Teaching for Passing Tests versus Teaching Critical/ Scientific/Skeptical Thinking

When a science teacher instructs his/her students with the primary goal of ensuring the students pass assorted tests, this is often done at the expense of teaching the students how to think critically, scientifically, and skeptically. Teaching towards test passage runs the risk of abrogating scientific thinking in favor of memorizing the "right" answers for passing the tests. Many of the best solutions to specific scientific issues are contextual, that is to say, dependent upon the specifics of the particular situation. This article presents an argument in favor of teaching to induce critical/scientific/ skeptical thinking along with how to go about it, and that by doing so, passing the various required tests will follow, and so much more, with students equipped to apply critical/scientific/skeptical thinking to everyday issues.

It is well known that for a student to advance, for schools to receive full funding, for college admissions, etc. he/she must pass numerous tests. These tests typically have questions with "correct" answers, and the teachers often teach in a manner to maximize students' passing such tests. This means many students wind up equating science with a body of pre-existing knowledge, portions of which must be memorized in order to pass.

Viewing science as a large, complex body of knowledge filled with "right" answers to memorize sucks the very life out of it. It is hard to imagine why students would want to go on pursuing science, or even reading about science, once they get out of school. In high school physics, a student will see F = ma, memorize it for the relevant test(s), and the forget about it because they do not learn how to connect the equation to what they see in real life. What if instead of memorizing the equation, they were instead challenged to determine the relationship between the three variables using marbles of different masses, adjustable inclined planes, and some means that they can figure out to measure force. The teacher could even let them figure out what measuring devices would work. It's possible that the teacher could learn something new along with the students by observing what the students come up with!

Common Teaching Methods

Full disclosure: I spent two years as a public school teacher. I have taught in community colleges, internationally to various scientific groups, domestically to companies ranging from small contact testing laboratories up to major pharmaceutical companies. I have taught, in a manner of speaking, NASA employees and regulatory agency members, along with compendial representatives. I am not mentioning this as a means of providing a mini-resume, but rather to give you an idea of the breadth of the problems I have seen inherent

in teaching the "right" answers versus working towards facilitating critical scientific thinking and skepticism. What follows are descriptions of some of the teaching (training) methods I have frequently observed.

1: The teacher stands in front of the students with a PowerPoint presentation on the screen. If you are lucky, the teacher uses the material on the screen as talking points. If you are unlucky, the teacher reads the material on the screen to the students, thereby causing death by PowerPoint. Often, after enduring the "teaching", a quiz may follow. More often than not, the expected answers to the questions may be lifted directly out of the teaching material, or from the included reading material. For example, let's say the teaching pertained to Newton's laws of motion. The associated book chapter includes the basic equations such as the previously mentioned F = ma. The quiz might ask what the F, m and a represent. It may ask for the calculation of the force exerted by a 10 g ball accelerating at the force of gravity (9.8 m/s^2) The "right" answer is supposed to be the regurgitation of what the F, m and a stand for, and the answer as per the calculation. Is this in any way a lively exercise? One is an exercise of rote memory, the other, basic arithmetic.

2. We live in an age of computers, so teaching delivered via interactive software is common. The basic information is provided, often with oral material and an accompanying transcript. Sometimes you can choose the exact order of the material to be covered, sometimes not. There can be questions posed throughout, or in the form of a quiz at the end. Again, most often the questions asked would require answers that can be lifted directly from the material as presented. Rarely will the questions require reflection upon what was presented in order to synthesize an answer that was not directly presented in the material. The primary goal, again, is to instill the "right" answers into student memories so that they may pass the assorted tests.

3. In this case, the approach is rather similar to #1 above, except that the teacher will write/draw a lot on a whiteboard (older schools will use blackboards). This approach could be much more entertaining if what goes up on the white/ blackboards represents the students' thoughts pertaining to questions such as "why don't we fly off the Earth if it is rotating at around 1000 mph", or "why do most plants have green leaves?" To a person educated in science, and the pleasures to be found in scientific thinking, these questions can be fun. To students who have grown up thinking of science as a vast body of knowledge from which the "right" answers to these questions may be extracted, they will not enjoy working through the possibilities. They will just want the "right" answers.

Sad to say, I have relatively recent experience from teaching a biology for nursing students class at a community college pertaining to the interest only in the "right" answers. The class was going through a laboratory exercise involving the behavior of various sugars (reducing, nonreducing) and associated color reactions. Some of the sugars were labeled, others were unknowns. Several students asked me which

of the unknowns were reducing sugars and which were nonreducing sugars. I suggested that they look at the results they got with known sugars, and based upon that, arrive at their own conclusions. This was hardly asking for deep scientific thinking. Later that week, I got called into the department chair's office. She informed me that a number of my students had gone in complaining because I didn't give them the "right" answers. I responded with my goal was to get them starting to think like scientists. She said that learning to think like scientists can wait until they reached upper level courses. Why was it so important to provide the "right" answers? Because the funding for the program from the state depended upon students making it through all of the required courses, and if they dropped out, funding would suffer. I was, and remain, appalled at this. Learning to think scientifically should begin as soon as reasonably possible in order for it to become second nature. It would seem that many of these students had not gone through their earlier education being taught how to think critically/scientifically/ skeptically, but I would bet a great many of them will have passed the assorted required tests. Thanks to that department chair, the community college students would have to wait to get started thinking scientifically, and I suspect it may be too late. I believe the love for critical/scientific thinking and scientific skepticism should be inculcated early in life, or else science will be forever a drudgery in far too many students' minds.

Replacing Routine Science Tests

If the goal of a teacher is to instill the "right" answers in his/her students, then the standard sort of testing is fine. Such tests will inform you as to how well they have absorbed and retained the answers required to pass the test. At least as of the test day. Ask the same questions a month later, and I would suspect the scores will be lower. Preparing for tests like this does not inspire questioning, solving unique problems, or any actual investment in the process of teaching one's self.

If, however, the goal of the teacher is to instill a passion for learning, for critical thinking, scientific thinking and the related scientific skepticism, preparing for testing such as described above is anathema to that very goal. Critical thinking/ scientific thinking/skepticism all require the ability to pose one's own questions, not merely an ability to answer another's questions. Perhaps a way around this issue is to think not in terms of testing, but instead, assessing how students are doing.

One possible approach might be to make a statement such as "vaccines don't work." The idea behind such a question is to motivate the student to ask questions such as "how can I find out if vaccines work", or "what evidence does the person who made the statement about vaccines have to support the claim." You could imagine vast number of similar such questions. The assessment then boils down to did the students come up with questions, and did they go about using effective means of answering their own questions? If a student does not come up with a

question, the teacher could suggest one to get them started. If the student chooses only to look at FaceBook, YouTube, or other scientifically questionable sources, the teacher could introduce them to scientifically suitable sources and how to find them. This assessment process does not produces failures, it produces people who can think clearly, critically, scientifically, and based upon keeping the open mind of a skeptic, always be learning and wanting to continue learning.

When the teacher poses questions, they should rarely have the answers directly provided in the documents or oral instructions used in the teaching. However, when the student can provide answers to these questions, the she/he will be in a much better position to address unexpected circumstances, and to be able to suggest fresh approaches upon such reflection.

Consequences of Teaching for Test Passage Alone

I am writing this during the summer of 2021. The Covid-19 pandemic is still very much with us, and there are many Americans who are hesitant about getting the vaccinations. Readers will find many opinions expressed in the various social media from such people, a few of which follow:

- Face masks don't work.
- The vaccines are a form of genetic engineering.
- The mRNA vaccine aren't real vaccines.
- We don't know about long term side effects due to the vaccines.
- ADE is a problem with Covid 19 vaccines.
- The Covid 19 vaccines were developed too rapidly to be safe.

One approach to handling these thoughts is to provide references, and quotations from the references, to counter the claims. This approach does not seem to change many minds. I know because I have tried them. I believe the principal difficulty with this approach is the most readers of such opinions are no longer interested in thinking critically, scientifically, skeptically. In other words, lacking interest in doing so, they evince a lack of interest in learning on their own. It is an extension of the "right" answer mode of education. The opinion is there in print, on the internet, expressed by many, and digging into the available information to find their own answers is unappealing.

What is to me even more distressing is that many readers no longer formulate their own questions, because if they were the creators of their own questions, the desire to answer them might lead them to the very sources a teacher might want them see. How much better would it be for critical, scientific, skeptical thinking if each statement solicited the associated questions (among others the reader might formulate):

- Face masks don't work.

    - How do we know if face masks work?
    - What harm could wearing a face mask cause?
    - Does having to wear a face mask violate a person's rights?
- The vaccines are a form of genetic engineering.
    - What is genetic engineering?
    - Are the Covid-19 vaccines different from earlier vaccines that were not called example of genetic engineering?
    - What are some examples of genetically engineered products that may already exist?
- The mRNA vaccines aren't real vaccines.
    - What is mRNA?
    - What is different about how mRNA vaccines work versus the other vaccine types?
    - Is it probable that mRNA vaccines are more likely to cause harm?
- We don't know about long term side effects due to the vaccines.
    - Historically, how long has it taken for long term side effects to appear?
    - Is it riskier to not take take vaccine, or to take the the vaccine and risk long term side effects?
- ADE is a problem with Covid 19 vaccines.
    - What is ADE?
    - How often has ADE been a problem with previous vaccines?
    - How likely is ADE to be a problem with Covid-19 vaccines?
    - How long does it typically take for ADE-related issues to arise?
- The Covid 19 vaccines were developed too rapidly to be safe.
    - What enabled the rapid development of the Covid-19 vaccines?
    - Were safety and efficacy tests too short to provide for adequate evaluation?
    - Is a vaccine used under an EUA experimental, and is it safe to use?

I am not sure if people who grew up under an educational environment that did not encourage critical, scientific, skeptical thinking, but instead under the "pass the test" paradigm, can be taught new ways. I hope that they can change, but that would require learning, questioning, and possibly discarding current thought and practices for new ones. There will be those who will not change, who will not come to understand the power and pleasure that come along with critical, scientific, skeptic thinking habits. However, I remain hopeful that many people can learn to think differently, to rediscover the ability of the very young to ask questions and to develop their own solutions and the enjoyment of learning.

I would suggest that it can be approached gently. That means tackling such an intensive project should not be started with something like the current (as of summer 2021) issues pertaining to vaccination and mask wearing, given the highly emotional nature of the debate. It could start with something as simple as showing a picture of a green leaf. The student could be asked if that picture inspires any questions. People far removed from their youthful questioning

facilities may say nothing. The teacher could start the ball rolling by asking "why is the leaf green?" Such a seemingly simple question can lead down many learning paths. Let the student decide how to proceed, and provide guidance along the way, but do not run point!

The Value of Motivation

From my experience, the way to effective learning is through motivated learners. A motivated learner is one who has taken ownership of the learning process, and this can be greatly facilitated by having the learner ask and then answer his/her own questions. Just the process of asking and answering one's own questions will increase the relevance to the learner. I do not believe that such an appreciation can be rammed down the learner's figurative throat. I believe the best way to motivate is by prompting the learner to form their own questions. At times, depending upon the learner, the teacher may have to present an example question. I also believe that the posing of questions goes both ways such that the learners must feel free to ask questions to the extent that they reach the point where they have satisfied themselves that what is being learned matters, and they understand why it is as it is. This may well provide opportunities for the teacher to lead by example as they seek answers for questions posed by the learners.

There are numerous modes whereby training for thinking can be delivered. In-person, classroom type settings can work assuming the instructor understands that the environment must foster bi-directional questions and answers. The instructor must also understand that an answer of "I don't know" can be acceptable. Electronic forms of instruction can also be effective assuming interaction of some sort is possible, and that any instructor-provided questions should invoke reflection, not regurgitation.By fostering such two-way questioning, genuine understanding can develop, and it is hoped that a life-long facility with the power and pleasure of critical, scientific, skeptical thinking will arise naturally, as motivation will be internal to that trainee.