Title	How ought science be taught and learnt?
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How Ought Science be Taught and Learnt?

To answer the question, "How ought science be taught and learnt?", we need first to ask ourselves, "What is science?"

Science is *not* merely a body of knowledge, that is, the current interconnected set of principles, laws, concepts, theories, together with the vast array of systematic information about the material world. To define science as merely a body of knowledge is to subscribe to a dated and static view.

Science is a *human activity, a process of inquiry*, of acquiring and refining knowledge of the material world. (Fitzpatrick 1960, and Ryan and Ellis 1974). As a process of inquiry and a human activity, there are at least three facets of science, namely,

(i) the products of inquiry or the body of scientific knowledge, which includes facts, concepts, principles and laws, and theories, which is tentative and changing all the time.

(ii) the processes or methods of inquiry which include process skills such as observing, classifying, measuring and using apparatus and equipment, communicating, interpreting information and inferring from data, formulating hypotheses, planning investigations to test hypotheses. These are relatively stable.

(iii) the mental attitudes and values which are intrinsically involved, such as curiosity, humility, impartiality, integrity, inventiveness, open-mindedness, perseverance and a positive approach to failure, cooperation with others, and care and concern for the environment. These attitudes and values are even more important than the other two domains of knowledge and skills. This is because students who have imbibed the proper attitudes and values would naturally go on to acquire the relevant knowledge and skills. The reverse could not be said of students who have a good grasp of scientific knowledge and/or skills; such students may not necessarily have acquired positive scientific attitudes and values, and may never become scientifically literate!

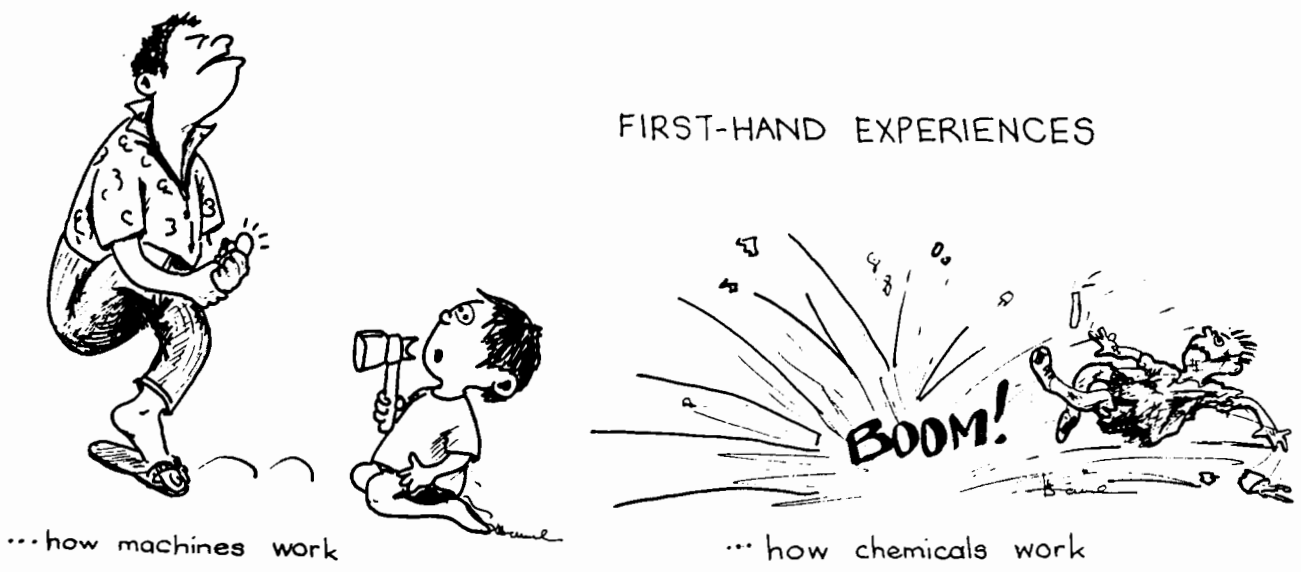
Thus following from the above definition of science, science education in Singapore, as in elsewhere, has a minimum of three aims, focusing on each of the above-mentioned three facets of science. These aims are:

(i) to promote the acquisition of scientific knowledge

(ii) to develop the ability to inquire and problem-solve through the acquisition and practice of science process skills as well as decision-making and problem solving skills.

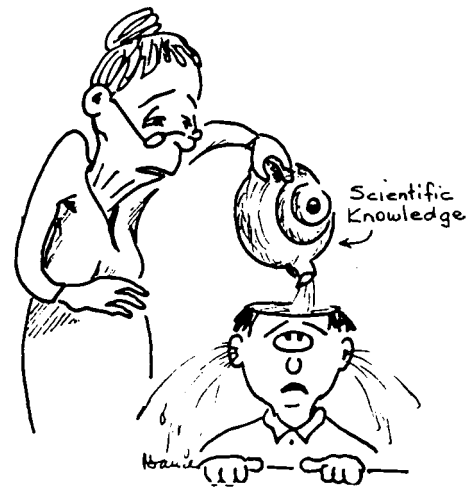
(iii) to develop attitudes and values such as those mentioned above, which are necessary for fruitful scientific pursuit.

In the past, the dated view of science as merely a body of knowledge was generally adopted by educators. Hence science teaching was narrowly focused on the aim of promoting the acquisition of scientific knowledge. Teaching thus tended to be didactic and emphasised telling students about science. Laboratory work tended to be "recipe-following" highly convergent practical activities, designed to illustrate a scientific concept or principle, and experimental results were foreknown to students.



However, today, with the broadening of the aims of science education to include the inculcation of process skills and attitudes and values, it must be clear to all concerned, that didactic methods alone do not suffice. Acquisition of process skills and proper scientific attitudes and values by students cannot be promoted through teacher exposition and routine "cookbook" type practical work alone. Since science is an activity and an inquiry process, students should not learn science by merely being told about the products of science. Just as we do not expect students to learn cycling or swimming or any other human activity by merely being told about such activity. Instead, students need to be actively involved in first-hand experiences with objects, events and phenomena in the natural world. They need to be involved in practising science, as real scientists do, in working cooperatively with others, in gathering facts, generalising, conceptualising, raising questions, hypothesising, hypotheses testing, interpreting data and constructing instruments, simple devices and physical models. In so doing, they would have opportunities for not only developing the skills of inquiry, but also for learning to exercise perseverance, inventiveness, cooperation, integrity and the other scientific attitudes. If students are to develop proper values and attitudes, opportunities would need to be provided for them to clarify, test and modify their values through activities such as discussions, debates and role play on topics such as environmental, social and moral issues in science. Further, if they are to develop a sense of care and concern for the environment, they would need to come into contact with the different components of the ecosystem and to appreciate the interdependence of all life forms on earth. Thus, it is obvious that today, a variety of teaching methods are needed in order to achieve even just the three minimum aims of science education. These methods would include:

- group as well as individual investigations,
- small group discussions and brainstorming,
- project work,



- field visits and outdoor practical work,
- debates,
- role play and simulations,
- pupil presentations and demonstration, as well as
- lecture and demonstration by the teacher and guest speakers.

Thus science classrooms and laboratories today will no longer be the fairly quiet and tame places they used to be, when students were expected to listen passively and take notes silently. Today science classrooms and laboratories will be bustling with hands-on and minds-on activities for students. There will be quite a high level of noise. However, this will be productive noise, which is generated as a result of expressing the thrills of discovery and in the process of exchange of ideas among students.

Where it is not possible for students to have first-hand experiences, such as where dangerous or harmful objects or materials are involved, or where objects, events and phenomena are not accessible within the constraints of time and place, a variety of media representations of these could be used. These could include slides and overhead transparencies, videotapes and audiotapes, computer disks, films and filmstrips, models and charts.

It is a pity that today, there are still some educators who are clinging to the dated view of science, and perpetuating the traditional mode of teaching. They see their main role as dispensers of knowledge. They treat students' minds as stores for scientific knowledge, instead of as potential generators of new knowledge. By so doing, they are in a sense dehumanising students, because human minds, unlike books, computer disks and microfilms, are meant for more than the mere storage of knowledge. By failing to equip students with the necessary skills, attitudes and values, they are rendering them dependent and ineffective as learners, and scientifically illiterate!

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