

2009

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Recommended Citation

David, Carl W., "Multiple-Choice Testing in Science and Technology Courses" (2009). *Chemistry Education Materials*. 71.
https://opencommons.uconn.edu/chem_educ/71

Multiple-Choice Testing in Science and Technology Courses

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(Dated: March 3, 2009)*

I. ABSTRACT

Wide spread and continuing use of multiple-choice testing in technical subjects is leading to a mindset amongst students which is antithetical with actual use of intellect.

II. INTRODUCTION

The idea that there is a coherent philosophy of teaching is odd to the teacher in the trenches who struggles each day to present material and hopes for some neural changes in students.

Just like Chairman Mao's often quoted "Let a hundred flowers bloom, let one hundred schools of thought contend", we have individual teachers, each in their isolated classrooms, alone with 30 to 300 students, using a plethora of techniques, some old, some new, hoping that something occurs that's worthwhile.

In introductory college science and mathematics [1], this means bringing the student to the level that s/he can do certain kinds of problems. The exact nature of these problems, the depths that they plumb, the ingenuity they require, the creativity they display, these are qualities which vary all over the map. But in the current context, something slightly beyond regurgitation is regarded as ecstatically successful learning (and therefore teaching).

In this paper, the argument will be made that multiple choice testing has (tragically) warped students thinking in ways which are inimical with mature, enlightened, scientific thought, and that the only way to return to a world where scientific creativity can emerge is to return to using constructed response items. In such examination schemes, the student's ability to delude him/her-self about his/her knowledge is eliminated, precursor materials are retained in students' armamentaria, and those who survive the education maze can emerge as true scientists, ready, willing, and able to advance knowledge.

À propos deluding ourselves [2], the following appeared on news wires at about the time this paper was being written:

"If improving science and math education is suddenly a national priority, someone apparently forgot to tell the parents and the students.

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In a new poll, 57% of parents say "things are fine" with the amount of math and science being taught in their child's public school. High school parents seem particularly content. 70% of them say their child gets the right amount of science and math. [3]"

It is interesting to ask the alternative question, how well prepared are, say, our juniors who have completed two years of calculus? If one were to ask the teaching faculty of such incoming upper classmen, one would find, I'm sure, a continuing unhappiness with the level of preparation, the amount of remediation required, etc.

But then again, like lawyers, we don't ask questions whose answers we don't want heard. In "the best of all possible worlds [4]", there's nothing to fear.

We emphasize here that only technical subjects are addressed herein. Selecting homonyms, or testing reading comprehension, etc., are beyond the scope of this article.

III. AN EXAMPLE OF WHAT WE EXPECT FROM JUNIORS

After 2 years of calculus, all engineering, chemistry, physics (and of course mathematics) students should be able to address the following question in an intelligent manner:

"Show [5] that, given

$$\int_0^\infty \left(\int_0^\infty e^{-xy} \sin x dy \right) dx = \int_0^\infty \left(\int_0^\infty e^{-xy} \sin x dx \right) dy,$$

one can obtain

$$\int_0^\infty \frac{\sin x}{x} dx = \frac{\pi}{2}$$

by elementary methods [6]."

We use this question as a probe and example, because it occurs in a textbook which assumes familiarity with calculus, but is not associated with an actual course. From our point of view, here, the ability to read this text and understand it is a mark of having been educated in our technical sense of the word. The ability of our graduates to be able to learn from the written word is the prime indicator that we've prepared them for post-college (technical) life.

How could we test that students actually can do this problem? Remember, of course, that this is not a multiple choice question, and in a sense, not even a constructed response question. It is a “demonstrate that” question, with the “answer” given! It falls outside the purview of normal testing, and yet it poses a powerful indicator of learning, since it doesn’t involve anything other than elementary concepts and methods. Any student who has passed 4 semesters of calculus *should* be able to do this problem, but if one were to walk out into the hall and actually ask a real junior to do this problem, the results would be quite devastating. The use of this testing item checks that student’s really have acquired certain skills. Large scale failure to be able to approach this problem as juniors, would indicate complete indictment of the system of passing courses being held equivalent to having been educated (mathematically).

We pause here to note that our posed problem does not fall naturally into the taxonomy of Bloom [7] since it involves more than “Synthesis” and yet does not require “Evaluation”.

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1. $-\int_0^\infty \left(\frac{\sin x}{y}\right) dx = -\int_0^\infty \left(\left[\frac{e^{-yx}}{1+y^2}(y\sin x - \cos x)\right]_0^\infty\right) dy$
 2. $-\int_0^\infty \left(\frac{\sin x}{x}\right) dx = -\int_0^\infty \left(\left[\frac{e^{-yx}}{1+x^2}(y\sin x - \cos x)\right]_0^\infty\right) dy$
 3. $-\int_0^\infty \left(\frac{\sin x}{x}\right) dx = -\int_0^\infty \left(\left[\frac{e^{-yx}}{1+y^2}(y\sin x - \cos x)\right]_0^\infty\right) dy$
 4. none of the above

etc. [8], but it is clear that this is an exercise in reading (and visual perception and acuity), not strictly in calculus.

Worse, since this is only the first line of a derivation, we can not have a written, machine gradeable examination present the next question without giving away the answer to the first question, unless we want to traverse an enormous set of solution trees, or, we want to fail students on their first incorrect response.

It is clear that this is nonsense, and that only an oral examination or a hand graded (with a constructed response (no helping hints)) written examination would do.

C. What do we mean by knowing?

Without being excessively philosophical, we instinctively know in ourselves when we do or do not know something (we are not talking about the religious “know” of the “truth”). When we know something, we can demonstrate it, and when we knew something, we can bring it back relatively easily (perhaps we need a memory jog for the details).

A. Attacking a hard calculus problem

The first thing a student should notice is that the order of nesting and therefore the order of integration is reversed in the two parts of the equation, the l.h.s and the r.h.s. are to be treated differently This should trigger some thoughts about when such interchanges are legal. For the curious, the Appendix deals with this problem in detail.

B. Multiple choice examining using (this) hard calculus problem

If, on an examination, we were to ask this question and we required machine grading, it would have to be phrased in multiple choice increments. Perhaps one could ask: As a first step in this derivation, which of the following statements is correct?

When a student needs the law of cosines, we don’t expect him/her to actually remember it, rather we expect the student to know

1. that the law of cosines (concerning triangles, their edges and included angles), not the Pythagoras Theorem, exists,
2. why the law of cosines is needed, and
3. how to look it up, interpret it, etc..

It’s a bonus if the student actually remembers it, but that’s not necessary.

Considering the hierarchical nature of the materials we learn in technical/scientific courses, it is imperative that our students never see for the first time precursor material required in a current course. Familiarity with everything that’s been previously taught (and presumably learned) is a prerequisite to continuing onto advanced materials. Our student might not recall everything being asked for from prior work, but we expect him/her in the classroom to know that s/he’s seen it before, and can (and will) re-learn it quickly and efficiently (since it was once “mastered”).

Multiple-choice, by its very nature, leaves us not quite knowing why a student got a right (or wrong) answer. The methodology never delves below the surface to see what was going on that the student could and/or did transmit as part of the answering process. For example, is a wrong answer due to precursor ignorance, arithmetic errors, logic errors, reading errors, etc.. Was the “right” answer a guess? Was the “right” answer gotten through “testmanship” strategies?

IV. MULTIPLE CHOICE ITEMS

It is for the above reasons that one sees that multiple choice questions in technical courses have led to a disastrous decay in retained knowledge, resulting in students who are “accredited” but not educated (nor trained). They are good guessers, good multiple-choice examination strategists, but they are not knowledgeable in the matters that presumptively were important and being tested. Having “passed” examinations, they’ve jumped over the barrier erected, but they have not achieved what the barrier was intended to measure and certify.

They bring different skills to tests, dominated by a strong skill in looking for tricks while reading (not necessarily a bad thing) and secondarily by a clear desire to winnow down the number of choices prior to guessing/choosing.

Nothing in the real world they are entering even faintly resembles multiple choice testing; nothing. In the “real world” the answer is not chosen from a list, it is constructed. What they are doing in school is jumping through hoops set up by adults, but they are not being educated!

It is interesting to note that Banesh Hoffman’s criticism [9] of multiple choice testing is, from our point of view here, not quite on target. He argued that the brighter, more reflective student had to, in essence, dumb-down in order to deal with multiple choice examinations. I argue here that examinees have to focus their thinking on aspects of testing which are not germane to the subject matter being tested, and that this is not only distracting, but is distorting, changing the nature of the meaning of getting the answer “right” (or wrong).

V. NUMERICAL RESPONSE QUERIES

Consider the freshman chemistry introductory question: “How fast are you traveling in miles per hour when you are traveling at 100 kilometers per hour (in Europe)?”

One can pose this question in an examination in several ways, the first of which (constructed response) is shown, with an answer to be supplied by the student.

1. Thus, the first way is just to ask:
“What is the speed (in mph)···?”

2. The second method might be a multiple choice method:

- (a) $speed = 100 \times \frac{1 \text{ miles}}{5280 \text{ feet}} \times \frac{1 \text{ feet}}{12 \text{ in}} \times \frac{1 \text{ in}}{2.54 \text{ cm}} \times \frac{1000 \text{ cm}}{1 \text{ km}}$
- (b) $speed = 100 \times \frac{1 \text{ miles}}{5280 \text{ feet}} \times \frac{1 \text{ feet}}{12 \text{ in}} \times \frac{1 \text{ in}}{2.54 \text{ cm}} \times \frac{1 \text{ cm}}{1000 \text{ km}}$
- (c) $speed = 100 \times \frac{1 \text{ miles}}{5280 \text{ feet}} \times \frac{1 \text{ feet}}{12 \text{ in}} \times \frac{1 \text{ in}}{2.54 \text{ cm}} \times \frac{1 \text{ cm}}{100 \text{ km}}$
- (d) none of the above

3. Alternatively, one can construct this in the form:

- (a) $speed = 100 \times \frac{1}{5280} \times \frac{1}{12} \times \frac{1}{2.54} \times \frac{1000}{1}$
- (b) $speed = 100 \times \frac{1}{5280} \times \frac{1}{12} \times \frac{1}{2.54} \times \frac{1}{1000}$
- (c) $speed = 100 \times \frac{1}{5280} \times \frac{1}{12} \times \frac{1}{2.54} \times \frac{1}{100}$
- (d) none of the above

4. and finally, one can pose it as

- (a) $speed = 0.61$
- (b) $speed = 0.00000062$
- (c) $speed = 0.0000062$
- (d) none of the above

For the last variant, it is not clear even if a student will write out his/her work, drag out his/her calculator, and ultimately “do the problem”. There are other tactics which work, so why bother?

It is indicative that experts, in instructing us how to make up multiple choice questions, use the term “distractors” for the wrong choices. Nowhere in life do we intentionally attempt to deceive and/or entrap (other than in criminal matters). Why one should be proud of seducing students into making errors is beyond me.

A. Constructed Response Items which are machine gradeable

For years, we’ve had the ability to machine grade items in which numerical answers were not chosen from lists, but were constructed, right or wrong, by the student (see Appendix 2). The method can be used where the student constructs his/her answer (in floating point format in this particular case, others are possible) such that the standard #2 pencil can be used to create spots which can be read by a Scantron-equivalent machine. Knowing that we’ve had the ability to examine this way, it is hard to understand why we’ve persisted in not using it. Perhaps there’s a perverse pleasure in sticking with the old, and eschewing the better. Perhaps its the same psychic pleasure that has doctors requiring interns to work the killing schedules the doctors did in the past; a rite of passage. In any case, there’s no need for using multiple choice examinations in technical subjects whose subject matter is numeric (i.e., not organic chemistry).

B. Excellent Multiple Choice Questions

The SAT multiple-choice questions have changed markedly from the days when we took them. In fact, the logic questions are excellent, requiring intense thought, careful analysis, etc., without being marred by the stigma of “distractors”. In questions in which there is a conclusion to be drawn about a person, and all candidate names are in the choice list, clearly, there is no distraction of the type we are discussing here.

For certain kinds of materials, multiple choice is really excellent, and there is virtually no other means for testing which can approach it in the accuracy of its reported results vis-à-vis the actual abilities of the examinee. Of course, the exception to the rule is guessing, i.e., multiple choice testing can never tell whether or not a “right” answer was arrived at “properly”.

But when the question is chemistry, or thermodynamics, or circuits, or Newton’s equations applied to a Hooke’s Law spring, etc., the multiple choice format interferes with the examining process, and leads the examinee to game-play the examination, rather than use it to measure him/her self.

VI. RESEARCH AND UNDERSTANDING

Modern research claims that multiple-choice items are equivalent to constructed response items requires that we stress that modern educational research envelops itself in a pseudo scientific authoritarian cloak by often times abusing statistics, or, believing that using statistics is a proof of something.

The worst error, constantly being committed is the “all things being equal” error which argues that in comparative instruments applied to different but randomly chosen populations, all the differences between the populations are washed out, and “all things being equal”, the results of the averages of the two groups are worth comparing. This article of faith buttresses almost all of the “research” one sees. But students aren’t molecules, and a cadre of students does not statistically stand equivalent to an Avogadro’s number of molecules. Were these “researches” valid, the enormous efforts expended should have lead to some kind of Gestalt about how to improve instruction; of course, there is none.

A secondary error, which occurs in other contexts also, is that the experiment can never be repeated, so the choice of “control groups” and other esoterica becomes, again, an assumption without verifiability. We can never give the same examination to the same student, so we never actually repeat any “experiment” in “educational research”. True experimental research allows for repetition of experiments under identical conditions.

As an example, we consider the paper of Hancock [10] in which an argument concerning multiple-choice versus constructed response items is made. His sole example

from the tests he administered concerned simple statistics:

“Sample 1 had $n=20$ scores and a variance of $s^2 = 50$. Sample 2 has $n=25$ scores and a variance of $s^2 = 100$. To one decimal place, what is the value of the pooled variance?”

His discussion of “distractors” concerns the superiority of the second set over the first:

a) 68.8, b)72.1, c) 75.0, d)77.9

versus

a) 75.8, b) 76.6, c) 77.9, d)78.2

He says

“A simple comprehension of the process of pooling variances will not suffice in this case; an examinee must apply the pooled variance formula to the given data. making this multiple choice item require application-level ability [11]. .”

The real question, it seems to me, is whether hand grading such a trivial question results in measuring the same thing as using a multiple-choice instrument. Hancock’s claim that the second set of “distractors” is superior to the first may be true, inside a multiple-choice universe, but having a student write:

$$s_{pooled}^2 = \frac{(20 - 1) \times 50 + (25 - 1) \times 100}{(20 - 1) + (25 - 1)}$$

and then finding an arithmetic error in a hand graded, constructed response item, is clearly superior to either of the “choices” he extols.

The distractors serve the function of actually seducing the examinee into having confidence in his/her (wrong) answer since it appears on the list of possible answers. More sophisticated examinees know that these choices are dictated by common errors that people make.

A third problem with this paper and its ilk, is that it can not be reproduced. The actual queries are not filed somewhere for an independent experimenter to validate the claims made. Were the constructed response items graded using partial credit? The reader doesn’t know, and can not find out. Normal physical science experimentation assumes that interested parties can validate past results by repeating the experiment, something precluded in this case.

A fourth problem concerns the actual “experimental design”, i.e., using two separate groups (again, the “all things being equal” business) rather than a single group with multiple-choice items which required that the work be shown, so that the student responses could be graded twice, once on their constructed answer, and once on their multiple choice answer.

It is important to remember that the odds of getting a multiple-choice query correct are $\frac{1}{n}$ if there are n items in the response list, while the odds of getting the query correct in a constructed response setting is nil. Therefore,

the motivation for any study in this area is to find evidence that the *a priori* odds are somehow circumvented in real world experiments, contrary to elementary logic.

Or, as asserted here, these two methods are not equivalent, and one is inferior to the other.

VII. WHO'S KIDDING?

The following is taken from [12] from the internet:

“Math strategies

Working Backwards

Rather than setting up and solving an equation to find the right answer, working backwards takes advantage of the fact that all problem-solving questions give you the right answer; you just have to work out which one it is. You do this by running the answers through the equation in the question until you find the one that works.

Use working backwards when:

- You are asked to solve an equation (this is especially true when the question is in the form of a word problem).
- The answer choices are numbers.

How to work backwards:

- Step 1: Start with answer choice (C).
- Step 2: Eliminate answers that are too big or too small. (If (C) is too small, everything less than (C) must also be too small, because the choices are arranged in order from smallest to largest. If (C) is too big, then everything greater than (C) must also be too big.)
- Step 3: Run the remaining answers through the question until you find the right one.

Plugging In Numbers

Plugging in Numbers works with the answers, eliminating incorrect ones, and homing in on the right one. It almost always involves less messy algebra, and so it is often a lot easier than using traditional algebra.

Use plugging in when:

- The answers are variables.
- You are working with percents, fractions, or ratios, and no actual values are given.

How to plug in:

- Step 1: Pick a simple number to replace the variables.
- Step 2: Plug your chosen number into the equations. The result is your target number.
- Step 3: Plug your chosen number into the answer choices, eliminating those that do not yield your target number.

To plug in numbers on percent questions, always use 100.”

No more has to be said!

VIII. AN ALTERNATE TAXONOMY

This tract suggests that reliance on multiple-choice has altered the intellectual horizons of our students, and that we need to return to constructed response items.

Further, perhaps, for technical subjects, we need an alternative taxonomy to Bloom's. Consider the following (sarcastic) proposal:

Students are

1. *problem regurgitators*: this corresponds to echoing back material without much if any thought. For required barrier courses, this might suffice.
2. *problem proficient*: this corresponds to being able to answer standard problems (such as those at the end of chapters which are not classified as “challenging” (or some other euphemism). For future practitioners, for whom training rather than education is paramount, perhaps “mastery” at this level is acceptable.
3. *problem competent*: this corresponds to being able to answer standard problems which have been paired together, without telling the examinee that this has been done. Clearly, solving such problems demonstrates a higher than the “monkey see, monkey do” paradigm of problem proficient.
4. *problem masters*: this corresponds to being able to answer problems in the domain known by the examiner to be “do-able” with the material so far known and covered, but where the examinee has never seen the material in this particular light. This most likely corresponds to proving that the education has been successful when an examinee can gather learned materials together and tackle something brand new. Here, the examinee is putting together parts which were taught separately, indicating that s/he has a command of the material in a larger sense than just “plug and chug”.
5. *genuine masters*: this corresponds to doing problems that have never been done before. We do not expect any educational system to bring students to this level. Period [13].

This taxonomy would allow us to set examinations in required terminal courses at the first level, required non-terminal courses at the second, and pre-professional courses at the third level, in an operational setting. Coupling this with ending our reliance on multiple-choice would rescue us from the impending mediocrity we face.

IX. CONCLUSIONS

It is clear that examinations have not received the attention that other aspects of the teaching/learning process enjoyed. In an era of “high stakes testing” one would think that attention would be paid, but it isn’t.

The central important point about current practice is that it is cheap and it is even-handed (non-prejudicial). As pointed out in the Appendix 2, it is possible to create constructed response items which are machine gradeable, i.e., cheap and non-prejudicial. The question then occurs, why have we continued to employ what students characterize as “multiple guess” items? This paper offers no explanation, but argues that the multiple-choice format warps thinking and mimics nothing of the “real world” that our students will face upon disgorgement from the academy.

I have suggested a computer assisted scheme [14] for doing this also, but that entails dealing with security and identity issues which are beyond the scope of this piece.

If it is desirable to test in subjects such as calculus or organic chemistry, where the ultimate constructed response item is represented symbolically rather than numerically, a web-oriented examination scheme employing sophisticated input schemes for allowing the student to construct his/her answers without choosing from a list of possible answers, would enlarge machine gradeable examinations to include enough subjects to guarantee that measurements of learning were taking place in an unprejudiced and economically effective manner in technical subjects, without bad side effects concerning “testmanship”.

X. APPENDIX

We recognize that the left-hand-side of the equation

$$\int_0^\infty \left(\int_0^\infty e^{-xy} \sin x dy \right) dx = \int_0^\infty \left(\int_0^\infty e^{-xy} \sin x dx \right) dy,$$

can be evaluated to

$$\int_0^\infty \left(\int_0^\infty e^{-xy} \sin x dy \right) dx = - \int_0^\infty \left(\frac{\sin x}{x} \right) dx$$

by carrying out the interior integral using elementary means. We have

$$\int_0^\infty e^{-xy} \sin x dy = - \frac{\sin x}{x} \Big|_0^\infty$$

($\sin x$ is a constant when integrating first over dy)

$$\int_0^\infty \left(\int_0^\infty e^{-xy} \sin x dy \right) dx = - \int_0^\infty \frac{\sin x}{x} dx$$

Now, re-doing the integral in the opposite order of integration (the right hand side of the original equation

posed as a “given”) we start with the interior integral (over dx)

$$\int_0^\infty \left(\int_0^\infty e^{-xy} \sin x dx \right) dy \quad (1)$$

which can be obtained by elementary integration i.e.,

$$\int_0^\infty e^{-xy} \sin x dx$$

is to be evaluated. Of course $\sin x$ is not constant this time! If you have forgotten that method, you might try integrating by guesswork, something which often works, i.e., asking what, when its derivative is taken, gives the desired integrand? In our case, we note that

$$\frac{d(-e^{-xy} \cos x)}{dx} = e^{-xy} \sin x + ye^{-xy} \cos x \quad (2)$$

so, to eliminate the second term on the r.h.s., we note

$$\frac{d(-ye^{-xy} \sin x)}{dx} = -ye^{-xy} \cos x + y^2 e^{-xy} \sin x \quad (3)$$

so, adding Equations 2 and 3

$$\frac{d(-e^{-xy} \cos x - ye^{-xy} \sin x)}{dx} = e^{-xy} \sin x + y^2 e^{-xy} \sin x = (1 + y^2)e^{-xy} \sin x$$

or

$$\frac{1}{1 + y^2} \int \left(\frac{d(-e^{-xy} \cos x - ye^{-xy} \sin x)}{dx} \right) dx = \int e^{-xy} \sin x dx$$

Equation 1 becomes

$$\int_0^\infty \left(\left[\frac{e^{-yx}}{1 + y^2} (y \sin x - \cos x) \right]_{x=0}^{x=\infty} \right) dy = - \int_0^\infty \frac{dy}{1 + y^2}$$

since at the upper limit, the exponential terms vanishes, while at the lower limit the $\sin x$ vanishes.

And this final integral is elementary. Just a reminder. Let

$$\tan x = y$$

so

$$d \tan x = dy$$

and the l.h.s. is

$$d \left(\frac{\sin x}{\cos x} \right) = \left(1 + \frac{\sin^2 x}{\cos^2 x} \right) dx$$

so we have

$$\left(1 + \frac{\sin^2 x}{\cos^2 x} \right) dx = dy$$

or

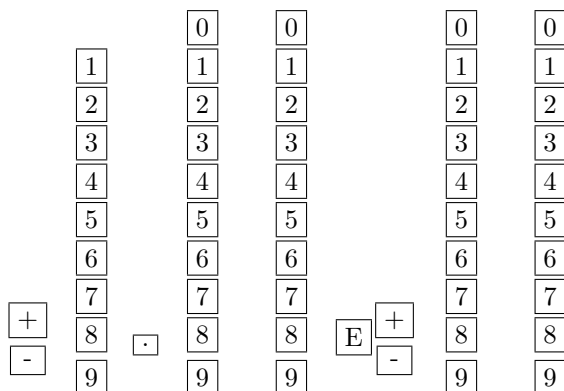
$$(1 + y^2) dx = dy$$

so

$$dx = \frac{1}{1 + y^2} dy$$

and except for fiddling with the limits, we’ve got it.

XI. APPENDIX 2



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- [1] C. P. Snow, “The Two Cultures and the Scientific Revolution” Cambridge University Press, United Kingdom, 1959. We eschew treating examinations concerning non-technical items here.
- [2] I’m as guilty as the next person in terms of self-delusion. Suffice it to say that under the current circumstances in which I work, multiple choice testing is the only option available for handling hundreds of students at a time in freshman courses. Were I still young, perhaps I’d act differently, but, given the situation, I have no recourse but to test the way I do. Forgive me the hypocrisy.
- [3] Posted 2/14/2006 5:35 PM by Associated Press
- [4] Gottfried Leibniz “Essais de Théodicée sur la bonté Dieu, la liberté l’homme et l’origine du mal (Theodicy), 1710. Funny, I thought this was from Voltaire, by way of Leonard Bernstein and Candide (and where’s Pangloss?)
- [5] Z. A. Melzak, “Companion to Concrete Mathematics, Mathematical Techniques and Various Applications”, Wiley-Interscience, New York, 1973, page 177.
- [6] This is akin to the infamous ‘it can be shown by the serious student . . .’.
- [7] B. S. Bloom et al, “Taxonomy of Educational Objectives: Handbook I:Cognitive Domain” Longmans, Green & Co., 1956
- [8] One could pose the question as $-\int_0^\infty \left(\frac{\sin x}{x}\right) dx = -\int_0^\infty \left(\left[\frac{e^{-yx}}{K}(y \sin x - \cos x)\right]_0^\infty\right) dy$ and ask for the “value” of “K” in the above as chosen from a list of candidates. Our point is not how to phrase the multiple-choice question, but whether or not one should phrase the question in this format at all.
- [9] B. Hoffman, “The Tyranny of Testing”, New York, Collier Books, 1962; and at least one article in the New York Times Magazine
- [10] G. R. Hancock, J. Experimental Education, 62, 143 (1994)
- [11] “Words, words, words, I’m so sick of words . . .”, Lerner and Lowe, My Fair Lady. Actually, the operative words in this context are “Don’t say how much, show me!”
- [12] http://education.yahoo.com/college/essentials/practice_tests/sat/overview/problemsolving_strat.html
- [13] Interestingly enough, this category includes examinees whose abilities possibly transcend our own, something which can be daunting to the insecure
- [14] C. W. David, “New Ways to Test Science”, College Board Review, 2, 119 (1981).