*Science & Education* 1, 337–348, 1992


# Hermeneutics and Science Education: An Introduction

MARTIN EGER

*Physics Department, The City University of New York, College of Staten Island, 130 Stuyvesant Place, Staten Island, NY 10301 USA*

ABSTRACT: This paper is a programmatic sketch of a line of theoretical investigation in the philosophy of science education. The basic idea is that philosophical hermeneutics is an appropriate framework for science education in most of its aspects. A brief discussion is given of hermeneutics in general, of the version of it developed by H. G. Gadamer, and of the reasons for its relevance to science and to the problem of meaning in science education. A key element in this approach is the suggestion that each science be viewed as a language. Arguments against the appropriateness of hermeneutics to natural science are also discussed. One application of the theory to ongoing educational research – 'misconceptions' – is specifically treated.

## THE PROBLEM OF MEANING

It is difficult to think of a more important problem for education than the problem of meaning – which, in relation to science, comes up in several different forms. The physicist Stephen Weinberg, for example, writes that after all the observation, the calculation, the modeling and theorizing that gave us the big bang scenario, he finds the result 'pointless' (Weinberg 1979, p. 144). In Europe, philosophers habitually differentiate between the humanities and natural science by saying that while the former seek 'understanding of meaning', the latter is 'based on causal explanation' (Apel 1973, p. 325). Debates abound on whether theories are to be understood literally, metaphorically, or instrumentally; and in educational research, the issue of 'meaningful' learning is central in the work on preconceptions, conceptual construction, conceptual nets, and critical thinking.[1]

For science education, the immediate problem is, of course, that increasing numbers of students fail to see meaning in crucial scientific ideas, though they may be competent enough in first-order knowledge and technical manipulation. Further, it appears this phenomenon is true not only of beginners; the same thing has been noticed, for example, among senior engineering students. Although the educational research mentioned above seems, in general, appropriate and well oriented, the question arises whether a more comprehensive look at the entire issue might not be in order. Is it possible to see things in such a way that the ongoing reform initiatives become pieces of a larger picture, to which still other pieces may be added once the full landscape is clear? Aside from the hints it would give about the still-missing pieces, the theoretical advantages of an

overall viewpoint are well known. They include, among other things, the possibility that underlying causes, hardly detectable in the individual parts, may come into focus.

On this level, the inquiry can lead to such questions as: What *sort of thing* is science education? What sort of thing is it from the point of view of the student? of the teacher? of society? Do scientists like Weinberg, philosophers, students and educators – each group in in its own way – face the same 'problem of meaning'? But these questions point immediately to an even more basic question: In what kind of thinking or academic pursuit do we find an approach that tackles the question of meaning in general, meaning in *any kind of study*? It is in this way that one is led to consider hermeneutics – which, precisely, is the reflection on how understanding of meaning comes about. The issue, then, is science education in a larger context. The ultimate aim is a philosophical framework, embracing the reform thinking already going on, but opening up more theoretical space. That aim is not pedagogy as such, though pedagogy lies nearby, along the way, and out in front. The hermeneutic approach, we will find, has the great merit that it relates a general philosophy of human *being* in the world to rather specific issues of practice, in education and elsewhere. The idea can only be indicated in this paper; the development will appear elsewhere.[2] Let me start by sketching in some aspects of hermeneutics that clearly show its relevance to science.

## INTERPRETATION

Hermeneutic thinking comes to us from the 19th century as a by-product of repeated efforts to improve interpretations of ancient texts — an unlikely source, if ever there was one, for an exciting philosophical trend. Nevertheless, this musty, bookish activity quickly led to a most fundamental epistemological problem: In a fragmentary text, written in a strange language, and belonging to a people whose concerns are radically different from one's own, the meaning of individual words usually depends on the meaning of the text as a whole; yet, the meaning of the whole depends on the individual words. How can one deal with this 'hermeneutic circle' in a non-vicious way? Clearly, some sort of a pre-judgement (prejudice!) must enter in, followed by corrections. Taking a part of the text as a starting point, we 'project' – that is, we throw out ahead – a general meaning for the text as a whole. By 'breaking into the circle' this way, with a 'pre-understanding' that may be conscious or tacit, we give to the parts their initial meaning; and this, in turn, allows us to see whether the parts add up consistently to support the whole. As more text is taken up, discrepancies lead to a second, corrected pre-judgement, and then to another, and so on. Interpretation thus takes place in a back-and-forth movement between the whole and its parts, involving mutual adjustment, and leading (one hopes) to ever smaller corrections.

It did not take long to discover that an almost identical process occurs in many other situations as well: in anthropology when trying to understand a foreign culture, in law, in art, and quite generally whenever someone is trying to tell us something unfamiliar or complex. By the time we get to H. G. Gadamer, the principal contemporary figure in this development, hermeneutics is universalized: '. . . the whole human experience of the world. I call this experience hermeneutical, for the process we are describing is repeated continually throughout our familiar experience' (Gadamer 1976, p. 15). Today, the term 'philosophical hermeneutics' refers to this generalized concept.

But before we apply to science any part of this framework, one key feature needs more discussion. To some extent, especially when the pre-understanding is tacit, it really is prejudice in the obstructive sense. A person with a true hermeneutic attitude is expected to be aware of this possibility, to minimize it at the outset, and in the back-and-forth movement of interpretation, to reduce it further. Originally, everyone thought that whenever the remaining prejudices could be made insignificant, the 'true' interpretation would be approached. In the 20th century, however, largely through the influence of Martin Heidegger (1926), it was realized that in the most urgent situations, 'true' interpretations are far more elusive. When a language partitions the world in a really different way than does our own, when it speaks of experiences we have not had or cannot have, then the pre-understanding includes also an unavoidable and *indispensable* part – intuitive projections that light up the unknown land, even if only for a time, and reveal pathways. For without any idea beforehand of what sorts of things to look for, no progress at all can be made in dealing with the 'circle'. Thus the 'prejudices' take on a positive role.

It follows that an irreducible contribution is made by the interpreter through the approach he takes, especially as it shapes the conceptual orientation. Interpretations are now viewed as *con*structions, not just *re*constructions, and the starting point is no longer irrelevant to the outcome. This does imply, when different interpretative attempts reach different conclusions, that the decision between them may not be possible. How large is 'interpretative freedom'? How wide may the gap be between competing interpretations? That certainly is a question to be faced when we consider different types of subject matter. For now, we need merely note that in the human sciences, of course, the gap is sometimes gigantic.

## SCIENCE AS LANGUAGE

Recall now Gadamer's universalist claim for hermeneutics – that it inheres in art, law, history, and the 'whole human experience of the world' – and in this light let us ask whether it inheres in natural science as well. Good reasons for a positive reply can easily be given. The notions of science as a *reading* of the 'book of nature', or *interpretatio naturae*, were there

already at the beginning of the modern phase – in the thought of Francis Bacon and Galileo, to take famous examples. Today, the oscillating motions called for by the hermeneutic circle are recognized immediately by all physicists as similar to the 'self-consistent' calculations used in many areas of research. Finally, if one compares recent changes in the philosophy of science with the changing view of textual hermeneutics, striking resemblances can be seen: here too we find a newly-discovered 'tacit' component, a new focus on 'theory-ladenness' of observation, a new questioning of the putative 'approach to truth'.[3]

Having noticed all this, and much more besides, a small number of theorists have indeed begun to describe natural science too as a hermeneutic activity.[4] Nevertheless, the consensus – of philosophers, historians, and scientists themselves – is overwhelmingly the other way. Although it is not possible here to discuss adequately the reasons for this – nor is such discussion necessary just now – let me briefly mention three major points.

The most prominent factor is that, traditionally, hermeneutics has been used to *distinguish* between the human and the natural sciences (as indicated by the earlier quotation from Apel). Hermeneutics, so it is believed, through its attention to *meanings*, bestows on the human sciences their *humanness*, and marks them off from disciplines where *elimination* of the specifically human perspective has become a principle. Related to this is the issue of 'decidability' – that natural science does decide contradictions and disputes as it progresses; that it 'logs in', so to speak, layer after layer of established knowledge – while hermeneutics remains associated with the phenomenon of 'undecidability'. But the most telling objection usually raised is that a structural difference between the subject matter of the human and the natural sciences makes the former only, not the latter, well suited for hermeneutics.

This difference consists in *language*: in the human or social sciences, the phenomena faced by the investigator are imbedded in a symbol system made for and by humans – a symbol system whose *meanings* must be understood as part of the investigation. The natural scientist, on the other hand, faces nature itself, not its symbols already in being; and the language that finally emerges for dealing with nature is the *scientist's* language, not nature's. Such an activity, therefore, cannot be construed as interpretation.

No doubt, all objections of this kind, and more, have to be dealt with sooner or later by anyone proposing a hermeneutic approach to science in any sense. For the moment, however, let me address the last point – the matter of language. What if we focus our attention not on science as research but on science *as knowledge*, as it faces us all when we *first encounter* it? Suppose we consider not the relation of humans *to nature* but their relation *to a particular science*. In that case, surely, what they encounter *is* a language already in being – the language of that science. And this language, before it is mastered, is for everyone as remote as any

the anthropologists have studied, since it too partitions 'reality' in a way different from the language with which we start, the natural language of the 'life-world'.

This shift of focus, from the study of nature to the study of science, is of course a shift to the *educational* situation. By turning immediately in this direction, we avoid for the time being the difficult philosophical question of whether the position of the *researcher* in natural science is itself hermeneutical or, as is often said, 'monological'.[5] Whatever the answer to that may be, regarding the position of the *student* (scientists included!), we are on much more solid ground: Whenever a strange language is encountered, does it not need interpreting? Whenever there is interpretation, does it not entail hermeneutics? For anyone with the experience of learning and teaching science, these questions ring true because, in such situations, what the human being faces are not really the phenomena of nature themselves, but various forms of written and spoken *text*, from lectures to research reports, to textbooks proper – literally, *texts*.[6]

What is proposed here, then, is to look upon science study as the *interpretation* of the language of science, and upon the teacher as the chief *interpreter*. The resulting task is to draw out fully the implications of this point of view. Although the task stretches well beyond the scope of a single paper, I will try here at least to indicate what sorts of implications these may be.[7]

That a science is a language is to be understood not as a provocative analogy, but quite literally, as is done in philosophy; for if we look, we find quickly many of the structural components seen in natural language. The semantics of physics receives much attention because in defining the objects of study – electrons, quarks, angular momentum – it goes far beyond the experience of the life-world. But from the point of view of the outsider, the syntax is no less a problem. It too reflects an as yet uncomprehended ontology. Beginners often say, for example, that a projectile 'has force', thereby revealing a common and historic preconception, held even by Newton (Westfall 1980, p. 416). That bodies 'exert' or 'experience' force, but do not 'have' it as they 'have' momentum or energy, is not a minor point in the study of physics, not merely a matter of 'saying it right'.

What is involved is a struggle by the newcomer for a clear view of the ontological landscape, in which forces, being relational terms, are different in kind from entities used to define the state – like energies and momenta. Today, this struggle, a recapitulation of the original Newtonian struggle, is made easier by the fact that an appropriate language already exists. But, as many educators now realize, to understand this language it is not enough merely to learn the definitions of the terms, and go over a few examples of their use. That is why there is an increasing demand for 'real world' experiences in education, an end to 'lecturing', and so on.[8]

Despite a whole series of reforms during the past decades, the feeling

remains, in science and elsewhere, that for some reason the *study* of things is still remote from the things studied; that it does not *enter into* those things, but deals with them from a distance. Hermeneutics suggests here a failure of interpretation – not of *translation*, which can be passive or automatic, but of interpretation as a mode of *being in* that which is interpreted. In developing this point along lines parallel to the work of Gadamer, a crucial transition has to be made, from an epistemological to an ontological point of view. The remoteness we sense in education involves a kind of double distancing: not only does science look upon the objects of its study from the outside, but, in addition, the student looks upon science from the outside. If the first distancing is to a great extent unavoidable (but even this has been questioned), the second perhaps is not. Addressing just this problem, *ontological* hermeneutics questions the modes in which we relate ourselves to the 'texts' of this world – the mode of the teacher, the student, the authors of the texts. This transition to an ontology of *science-as-education*, is, I believe, the most interesting and promising avenue for reconceptualization of the issues, a development that cannot be pursued here any further. We can, however, take a quick look at an area where the situation, though simple, is highly suggestive.

## MISCONCEPTIONS AND PRECONCEPTIONS

The most clear-cut evidence that hermeneutic thinking is already under way is the work of the past decade or so in the area called 'misconceptions' (Champagne *et al.* 1980; Novak 1987; Mestre 1991). Out of the realization that meaning is being lost in present-day science teaching, a branch of research has arisen that tries to analyze in some detail how new meaning arises within an already existing conceptual structure. In these studies, using in-depth interviews and other techniques, researchers attempt to identify the ideas students already have about natural phenomena, prior to formal schooling. It turns out that some of these, though contradicted by science, nevertheless persist after the relevant subjects have been studied. Significantly, such 'misconceptions' do not always prevent students from attaining a certain 'success' in problem solving and in their courses. While they have learned some elements of the grammar of the new language, their pre-understanding of the *events* handled by this language has remained unchanged.

However, in the literature that describes all this, after the problems are identified, discussion often becomes diffuse because the origin and character of the 'misconceptions' are poorly understood. The remedy most often prescribed is dialogue, designed to show up internal inconsistencies in students' beliefs. It is here that, even in their epistemological sense, hermeneutic categories and ideas could prove their value most explicitly.

In some discussions, for example, all preconceptions are subsumed under one label (*mis*conceptions), all equally mistaken, it is implied, all

to be addressed by guiding the students, first, to see the 'error' of their ways, then to 'construct' the same concepts or ideas that science has already constructed. Consider the much-discussed case of the succession of seasons: for many people who attribute seasons to the earth's changing distance from the sun, all that is needed is a reminder that south of the equator the seasons are reversed; this quickly breaks down the preconception, and clears the ground for other possible causes. So far, so good. Here we had simply a plausible but bad theory. We supply relevant data, elicit normal reasoning, and students usually turn off the wrong path. But other preconceptions on the same list are of a different kind altogether.

When asked about a ball thrown upward, nearly everyone will say that at the top of the trajectory (where the ball is instantaneously at rest), the acceleration is zero; and here no amount of dialogue or reasoning is likely to lead to the desired result, *as the research seems to show*.[9] Why? Hermeneutic categories distinguish preconceptions due to experience in the life-world from other kinds. Such preconceptions (called 'fore-having') are formed prior to scientific reflection because we 'already have', in some natural way, the thing later treated in a scientific way. What actually happens then is not 'correction' by science of a mistaken idea, but an *extension of language* reflecting an extension of concept. We naturally associate acceleration with the experience of cars and, to some extent, with elevators or sports like skiing. In all these situations, acceleration without motion is hardly conceivable, much less can such a thing be recalled. It is not an error, therefore, to surmise that an object at rest, even instantaneously, cannot be accelerating.

Physics says otherwise for internal reasons, not through observation. To understand it, we need some idea of the limit process, at least qualitatively; we look to Newton's second law for coherence; we graph the motion and examine slopes. All this shows why science *does* in fact make this extension of the life-world concept of acceleration – an extension beyond experience, to bodies instantaneously at rest. And it shows clearly why high school students cannot be expected to do this on their own, with or without coaxing. The understanding of the new extension of 'acceleration' relies exclusively on use of the rest of the language of physics, most of which has not yet been grasped. This, precisely, is a job for the interpreter. It is not that students must then be passive, that no further construction is left for them. Rather, interpretation becomes a common task in which the teacher-interpreter, bridging the 'horizon' of physics and the 'horizon' of the life-world, and using the preconception itself as starting point, shows the available routes.[10]

We cannot discuss here what a good interpretation of this kind might look like, or what its possible ontological aspects may be, but hermeneutics suggests at least this: since the student's use of the word 'acceleration' was not really 'wrong' within his own horizon, in the sense of the life-world, the whole exercise should not be treated as a 'correction'. There was indeed a *pre*conception, but no *mis*conception. To the contrary: with

great difficulty and good reasons, physicists have used the preconception – the knowledge of acceleration we 'already have' – to construct this new extension of a common concept. But to ask people to construct it anew, *ex nihilo*, during a short dialogue, reflects yet another misunderstanding. When they begin, the conceptual horizon of students does not extend far enough to make sense of any such phrase as 'the acceleration of a body at rest'. As the interpretation proceeds, as students move back and forth between the *part* (the trajectory) and the *whole* – the language of science with its limiting process, its laws of motion, and the rest – their *horizon expands*, increasingly overlapping the horizon of the 'text' (physics itself). Just this, this activity of interpretation in which horizons 'fuse', Gadamer takes to be what understanding *is* (Gadamer 1975, p. 273).

## HERMENEUTICS IN SCIENCE EDUCATION

Enough has perhaps been said to indicate that a hermeneutic approach to the language of science is neither an arbitrary idea nor a spurious one. Much has been left out. One goal here was to show that a very general theory of this kind, embracing realms beyond science and education, can also have specific consequences for practice; and that was the point of the discussion of preconceptions. It remains now to take up again, however briefly, some of the other objections that arise whenever hermeneutics is suggested as appropriate to natural science. These do seem formidable at first, and explain why European philosophers like Jurgen Habermas and Gadamer himself have eschewed the step proposed here.

The whole drive to mark off sharply the human from the natural sciences represents, for the guardians of the former, a fear of *scientism*, and for the guardians of the latter, a fear of the *loss of objectivity*. On one side, the formal, operational *methods* of science are invidiously contrasted with *human* concerns; on the other, vagueness and undecidability are seen as inimical to the scientific ethos. Let us begin with the question of humanness. If it is true that hermeneutics in the social sciences promotes there a specifically human perspective, and if, in science education, problems of meaning arise (to some extent) because of the *lack* of such a perspective, then, does it not follow that in the latter realm too hermeneutics should arouse some interest? For the same reason it is valued there, could it not be of value here? The loss of meaning is a general, cultural phenomenon of our time; but too often it is taken for granted that science precisely is the *source* of that problem – the origin of a detached, objectivising, attitude that brings, first to its own realm, then to the rest of the world, a lifeless, alienated experience. But what if science too – especially the appropriation or study of it – were a *victim* rather than the chief purveyor, of whatever it is that increasingly spoils much of our public and private life, draining their human meaning? Is it possible for natural science itself to be afflicted by scientism?

This is a large question, of course, and it is broached here only to counter the idea that the human/objective dichotomy must necessarily be accepted as commonly understood. I am suggesting that it is not in the best interests of education, nor of science, nor of society – and certainly not in the interest of students and teachers – to 'write off', so to speak, the *human component* involved in the appropriation of science. How to address this component remains a problem, but it is arguably the most serious long-term problem for science in relation to students and to society as a whole.[11]

Finally, there is the issue that, to the scientist at least, may be the largest stumbling block: hermeneutics is about interpretations, and especially about interpretations that do not converge – differing interpretations. How, in the study of established science, can that possibly enter? For it has always been a goal in education to show that *here*, where there are *right answers and wrong answers*, where *secure* knowledge is sought, we speak briefly, to the point, and we avoid rhetoric. The response to this basic question cannot be given in a few paragraphs. But I would like to indicate, at least, the kind of response suggested by the framework toward which this paper is a small step.

As background, recall that even in the hermeneutic disciplines *par excellence*, in history for example, there are plenty of facts, and plenty of questions for which a unique answer exists. Any interpretation of the American Civil War has to retain the facts, for example, that Lincoln was president, that slavery was an issue, and so on – these are the 'invariants', so to speak, under interpretative transformation. Reinterpretations of the Second World War that deny the Holocaust have been produced, but so have 'crackpot' theories about science. None of this need concern us here. The point is that neither 'facts' nor questions with unique answers are the distinguishing mark of the study of nature.

In this regard, it is especially thought-provoking that lately, out of the heart of the engineering profession, have come demands for a more 'interpretative' type of education, more work on problems where there are *no* unique answers.[12] Even engineers, it turns out, cannot merely 'consume' texts and routinely solve cut and dried problems without real context, without meaning. On the one hand, graduates of this kind of study are proving inadequate; on the other, the students themselves are increasingly dissatisfied. There are signs that this accounts for some of the loss of enthusiasm among Americans for an engineering career. It is clues like this that lend credence to the speculative question raised above: should we begin to view science itself as territory penetrated by 'scientism'? And should we perhaps, as we look for deeper causes, look also for a better name for this disease?

Certainly, the remarks above do not address the broader question of the multiplicity of interpretations. For those who might point to Newton's laws and similar established science, implying that no such multiplicity exists there, I would, for the time being, go only one step further. We

cannot take up now the philosophical discussion of the general issue of the underdetermination of theory, though this issue is not irrelevant.[14] Rather, as the final point, let me turn to a favorite analogy in the literature of hermeneutics — the performance of a piece of music or the staging of a play. In all such cases, we start with an accepted script or musical score, which may not be altered. Yet, by common assent, what the audience sees in the work depends on the *interpretation* (the performance) as much as on the script or score itself. Yes, in its bare essentials, in its skeletal form, as a 'script', Newton's second law must be the same in all textbooks, all courses; but that is only the beginning, not the end, of the process of meaning-giving and interpretation.[14] It is true that in *normal* physics the various interpretations will not conflict, as they do in some social sciences. This much, then, but no more, may still be left for those who would press the argument. However, to insist that differing interpretations matter only when they conflict, is to miss the whole point of philosophical hermeneutics.

The present paper is a programmatic sketch of a possible line of theoretical inquiry. If the pursuit of this inquiry sheds light on the problems of *understanding* science, one may perhaps hope that by reflection, as it were, some fraction of the light might fall even on science itself. The separation, in thought, of the activity of science and the activity of studying science is, after all, one of those dichotomies questioned by this inquiry.

## NOTES

1. For the general problem of meaning in education, see Ausbel (1963); conference papers on preconceptions are collected in Novak (1987); for constructivism, see for example von Glasersfeld (1989) and Mestre (1991); the *National Forum*, Winter, 1985, features critical thinking; and an *Education Week Special Report* (October 9, 1991) reviews several related approaches of cognitive science.
2. Eger, M.: 'Hermeneutics as an Approach to Science' (forthcoming).
3. These major post-empiricist developments can be found, for example, in Polanyi (1958; 1969), Hanson (1965), Kuhn (1970). Richard Bernstein is one of the few philosophers who sees in these developments a meaningful parallel to hermeneutic theories in the social sciences. See especially the introduction and 'PART III' of his (1985).
4. Hesse (1980) and Arbib & Hesse (1986) include hermeneutics within a general schema theory; Heelan (1983; 1988) treats science specifically within a phenomenological-hermeneutic approach, with special emphasis on space perception.
5. The contrast is between natural science as a 'monologue' and the humanities as 'dialogue'. See, for example, Habermas (1988 [1971], pp. 291–301).
6. I leave out, for special treatment at a later time, the role of experiment and demonstration in science education. On this, Heelan (1983) will be especially relevant.
7. By focusing on the study of science rather than of nature directly, I do not imply that the *goal* is to understand science *rather* than nature. The difference is of course a basic philosophical problem that we do not address here. That there stands something 'real' beyond the 'language of science' is neither neglected nor affirmed in this first order phenomenological description. A more detailed treatment is given in the reference of note 2.
8. The linguistic aspect of science has, of course, been widely noted, in education as well

as in philosophy. See for example Schick *et al.* (1989, p. 326), Thompson & de Zengotita (1989), and Champagne *et al.* (1980).

9. Mestre (1991) gives the transcript of a student-teacher dialogue on this point, which must have lasted ten to fifteen minutes. At the end, the students were no closer to the 'right' answer than at the beginning.
10. The concept of 'horizon', crucial to hermeneutics, is used by Gadamer (1975 [1960], p. 269) to indicate the entire field of objects and events that may be seen from a particular standpoint or orientation to the world.
11. One who has dealt with this problem extensively, though not specifically within education, is Michael Polanyi (1958).
12. My direct experience is with ABET (American Board for Engineering and Technology), which demands a greater role for 'design problems' or 'projects' in the standard curriculum, and insists that such problems must have more than one answer.
13. Underdetermination of theory by observation was treated at length by Duhem (1954 [1914]). Kuhn (1970), Laudan (1977), Hesse (1980), and others, have based their theories on this point.
14. That is why, for example, Kuhn (1970, pp. 187–9) calls Newton's second law a 'law sketch'.

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