

CRITICAL ROLE OF THE TEACHER

Developing Teachers

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A 1929 text for science teachers describes a successful science teacher as one who:

"...knows his own subject ... is widely read in other branches of science ... knows how to teach ... is able to express himself lucidly ... is skillful in manipulation ... is resourceful both at the demonstration table and in the laboratory ... is a logician to his fingertips ... is something of a philosopher ... is so far an historian that he can sit down with a crowd of [students] and talk to them about the personal equations, the lives, and works of such geniuses as Galileo, Newton, Faraday and Darwin. More than this, he is an enthusiast, full of faith in his own particular work."

Eighty years later this still holds well, though one might like to add some more caveats to this description of an ideal science teacher, apart from over writing the gender bias. While this may sound too idealistic to achieve, it helps in giving a perspective for teacher education. How to design a teacher education program that may achieve this goal? More specifically, what should happen in a good teacher training?

In interactions with teachers I try to engage them in exploring a particular question or concept rather than giving a lecture (or power-point presentation) on the principles of good science teaching. One such question is about falling bodies. If we drop, from a height, a heavy body and a light body together at the same time, which of the following is expected to happen:

- (a) The light body reaches the ground before the heavy body.
- (b) The heavy body reaches the ground before the light body.
- (c) Both reach the ground at the same time.

Interestingly, invariably a large majority opts for option (b). Initially their response provoked a sense of dismay at their knowledge of high school science. But

one can understand the cause of this confusion. Our daily experience reminds us of dry leaves, pieces of paper or feathers drifting slowly to the ground as compared to a stone falling. Even the great Greek philosopher Aristotle surmised that the speed of a falling body would be proportional to its weight. Galileo, nearly two thousand years later, questioned his view by dropping a canon ball and a musket shot from the Tower of Pisa. Educational researchers have identified this as the problem of transition from naive or intuitive to counter-intuitive conceptualizations.

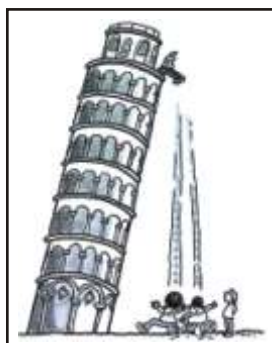
Inclusion of such conceptualizations in a list of "hard spots" and repeated attempts to explain them does not solve the problem. There is a need to initiate a process of rationally re-examining the conceptualization with the students/teachers. Often this process can begin with an experiment that provokes the thinking process.

A simple experiment with a note-pad and a page taken out from it makes a good beginning. Releasing the paper and the note-pad from a height (enough to stand on a chair or a table) simultaneously, confirms Aristotle's surmise.

What if we place the paper right under the pad and release them simultaneously? Everyone agrees that the heavier pad will take the lighter paper with it and both will hit the ground in the same time. The experiment demonstrates a minor success of an experiment confirming theory!

In the next experiment, the paper is to be placed on top of the pad totally aligning with it. Which will reach the ground faster - the paper or the pad? I have seldom found doubters that the heavier pad will leave the lighter paper far behind. The experimental result often leaves a surprised silence. Try the experiment yourself and see the paper fall with the pad! Some would even like to come and try it themselves, suspecting some trick behind it - they deserve to be welcomed and encouraged in the true scientific spirit.

An animated discussion follows. Are we right in assuming that a heavier body will fall faster than a light body, in proportion to their weights? A consensus emerges that the difference in this case was probably due to the difference in resistance offered by air during the downward journey of both the objects. Yet there are skeptics enough who cannot accept the idea that weight probably is not a factor at all. This is when the situation is ripe for the next experiment. The same paper is crushed into a tight ball, and the note pad and the paper ball dropped again. They almost seem to fall together, but doubts are expressed whether they were dropped at exactly the same instant or not. It excites some groups to get up and devise methods of ensuring that the paper ball and the pad are released exactly from the same height and at the same time. They also want to ensure that the time of hitting the ground is observed as accurately as possible for both the objects. Mobile phones, with stopwatches measuring time up to a hundredth of a second, are often available in teachers' pockets. 'Wasting' some time in devising as accurate an experiment as possible, and trying to evolve an empirically verifiable conclusion about the three statements, is more than worth it.



It is now time to bring in Galileo and his experiments with a 100-pound cannonball and a half-pound musket shot. Our crude paper ball and notepad experiment is a repetition of the experiments that he is said to have performed from the Tower of Pisa. It convinced him to claim

that Aristotle never did an experiment to verify his surmise and hence was incorrect. But he went on to develop the argument in an interesting way. The argument is narrated in his book *Dialogues on Two New Sciences*. The dialogues take place between three interlocutors - Salviato presenting Galileo's own arguments, Simplicio propounding Aristotelian views and Sagredo, a neutral rational-minded interlocutor commenting on the dialogues between the two. One can

dramatically narrate various aspects of Galileo's life and work but the essence of the argument relevant to our theme follows.

Accepting Aristotle's surmise, if we drop the two balls tied together, theoretical logic can lead us to two conclusions. Since the lighter ball takes more time to fall, it will retard the speed of the heavier ball, and the two together will take more time than the heavier ball in reaching the ground. However, if we consider their combined weight, it is more than the heavy cannonball and should therefore take less time than the heavier ball. The two deductions are both logical but contradictory. Galileo asserts that this implies that the initial surmise is not tenable and that the weight of a body directly does not affect the time taken or the speed of falling. The difference that we perceive is because of the resistance offered by the medium in which the body is falling, which depends on various combined factors like shape, density of the body's material, density of the medium, movement of the medium itself, etc.

Galileo then took a logical jump of imagination to say that in a medium-free situation - a vacuum - a lighter and a heavier body will fall exactly in the same time. It needs patience and repetition to help every person in the group to absorb this theoretical argument. Training in such logical argumentation is as essential a part of learning science as developing experimental skills.

In 1971, the astronaut David Scott, of the Apollo 15 mission to the moon, dropped a hammer and a feather. The video shows both of them falling at the same speed reaching the ground together on the airless surface, experimentally confirming Galileo's logic.

In further discussion, one can point out a very significant aspect of this conceptual development. Galileo's experiments did show that Aristotle's surmise was not correct but given the effect of air, he could not confirm his own assertion with total accuracy, as recorded with full honesty and amazing precision. It took two decades of painstaking experimentation and theory building to make the assertion that introduced two new ways of doing science - idealization and

thought experiment. There can be a number of interesting questions to put before the class to excite them and lead them to deeper enquiry. How could a wise man like Aristotle make such an assertion? What were the theoretical premises that led him to that? Can we still say that in a perfect vacuum on another planet, the hammer and the feather will fall in precisely equal times? Some of these questions are still open questions of science, and more can be thought of.

An important question raised is - would the teachers have now acquired deep enough understanding to tackle questions like the one we began with? The answer can be - maybe or maybe not. But what one can say with confidence is that they would have embarked on a conceptual journey that can now take them to Galileo's investigations with inclined planes and pendulums and onwards to Newton's laws of motion and gravitation, deepening their understanding of motion; as Newton put it, "... (prepare them) to see beyond, from the shoulders of giants". Excited and serious responses and questions from teachers, after such sessions, are most gratifying and encouraging.

It now remains to put down the assumptions behind adopting such an approach. The way we teach science and do science is crucially dependent on the dual understanding of its method and its conceptual structures. This dual understanding goes along with our ability and confidence to practice science. As Einstein put it with great clarity :

"There is no empirical method without speculative concepts and systems; and there is no speculative thinking whose concepts do not reveal, on closer investigation, the empirical material from which they stem."

"Every great advance in natural knowledge has involved the absolute rejection of authority."

- Thomas H. Huxley

Use of History and Philosophy of Science reveal to teachers and students how the method and the conceptual structure evolved. Retracing some of those crucial steps, help in developing their understanding and the skill to use it. It brings out

crucial values associated with scientific practice - skepticism, not accepting any dogma based on authority, and the crucial role of evidence and rational reasoning in drawing or defending inferences.

Along with consolidating their knowledge of the subject and the skills associated with it, this approach exposes the teachers, and through them the students, to the central question of what is knowledge, epistemology and the goal of all education. It also gives them another view of sociology of science, its ethics and values. It all amounts to a much maligned term - 'scientific temper' - a commitment in the Indian Constitution.

We are more used to teachers being talked down to, of how they should teach and what they should teach. It is time for the teacher educators, curriculum designers, administrators and policy makers to show in practice what they preach to the teachers. In doing so, they will also counter the usual criticisms of such approaches being too time consuming and how the entire syllabus would not be covered this way. The central issue is not the syllabus but the goals of our education.

References

Cajori, F.: 1920, "Aristotle and Galileo on Falling Bodies," *Science*, New Series, 51(1329), 615-616.

Following the Path of Discovery: Famous Experiments and Inventions, Galileo Galilei: The falling Bodies Experiment. Retrieved from <http://www.juliantrubin.com/bigten/galileofallingbodies.html#galileodispute>

Fowler, M.: Galileo and Einstein: Lecture Notes, <http://galileoandeinstein.physics.virginia.edu/tns.htm>

Galilei, Galileo: [1632] (1953, revised 1967), Stillman Drake translator, Albert Einstein foreword, *Dialogue Concerning the Two Chief World Systems: Ptolemaic and Copernican*, University of California Press, Berkeley.

Galilei, Galileo [1638, 1914] (1954), Henry Crew and Alfonso de Salvio, translators, *Dialogues Concerning Two New Sciences*, Dover Publications Inc., New York.

Matthews, M.R.: 1994, *Science Teaching: The Role of History and Philosophy of Science*, Routledge, New York.

Rabinowitz, M.: 1990, Falling Bodies:the Obvious, the Subtle and the Wrong, IEEE Power Engineering Review, 10, 27-31. Retrieved from <http://arxiv.org/ftp/physics/papers/0702/0702155.pdf>

Schrenk, M.A.: 2004, "Galileo vs. Aristotle on Free Falling Bodies," Logical Analysis of Philosophy, Vol. 7: History of Philosophy of Nature. Retrieved from http://philsci_archive.pitt.edu/archive/00002524/01/Galileo_vs_Aristotle_on_Free_Falling_Bodies.pdf

The Galileo Project: On Motion. Retrieved from http://galileo.rice.edu/sci/theories/on_motion.html

The MAP project: The case of falling bodies project, http://ppp.unipv.it/map/pagine/intro_00.htm

The Physics Hypertextbook: Falling Bodies, <http://hypertextbook.com/physics/mechanics/falling/>

Thinkquest: Galileo, <http://library.thinkquest.org/29033/history/galileo.htm>

University of Hawaii: The Nature of Physical Science: The First Scientist, Program 13, Lesson 2.5. Retrieved from <http://honolulu.hawaii.edu/distance/sci122/Programs/p13/p13.html>

University of Hawaii: The Nature of Physical Science: The New Physics, Program 14, Lesson 2.6. Retrieved from <http://honolulu.hawaii.edu/distance/sci122/Programs/p14/p14.html>

Westway, F.W.:1929, Science Teaching, Blackie and Son, London.

Wikipedia:Galileo Galilei, Retrieved from http://en.wikipedia.org/wiki/Galileo_Galilei

Youtube.com: The Hammer and the Feather, <http://www.youtube.com/watch?v=4mTsrZEMwA>

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The Agency of School Teachers

Vijaya Varma



Experiments with reforms in school education in India, like the Hoshangabad Science Teaching Programme, have shown that teachers are critical to the enterprise of quality education. Whenever a teacher buys into the idea of reform, the reforms stand a chance of succeeding, but whenever a teacher is hostile or indifferent, the reforms are headed for failure.

The normal process of curriculum development or textbook preparation, particularly when steered by organisations like the NCERT, is a highly centralised activity characterised by a very hierarchical, top-down approach, in which most of the wisdom is supposed to reside in the organisation or the panel of 'subject experts' drawn up by the organisation, with (at best)

only a token involvement of some teachers who are chosen primarily for ease of availability. Such efforts usually ignore the fact that in developing a curriculum (that stands a chance of being successfully implemented), one must not only be responsive to the demands of the discipline, but also take into account the conceptual development of the children for whom it is meant, the resources that are available in the schools and, most importantly, the readiness and the preparation of the teachers who are actually going to do the teaching. The only way this can be done is if the team that is charged with the responsibility allows teachers from the field to be central to the process. The team should also not be so prescriptive in its approach that no space is left for the teacher to own the curriculum, by