs during my lectures, it occurs when the students apply knowledge (the classroom lessons) in problem-solving situations.

Furthermore, students can read. If I am teaching students to be prepared for a lifetime of learning, I have to encourage them to read and extract information from textbooks and original research papers. With the invention of the printing press and the more recent invention of the Internet, access to information is no longer the problem. If the only way students can learn is to transcribe my lectures, then I have failed as a teacher. Successful teaching means that my students have learned something about how to learn on their own.

Ironically, as I gave up covering a set amount of material, student achievement and learning increased. My determination that students learn the basic material before they continue in the course means that I spend a lot of time building the basic knowledge framework for my courses. The basic material is the "stuff" that we, as faculty, find to be "old hat" and uninteresting. We like to teach the more recent, advanced material. However, as students begin to build frameworks of basic knowledge, each new piece of information is more easily learned. When I do get to the new exciting information, my students are able to understand it. More than that, they seem interested in learning it.

Lesson 5: Good teaching is hard work. It is much easier to construct and grade a multiple-choice test (Scantrons!) than it is to construct and grade a test with problems and essays. However, if I want my students to apply genetics to laboratory situations, I have to evaluate them in ways that reinforce that particular goal. If I expect my students to be able to design and experiment and analyze data, I have to give them ample opportunity to practice those precise skills. Such a commitment to teaching, is unfortunately, difficult for research-active professors within a large R-1 University. But the effort is worth the results.

Good teaching, like good research, transforms the professor, leading him/her into intellectual pathways that were never apparent before.

Reflections on the Drunken Walk

Three years ago, I was sitting in this office trying to imagine what I might actually get out of this thing called SENCER and the 2002 Summer Institute. Now I am looking forward to fully enjoying SSI 2005. I have taken two teams to SENCER and I have watched many of my team members go through transitions similar to mine. In the reflections that follow, I am now speaking for my entire team.

First, SENCER has reminded us that we actually do know a great deal about teaching. Some of the things we do in teaching are new, but most actually come from our knowledge and experience. That is, SENCER reminded us that we have brains. Secondly, becoming part of a community of intelligent, dedicated teachers is invaluable. With community backing, we have gained the courage to change the way that we have always done our courses. I previously mentioned that colleague Dan Ogilvie (SSI 2004) modified his *Principles of Personality*

Psychology course. In his report to me, Dan stated that "I made it even more engaging by introducing some class participation exercises *that I doubt that I would have dared to try* had I not attended the conference"(italics mine). I introduced one-minute assessments for very much the same reason. That is, SENCER gave us courage. Finally, SENCER reconnected us with our students. We want to share our excitement about science and we want them to do well. Kathy Scott (SSI 2004) had this to say about her students:

> *"Discussions at SENCER workshops convinced me first of all that it is critical to convey to students that you want them to succeed, and will help them do this."*

We listen to our students and help them to learn. We are moving to become the "guide on the side" and not the "sage on the stage." (Ironically, this move hasn't made us "buddies" with students as much as it has re-established the authority we had lost on the stage!) SENCER gave us heart.

To recap, we have a golden intellectual pathway and newly discovered brains, courage, and heart. I will leave it to your imagination to identify the Wizard and Glinda. Like Oz, for me SENCER is a magical place. It is full of wonder. It is not without perils and problems, but like any magical place, it offers the opportunity for personal growth. When you return home to "Kansas," you bring a little piece of the magic with you.

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