Teaching Lessons Learned: There's a Big Difference Between "Telling" and Teaching

by Daniel J. Schneck

In 1973, when I started teaching at Virginia Tech (Blacksburg, VA), the average class size for our basic undergraduate Engineering Science courses (Mechanics: Statics/Dynamics; Mechanics of Materials, and Fluid Mechanics) was 25 students per class, i.e., the student-to-faculty ratio was 25. If one was teaching a class of 30–35 students, that was considered a large section and a teaching overload. Typically, on a full-time basis, one taught two to three courses per semester, provided he or she was not endowed with enough research funding to "buy" his or her way out of teaching (a practice, by the way, that I totally disapproved of for many reasons, but I won't go into that now).

Back then, in order to determine how many sections of any given basic subject were to be offered in any given semester, we simply estimated the total number, N, of students who were expected to sign up for the course, and divided N by 25. That ratio, N/25, usually yielded a rather large number of sections that were then scheduled during the early morning hours (8:00–10:00 a.m.), mid-morning (10:00 a.m.–12:00 noon), early afternoon (12:00 noon–2:00 p.m.), mid-afternoon (2:00–4:00 p.m.), and late afternoon (4:00–6:00 p.m.). Evening class offerings were rare, but students did have various time options spread throughout most of the day, along with choices among several professors (listed as "staff") who were assigned to teach the course. Our basic service courses were also offered during the entire academic year and both summer sessions, so, in addition to time-of-day and choice-of-professor options, students could also pick and choose (within prerequisite constraints) when, during the year, they preferred to take any given class. That's the good news.

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The bad news is that, by the time I retired in 2001, the number of sections offered for any given class was no longer determined by the ratio N/25. A decreasing allocation of full-time faculty positions, graduate teaching assistants to help with grading, staff, and resources, coupled with an [in]creasing pressure for faculty to devote more and more time to generating research funding (especially overhead-producing funds), forced us to abandon the luxury of small class sizes. Instead, the number of sections, M, to be offered for any given class was now determined arbitrarily, up front, independent of N. *Surprise surprise*: M << [N/25]! Aside from giving students less choice of professor and time of day/year during which they could sign up for a particular course, the most significant consequence of this change was that class sizes skyrocketed, first to 50, 60, 70 students per class, and then, more recently, to as many as 300 and above! These numbers, mind you, are for enrollments in *highly technical subjects*, requiring sophisticated problem-solving skills.

I tried in vain to explain my point of view to a rather apathetic Department Head: "Look, three times a week, for 50 minutes at a time, I can go into a Dynamics class of 150 students and *talk* to them about the subject, but there's no way that I can *teach* them anything about it!" He responded in textbook administrator fashion: "Just do the best you can," and then rationalized the new policies by quoting me chapter and verse of "scientific" studies that proved me wrong. Never mind that close scrutiny of those studies would reveal that all of them were highly biased, being carefully devised to make the results a self-fulfilled prophecy! Indeed, if one has ulterior motives, like leaving more time for research, which necessitates moving to larger class sizes and bigger student/teacher ratios, one can easily "prove" that there is no concomitant loss in teaching/learning effectiveness by making such a move, and one would be *wrong*.

In the first place, given class sizes of 150–300 (or more), it is impossible for a professor to get to know each student individually, and vice versa; students fail to establish a meaningful relationship with their professor. As it relates to the former, I have made the point here and elsewhere that getting to know one's students is, if not *the* single most desirable attribute of a dedicated mentor, certainly among the most distinguishing features that separate "telling" from *teaching*. You can't encourage students to believe in themselves and do their best if you don't even know them.

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With regard to students establishing a rapport with their professor, I have an amusing anecdote that relates to my experience in attempting to "teach" a class of almost 200 students in a large lecture hall. One day, about two-thirds of the way through the semester, I became rather ill and it was apparent that I would not be able to make it to class that afternoon. Since this realization came too late to attempt to contact all of the students in the class, I asked my dear wife, Judi, to do me a kind favor: Please go to this huge lecture hall on campus and announce to the class assembled there that Dr. Schneck is ill and has cancelled class for today. Since Judi had never been to this lecture hall, she thought it wise, before making the announcement, to check with one of the students in order to make sure that she was in the right place, dismissing the right class. So she inquired of a young gentleman sitting in the back row, "Is this Dr. Schneck's class?" To which the young man replied, "Lady, I have *no idea* who teaches this class!"

Now I would like to think that the above anecdote is an exception to the rule, rather than the rule itself, but so many of my colleagues have related similar experiences that, incredible as it might seem, it is fairly common for students to go through an entire semester and never even know the name of their instructor (much less care)! Students, that is, who come to class at all! Indeed, one's anonymity in a large class makes it easy to cut class without being noticed. It also *dis*courages those in attendance from actively participating in class discussion, asking questions, and taking careful notes, while at the same time *en*couraging daydreaming, writing letters to friends and family, doing homework from other classes, and being otherwise preoccupied and distracted from paying attention and focusing on the subject matter being addressed. After all, who will notice (or again, care)? Where's the incentive to be an active participant in the class when you represent less than one-half of one percent of it?

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The impersonal nature of large class sizes is a major problem, but not the only one. There are many others, among them:

- The issue of dealing with the one-size-fits-all mentality of our educational system. That is to say, a given instructor has his or her unique style of lecturing (*transmitting*) to a large class, and the class, as a whole, has no choice but to be exposed to (*receive*) that specific style of information transfer. It might work for some; it will probably not work for most. That's because, whereas the instructor can only *tell* the students what he or she knows according to his or her one particular way of communicating, 200 students *learn* 200 different ways! What the instructor thinks he or she is transmitting, or intends for the class to learn, is not necessarily what every individual in the class is *receiving* or interpreting in a one-to-one correspondence with the "intent." Quite to the contrary, in my experience, I have found that more often than not we do not teach in a manner compatible with the way people learn. Indeed, they ultimately learn not because of our efforts, but rather in spite of them!

- Along the same line of reasoning, there is the issue of adequate stimulus or mode of information transfer. Studies involving "learning-challenged" individuals have shown that, in processing sensory information (adequate stimuli acquired in the classroom or otherwise), we all have a tendency to rely heavily on only one of three primary modes of special-sense stimulation: visual (*seeing*), auditory (*hearing*), or kinesthetic (*feeling*). Thus, for example, one might appear to be "learning disabled" if his or her instructor's main information-transfer modality (which might be auditory in a large classroom setting) is contrary to the given student's preferred primary information-processing modality (which might be visual). Indeed, in one study, all of the teachers in a given school district were evaluated to determine their preferred mode of information processing, as were all of the students in the same school district. When students and teachers were then carefully matched according to their corresponding adequate-stimulus preferences, district-wide test scores rose on the order of 18%.

  These types of investigations suggest that instructors need to be aware of, and take into account when they present information to others (especially in a classroom setting), both their own information-processing preferences and those of their pupils. Differences among students who process information most effectively and efficiently according to varying modes of sensory stimulation are sure to have a significant effect on the corresponding "learning" environment. An instructor who does not take into account such differences (and this is most assuredly impossible to do in a large class) can do a grave disservice to his or her students, who, incidentally, might themselves not even be aware of how they learn best. All they know is that, in a given classroom experience, they were either successful or not, but they don't know why.

- Further to the issue of adequate stimuli and the lack of student constancy as it relates to their receiving and processing information uniformly across all sensory modalities, one has also to distinguish between *active*, hands-on learning styles and *passive* "book-learning." Our own daughters, for example, had difficulty relating to the sterility and abstract nature of book-learning. They did (and continue to do) best in the more practical, on-the-job training setting. That's one of the greatest advantages of academic Cooperative Education (Co-op) programs, which give students the opportunity to alternate "ivory tower," on-campus, classroom experiences with semesters spent off-campus, in the real-world workplace. I am a great advocate of Co-op programs.

- Another advantage of Co-op programs is the individualized, one-on-one nature of the learning experience. That's something that I always envied about Judi's violin teaching: She was (and still is) able to work one-on-one with each of her students, adapting her teaching style to best fulfill their individual learning styles and information-processing needs. The results are astonishing! Some students work and learn best under these conditions, seeming, in other circumstances, to be "learning disabled" when thrust into a class of 200 people! Indeed, among Judi's best violin students, and those who take to music like a duck to water, are those who, in their own schools, have been technically labeled LD (learning disabled), which just goes to prove, "There Is No Such Thing as a Learning Disability...Only *Teaching* Disabilities!" (*American Laboratory* Dec 2000, 32[24], 6–8; also see, "Scaling 'Unreachable' Heights," *American Laboratory News* Nov 2002, 34[23], 4). Now I am not naïve enough to believe that our mass-education system can reach and teach effectively each and every student according to his or her own unique learning skills, but I *can* say with a reasonable degree of certainty that moving in the direction of larger and larger class sizes and bigger student-to-teacher ratios is definitely going in the wrong direction!

- And while we are on the subject of *learning* skills, how about the related issue of testing and test-taking skills? First of all, how does one manage the logistics of giving problem-solving exams (or homework) in a class of 200 or more? In a practical sense, how do you grade homework assignments on a day-to-day basis, and exams in a timely manner? Are you forced to go to an impersonal, computer-graded, multiple-choice format? If so, what are the advantages/disadvantages of such formats? What, exactly, are you "testing"? How much *meaningful* feedback is the student getting in order to assess his or her learning progress in the course?

  Then, too, there are the well-documented psychological factors from which students often suffer in an exam situation, things like performance anxiety, or "freezing" on a test; panicking during a common-time common exam administered to a group of large classes in a large lecture hall; suffering from stage fright during oral presentations (e.g., some Ph.D. qualifying examinations or dissertation defenses); doing poorly in the restricted confinement of a massive classroom setting, under strict time constraints and supervision, as opposed to a take-home test format that can be executed in the comfort of one's own space, at one's own pace, without a proctor looking over one's shoulder, and so on.

- And finally, speaking of time and space, we've come full circle to the previously mentioned aspects of learning that relate to individual *biorhythms*. Some folks, me included, are "morning" people. Give me anything to do, learn, write, perform, etc., between the hours of 6:00 a.m. and 1:00 p.m. and I'll shine! On the other hand, my sister doesn't "wake up" until after lunch. Don't even ask her her name prior to noon, or you will get gibberish in return. Give me a project to complete in mid-to-late afternoon and my performance will be subpar, but my sister will shine! In other words, paralleling our own body's diurnal, circadian, and circannual biorhythms, there are cyclic variations in the ways that we handle and process sensory information. I am a morning person, learning and performing best in the a.m.; others would much prefer to have classes after noon. I happen to like fall and winter best; others might prefer spring or summer. That's why offering many sections of a class, at various times of the day, throughout the calendar year, is advantageous for students who have preferences directly related to optimizing their learning skills.

I could go on and on—the list is long—but the bottom line, in my humble opinion, is that whereas there is a lot of "telling" going on in our nation's undergraduate classrooms, there is very little actual *teaching*!

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On The "Scientific" Method

One of the strongest of basic human drives is the search for knowledge, and through it, truth. But there are often many obstacles standing in the way of pure, absolute, totally objective inquiry, among them:

- Strong personal beliefs (including religious beliefs)
- Unavoidable human bias (subjective orientation)
- Circular reasoning
- Ulterior motives
- The self-fulfilling prophecy trap
- Anatomic/physiologic information-processing constraints.

In an effort to minimize the effect of these limitations on the search for knowledge, and to optimize the process, the Scientific Method was devised by well-meaning investigators. Some historians trace various aspects of this method back to antiquity, but "officially," the Italian physicist/astronomer Galileo Galilei (1564–1642) is generally given credit for formalizing it into a rigorous procedure. For convenience, I think of this "procedure" as consisting essentially of 12 discrete steps:

Step 1: *Observe*. The procedure begins by:

- *Explicitly* defining, precisely, a specific problem to be solved, or
- Becoming aware, *implicitly*, of an issue that may derive from the puzzling features of events in common experience, or
- Observing curious phenomena that need to be explained. This leads one to:

Step 2: *Collect data*. Search, explore, and accumulate evidence. In this step, all pertinent observations and pieces of significant testimonials related to the explicit problem or implicit issue are carefully gathered:

- In a particular (often observer-dependent) frame of reference
- At a specific scale of perception (within a doubly infinite domain of realization), and
- Constrained by a precise window and accuracy of resolution.

Data gathering can be deliberate, based on well-defined evidence-seeking paradigms that are planned, in advance, with specific goals in mind, or the information can be serendipitous, being derived from unforeseen (or unanticipated), fortunate discoveries that are come upon entirely by accident. In either case, one now proceeds to:

Step 3: *Confirm the data*. Repeated observations yielding similar or identical results validate the data, converting them into legitimate evidence, which is now classified as facts—structure—the attributes that characterize a particular manifestation of reality, be it the explicitly defined problem being considered, the implicit issue that has emerged, or the phenomena in need of an explanation. Careful evaluation of the structure leads one to:

Bias and human error are unavoidable pitfalls of the scientific process.

Step 4: *Generate information*. Structure becomes "information" when the confirmed data are reduced to reasonable common denominators, from which there emerges an abstract interpretation of observations and experiences: a working hypothesis. In turn, this leads to the formulation of creative and logical alternative solutions to the problem, or plausible explanations of the evidence (best "educated guesses" of what is going on).

Step 5: *Inductive reasoning*. Critical thinking is now employed to work backwards, attempting to discern patterns in the common denominators, and see how well these can be explained by the working hypothesis. The investigator seeks to derive some order to the plethora of information thus-far gathered, and thereby gain some sense of temporal sequencing and spatial arranging of structure.

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Step 6: *Search for relationships*. Within this ordered structure, one now seeks intimate associations that are embedded in the accumulated information, associations that can help to further elaborate and strengthen the evolving working hypothesis by:

- Clarifying ambiguities and minimizing confusion
- Identifying similarities, looking for affiliations, and seeking even more connections and common denominators
- Avoiding chaos
- Creating the most likely, stable, consistent, and meaningful interpretation (explanation) of what is being observed. Such interpretation allows the investigator to go to:

Step 7: *Generalize, with good judgment and as little bias as reasonable*. This may require further "tweaking" (fine-tuning) of the working hypothesis. Step 7 culminates in the synthesis of relationships into a tentative, plausible theory that addresses the who, what, where, why, when, and how aspects of the problem or issue under investigation. Now it's time to take action!

Step 8: *Deductive reasoning*. We now work forward. The tentative, plausible theory is used to predict likely, testable outcomes in various situations claimed to be governed by the alleged formulation. This is the "Let's see what (and how well) the theory predicts. . ." step in the scientific method, designed to challenge it by:

Step 9: *Testing predictions*. This is done by accurately designing and properly executing carefully controlled, double-blind, randomized experiments/studies that allow the investigator to collect relevant and meaningful, quantified results. "Accurately designed and properly executed" includes:

- Clearly defining (in an unambiguous, operational sense) all relevant (especially confounding) variables, which is essential for both proper interpretation and replication of the investigations
- Ensuring that the experimental protocol quantifies these variables in accordance with appropriate analytical theories, procedural principles, technical methods, and reference values.

Step 10: *Validating the proposed theory*. Results obtained in the supporting and operating Steps 7–9, when objectively analyzed, interpreted, and properly evaluated, are used to test the strength of the tentative, plausible theory, and the conclusions reached therefrom. Indeed, faith in the utility of a proposed theory ultimately derives from validating its deductive predictions. Thus,

Step 11: *The "proposed" theory becomes a working theory!* When:

- Reasonable conclusions can be drawn that follow directly and logically from a meaningful, objective, unbiased discussion of results obtained as above
- Enough credible (reliable), substantiated (reproducible) evidence (more observations) accumulates to support the predictions of a proposed theory, and
- Seemingly contradictory observations offered to refute the working hypothesis can be satisfactorily explained in a manner that shows coherency (logical connections) and self-consistency (total agreement), then:

the working hypothesis is considered to be verified (note: not proven!), and the proposed theory is assumed to be corroborated by preponderance of the evidence. Thus, "proposed" is replaced by confirmed," "working," or, simply, a *theory*: the "rule."

tep 12: *Theory becomes law.* A theory (rule) that:

- Stands the test of time
- Consistently predicts repeatable/reproducible results that occur invariably under identical conditions
- Survives all valid attempts to falsify it, without succumbing to viable alternative hypotheses, and withstanding exposure to "exceptions to the rule"
- Maintains self-consistency, coherency, and the ability to be fine-tuned without major alterations, and
- Can be independently confirmed

ecomes a law, beyond a reasonable doubt, *but still only corroborated, not proven*. It is both feasible and acceptable as long as it emains verified, and the accumulating evidence continues to ttest to its validity. Moreover, the entire process described above pplies equally well to a theoretical/analytical formulation or to an xperimental investigation. However, as nice as it sounds on paper, everal caution flags need to be recognized, among them:

The "Method" is a hypothetical idealization of a process that is seriously and unavoidably constrained. Our ability to "know" is severely limited by factors over which we have little or no control, including:

- Technological constraints (not the least of which often include time, money, and practical considerations) that limit our ability to measure *everything*—in a totally unbiased, objective way—with the highest accuracy and finest resolution
- Anatomical/physiological sensory limitations that prevent us from experiencing, altogether, more than a miniscule fraction of the multifarious manifestations of "reality"
- In order to avoid clutter and information overload, anatomical/physiological information-processing constraints that filter out and modulate ("censor") the sensory stimuli to which we *are* responsive, and,
- Anatomical/physiological perceptual limitations that limit our ability to objectively interpret the information that does eventually make its way to conscious, cognitive cerebral levels. Indeed, bias and human error are unavoidable pitfalls of the scientific process. Thus, it is not uncommon for it to succeed in spite of rather than because of its inherent attributes, so we must never become complacent. Thus, finally,

Step 13, if you will, should always be *skepticism*, lest we fall victim to what I call "The Emperor's New Clothes Syndrome" in science; that is, being bullied by misguided authoritarianism.

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