Teaching Scientific Temper*

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Suppose a science teacher expects her students to develop 'scientific temper'. How should she orient her teaching? What should be her conception and approach in teaching 'scientific temper'?

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Introduction

This passion of our kind
For the process of finding out
Is a fact one can hardly doubt,
But I would rejoice in it more
If I knew more clearly what
We wanted the knowledge for,
Felt certain still that the mind
Is free to know or not.

From *After Reading a Child's Guide to Modern Physics*, By W H Auden [1].

The aim of teaching is learning. Science teaching is successful when students learn science. There are two sides to the story of science education. One, the teacher is expected to teach science, not something unscientific in the name of science. And two, the students are expected to learn to be scientific: learn theories in science, learn the exemplary as well as routine practices that lead to the development (and application) of these theories, learning, in turn, the standards that delimit science from non-science [2, 3].

An important question for the science teacher is: what sets the learner of science apart from someone who is not learning science? This question could be answered in various ways at various

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levels of complexity. The science learner's descriptions and explanations will be markedly different from that of a non-science learner. The science learner has well-qualified ways of delimiting and substantiating her experiences, she approaches problems and evaluates solutions in a manner characteristic of the discipline of science.

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Teaching is constrained by the preparedness of the learner, and by the nature and value of what is being learnt. Teaching exemplifies content as well as character. In education, the content of science cannot be severed from its character and conduct. Science education concerns as much with the nature, character, and conduct of science, as with its content [4].

Temper of Science

Temper is what defines and animates a state of being; it characterizes and channels human actions: we talk of sweet-tempered children or ill-tempered teacher. We also talk of keeping temper in the sense of maintaining balance or internal-harmony in the face of adversaries. Note that temper characterises the complete being—the whole person is good or bad-tempered, not her hands or tongue alone. In the same sense, a person is said to be scientifically tempered. Scientific temper should come to characterize the whole of a learner—a teacher should be in a position to say that her pupils are learning to be *scientifically tempered persons*. When we think of a person as such, we think of her conviction, expression and action. A person who is learning science has to learn to act in line with her beliefs and have beliefs with the right regard for facts or truth. Consistency and coherence is a mark of science. But it is not an exclusive feature of science. Coherence of thought and action with what is known to be true and right is a necessary element of every rational moral human enterprise, including education [5]. This necessity is often muted in science education though, partly because of the overtly procedural-mechanistic construal of the scientific method. When a science teacher demands accuracy and honesty in reporting ex-

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perimental data, or transparency and systematic rigour in representing results, the teacher is indeed expecting her students to be honest and courageous— to be categorically evidence-bound. Similar epistemic and ethical values motivate the scientific community to place a high premium on the right communication and discussion of results and ideas in appropriately open spaces of journals and conferences [6]. To hide an insight or to keep a path-breaking experimental finding under wraps is contrary to the values of science. Unless the achievements and failures of students (as those of scientists) are open to the tests of truth, science will not flourish in the long run. Students have to learn that conceit is anti-scientific, and her conduct must reflect this. When science students fail to confront falsehood with the courage and temperance of tentative but known truths, the teacher knows that something is amiss.

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Values in Science

A well-educated person of science is one who excellently exemplifies scientific temper. She is a person who abides by the values in science in her convictions, actions, and affection. Developing such a person is the aim of science education. To achieve this aim, the science teacher has to have an explicit understanding of the values or principles that set the standards of scientific theorizing and practice: the principles that the student should refer to while evaluating knowledge claims, thereby calling certain human actions or aims as rational and demarcating these from the irrational or unscientific[1].

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A substantive discussion of values or principles responsible for determining the standards of science will take us into deep historical and philosophical waters (which is not possible in this short piece). We have to note that values are an integral part of developmental history and status of scientific knowledge [6, 7]. And that these values (or principles) are both theoretical and practical in nature, helping us define the limits and depths of theory and practice in science. In other words, these values are both epistemic-

[1] Karl Popper's 'demarcation problem' was, in a way, the problem of scientific temper. See [2] for example.

aesthetic (concerning knowledge) and ethical (concerning the knower). Values in science may remain implicit or unacknowledged in the world of working scientists. But they have to have a well-marked space and weight in the world of science students and teachers. A student of science must learn that all ideas do not have equal value in science. For every idea does not meet the scientific standards of intelligibility, explanatory sweep, and well-demonstrated consistent support of empirical evidence from which existence of the postulated causal entities could be reliably inferred.

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The just mentioned values are the values of scientific justification and explanation. These values, along with the personal-ethical values discussed in the previous section, together define the scientific temper. As a brief illustration, we could think of the scientific character of Darwin's theorizing. Why every idea of evolution is not of equal scientific value? Or, what is distinctively scientific about Darwin's idea of natural selection? Think of Darwin's tenacity and determination to develop the idea of natural selection, but within the rational limits of natural philosophy. The latter is demonstrated by the limits Darwin set on his evolutionary theorization: his theory limits itself to the question of the evolution of life; he stayed away from the question of the origin of life in his theorization. Further, Darwin's simple and unifying explanation restricts itself to causes within the bounds of this empirical-natural world (variation and heredity) and makes evident their ubiquity as well as necessity across the present and past living world [8]. In the theorising of Newton, we find a similar restraint. Newton too was wary of delving deep into the nature or cause of gravity while being convinced of its universal presence [9]. The purpose of these examples is to illustrate the temper of scientific theorizing. It is not to suggest that something programmatic could be extracted from these examples.

Method of Science

Learning is not memorizing. The purpose of science teaching is not restricted to memorizing facts—facts about plants and an-

imals, about physical and chemical properties of matter, about how bodies move and behave, etc. Learning science is distinct from rote learning. If the student remembers science as a body of constant, universal, necessary, diverse but law-bound facts of nature, then such memory is at best a poor partial representation of what science actually is. Science educationists are not wrong in striving to move away from learning by rote. But what is the typical way out that is suggested? "Activity-based learning". The activities in science classrooms—collecting data to employ theories in solving problems—are supposed to be representative of activities of scientists. And scientists, in turn, are supposed to follow a well-defined method. Moreover, the success of science is attributed to the method of science, and it is argued that to learn science is to master its method. I will call this a method-centric conception of science teaching. Scientific temper can rarely flourish in method-centric science teaching. The reasons are clear: method-centric conception ends up focusing on predictive success at the cost of sciences' explanatory "success (and failure)" while attributing the predictive success to the efficiency of procedures in science. Method-centric science teaching has a highly impoverished view of scientific practice. It is ignorant about the historical and philosophical dimensions of developments in sciences. For instance, to continue with the earlier Darwin example: Darwin's theorizing cannot be captured in a schema that swiftly moves from collection of data on individual variation and adaptation to the idea of natural selection. Such a scheme will not only ignore the complex historical and philosophical considerations that Darwin had to struggle with, but also the specific details of the development of his idea—the role of analogies and inference to the best explanation in his theorizing, for example. [10, 11] Teaching scientific temper without an adequate understanding of historical and philosophical dimensions of science is an impossible proposition. In the absence of this understanding, teachers will reduce science to sets of steps to follow—they will have an unprincipled notion of scientific practice. To develop scientific temper is to develop a principled understanding of science [4].

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Scientific temper can rarely flourish when science teaching emphasizes procedural-prediction and ignores the development of explanatory-understanding.

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A story of the success of science is a story of the success of principles—ethical and epistemic values—which ordinary women and men of science were "committed to, in their work" to develop justifiable descriptions and explanations of various aspects of the natural world. Human progress runs on "resolving the contradictions" in human life—in human experience and knowledge [12]. However motivating child-friendly and popular, teaching unprincipled practices in the name of science is anti-scientific. It is fated to kill scientific temper and in the long run the institution of science itself.

Conclusion

Science teachers' usual focus is on the content of learners' beliefs. Learning content is necessary but not enough for the development of scientific temper among the students. To develop scientific temper, the teacher has to focus on the learner per se: think of the learner as a person of certain conviction and conduct. The teacher of scientific temper has an eye on qualities of character—like honesty and consistency and has to reflect on the contributions of science education to the development of such qualities among students. What is it that the student values in science, and why she values what she values—on what principles? While thinking of the personal development of her students, the teacher has to reflect on the nature and character of the development of scientific knowledge—on the epistemic and ethical values that demarcate and direct theory and practice of science. Science is neither a permanent set of facts nor a pre-defined set of procedures that guarantee success to its practitioners. Science has flourished because of the temper of persons of ethical and epistemic excellence. Teaching scientific temper is teaching the values in science for "personal-ethical, and consequently, social betterment". A scientifically tempered citizenry values truth over rhetoric in a culture capable of honouring ethical and aesthetic excellence.

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Suggested Reading

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