INFORMATION AGE TESTING: MAKING RIGOROUS EXAMS FUN TO WRITE AND EASY TO GRADE

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This essay discusses methods by which an exam writer can achieve three objectives: 1) producing questions that test a student's understanding, defined as the ability to apply knowledge in a novel context; 2) writing questions that require minimal grading time; and 3) keeping current and excited about the field, which is critical for transmitting personal enthusiasm to students. Included are descriptions of practical, time-saving methods for processing and filing examination material; ways to use readily available databases for quickly generating rigorous, interesting questions, with examples of questions generated in this way; suggestions for structuring questions so that they are easily graded; and general advice for preparing students to take this kind of examination.


Key words: examination; database; testing understanding

Beginning in the first grade and continuing through graduate school, I repeatedly awoke in a panic from a recurring nightmare that I suspect is shared by students the world over. In this dream, I find myself in a classroom where students are gathering to take a test in a subject about which I know nothing. I have not studied. I have failed to do the problem sets. Usually I have not even bothered coming to class. Arriving in my pajamas (if I am lucky—sometimes I am wearing nothing at all) adds another dimension to my humiliation, but this is the topic of another discussion entirely.

After I completed my PhD and put test-taking days behind me, I fully expected my dream life to take on new subject material. I soon found, however, that the old dream kept popping up, this time with a twist appropriate to my new role in the classroom as teacher. Now, I find myself in that same classroom where students are gathering to take an exam...but I have not yet finished writing the questions. Exam writing can be one of the more anxiety-provoking tasks faced by teachers. Here are some thoughts on how to improve the experience for everyone.

OBJECTIVES FOR WRITING EXAMINATIONS

Objective 1: An Examination Must Test Understanding

Under the influence of colleagues and education specialists, I have come to make a distinction between examinations that test knowledge and those that test understanding. A student's knowledge is adequately tested by questions that require the student to repeat memorized material, which may range from single-word answers to lengthy essays detailing a biochemical pathway, outlining a learned set of arguments for and against a theory, or explaining the mechanism by which an organ functions. Insofar as a student is allowed to remain within the context in which the material was learned, however, that student has not
demonstrated understanding. Understanding can be tested only by requiring the student to apply what he or she knows in a novel context. This requirement, however, places an added burden on the exam writer, who must in turn create these novel contexts. Balanced against the convenience of simply extracting portions of lecture material for exam questions, the time and effort required for this approach may seem prohibitive. I will argue, however, that recent advances in database accessibility and a few filing habits can make this task nearly painless. I will even argue that you will have fun doing it.

Objective 2: Examinations Should Be Easy to Grade

I have weaned myself of the misperception that a short answer is necessarily the answer to an easy question or that a question calling for a long answer necessarily requires anything more than a capacious memory. Dr. Robert E. Savage, a cell biologist now retired from the Department of Biology at Swarthmore College, is well remembered for his wonderfully thought-provoking examinations. On each exam, he summarized his expectations in the phrase “think a lot, write a little.” His questions were current and novel, and their formulation was usually preceded by a trip to the library, where he would browse through recent papers in the primary literature for ideas. I will expand on this approach, now made profoundly easier by the greatly increased accessibility of electronic databases and journals.

Objective 3: Keeping Ourselves Entertained

Reflecting at his retirement banquet on his life as a teacher, Bob Savage made the remark that one of a professor’s greatest challenges is to keep him- or herself entertained. He meant, of course, that education is about the excitement of discovery and that this excitement is best imparted to our students by example. The best way I know to keep myself entertained is to continue to learn new things, and writing examinations is just one context in which I can do so. Novel context is necessary for testing a student’s understanding, but there is no reason that the context cannot be novel to the exam writer as well. Examinations are an opportunity for living up to Frank McCourt’s observation that “if you aren’t learning while you’re teaching, you aren’t teaching.”

PRACTICAL SUGGESTIONS FOR WRITING EXAMS

Keeping Current

I do not like reusing old exam questions for several reasons. There is, of course, the nagging suspicion that answers will be memorized from copies of old examinations, which are useful and legitimate study tools for students who are getting used to a new style of examination. Greater, though, is the sense that reusing my old questions is incongruent with the message I wish to give my students, namely, that science is about discovering new things about the world, new ways of looking at old problems, and developing new tools for seeing things we could not see before. We need not abandon the basic facts of biology, but we need to recognize that the “old facts” are constantly being added to and modified by new information.

Journal subscriptions. There are lots of journals, and they are getting more voluminous by the year. We cannot begin to process (or afford) more than a few. I recommend a subscription to a high-profile, broad-spectrum journal such as Science or Nature as well as one or two journals in your specialty. If a colleague discards a journal when finished reading it, consider sharing (or parasitizing) a subscription. You might also try an excerpting journal like Science News, which covers a wide range of science fields and can direct the reader to the original papers for articles of interest.

Rip and file. I do not have time for a careful reading of more than a few papers a week, and my personal
random-access memory is already filled to capacity. For me, the best use of time is to scan my weekly journals quickly (in just a few minutes each), rip out the papers that I will want on hand for a particular lecture topic and file them in the appropriate folder for that course. (If you share a journal subscription with another ripper, choose someone with interests different from your own!) As I read, I frequently think of exam questions. I jot them down immediately on whatever is handy—a separate piece of paper, the back of an envelope, a postcard—and put them in my “examination and study questions” folder, which has the same subheadings as my lecture topic files. Telling myself that I will remember these questions later, when I am actually putting an exam together, is wishful fantasy. Recording them immediately saves immeasurably on time and anxiety later.

**Customized journal updates.** A recent invention that can alert you painlessly (and treelessly) to interesting developments in your field are services such as Uncover Reveal, which allow you to configure a search profile by journal title, keyword, or author. Tables of contents for journals (the ones you cannot afford or find shelf space for) and citations for papers meeting your search criteria are automatically E-mailed to you very shortly after the publication date. You can check through these quickly for items of interest, print out the citations, and file them, all in very short order. I use keywords and authors for papers in my research specialty but journal titles such as *Proceedings of the National Academy of Sciences* and some of the *Trends in...* publications for quickly scanning subjects that I cover in my courses. Consult your science librarian to find out whether your institution offers such a service.

**Databases.** Despite the wealth of examination questions yielded by regular journal reading and Reveal updates, these methods inevitably fall short of providing the kind of coverage I desire for my examinations. Information delivered weekly, in print or electronic form, must be kept to a small, manageable volume that you will actually read and process shortly after it arrives; it is not feasible to search weekly for all the subjects on which you teach or examine.

For tailoring questions to a specific topic, databases provide the modern counterpart of Bob Savage’s preexamination trip to the library. In most institutions, access is now as near as the computer on your desk. Some of the databases I use frequently are publicly available on the web (PubMed can be found at [http://www.ncbi.nlm.nih.gov/PubMed/](http://www.ncbi.nlm.nih.gov/PubMed/), and the University of California’s new Searchlight can be found at [http://searchlight.cdlib.org/cgi-bin/searchlight](http://searchlight.cdlib.org/cgi-bin/searchlight)). Other databases, such as ISI’s Web of Science, the Cambridge Life Sciences index, and Carl Uncover, must be accessed through an institution’s database system from on-campus computers; database offerings will vary from institution to institution. In either case, a quick search can generate good exam questions that test understanding. Here are a few examples from recent examinations given in my Animal Physiology course.

In our unit on thermal biology, we had discussed the maintenance of cell membrane fluidity over wide temperature ranges. To compose a question, I searched in a Web-based database for the keyword “desaturase” (an enzyme that produces unsaturated fatty acids, thus increasing membrane fluidity at low temperatures). In seconds, this search yielded a manageable number of references. It took a couple of minutes to scan them before I found what I was looking for—a paper discussing the role of desaturase in the ability of *Escherichia coli* to resist the effects of metabolic poisons, large ion channel-bearing molecules that insert themselves into the mitochondrial membrane, thus dissipating the energy stored in the transmembrane ion gradient as heat and greatly decreasing the production of vital ATP. This was quite a find. I had known about bacterial resistance to antibiotics that interfere with transcription and translation, but I had had no idea that resistance could develop against this class of metabolic poisons as well. A task that I had been dreading (writing new exam questions) had been transformed into an entertainment; now I was having fun.

Furthermore, because the examination was to cover both metabolism and thermal relations, this discovery allowed me to ask a question for which students had to integrate two separate parts of the course in a novel context. In the resulting three-part question, I first asked students to propose a molecular mechanism by which an organism might develop resistance to uncoupling agents, the structure and function of which we...
had discussed in class; a wide variety of answers was acceptable, as long as they were based in known metabolic mechanisms. Students were then asked to propose a mechanism by which a genetic mutation causing the production of a defective desaturase could confer resistance to uncoupling agents. Finally, they were asked how an increase or decrease in ambient temperature might mimic the effects of a defective desaturase on uncoupling resistance. The whole process took a few minutes—the abstracts contained all the information I needed to proceed with writing the question.

On the same examination, I wished to query students about the application of techniques for measuring metabolic rate. I was searching for a novel field problem that would require the use of several types of metabolic measurements; students would then be asked to describe the methods they would use to solve the problem. Introspection yielded some serviceable but not overly exciting examples. I searched a database for the keyword “doubly labeled water,” a technique by which metabolic rates can be measured in free-living animals. Among the resulting citations, I found what I was looking for, a study using doubly labeled water in AIDS patients, to determine how food consumption, metabolic rate, and other factors contributed to weight loss in the wasting phase of the disease. I described the patients’ symptoms and asked students to use techniques they had learned to answer the question posed in the study, listing the limitations and assumptions of each of the methods they were proposing to use. I learned something new, and so did the students.

Other types of novel contexts for framing questions. New subject material is by no means the only way of asking students to consider information in novel contexts. A different way of representing data, such as a graph that depicts a phenomenon that students have previously considered only in words, can also be used as the basis for testing a student’s understanding.

Putting the Exam Together

Structuring questions and answer spaces for easy grading. My students love to write. If I let them, they would write a paragraph or more where a single sentence would suffice. Because my students have ample opportunities to hone their writing skills in assignments other than exams, I strive to compose questions in such a way that only short answers are required. In addition, I break the question into small units whenever possible, providing a space of the dimensions required for the length of answer I desire. I ask students to organize their answers into lists instead of paragraphs wherever possible, and I show them where on the page the list should go so I do not have to search for it. The beauty of “think a lot, write a little” questions is that they test understanding rather than the manual stamina of the exam taker or the time and patience of the exam grader.

How long should the exam be? One of the most difficult aspects of writing examinations that test understanding is gauging how long it will take students to complete the exam. A method that some of us use is to take the exam ourselves and multiply this by some factor (3 is a factor suggested by one of my colleagues). On exams such as these, however, this method may substantially underestimate the time it will actually take a student. Because I wrote the questions, I have already “thought a lot”; “writing a little” then takes only a small fraction of the time it would take a student to process the question and compose an answer.

Because I do not always gauge the length of an exam correctly, I pay close attention to comments from students and try to modify the length of the next examination accordingly. In my experience, students...
who know their opinions are taken seriously will offer constructive suggestions. They also appreciate exercising their minds on exams and most tell me they enjoy questions that require them to propose explanations for data they have not previously seen or draw new associations between different parts of the course. Many, however, find this type of examination difficult at first. I recommend exposing students to exercises requiring this kind of thinking throughout the course, so they can practice problem solving in a relaxed atmosphere with their peers, before the pressure of an examination is upon them. The most noticeable result in my classroom has been that students exposed to such exercises develop much higher criteria for themselves when assimilating new material, a skill that will serve them well in any field.

The ideas presented here are not entirely my own but, rather, represent the combined wisdom of many teachers and colleagues. Ingrith Deyrup-Olsen was one of my first and best teaching mentors when I was a teaching assistant in graduate school. Lee Gass continues to stretch my concept of learning and teaching, and knows the heuristic value of making me squirm every once in a while. Continuing appreciation goes to all the members of the Department of Biology at Swarthmore College, with special thanks to Scott Gilbert, Rachel Merz, Bob Savage, Liz Vallen, and Amy Vollmer for discussions and examples, and to my students for their enthusiasm, ideas, and input.

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