

Text for the interview:

Art on Science

I have a very modest aim, that I have had for 25 or 30 years. My aim is to liberate ourselves from textbook-centered teaching, as it is done today. Another one is to use contextual and history-based teaching. Finally, we should use drama, skits and theater, and all of these should be incorporated into a total picture of teaching science.

I do a three-hour presentation, a workshop, about the history of energy, -I do others, on force, for example. In the history of energy I usually start by asking the students: "What is the definition of energy?" Everyone comes up with the (expected text book definition) that "energy is the ability to do work". Then I say: "you no what, it is wrong, -at least incomplete". It is useful in solving physics problems. But I have another definition for you, by the poet Blake, (who was not a physicist). His definition is very simple, it is "energy is eternal delight". And then I say to my students: "when I am finished with you, you will agree with me that his definition is closer to what the great physicists understood by energy, especially the law of conservation of energy, than the conventional text book definition.

The big concepts of physics, such as energy and centripetal acceleration, have to be revisited, but not in the fashion done in schools. The definition of "energy is the ability to do work", is something that students learn when they are in grade six, and then again in grade nine, and finally in grade 12, exactly the same way. By that time students say "My God, how boring". The idea is to introduce these big concepts on a higher level of sophistication and in richer contexts. If you don't do that, students will never really learn these important concepts (beyond simply memorizing them).

When I was a student I was very curious about (using) literature, theater and all those things which are not studied in physics (found in physics textbooks). Students are taught to solve problems and thinking about physics concepts. I took a BA in the humanities (after my degree in physics) and then a degree in science education. I then decided to teach high school for a couple of years.

What I found was that my students were not really ready for the physical ideas that I tried to teach them. I tried to use the "scientific method", I was young and inexperienced. I was disappointed, but I loved the students. One thing I discovered to my delight was that I learned my concepts on a much higher level by teaching them. And this discovery formed the background to my pedagogical approach (to the teaching of physics).

You have to use a spiral curriculum. The idea of memorization and then producing successful textbook solutions to problems has been a source of great dissatisfaction in the physics community for the last twenty years. The American physicists (and physics educators) who talk about it (changing this approach), have been listened to and it (this

idea) is now incorporated in textbooks. But textbook only produce an artificial connection with the idea that we have to teach concepts rather than algorithms, ..but ultimately both. And that constructivist ideas, that students develop their on preconceptions—they (textbook writers) now recognize that the qualitative aspects of concepts are important but they usually relegate historical (stories and vignettes) to the end (of chapters) as references or added as “addenda” which may or may not be read.

The constructivist ideas that we have to recognize students’ preconceptions, - and not just recognize them, but respect them, and not just respect them, but build on them. This (recommendation) is only suggested at the end or at the beginning (of chapters) and then totally disregarded in the presentation.

I think the first thing we have to do is create contextual settings that attract the students’ attention and imagination. From which then they will individually or collectively generate questions (which in turn suggest problem solving). These (questions and problems) occur in textbooks in a contrived way. These questions and problems generated by students are meaningful to them.. Then you build the physics based on these questions. When you are finished, (and assuming that you are a skillful teacher) you might find that these questions and problems will cover all of those in textbooks but in a more meaningful and interesting way and make more diverse connections for the students.

You cannot teach a course called “Poetry and Physics” and expect students to understand physics. However, if we set a context or a situation (using history and or drama) in which students become interested and once they are interested, you can then present the “boring” algorithms of physics.

Newton was sitting under an apple tree and when the apple fell on his head he said: “Ah, $F = ma$. It is not that simple. This is how textbooks say the great man came up with his laws. --It is a silly story, and students really believe that the great thinkers like Einstein, Newton, and Gauss the mathematician, come up with ideas instantly. The story of how these ideas arise, especially ideas like Newtonian physics, have a long history which show that it (science) is a human activity that involves other people. People in the shadows are never mentioned, concepts are a human product and in order to show how that develops you have to show how things are connected, you have to dramatize things.

I think of drama, for example, I would take my “Age of the Earth” as my favorite play, and I have written a number plays, as you know. I am just now writing one about Galileo, which will be performed in Munich (in German) and in Budapest (in English) and also I hope here. That particular play is commemorating the 400th anniversary (not 500, as I mistakenly state in the interview) of Galileo discovering the moons of Jupiter. In fact, this was the first direct evidence that maybe the Earth is not standing still but is moving around the sun.

In this context you can learn a lot about how Galileo actually came up with this idea (that the Earth is moving), how Kepler, for example, argued with him. I bring Kepler from Germany down to Padua. This is a plausible situation, and everything else I have done there, I have taken the conversations and based them on letters that they have written to each other over a 20 year period. So, everything is authentic, except that the meeting of Galileo and Kepler is a poetic invention. But it works. Also the Cardinal is a third person. Cardinal Bellarmine actually was a friend of Galileo's, they met several times and they exchanged letters over a long period. So I took all of this, and using poetic license, put them in a scene where it is plausible that they could have said those things if they had met in April of 1611.

I think you learn a lot here, For example, you learn how Galileo came up with the idea of what produces the tides. He thought that this was the first direct proof, confirmation, that the Earth moves. And then Kepler had the idea of some kind of attraction between the Earth and the moon (not the moon and the sun, as in the video). This was a kind of preconception (foreshadowing) of what Newton came up with about 60 years later with his idea of gravity. Kepler's idea was occult, mysterious, he did not understand this notion. Galileo suspected this, and he says: "I don't like what you have done with this occult attraction between the Moon and the Earth. Only a Northern mathematician could have come up with something as silly as that", and he totally dismisses it.

Less is better, and less is more. This is a basic thing. We should cut down rather than add. We should pick out the important concepts and make them come alive through historical and contextual settings. We have to make decisions about what is important and what is not important. The algorithms that students learn for calculating physics problems, which are necessary for physics, should come naturally out of the context and seen as necessary rather than as something that they have to memorize in order to pass examinations.

So, you can do it, if you have two things: one, that teachers are trained in modern pedagogical and constructivist methods, and two, that they have more than a cursory understanding of the history of science. And that I hope my students have.