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VALUE JUDGEMENTS AND THE ACCEPTANCE OF
HYPOTHESES IN SCIENCE AND SCIENCE EDUCATION*

by

Michael Martin

Introduction

The relevance of philosophy of science for science education has too long been neglected. By and large philosophers of science have failed to help science educators and most science educators have failed to profit from the insights of philosophy of science. In some recent publications this unhappy tendency has to some extent reversed itself. However, the full potential of philosophy of science for science education has yet to be realized. In this paper I will not fight for ground already won; instead I will endeavor to suggest new paths that philosophy of science may open up for science education, new insights that philosophy of science may provide.

Philosophy of science as it will be conceived of here has two basic tasks: (1) the analysis, clarification and critique of certain concepts, methods and problems found in all or nearly all science, e.g. the concepts of definition, observation, explanation, the methods of experimental inquiry, the problem of the comparability of scientific theories; (2) the analysis and clarification of concepts, methods and problems found in more restricted parts of science, e.g. the concept of operational definition of length in physics, the method of participant observation in anthropology, the problem of the objectivity of social science. Philosophy of science in this sense might be called analytic philosophy of science.

There are at least two contributions that analytic philosophy of science can make to science education. First, analytic philosophy of science may suggest new pedagogical insights and perspectives for science education, new ways of looking at and examining traditional approaches, new research problems and goals. Let us call the value that philosophy of science may have in suggesting new approaches and problems the heuristic value of philosophy of science for science education.

Secondly, analytic philosophy of science provides clarification and analysis of some of the major concepts in science education—namely, the concepts of science itself. Let us call the value that analytic philosophy of science has for science education in clarifying some of the concepts of science education the analytic value of analytic philosophy of science for science education.

As we shall see, the analytic value and the heuristic value of analytic philosophy of science go hand in hand. Philosophical analysis and clarification reveals distinctions, analogies, and ambiguities that are suggestive for science education.

Analytic philosophy of science should be contrasted with a more traditional view of philosophy of science. Traditionally 'philosophy of science' was used

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to refer to the construction of a scientific world view. The philosophy of science in this sense would attempt to construct a systematic and unified picture of the world as presented by the particular sciences. This enterprise—which might be called speculative philosophy of science—would attempt to answer questions about the origin of the universe (cosmology) as well as questions about the ultimate make-up of the universe (ontology). I cannot consider here the possible value of speculative philosophy of science for science education. However, I have argued elsewhere that it may have value.³

Analytic philosophy of science, as we have seen, clarifies and evaluates the concepts, methods and problems of science. Such analysis and criticism can enter into science education in at least two ways:

(1) Students of science could learn the analysis and criticism of scientific concepts, methods and problems.
(2) Science educators could learn the analysis and criticism of scientific concepts, methods and problems.

Now although I do not deny that the study of analytic philosophy of science may be useful for science students,⁴ I will concentrate here on the value of the study of analytic philosophy of science for science educators. I will discuss briefly some of the roles that value judgments play in connection with science and will then examine the recent controversy in philosophy of science over the acceptance of hypotheses. I hope to show that the clarification and analysis of the roles that values play in connection with science has both heuristic and analytic value for science educators.

Values and Science

There is no doubt that values and science are connected. First, science seems to be committed to certain general values, e.g. truth, knowledge and objectivity. Indeed, it would seem that without such commitment science would be impossible. Secondly, scientists normally are committed to the value of particular theories, techniques, approaches. Such commitment can lead to problems and, indeed, seems at times to conflict with the commitment of science itself to objectivity.

Scientists are human; like everyone else their behavior and even their perceptions are sometimes affected by their value commitments. They believe that certain things are good or bad, and have strong feelings about this. Their beliefs and attitudes may induce them—either consciously or unconsciously—to overlook evidence or to misconstrue evidence that might go against their well-entrenched views and commitments. As a result they may produce work which is biased. For example, a medical researcher with a strong liking for things oriental may tend to overlook negative evidence for the curative powers of acupuncture. Consequently his research report may be biased.

This insidious influence of value commitment on the results of scientific research is something that ideally should be excluded from science. It is at
least in part a scientific question how the biasing of results can be prevented; what techniques and procedures scientists can use to prevent their value commitments from causing them to overlook evidence and misread the data. However, the problem is partly an educational one as well. What pedagogical procedures are best for training scientists to be sensitive to negative evidence, to data that conflicts with their most cherished views? I have suggested elsewhere some pedagogical procedures for decreasing the insidious influence of theory laden observation. Other procedures, for example having science students subject their own value commitments to self-criticism, also need to be considered.

Now scientists may not only have value commitments which result in biased findings; they may also be called upon to answer value questions. For example “Is science worth engaging in?”, “Is a particular scientific problem worth studying?”, “Should a particular scientific finding be given practical application?” It may be argued however that these questions, whatever their importance, are not questions a scientist qua scientist answers; that they are not questions within science. The question of whether it is worth engaging in science, it may be argued, is a pre-scientific question as is the question of whether a particular scientific problem is worth studying. The question of whether certain scientific findings should be applied, it may be maintained, is a post-scientific question.

I for one find this argument too pat. For the question of whether a certain problem is worth studying seems to be something that a scientist has special competence to answer since the answer to it should be based, at least in part, on the consequences of studying this problem for the growth of science. Similarly the answer to the question of whether a certain scientific finding should be applied to solve a practical problem should be based in part on the probability of success.

Now it may be argued that answering the question about the desirability of studying certain problems scientifically and the question about the desirability of applying the results of science also depends on value judgments, e.g. the value judgment that the growth of science is desirable or that the solution of a practical problem is desirable. These value judgments, it may be argued, are surely beyond the competence of the scientist.

Whether or not value judgments are beyond the competence of the scientist depends on what view of ethics is correct. On a naturalistic interpretation, for example, value judgments are equivalent to scientific judgments. The question of the desirability of engaging in science is, then, on a naturalistic interpretation, a question that could be answered by science.

Now given a naturalistic interpretation one might still want to call the above questions pre and post scientific, thus distinguishing them from the more typical questions arising within science. But on a naturalistic interpretation the distinction between pre and post scientific questions on the one hand and questions falling within science on the other clearly could not be made on the grounds that the scientist has no special competence to answer the former sort of question. There would be no basic difference between the methodology used to answer typical scientific questions. Consequently the scientist qua scientist would on a naturalistic interpretation answer these post and pre questions as well as
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questions falling within science.

Given a non-naturalistic interpretation of value judgments there would be basic methodological difference between questions within science and pre and post scientific questions. Whether a scientist qua scientist should be expected to answer pre and post questions of the sort we have been discussing would then be problematic. However, the important point to note is that the neat separation on methodological ground of these pre and post scientific questions from questions arising within science does seem to presuppose a particular meta-ethical position, namely non-naturalism. Without this presupposition the role of the scientist qua scientist is not so narrowly circumscribed.

Suppose my suspicions are groundless and a scientist qua scientist should not answer what I have called pre and post scientific questions. Suppose that naturalism is untenable. A pedagogical issue of great importance can be raised. One can still ask: How should science education be conceived? Should science education be conceived of as an education designed to train a scientist qua scientist—an individual who has no training in answering pre and post scientific questions? One might well opt for science education more broadly conceived in which science students are trained not only qua scientists but in answering these pre and post scientific questions as well. Or one might argue that science education can be narrowly conceived so long as students of science are at some point given an education in problem solving in pre and post scientific questions.

In any event, a case can be made for an education—call it a scientific education or not—which is concerned with value questions about the desirability of science, the desirability of studying certain problems rather than others, the desirability of the application of certain scientific results. Indeed, it is just these sorts of questions that relate science to humanistic concerns and traditions and illuminate science as a social institution.

Now in recent years the major controversy among philosophers of science about the role of value judgments in relation to science has been over the question of whether scientists qua scientists should answer a rather different type of question, namely "Should a particular hypothesis be accepted?" It has been argued by some that this is a value question arising within science, that it is a question a scientist qua scientist answers. The basic argument for this position is this: No scientific hypothesis is ever certain; hence in the acceptance of a scientific hypothesis there is always the possibility of error. Consequently, whether a scientist accepts a scientific hypothesis or not will depend on the seriousness of the mistake of accepting the hypothesis if it is false. However, an answer to the question of whether a mistake is serious or not is certainly based on value judgments held by the scientist. But since the scientist qua scientist accepts hypotheses, value judgments are an essential part of science, they are found within science. On this view the value judgments connected with the acceptance of scientific hypotheses are legitimate and indeed indispensible in science.

This view has not gone unchallenged. It has been argued that scientists qua scientists do not accept hypotheses and hence the value judgments connected with acceptance are not part of scientific practice. Put in the terms introduced
earlier, the argument is simply that the question of whether a hypothesis should be accepted or rejected is a post scientific question. As we have seen if naturalism is correct, post scientific value questions are questions that a scientist qua scientist can answer. So the value questions connected with the acceptance of a hypothesis would be value questions a scientist qua scientist can answer. Thus this view must be committed to some form of non-naturalism. In any case, on this view scientists qua scientists gather evidence and specify how probable hypotheses are relative to the evidence, it is said. But as scientists they do not accept or reject such hypotheses. The acceptance of scientific hypotheses is left to others or to the scientist in some other role than that of scientist. This view, sometimes called "the odds maker view of science," has been advocated by such philosophers as Carnap and Jeffreys.

However even among those who argue that scientists qua scientists accept hypotheses there is controversy. The controversy is over what sort of value judgments are relevant to the acceptance of a hypothesis. On one view the acceptance of hypotheses depends on considerations of epistemic or theoretical value, i.e. values associated with achieving truth, simplicity, explanatory power and so on. This view has been advocated by Hempel and Levi. We will call it "the theoretical acceptance view." Another group of methodologists, namely Rudner, Brathwaite, Churchman and Leach maintain that the values involved in the acceptance of scientific hypotheses are not completely epistemic or theoretical but also involve non-theoretical or practical values, values associated with human life, the saving of time and energy, and so on. Let us call this view "the practical acceptance view."

Evaluation of the Controversy

In order to evaluate this controversy it is necessary first to clarify the notion of acceptance and then to clarify the nature of the claims of the parties to the controversy.

Two different concepts of acceptance can be distinguished. In one sense of "acceptance" to accept a hypothesis is to believe that it is true. Let us call his sort of acceptance, acceptanceB—the subscriptB to remind us that this sense of acceptance has to do with the belief that the hypothesis is true. In science, of course, such a belief would be a tentative one subject to change in the light of new evidence and argument.

In another sense of "acceptance" to accept a hypothesis is not necessarily to believe that the hypothesis is true; rather it is to be disposed to act as if the hypothesis is true in a given context because it is believed that the hypothesis is a useful working hypothesis in that context. Let us call this sense of acceptance, acceptanceU—the subscriptU to remind us that acceptance refers to the usefulness of the hypothesis as a working hypothesis in a certain context. Again, in science acceptance of this sort is tentative, subject to change in the light of the evidence.

It is important to see that these two senses of acceptance are logically independent of each other in that one could acceptB a hypothesis H without
accepting $U \text{H}$ in a given contest and not accepting $B \text{H}$. For example, the evidence that a certain drug can cure cancer may be weak, so weak that it does not warrant our acceptance $B$ that the drug is effective; yet, since there is some evidence, albeit meager, for the effectiveness of the drug and good evidence that the drug has no damaging side effects, a medical therapist may accept $U$ the hypothesis, i.e. he may be disposed to act as if it is true in the context of medical therapy. Conversely, there may be strong evidence that a drug can cure cancer and yet some evidence that the drug has lethal side effects. One might therefore accept $B$ that the drug is a cure for cancer and yet not accept $U$ that the drug is a cure for cancer in the context of therapy; that is one would not proceed on the assumption that the drug was effective and start using it on cancer patients.

Once the distinction between acceptance $B$ and acceptance $U$ is made there are several different things that the adversaries in the above-mentioned controversy could be saying. Let us consider some of the possibilities connected with the odds maker view of science:

(1) A scientist qua scientist can not accept $B$ any scientific hypothesis.
(2) A scientist qua scientist can not accept $U$ any scientific hypothesis.
(3) A scientist qua scientist does not accept $B$ any scientific hypothesis.
(4) A scientist qua scientist does not accept $U$ any scientific hypothesis.
(5) A scientist qua scientist should not accept $B$ any scientific hypothesis.
(6) A scientist qua scientist should not accept $U$ any scientific hypothesis.

Consider (1) and (2). The “can not” is to be understood as a logical “can not” in the sense that a brother can not be a female. Interpreted in this way (1) and (2) certainly seem to be dubious if “scientist qua scientist” is interpreted in its usual sense. It does not seem to be part of the ordinary meaning of “scientist qua scientist” that a scientist qua scientist can not accept scientific hypotheses in either of the senses of acceptance.

Of course, the claim may not be a claim about the ordinary meaning of “scientist qua scientist.” Rather a proposal may be implicitly being made about how “scientist qua scientist should be understood. In short, (1) and (2) may be implicitly normative. We will consider the odds maker view as a normative claim in a moment.

What about (3) and (4)? If (3) and (4) are factual statements they certainly seem dubious. Scientists qua scientists as a matter of fact certainly seem to accept some scientific hypotheses in both senses of “accept.” It would seem that the most plausible way to interpret the claim of the odds makers view of science is not as a factual claim about what scientists qua scientists do not do or logical claim about what they can not do but as a normative claim about what they should not do—that is as (5) and (6). Given this interpretation the theoretical acceptance and the practical acceptance views can then be interpreted as claiming that (5) and (6) are mistaken although advocates of the theoretical acceptance view and the practical acceptance view have different reasons for claiming that they are.
But is there any reason to suppose that these normative claims made by advocates of the odds maker view of science are correct? What might be the rationale for (5) and (6)?

It is not completely clear what rationale methodologists have for making these claims. But one plausible guess is this. Since they maintain that acceptance involves value judgments, they might well believe that acceptance of scientific hypotheses introduces an element of subjectivity into science. The odds maker view keeps this subjectivity out. Since subjectivity is thought to be undesirable in science, (5) and (6) are advocated. Furthermore, advocates of (5) and (6) think that the practical acceptance view is the only alternative to their view: they think that either one does not accept scientific hypotheses as a scientist or one accepts them in terms of practical values. One may guess that they believe that judgments about practical values are particularly subjective and rationally indefensible.

This argument for the odds maker view of science seems to me to be a very weak one. First, as we have seen the practical acceptance view is not the only alternative to the odds maker view. There is also the theoretical acceptance view. Even if judgments about practical values are subjective and not capable of rational defense or criticism, judgments about theoretical values may not be subjective. Thus, if the acceptance of scientific hypotheses is based on theoretical values there might be nothing subjective in the acceptance of scientific hypotheses.

Secondly, even if the practical acceptance view were the only alternative, it is not clear why judgments about practical values would necessarily be subjective. The idea that they are rests perhaps on a particular brand of non-cognitivism, i.e. the view that certain value judgments are expressions of emotion that are without rational basis. However, there is no good reason to embrace such a view and, indeed, such a view has serious problems. It is important to see that naturalism in ethics is not the only alternative to the sort of crude non-cognitive view that would make judgments of practical value irrational and subjective. A naturalistic interpretation but also certain sophisticated non-cognitivist interpretations of value judgments would entail that value judgments are rationally defensible or criticizable and hence objective. Consequently, non-cognitivism in ethics, a rejection of the odds maker view of science, and the objectivity of science are logically compatible.

Now whether naturalism or some sophisticated type of non-cognitivism is a correct meta-ethical position is a long story, a story we cannot go into here. But there does certainly seem to be much more reason to embrace one of these meta-ethical positions than to embrace the crude non-cognitivism that seems to be presupposed by the odds maker view. There may, of course, be other reasons than the ones I have rejected here for accepting the odds maker view, but until they are brought forth there is good reason for rejecting that view of science. This does not mean, however, that the odds maker view may not be useful in science education. Indeed, I shall argue later that the odds maker view may in certain pedagogical contexts be very appropriate.

So far I have rejected the odds maker view of science. Two views remain: the
theoretical acceptance view and the practical acceptance view. Let us interpret these two positions not as descriptive claims about how science does in fact operate but as claims about how science should operate. Interpreted in this way we can distinguish two variants of each position depending on which meaning of acceptance is at issue:

(7) For a scientist qua scientist the values which determine acceptance or rejection of scientific hypotheses should be epistemic values only.
(8) For a scientist qua scientist the values which determine the acceptance or rejection of scientific hypotheses should be epistemic values only.
(9) For a scientist qua scientist the values which determine the acceptance or rejection of scientific hypotheses should be, at least in part, practical values.
(10) For a scientist qua scientist the values which determine acceptance or rejection of scientific hypotheses should be, at least in part, practical values.

Consider now an argument of Rudner's for the practical acceptance view. Rudner argues:

Obviously our decision regarding the evidence and respecting how strong is 'strong enough' is going to be a function of the importance, in the typical ethical sense, of making a mistake in accepting or rejecting the hypothesis. Thus to take a crude but easily manageable example, if the hypothesis under consideration were to the effect that a toxic ingredient of a drug was present in lethal quantity, we would require a relatively high degree of confirmation or confidence before accepting the hypothesis—for the consequences of making a mistake here are exceeding grave by our moral standards.1

Undoubtedly Rudner assumes here that the drug will be given to human beings for presumably if the drug were given to monkeys the consequences of making a mistake would not be “exceeding grave” by our moral standards. Rudner's argument is an excellent argument for (10), that is, it is an argument for the advisability of taking practical values into account if one accepts or rejects a hypothesis. Thus if one were to act as if the hypothesis that the drug was not toxic were true in the context of medical therapy the danger to human life would have to be taken into account. But this says nothing about whether one should accept or reject the hypothesis and with respect to acceptance or rejection of the hypothesis, only epistemic values seem to be relevant. Thus Rudner's argument does provide good reason for maintaining that (10) is correct and that (8) is not correct but it provides no reason for maintaining that (9) is correct and that (7) is not.

Leach gives another argument for the practical acceptance view. The strategy of Leach's argument is to show that what I have called acceptance involves acceptances, and that despite my attempt to separate these two senses of acceptance there is a close connection between them. Leach admits, of course, that one can not straight-away identify acceptance and acceptance.
To say that one believes that the hypothesis is true is not to say that one would act on the hypothesis in a given context, that one believes that the hypothesis would be a useful working hypothesis in this context. Leach does argue however that there is a more indirect connection between them.

He maintains that if some person P believes that H, then P has as a matter of fact a disposition to act on that hypothesis relative to some specific goal or other and that if a person P does have such a disposition, he will act on the hypothesis in certain circumstances. In this way Leach argues that there is a link between what I have called acceptance_B and acceptance_U. The link is a contingent one however. There is no logical necessity that if a person P believes that H, then P has a certain disposition to act.

Consider a medical researcher who accepts_B that a drug does not have a toxic agent present in lethal quantity. I have suggested that despite his acceptance_B the researcher might not accept_U this hypothesis in the context of medical therapy with human beings. For because he is dealing with human beings the researcher might believe that although the evidence warrants acceptance_B the hypothesis does not warrant acceptance_U in this context.

Leach's point, as I understand it, is that despite what I have just maintained, if the medical researcher believes that the drug does not have a toxic agent in a lethal amount, then he has as a matter of fact a disposition to act as if the hypothesis is true relative to some specific goal or other and would act on the hypothesis given certain circumstances. Leach may well be correct in this. For the researcher may have a disposition to act on the hypothesis relative to the goal of curing monkeys and given appropriate circumstances would try the drug on the monkeys.

Leach seems to believe that once he has shown that acceptance_U is connected in the way he suggested with acceptance_B practical values are relevant for determining whether someone should accept_B some hypothesis. But it is difficult to see why this is so. Consider the above case. The fact that the researcher's belief that the hypothesis is true is contingently connected with his disposition to act on the hypothesis in some practical context does not mean that practical values should determine whether he should accept_B the hypothesis. It is still possible that his acceptance_B of the hypothesis that the drug has a toxic agent is something that should be a function of the evidence and epistemic values only; and that his acceptance_U of the hypothesis, i.e. his disposition to act in a certain way in a given context is something that should in part be determined by practical goals. The fact (if it is a fact) that his disposition to act and his belief are contingently related may be of great psychological interest. However, it seems to have dubious relevance to the normative question of what sort of values are relevant to acceptance_B and acceptance_U.

To make this clearer consider an analogous case. Suppose there were a contingent relation between aesthetically pleasing actions and actions that are morally obligatory such that X is a morally obligatory action if and only if X is an aesthetically pleasing action. If such a relation held, one could use moral criteria as reliable signs of aesthetic worth and vice versa. This is because the presence of moral criteria such as benevolence and justice would be reliable in-
dicators of aesthetic criteria such as form and harmony, and conversely. However, this would not mean that aesthetic criteria were moral criteria or vice versa. Benevolence and justice would still be the relevant moral criteria and harmony and form would not be; harmony and form would be the relevant aesthetic criteria while justice and benevolence would not be.

In a similar manner if there is a close contingent relation between acceptance \( B \) and acceptance \( U \), a criterion used to evaluate whether one should accept \( U \) a hypothesis, e.g. the criterion that acting on the hypothesis will adversely affect human life, might be a reliable indicator of whether one should accept \( B \) this hypothesis. But this might be the case simply because practical consequences were a reliable indicator of the criteria relevant for acceptance \( B \), e.g. simplicity and explanatory power. If so it would no more mean that practical values are relevant to what one should accept \( B \) than that moral criteria in the above example are relevant to what is aesthetically pleasing.

I conclude that Leach’s argument gives no support for \( 9 \) and does not refute \( 7 \). Indeed, it seems to me that the above considerations suggest that \( 7 \) is correct and that \( 9 \) is incorrect. I find it difficult to see how practical consequences of my acting on a hypothesis could be relevant to whether I should believe that a hypothesis is true unless acceptance \( B \) and acceptance \( U \) are logically related in a very strong way.

If for example “X is disposed to act as if \( p \) is true” entails “X believes that \( p \),” then if one should be disposed to act as if \( p \) is true because of certain practical consequences resulting from one’s action, one should believe that \( p \) is true because of these consequences. Again if “X believes that \( p \) is true” entails “X is disposed to act as if \( p \) is true,” then if one should not be disposed to act as if \( p \) is true because of bad practical consequences resulting from one’s action, one should not believe that \( p \) is true because of these consequences. But these logical relations do not hold between acceptance \( B \) and acceptance \( U \) between belief and the disposition to act as if. Any contingent relation of the kind specified by Leach is not strong enough to show the relevance of practical values for acceptance \( B \). As we have seen this does not exclude the presence of practical values being a reliable sign of the presence of epistemic values. But if they are, it does not mean that practical values are relevant for acceptance \( B \).

Who is correct then: advocates of the practical acceptance view or advocates of the theoretical acceptance view? The answer to this depends on what sense of “acceptance” one is talking about. For we have seen that Rudner’s argument has established \( 10 \) and refuted \( 8 \). So if we are talking about acceptance \( U \) the practical acceptance view is correct. My criticism of Leach’s argument suggests that practical values are irrelevant for acceptance \( B \) unless certain unplausibly strong connections are supposed to hold between acceptance \( B \) and acceptance \( U \). So if we are talking about acceptance \( B \) \( 7 \) seems to be correct and \( 9 \) to be incorrect. However if this is so, it follows that the practical acceptance view is correct when acceptance is restricted to acceptance \( U \) and that the theoretical acceptance view is correct when acceptance is restricted to acceptance \( B \). Thus with respect to what hypothesis a scientist should accept \( B \), i.e. believe is true, epistemic values are the only relevant ones while with respect to what a scientist...
accepts, i.e. what he should be disposed to act on in a particular context, practical values should come into play.18

Science Education and Acceptance

What relevance has the above analysis for science education? Let us consider its relevance with respect to four types of science educators: (1) science teachers, (2) science curriculum planners, (3) science textbook writers, and (4) researchers in science education.

Science Teachers

Philosophy of science has analytic value and heuristic value for science teachers. For example, a science teacher explaining the rationale for theoretical physicists rejecting Newtonian mechanics might find it useful to keep in mind the distinction between acceptance and acceptance. Although theoretical physicists reject Newtonian physics, engineers and applied physicists accept Newtonian physics in some of their work. Indeed without this sort of distinction clearly in mind a science teacher might not be able to explain to his class (or get them to discover) the different value commitments of theoretical scientists and applied scientists and the different roles of Newtonian theory in theoretical and applied disciplines.

Furthermore, the knowledge that value judgments are involved in the acceptance of hypotheses may enable the teacher to bring out to his class important similarities and perhaps differences between different branches of study. Thus bringing out the similar epistemic values involved in the acceptance of theories in physics, biology and chemistry may provide unity and coherence in science courses that is too often lacking and even perhaps suggest important similarities and differences with the humanities and the arts.

We have seen that the odds maker view of science seems an implausible view of how a scientist qua scientist should operate. But it may be very suggestive for how science teachers should operate. Should science teachers maintain that certain scientific theories which are well supported by the evidence should be accepted relative to certain values? Or should science teachers become odds makers, presenting theories and the evidence for them, perhaps discussing the epistemic and practical values involved and then letting the student decide whether to accept or reject the theories without any recommendation from the teacher? In short, should the science teacher advocate the acceptance or rejection in either of the senses discussed of any scientific theories?

I do not believe that any general answer can be given to this question. Much will depend on what the teacher is trying to do in the class, the level and maturity of the students and the type of material investigated. In small classes with mature and self-reliant students the odds maker approach may be stimulating and productive; in large classes with naive and slow students the odds maker view approach may be too heady and anxiety provoking. But in any case the odds maker approach to teaching science is an approach that is well worth
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considering in some contexts.

Science Curriculum Planners

Analytic philosophy of science has special relevance to science curriculum planners. This is because of the profound changes that have occurred in science curriculum theory in the last several years. Although a coherent articulation of this new movement is not complete, even now one can discern two important facets. First, recent science curriculum theorists have stressed that science should not be taught as an inflexible and unchanging body of doctrine. The tentativeness and revisionary character of science should be stressed in science education; science should be taught as a flexible, everchanging method of inquiry. Thus Schwab has argued:

What is required is that in the very near future a substantial segment of our public become cognizant of science as a product of fluid enquiry, understand that it is a mode of investigation which rests on conceptual innovation, proceeds through uncertainty and failure, and eventualizes in knowledge which is contingent, dubitable and hard to come by.\(^\text{19}\)

In the area of social studies curriculum Massialas and Cox have maintained that social studies courses in the public school should have as one of their goals teaching the individual a method of inquiry which allows him to “reconstruct his system of beliefs and values in the process of inquiry.”\(^\text{20}\)

Secondly, recent science curriculum theorists have stressed that the structure of science should be taught. What exactly ‘structure’ means is not exactly clear but people who emphasize structure in science education seem to have in mind the basic concepts and methods of particular sciences and perhaps of all or most sciences. Thus Jerome Bruner, who has done so much to popularize the notion of structure in science education, illustrates the idea of structure by citing the concept of function as an “organizing concept” in biology\(^\text{21}\) and argues for the importance of this concept in the teaching of biology. Bruner also suggests that operational definition is a “recurrent idea that appears in virtually all branches of science.”\(^\text{22}\) Here Bruner seems to be suggesting that structure sometimes refers to concepts basic to all or most sciences and he goes on to argue that structure in this sense may play an essential role in at least general science courses.

Schwab advocates the structural approach to scientific education also. He distinguishes three senses of structure that play an important role in science education.\(^\text{23}\) In one sense, to say that one should teach the structure of science is just to say that one should teach the interrelations between scientific disciplines. Under this heading would fall the relations between formal sciences, e.g. mathematics, and non-formal sciences as well as the relation between physical sciences and social sciences. In another sense to say that one should teach the structure of science is to say that one should teach the basic concepts and theories of a scientific discipline. For instance, one might teach the theory...
of universal gravitation in physics. Schwab calls this substantive structure. In a third sense, to teach the structure of science one would teach the canons of proof and evidence in scientific disciplines. This Schwab calls syntactical structure.

Whatever the merits of the inquiry and structure approach to science education—and we believe they are many—analytic philosophy of science has great relevance. First it is analytic philosophy of science—in particular inductive logic—that investigates the logic of scientific inquiry. Secondly, analytic philosophy of science, as we have already mentioned, investigates the basic concepts of sciences. Analytic work has already been done by philosophers on the notion of function in biology, and on operational definitions. Philosophers of science have discussed at length the relation between formal and non-formal sciences and the relation between the natural and the social sciences. Particular concepts of physics, biology, anthropology, psychology and so on have been analyzed by philosophers of science. The canons of proof and evidence in science have been analyzed by analytic philosophers of science and inductive logicians.

It would seem, therefore, that a science curriculum construed in terms of inquiry and structure would be illuminated by the work of analytic philosophers of science, and that curriculum planners who utilized the notions of inquiry and structure in their work would benefit from the study of analytic philosophy of science. Indeed, it would not be too far wrong to say that the educational potential of the inquiry and structure approach to science education will not be fully realized until science educators realize the need for the analysis and clarification of the key notions of inquiry and structure.

One of the key notions in scientific inquiry and the structure of science is the notion of acceptance. Part of scientific inquiry—except on the odds maker view of science, a view which we have found no reason to embrace—is the tentative acceptance and rejection of hypotheses. Acceptance also seems to be one of those general notions that Bruner has in mind when he talks about the structure of science. Schwab’s syntactical structure is concerned with the canons of proof and evidence in scientific disciplines. But as we have seen the canons of evidence and proof are closely connected with the gains and losses involved in accepting or rejecting hypotheses in terms of practical and theoretical values. It seems obvious that curriculum theorists who would teach science as inquiry and who would teach the structure of science can profit from the philosophical analysis of the relation between acceptance and values.

Science Textbook Writers

Analytic philosophy of science has both analytic and heuristic value for science textbook writers. The science textbook writer often deals with general concepts in his work that have been analysed and discussed at length by analytic philosophers of science. The textbook writer is usually ignorant of these analyses and the textbook which is the result of his work suffers accordingly.

That the scientist qua scientist may make value judgments in the acceptance
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of scientific hypotheses is something that is usually overlooked in the typical science textbook. Indeed, science textbook writers often present complex and difficult scientific theories along with the most simple minded views about the acceptance of these theories.

Consider for example a passage in ESCP Investigating the Earth. The authors say

What is the difference between evidence and proof? . . . Evidence is observation that tends to support a conclusion. A conclusion is an interpretation or judgment based on the evidence. When there is a little evidence for it a conclusion is only probable. The conclusion becomes proved when there is sufficient evidence to support it.

Now one plausible way of interpreting this passage is that when the authors say that the conclusion becomes proved when there is sufficient evidence to support the conclusion they mean that the conclusion should be accepted. Since no evidence ever makes the conclusion certain the question of when the evidence is "sufficient" for acceptance remains. The authors say nothing about this and indeed do not even seem to realize there is a problem. However, it is here, as we have seen, that value judgments enter into the picture. The question is what is at stake either epistemologically or practically, what gain and losses might accrue, in accepting a hypothesis that is less than certain.

Consider, for example, acceptance and suppose the hypothesis at issue is the hypothesis that some particular individual has ESP. Now the acceptance of this hypothesis may have grave repercussions on the whole scientific framework since it is not implausible to suppose that ESP can not at the present time be easily assimilated into our scientific framework. To assimilate this hypothesis without radical change in our basic assumptions may involve the acceptance of a variety of ad hoc hypotheses which may seriously affect the overall simplicity of the scientific world view. Since simplicity is one epistemic value sought in science, what will be considered sufficient evidence for the acceptance of the ESP hypothesis may have to be different from more typical cases of acceptance where this simplicity is not in question.

Supposing acceptance is at issue, then practical values enter into the picture. Suppose the hypothesis is that a drug is a cure for cancer and has no toxic side effects. As we have seen much would depend here on the context of the acceptance e.g. whether it involved human or animal subjects. What would be sufficient evidence in the one case would not be sufficient in the other.

There is no discussion of these points in Investigating the Earth. This is especially unfortunate since students using this book are asked by the authors whether certain data is evidence or proof that the earth is round. Interpreted in the way we have suggested this comes down to asking whether certain evidence is sufficient for accepting the hypothesis that the earth is round. It is unclear how students could possibly answer such a question unless the authors clarified the values which are at stake in the acceptance of the hypothesis and what sort of acceptance is at issue. For example, in the context of a long ocean trip it
might make some difference if acceptance\textsubscript{U} or acceptance\textsubscript{B} was at issue. For Magellan certain practical values were at issue e.g. the value of his life and his crew in the acceptance\textsubscript{U} of the hypothesis. If only acceptance\textsubscript{B} were at issue one might want to know how the hypothesis that the earth is round, if it were accepted\textsubscript{B}, would affect certain epistemic values such as the simplicity of the scientific framework.

Knowledge of the philosophy of science could have had analytic value for the authors of *Investigating the Earth*. It takes little imagination to see how such knowledge might also have suggested different approaches to the material, i.e. have had heuristic value. For example, some clear idea that values enter into the acceptance of hypotheses in science might have suggested to the authors a number of new examples to utilize in the text, ones that bring out some of the epistemic and practical values that operate in the acceptance of hypotheses in science. Moreover, knowledge of the importance of values in the acceptance of scientific hypotheses might have suggested that different epistemic values operate in the context of pseudo-science than in science. The "flat earthers" for example can accept\textsubscript{B} that the earth is flat so long as certain complex auxiliary hypotheses are accepted. A discussion of whether flat earthers with their strange beliefs and modes of reasoning can be committed to the epistemic value of simplicity that scientists are committed to might provide an illuminating contrast with scientific epistemic values.\textsuperscript{31}

Researchers in Science Education

Analytic philosophy of science has analytic and heuristic value for researchers in science education. We have already mentioned in passing one question that might be pursued in such research, namely: What affect does a science teacher who adopts the odds maker view have on his students? We have suggested earlier that a science teacher might adopt the odds maker view in certain contexts. Whether this approach would be fruitful is something the educational researcher can help decide. In any case, a number of hypotheses suggest themselves. For example, since on the odds maker approach to science teaching the teacher never advocates the acceptance of any hypotheses and the student is left entirely on his own whether he accepts or rejects a hypothesis the following hypothesis H is suggested:

H Science teachers who teach science as odd makers tend to produce students who are less dogmatic than do science teachers who do not teach science as odd makers.

Whether H is true is something that only educational research can decide.

Educational researchers in their work accept\textsubscript{U} or reject\textsubscript{U} hypotheses e.g. hypothesis H suggested above, in the light of the evidence and certain practical values.

To use a recent example from educational psychology: Should educational researchers accept\textsubscript{U} the hypothesis that Whites as a group have a higher I.Q.
than Blacks as a group the difference between I.Q. being due to genetic factors? Whether educational researchers should accept this hypothesis should involve the consideration of the practical values involved in doing so. One effect of educational researchers accepting this hypothesis in their work might be serious racial unrest. Whether this effect is likely is an open question but if it is the value of domestic peace and human brotherhood must be weighed against any epistemic values that such research might achieve.

Perhaps part of the controversy between Jensen and his critics is over just this point. Jensen in some of his writing plays down the question of whether people should accept his hypothesis about White genetic superiority. He may be interpreted as advocating, rather, that scientists should take his hypothesis seriously; that they should consider it a fruitful working hypothesis in the context of empirical research at least, that the hypothesis should be accepted. Either Jensen seems not to consider the practical values involved in doing this or else he seems to believe that no practical considerations could outweigh the epistemic gains. His critics, on the other hand, take the practical values involved very seriously and play down any possible epistemic values that might be the result of scientists accepting his hypothesis.

It is difficult to say who is correct in this controversy. But two points need to be stressed. First, accepting Jensen's hypothesis in the context of genetic research does not entail that one should accept this hypothesis in the context of educational policy making. Secondly, accepting Jensen's hypothesis in the context of educational policy making does not entail that the traditional goal of educational equality should be given up. Indeed it might be plausibly argued that far from Jensen's hypothesis justifying giving Blacks an inferior education it suggests that Blacks should be given an intensive and superior education not for environmental deprivation but for genetic deprivation.

Perhaps if these points were clearly understood the acceptance of Jensen's hypothesis in the context of empirical research would not be thought to have such drastic practical consequences. In any case some understanding of the practical and epistemic values involved in the acceptance of scientific hypotheses may bring some illumination to this controversy.

Conclusion

I have argued that a recent controversy in the philosophy of science concerning the acceptance of scientific hypotheses is illuminating for science education; that clarification and analysis of this controversy provides insights useful to science educators. I have tried to sketch in what some of these insights might be for various types of science educators. It is my hope that science educators will take these suggestions seriously; I hope even more that philosophers of science will take science education seriously enough to make other suggestions and criticize the ones I have made.
FOOTNOTES

1See for example Michael Martin Concepts of Science Education: A Philosophical Analysis (Glenview, Ill.: Scott Foresman, 1972); James T. Robinson The Nature of Science and Science Teaching (Belmont, Calif.: Wadsworth Pub. Co. 1968); Martin Leévi Philosophy of Science and Problems of Education (Urbana, Ill.: University of Illinois press 1972).


5Martin Concepts of Science Education pp. 124-126.


14For a similar distinction see I. Scheffler Science and Subjectivity (Indianapolis: Bobbs-Merrill, 1967) p. 86.


16Rudner, op. cit. p. 2.

17Leach, op. cit.

18We have not considered in this paper how exactly values should enter into the acceptance of scientific hypotheses. In particular we have not considered whether a cost-benefit of a expected utility analysis is more desirable. For a defense of the cost-benefit approach which I find very persuasive see Alex Michalos "Cost-Benefit vs. Expected Utility Analysis" a paper read at the PSA meeting in Boston in 1970.


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30 Earth Science Curriculum Project, Investigating the Earth, (Boston: Houghton, Mifflin Co., 1967) p. 61. For a critique of this passage along different lines see Martin Concepts of Science Education pp. 36-38.

31 For an interesting discussion of flat earthers see Martin Gardner, Fads and Fallacies in the Name of Science (New York: Dover Pub., 1957) Chapter 2; for a discussion of the use of pseudo-science see Martin Concepts of Science Education, p. 40-42.


33 Michael Martin “Equal Education, Native Intelligence and Justice” unpublished.