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ABSTRACT

This essay examines flaws in the standard hypothetical-deduction inquiry model and offers another quite different model of inquiry, the multiple-completing model, for use in the school classroom. In positing this new model of inquiry the assumption has been made that a pedagogical inquiry model need not necessarily be an accurate reflection of scientific inquiry. Two things must be expected of a pedagogical model: that it encourage students to make bold conjectures and to severely test these same conjectures. Problems with use of the hypothetical-deduction model, which represents science for most people and which is at the heart of all inquiry models advocated for classroom use, have to do with the nature of hypothesis formation, with the bias created by the hypothesis, and with the easy acceptance of an hypothesis on the basis of any degree of confirmation. The multiple-competing hypothesis model meets the requirements for a pedagogical model through the formulation of several hypotheses which are mutually exclusive and which must be refuted by the student rather than proved. (Author/JH)

The Failures of Inquiry:

A New Proposal

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The Failures Of Inquiry: A New Proposal

One of the problems with an idea that once had a great deal of merit is that it tends to persist far beyond its actual usefulness, and there is a certain hesitancy to replace it. Pedagogical inquiry models as developed by John Dewey are one such example. It is not the notion of inquiry, per se, which presents the problem so much as it is Dewey's particular formulation of inquiry. His particular set of inquiry procedures, and the multitude of variations developed since his work, present education and teaching with several serious problems which might well be avoided if a different inquiry model were formulated and brought into use. This essay will attempt to do two things: First: it will examine the flaws of the standard inquiry model (Dewey's) and, secondly, it will offer another, quite different, model of inquiry for use in the school classroom.

One point which needs some clarification before proceeding is the difference between what I will refer to as a pedagogical model of inquiry and a logical one. A logical model of inquiry will refer to those descriptions of socio-scientific inquiry which are strictly philosophical, or discipline orientated. The individual who either constructs or describes a model of science does not have as his primary interest the teaching-learning situation, while one who develops a pedagogical model of inquiry is specifically interested in the instructional application and utilization of the model. There is no attempt in this paper to differentiate between a logical model of inquiry and a pedogogical model of inquiry except on the basis for which one intends to utilize it. Indeed, a logical model of inquiry can easily become a pedogogical model of inquiry simply by advocating its usage in the classroom, and in fact this has been what has usually happened. Inquiry models have seldom been designed strictly for pedogogical reasons and most are adapted from other sources. This essay will attempt to formulate an inquiry model strictly from another era of philosophical analysis. Also while a goodly number of psychological studies have been done on the effectiveness of learning through inquiry strategies they have generally resulted in the usual set of mixed conclusions: More importantly though they do not seem to have found inquiry presentations to be any more effective than any other instructional strategies. These results have caused people to question the use of inquiry strategies (or in some cases the effectiveness of psychological studies) but no one seems to have questioned the nature of the inquiry model that was used, and more importantly whether another model of inquiry might have brought about different results.

Scientific Procedure As Inquiry

The model of inquiry found most often in education is the hypothetico-deductive. Indeed all styles of inquiry in education are a variation of this. Hypothetico-deduction also formed the central core of John Dewey's model of inquiry.[3] The clearest, and indeed simplist, version of his model is found in How We Think. It is also the book most often referred to by educators and in many ways this is unfortunate for Logic: The Theory of Inquiry is a much more mature book. Essentially How We Think is a philosophy book written for nonphilosophers and it represented Dewey's desire to translate a theory of knowing into action. Always the reformer, it was only logical that his theories of knowing be developed into an educational theory. It is unfortunate that Dewey was perhaps the last philosopher to make this connection between a theory of knowing and a theory of education and since his time philosophy has moved into areas of increasing technicality. The logical techniques have become highly refined and the areas of life to which they are applied have become increasingly smaller. The result is that no technical philosopher today has much impact on the field of education and the consequence is little, if any, integration between theories of knowledge and theories of teaching.[4] Things remain about where they were when Dewey finished his work. It is always tempting to hold that nothing remains to be said after Dewey, but a more realistic assessment might be that with the narrowing of philosophical concerns, coupled with the greater role of psychology, philosophical issues have simply not had much impact since Dewey. This is especially true in the area of what one might call educational epistemology. Thus, education is left operating with a hypothetico-deductive model of inquiry: A logical artifact from another era of analysis.

It is essential that this model be examined carefully in an attempt to evaluate its limitations for the development of teaching strategies. This examination can center around two points. First one can consider the correctness of the model as a description of scientific inquiry, for if hypothetico-deduction is not an accurate description of scientific activity then certain assumptions that have traditionally been made about the instructional utility of the model need careful reconsideration. Another point around which such an examination might revolve is the instructional utility of hypothetico-deduction, disregarding whether or not it is an accurate description of scientific practice. It is this second point which would appear to the more useful, and indeed more critical tact in such a critique, for if a model of inquiry has drawbacks as a model for instruction then it ought to be dropped, regardless of its accuracy, or inaccuracy, as a description of modern scientific practice.

Before proceeding any further it is important to clearly deliniate between a descriptive model of inquiry and a prescriptive one. It is true that most philosophers would not object if their analyses led to some small reforms in the way science is done but this is not their primary concern. The emphasis is generally on accurate description: A description which in turn allows one to better understand scientific practice. The philosopher is generally motivated by analytic concerns and there is always a striving for a description which is more illuminating of the structural aspects of science than previous ones. As this description becomes more and more complete it may indeed develop into a theory of science which will then enable us to better understand science, but not necessarily the products of science. Also it is important to remember that a theory of science is neither necessary nor sufficient for doing science. To some philosophers this situation is not an ideal one, and indeed the literature is full of philosophers bemoaning the situation. The only difference of opinion is among those who feel that the fact scientists are so little interested with philosophical concerns is illustrative of the bankruptcy of philosophy, while others feel that the situation is illustrative of the bankuptcy of science.[5] At any rate most philosophers would agree that the philosophy of science has relatively little impact on science itself. Thus current descriptions of science play only a minor role in helping scientists go about their tasks and to assume any more would make one guilty of both arrogance and ignorance. . Modern philosophy is primarily descriptive in nature whether one approves of the situation or not.

The situation in education is quite different. By giving the students a model of inquiry, no matter how loosely structured it may be, one is engaging in prescriptive behavior. By giving the students a theory of science, or a theory of inquiry, the teacher becomes an advocate of that theory. He is stating that a student ought to utilize such a model. The subtle nature of this act makes little difference. In advocating this a value judgment is being placed on a certain model, or way of knowing. The teacher is saying that this model is worth utilizing and this is very different from simply creating a logical reconstruction of scientific practice. To describe a set of procedures, as one does in the case of a philosophical analysis of scientific practice, is primarly an empirical act in that, at least in principle, one can ascertain whether or not the description is accurate. Indeed a great many of the current debates in philosphy are over the issues regarding the accurcy of description.[6] Education though is generally concerned with the prescriptive uses of inquiry, and the focus is on the learning, and utilization, of a given set of methodological procedures. This prescriptive action necessitates that the consequences of advocating a given inquiry model be carefully examined. In using hypothetico-deduction we must scrutinize what happens when the description becomes a prescription. This model was originally intended to be a logical reconstruction of scientific practice and when we use it in the classroom we are putting a burden on the model that it may or may not accept. Before determining that though one must examine the accuracy of the description. It is axiomatic that a descriptive model be accurate. Whatever else is required of a logical reconstruction of scientific inquiry it is of critical importance that it be accurate; i.e., it should be an accurate description of what the scientist does. If it is not then the model is of little use except as a subject of conversation amongst philosophers of science.

No matter how hard one might attempt to describe scientific practice one can never be perfect. Abraham Kaplan, in The Conduct of Inquiry, refers to this as the difference between logic-in-use and reconstructed logic. Logic-in-use is what a scientist does, while reconstructed logic is what the scientist, or some other individual, says he does.[7] The goal is that reconstructed logic be congruent with logic-in-use, but there are any number of reasons why the two may not be the same. The most obvious problem is that few scientists are really accurate in describing what it is they do. As Enstein used to remark, "If you wish to know what a scientist does; watch him do not listen to him." Another problem is that logic-in-use tends to become idealized and the edges are smoothed in the writing of the final research report. This forever obscures the logic-in-use.

One of the major criticisms against the hypothetico-deductive model has been that scientists really do not feel that it describes what it is they do. Indeed, as was earlier discussed, most scientists would agree that the entire field of philosophy of science is presently quite removed from actual scientific practice. That this is considered to be both a justified and serious criticism indicates that the descriptive function of scientific logic is of some importance. Thus, one of the functions of philosophy must be an ever continuing effort to bring reconstructed logic into greater congruence with logic-in-use. If one desires to be critical of scientific practice it is imperative that one criticize what it actually scientific practice and not some mythical conception of it.

In education when we discuss the utilization of inquiry models it is not critical that the pedogogical inquiry model be absolutely reflective of scientific logic-in-use. An accurate description of scientific practice is really not that critical for an inquiry model in the classroom. Indeed, one could even ask — "Description of what?" There is really no practice which we wish to duplicate exactly — unless of course one desires to manufacture junior level scientists. Thus, the task of formulating a classroom model of inquiry must begin by deciding what it is that students should be able to do, know, or feel, as a result of utilizing a model of inquiry. The tacit assumption of many of the inquiry programs formulated during the 1960's was that they were to model the achievements, and procddures, of the sciences. Indeed one writer went so far as to say that "a method for judgement should be scientific . . . ."[8] The worship of science expressed by this writer is not only total but also amazingly uncritical. The problem is that even today too many people accept the idea that "the social sciences and social studies. . . are in large measures indebted to the physical scientists who have accomplished the developmental work on the scientific method."[9]

In many respects both of the above expressions were a result of an uncritical acceptance of science. It was assumed that all people should be able to utilize "the" scientific method as a mode of reasoning. It never seemed to occur to educators that a procedure that was developed to make accurate predictions possible might well be inappropriate for use in classroom situations where the goals are quite different from those in science. It is hardly reasonable to expect that the task of youngsters is the production of new and reliable knowledge. Rather, it would appear that what the objective is to develop a set of procedures whereby the students can develop a set of critical thinking skills that will better enable them to deal with problems they might confront. If the hypothetico-deductive model of inquiry can do this then fine, if it happens that another model is more effective then so much the better. It is really of little importance that a pedagogical model of inquiry be an exact replica of scientific practice.

At any rate we must first consider the major reasons for the utilization of inquiry tactics in the classroom. Here a return is made to the vague item of critical thinking skills. This generally would include such items as whether a student is able to judge whether or not a given conclusion follows from the data offered; whether a certain line of reasoning is ambiguous; and being able to determine if a given generalization is warranted.[10] Essentially these items can all be embraced by two basic statements. First, we want the student to make bold condjectures, and secondly the student should severly test these conjectures. How effective an inquiry model is in engaging students in these two tasks is the criterion by which one should select a given model of inquiry. How well a given model describes scientific inquiry is unimportant. What is needed then are comparisons of different inquiry models regarding how effective they are in getting students to propose and test their conjectures. (Not for instance, a comparison of inquiry with expository teaching, or simulation games.) If another inquiry model is more potent in the achievement of such skills then the case for dropping the hypothetico-deductive model becomes even stronger since, as was just pointed out, the major reasons for using inquiry center around the aquisition of critical thinking skills, not the acquisition of knowledge. Most of the empirical research which has been done with the hypothetico-deductive model has been done in comparision with non-inquiry procedures. This includes lecture and expository styles of instruction. There has been little comparison done between the hypothetico-deductive and any other inquiry models. The major reason for this lack of comparison is that different models of inquiry have never been used in instructional settings. Thus, any research of this type has been impossible. The question as to whether one model has greater potency in helping students acquire certain skills goes unanswered because of lack of comparative opportunities. Everything is modeled after hypothetico-deduction. What little variation there is between the work of Massialas, Fenton and Goldmark, is relatively minimal. They are simply variations on the theme of hypothetico-deduction.

The model of classroom inquiry advocated by Dewey has been widely accepted not because of its instructional utility but rather simply because it appeared to be a model of scientific inquiry. The major problem has been that since few can quarrel with the success of scientific achievement any model based on scientific procedures is generally considered to be a very good one. This aura of great achievement not only entraped educators but also a great many others. Social scientists, for instance, have been attempting to model the physical sciences for number of years now with what many claim is little success. In this respect the methodology of the physical sciences has acted as a siren lady for a great many people including educators. A tremendous amount of effort has been expended in attempts to utilize the same procedures which have produced tremendous advances in our knowledge of the physical world. The interesting question remains: What results might have developed in education, and the social sciences, had a different methodological course been followed?

Since hypothetico-deduction has come to represent science for most people it is this model which is at the heart of all of the inquiry models advocated for classroom use. Rather than deal with all of the variations it might be best at this point to simply examine the basic format and its attendant problems in some detail. In its barest form hypothetico-deduction calls for the establishment of a particular predictive statement from a general hypothesis which is coupled with another statement giving the initial conditions. This single predictive statement (an hypothesis) is accepted, at least for a time, as true. The next step is to devise an experiment, or a series of observations, to determine whether or not this predictive statement is true or false.[11] If this original predictive statement turns out to be false then the hypothesis is disconfirmed or dropped. If the predictive statement, after examination, or experimentation, turns out to be correct then the hypothesis is considered to be confirmed (but not true) to some degree.

This problem of confirmation, and disconfirmation, is not an easy one and one that needs to be dealt with further. A point of some controversy has developed around the notion of a single disconfirming instance. It is worth noting that on some occasions a single disconfirming instance will not be sufficient cause for dropping, or rejecting, the prediction. Rather, one must examine the data, or event, to see whether the event or data in question is merely an aberation or whether this disconfirming instance does indeed merit further consideration. This is a Baysian notion of sorts and an approach which seems to have some merit since essentially we are dealing with the problem of prior probabilities. Thus, if in the past there has been a considerable amount of data generated in support of a given hypothesis, or set of hypotheses, a single disconfirming instance would not be considered sufficient to cause rejection of the hypothesis. The hypothesis would continue to be held to have some degree of confirmation, although perhaps less than before the disconfirming instance was discovered. The more complex problem arises though when one encounters confirming instances of data. If the deductive statement that was generated from the hypothesis turns out to true,we do not consider the hypothesis to be verified. Indeed, no number of confirming instances can completelyverify the hypothesis. Complete verification is simply not obtainable. The best that one can do is to have an hypothesis which has received a high degree of confirmation, but at the same time no degree of confirmation can be of such a high level as to consider the hypothesis fully confirmed.[12] This point is an important one, especially for teaching-learning situations, and one which has been largely overlooked.

The reason for this situation was first pointed out by David Hume. He explained in Enquiry into Human Understanding that there was simply no logical basis for assuming that the future will be in any way similar to the events of the past. In other words, there is no logical basis for assuming that unobserved cases will resemble observed ones. The reason for this is that ". . . what has happened imposes no logical restriction on what will happen."[13] Thus, as Hume puts it we have a very basic problem in predicting knowledge.

> Let the course of things be allowed hitherto be ever so regular; that alone, without some new argument or inference, proves not that, for the future, it will continue so. In vain do you pretend to have learned the nature of bodies from your past experience. Their secret nature, and consequently all their effects and influence, may change, without any change in their sensible qualities. This happens sometimes, and with regard to some objects: Why may it not happen always, and with regard to all objects? What logic, what process of argument secures you against this suppostion? My practice, you say, refutes my doubts. But you mistake the purport of my question. As an agent, I am quite satisfied in the point; but as a philosopher, who has some share of curiosity, I will not say scepticism, I want to learn the foundation of this inference.[14]

As the question is posed here, the problem is essentially one of justifying conclusions concerning unobserved phenomena or concepts. Given that one has "established, or highly confirmed, a certain conclusion according to the accepted cannons of scientific justification, on what grounds may we accept this conclusion as embodying knowledge."[15] When the teacher has the student apply a scientific method, it usually done so in anticipation that the student will gain new knowledge, at least new for him. What David Hume did was to point out how difficult this process actually is. The student, and indeed the scientist, finds himself in a situation where it is extremely difficult to legitimize his knowledge claim.

The student, or again the scientist, can act on the basis that the future will resemble the past, in which case he would be acting only on a psychological basis though not a logical one. The logical problem remains. Thus, the problem really has two parts; a psychological one, and a logical one. The fact that induction cannot be justified is a logical problem. The fact that we act as if induction has been justified, or act as if the future will resemble the past, is a psychological response. This response does not though in any manner solve, or even resolve, the logical problem of induction. This inductive problem is even more important in the context of teaching, where the researcher may not be as tough-minded as need be, or where the results are not severly examined by a friendly-hostile peer group. It is all too easy to verbally accept the notion that one's hypothesis is always tentative (to a greater or lesser degree) but inwardly feel that one is totally correct. Indeed, this is exactly the position of many students in our schools.

Of course in principle the student may very well acknowledge that his hypothesis is only highly confirmed, as opposed to being true. The problem is that the student usually <u>only agrees in principle</u>. He <u>acts</u> as if the hypothesis were true. Actually one could argue that this is a psychological problem and this may be true, but nonetheless the origin of the problem is essentially a logical one. As was pointed out earlier the logical problem of induction is often times dealt with in a psychological manner, but this does not lessen the magnitude of the logical problem. It is simply a way of dealing, or coping, with it. A psychological response cannot solve a logical problem. Any new inquiry model designed for instructional use must deal with Hume's problem in some sort of logical manner.

Another basic problem with hypothetico-deduction is that of hypothesis generation. The hypothetico-deductive model takes the hypothesis as a given. As the late N.R. Hanson pointed out it is like a recipe for cooking trout. All of the recipes found in cookbooks assume that one already has a trout. In some cases it may very well be necessary to first go fishing and catch one. Philosophers have discovered that a convienent way of surmounting this problem of hypothesis formation has been to hold that hypotheses formulation is a psychological problem, not a logical one. Thus, the hypothetico-deductive account of science not only does not deal with the problem of hypothesis formation, or the logic of discovery, but also insists that a logical formulation cannot be created. Most modern logicians have only described what one does with a hypothesis <u>after it is proposed</u>.[16] This approach is being challanged in philosophy and it is something which any pedagogical model of inquiry <u>must</u> deal with since teachers cannot assume brilliant flashes of insight on the part of all students, as many philosophers assume is the case with scientists. There must be some sort of procedural guideline for the development of hypotheses: Not guidelines in the sense of a set of steps, but rather guidelines in the nature of a reasonable procedural outline that aids students in developing hypotheses.

A third point in this process of hypotheses formation that must be considered is that ". . . the process of fabricating a hypothesis comes after a study of at least some part of the field with which it deals."[17]

This seems obvious, but is too often forgotten. Teachers in an effort to create problems which students can inquire into too often forget that students generally begin with a rather different knowledge of the field than the teacher. This has fairly significant ramifications and these will be discussed shortly, but for now the point is simply that "hypotheses are never conceived ab initio, arbitrarily, or independently of any logical process of discovery."[18] Rather, they develop out of past theories or patterns of facts and are generated from some body of data which the investigator has in internalized. This could be a body of data collected in a previous experiment, or it could even be a complete conceptual organization. The point being that neither perception nor hypotheses formation is a totally free act. It might be going too far to say that one sees only what he wishes to see, but likewise it would be too naive to say that one sees exactly what exists. The very fact that hypotheses grow and develop through a theory-laden process means that researchers, and students, have already developed a certain amount of affection for a hypothesis upon formulating it. Anyone who believes that they are a strong enough individual to resist this tendency would do well to read the controversies over Newtonian mechanics or Ensteinian physics. The cliché that the facts determine the truth or falsity of an hypothesis is simply that — a trite chiché. The history of science offers numerous examples where in reality it appears that the hypothesis determined the facts and data that were gathered. The more one works with a given hypothesis the more this hypothesis becomes the master of the data. Indeed this is Kuhn's point in The Structure of Scientific Revolutions. There are times in all sciences when a paradigm, or developed theory, controls the type of data, and research, that is done. This paradigm controls the questions that one asks as well as the hypotheses that one formulates. Thus, we have a situation in the hypothetico-deductive model of inquiry where it is held that hypothesis formation is extralogical, or at least alogical, but at the same time we find that it is actually a heavily theory-ladden process which directs not only the questions we ask of a situation, but also has a bearing on what data is considered important. Indeed Dewey calls the hypothesis "the guiding idea."[19] The problem is that the hypothesis acts all too well as the guiding idea. The students direct all their research and experimentation towards the proof of this hypothesis and the inquiry is already heavily weighted upon the formation of an hypothesis. The students immediately begin their search looking for positive instances. These are often similar to unsolicited testimonials; they become a special case of pleading.

The problem is that "any such preference for verification . . . is bound to weight the scales in favor of the theory."[20] "It is easy to obtain confirmations, or verification for nearly every theory - if we look for confirmations."[21] This compulsion for proof is a very strong one not only with students but also with scientists. Indeed, many students, as do many scientists, come to cherish their hypotheses more then they research them. A very basic reason for this is that too often students, and teachers, have failed to consider the speed with which they embrace the first reasonable hypothesis that makes an appearance. As a little effort is devoted proving this hypothesis one develops an even greater affection towards it; an affection which grows geometrically over time and effort. The degree of impartiality tends to lessen and the degree of conviction surrounding the tentativeness declines even further. It is of some importance that this process occurs at the very time one is attempting to test an hypothesis and at a time when skepticism should be greatest. It is easy to exhort that the students should remain open and constantly be ready to reject the hypothesis, but this is seldom successful. Thus, any new model of pedagogical inquiry must deal directly with the problem of hypotheses formation and at the same time alleviat the problems which cause the hypothesis to become something which _must_ be verified, or confirmed.

There is also a third problem which is seldom raised in the literature and it is that to posit an hypothesis to a problematic situation is to assume that the problem can be solved.[22] The unstated nature of this belief makes it even more dangerous. In a way this confidence that all problems can be resolved is testimony to our great faith in rationality. Indeed Dewey's definition of inquiry states this belief rather clearly. He defines inquiry as ". . . the controlled or directed transformation of an indeterminate situation into one that is so determinate in its consitituent distinctions and relations as to convert the elements of the original situation into a unified whole."[23] The stress in all of his writings is that inquiry grows out a problem for which some solution is needed. This would appear to imply that once a problem is felt then one is admitting that it is capable of solution.[24] This is an unstated assumption which appears throughout the literature on inquiry in the classroom. The consequence of this assumption is that the attempt to prove the hypothesis becomes more of a test of the students' skill than a test of the given hypothesis. It is small wonder then that students gravitate towards certain hypotheses. There is a feeling that it _must_ work out. The source of this assumption stems both from a very firmly entrenched faith in rational behavior and thought, while another part of it seems to be derived from pure optimism. At any rate this belief is something which students find very frustrating to deal with. A failure to validate one's hypothesis, or any hypothesis for that matter, is seen as a failure in one's ability. "If I cannot arrive at a satisfactory rational solution to a problem then the fault must lie with me:" At least this is the way many students seem to react. What we have perhaps is a logical model creating a psychological state. Inquiry becomes a way of testing one's problem solving abilities rather then being a way of attempting to solve problems.

Thus, there are three basic problems with the hypothetico-deductive model of science as a pedagogical inquiry model. First, there is a rather significant problem surrounding the nature of hypotheses formation. If one maintains that the formation of an hypothesis is essentially an alogical event there is little hope for the creation of teaching strategies for helping students create hypothesis to problematic situations. This leaves one resigned to the fact only students with creative abilities, or those given to flashes of insight, will be able to be productive inquirers. Secondly after the student develops the hypothesis (assuming he does) the problem becomes one that it acts as too strong of a guide for research. Students develop too much of a vested interest in proving the hypothesis true. The hypothesis becomes a challenge to prove rather than an idea about which one maintains a detached neutrality. A third point, and this is tied to the second one, students tend to regard any degree of confirmation, no matter how small, as proof of the truth of their hypothesis. There tends to be a rather dogmatic approach regarding the nature of the conclusion.

Thus, we have three rather serious problems with hypothetico-deduction, any one of which should force a serious considertion of the pedagogical applications of the model. The limitations would appear to be of such a nature that instructional technique cannot overcome them. Indeed, this has been tried before and almost every book or article contains a number of suggestions for dealing with the problems. Usually they refer to the need to have students think creatively and remain open to different possible solutions to a problem. Sometimes these work and on other occassions they do not. What I am suggesting here is that such things are actually psychological band-aids for logical problems. It may well be more productive to consider the construction of a new model than to work with Hypothetico-deduction any longer.

A MULTIPLE HYPOTHESIS CORRABORATIVE INQUIRY MODEL

A Logic of Discovery

In developing a new inquiry model the obvious place to begin is with the first problem. That is, what does a logic of discovery look like. It is also the most difficult problem and I do not intend to solve it at this point. It is enough for now to sketch out the directions that a solution might eventually take, though it would be an understatement to say that much work remains in the development of a logic of discovery. At the same time though the work of the last decade does indicate that such a logic is possible, something Carnap and Reichenbach, among others, once held impossible.[25]

It is important at the outset to distinguish between two statements:

1) reasons for suggesting H in the first place, and

2) reasons for accepting any hypothesis H.

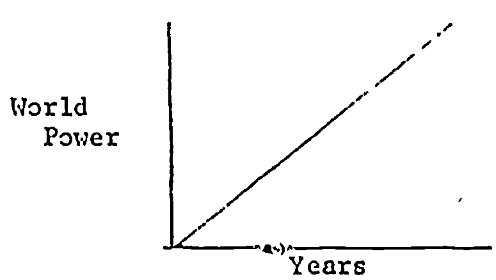
The second point here raises the question as to why a student even suggested H as being possible in the first place. This is not the same as asking why he decided that H might be possible. It may very well be the case that the two utilize quite different types of logic and that the reasons for suggesting H would never allow for the confirmation of H.

The question here is what might some of these types of reasons be.

One type might be analogical reasoning.[26] In this situation the student would be arguing that X, since it appears to very similar to all of the other X's he has known, then perhaps in similar situations, X will behave the same way as all other X's. An example might be drawn from a sociology class where the student suggests that because Japan is an idustrialized nation, as is the U.S., there is a great likelihood that it has a system of social classes. What the student is doing in essence is making an inference that if A, B, and C exist in both the U.S. and in Japan and D exists in the U.S. D must exist in Japan also. The argument thus is that if X_1 X_2, X_3, always exist in together then X_4 is also a common element. It is important to note that I am not using the term analogy in the manner which would suggest that an analogy is the same as an analogous or an interpretative model of a theory or for the theory. Rather I am using the term only in the common garden variety sense of analogy.

The important point is that an argument such as the one where the hypothesis posits the existence of a social class system in Japan is essentially different from the data needed to confirm such an hypothesis; data which might either confirm or deny the existence of such a class system. The student could point to an unending number of similarities between the U.S. and Japan but he would still not be confirming his hypothesis; i.e., Japan has a system of social classes. The hypothesis will need to be confirmed in a way other analogical reasoning. This is what is meant as the difference between the reasons for suggesting H in the first place as an hypothesis and the reasons for accepting H as an hypothesis.

Another example of a possible logic of discovery might be where the student argues that H is a possible hypothesis on the basis of symmetry.[27] This principle is often applied in the classroom. It is where one naturally assumes that the hidden part of circle resembles the part which one can see. Students seem to reason on this basis a great deal in their history classes and what is proposed here that such inferences be exploited as a means of encouraging students to develop the bold conjectures mentioned earlier. An example might be where the student makes a conjecture that the United States is steadily declining as a world power. The U.S. began as a colonial nation and rose in less than two hundred years to be the premier world power. It appears that the peak has been reached in this process and we find ourselves in some new relationship with the remainder of the world. What we have essentially then is a curve with years on one axis and world power on another.



Thus one could argue on the basis of symmetry, that within about one hundred and fifty years we will no longer be a world power. This approach is essentially a rational way to develop hypotheses. It should be obvious in this example that one could never seek to prove the argument on the basis of symmetry, but this in no way rules out the fact hypotheses cannot be developed in this manner.

Still a third reason that a student can have for suggesting H as an hypothesis is on the basis of authority.[28] In fact, I would suggest in most classroom situations this is what often happens. The student suggest a particular hypothesis because it supports the ideas of the teacher, or their parents, or any other authority. An example here would be where a student argues that the frontier played a dominant role in the development of the United States because Turner was a prominent historian. The argument might be that since Turner is a famous historian his theory must be right. One cannot become the paramount figure in a field by positing false arguments. The student here is arguing from a basis in authority and not from data and research. This is obviously not a correct strategy for confirming an hypothesis, but at the same time it is a very plausible argument for suggesting the testing of Turner's frontier thesis. Indeed the stature of Fredrick Jackson Turner has been perhaps the reason that so much has been written on the frontier: It is always a good idea to take on the biggest name in a field. Thus offering or formulating an hypothesis on the basis of authority is a very reasonable process. It can easily be seen that one cannot prove a hypothesis on this basis; at the same time though it is a very reasonable basis for suggesting H in the first place. Thus, once again, the reasons for suggesting H are quite different from the reasons for accepting H as an hypothesis.

A fourth type of reasoning may be simplicity.[29] A student suggests H as a possible hypothesis simply on the basis that it appears to offer the most unencumbered explanation to a puzzling situation, anomolie, or problem. An example of this might be the argument that a guaranteed annual income would be a bad idea because it would destroy any incentive to work. This is about one of the simplest ideas that one can formulate against such a social policy; thus, it can become a hypothesis that merits further testing. The process by which one develops such an hypothesis is hardly a brilliant flash of insight, or a creative leap. In fact there is nothing mysterious and psychological about a theory, or hypothesis, that if you give people money they will not work. Rather it is a very simple non-involved response to a question concerning social policy. Once again this is hardly going to provide one with a rationale for finally accepting H, but that is exactly the point being made here: The reasons for suggesting H may be quite different from the reasons one might need for accepting H.

This is not to argue that discovery is a purely logical act, rather it is an argument against the purely subjective and psychological theories of discovery. These very familiar, and important, aspects of discovery come all too quickly to dominate all of our thinking. It appears in many cases to have led to a euphoria with highly permissive attitudes towards any creative experience. Education embraces this notion of creative euphoria as a means of developing hypotheses all too readily. Dewey believed that any hypothesis occured spontaneously; it just seemed to pop up or spring into being, ". . . The idea just comes or it does not come; that is all that can be said. There is nothing intellectual about its occurrence."[30] Hunt and Metcalf write that the process of "Thinking up' a hypothesis puts [a] strain on the imagination and knowledge of students.'[31] As they go on it becomes clear that they see the process of hypotheses development as more of an imaginative process than one which involves knowledge and skill. Indeed they maintain that 'the more unimaginative a group of students is . . . the more assistance they require from a teacher."[32]

What the earlier four points have attempted to do is provide a beginning point at which work can begin before the concept of discovery is lost to the psychologists forever, and in this respect the model presented here is different from the hypothetico-deductive model in use today. Perhaps a successful strategy might be for a teacher to develop materials in such a way that a student comes to suggest hypotheses on all of the various points suggested. That is, a student would be asked to suggest an hypothesis on the basis of simplicity, another on the basis of analogy, another on symmetry, and yet another on the basis of an authority. This would serve the purpose of developing a wider range of hypotheses than are presently developed under the psychological basis of discovery, as well as perhaps allowing for the training of a student in hypothesis development skills.

Multiple-Competing-Hypotheses

This brings us to the second problem which was raised in the first half of this essay: The way in which a given hypothesis directs any research effort. This is not always a bad thing and in fact one of the functions of the hypotheses is to give direction to one's research. The problem is that a single hypothesis usually does this all too well. It is important to remember that an hypothesis is always developed within a given context; no hypothesis is ever developed in a vacuum, and it is simply naive to believe that a student begins forming hypothesis *de novo*. The process whereby a student develops hypotheses is in a very real sense a theory-laden one. The student begins the process with a background that is already formed; and when asked to develop an hypothesis, he will formulate one which fits this background. Thus, rather than challenging his beliefs this very first step in a traditional inquiry model generally tends to allow for the reinforcement of ideas the student already holds. This, some will argue, can be avoided by a skillful teacher. Perhaps, but the teacher also brings a background, complete with preconceptions, to the classroom, and only if the student and the teacher have opposite theories will the opposing views be compared.

In this case perhaps both parties will allow for the testing of their ideas but even so there are still only two hypotheses, or alternatives, to a given problem. Both sides of course believe their hypothesis to be the correct one and direct all their efforts towards the validation of their own hypothesis. The result of such an inquiry is generally seen as a situation where one person loses and one person wins. Inquiry then becomes a game. In either case each individual comes to generate only one hypothesis and research is only done along one avenue, and done in such a way as to prove the hypothesis correct.

One way of circumventing this problem is to force the individual to generate more than a single hypothesis. Thus, there will be an emphasis placed upon the need to search for alternative explanations which should reduce the vested interest that a student has in proving a single hypothesis correct. If a student is allowed three, or possibly more, different alternatives then there is little need to prove one particular hypothesis right. Thus, a student's research should be much more open and wide ranging. To return to the example used earlier in the paper, the student is no longer soliciting testimonials for his product, but rather he has a number of different products, any one of which it is equally rewarding to sell.

The attempt in such a situation is to get the students making bold conjectures: Conjectures which in many cases will refute experience and ignore perceived regularities. In the past the reasonableness of new ideas has been stressed and this has been done at a cost to new ideas.

It is essential that teachers and students remember that "all acquired knowledge, [and] all learning, consists of the modification (possibly the rejection) of some form of knowledge, or disposition, which was there previously . . . ."[23] In this new model it is essential that the students develop every possible type of explanation for a problem, or question. No effort need be, or should be, taken to curtail the range or types of possible explanations offered. The task at this point is solely one of propagation. Once the student begins to develop multiple hypothesis the investigation takes on a fuller demension. A single idea, or hypothesis suggests a single direction. With several hypotheses several directions are suggested. The lines of demarcation surrounding an investigation become erased while the types of possible outcomes are greatly increased. In essence the scope of the investigation becomes more complex.

Some might argue that they have always advocated the formation of several different hypotheses and find little new in this model. The difference is that in this model the hypotheses are to be competing. That is, they are to be formulated in such a way that no two can be considered verified at the same time. In order for one hypothesis to be verified the others will have to be proven false. Multiple-competing-hypotheses should be structured in such a way that the verification of one <u>necessitates</u> the falsity of the others. The students rather than proving an individual hypothesis must seek to disprove all hypotheses. Verification is no longer the goal that it was with hypothetico-deduction.

A related problem that occurs too often in schools, and could perhaps be minimized with a multiple-competing-hypotheses formulation scheme is the notion that one idea is as good as another. This idea is so obviously false that it should really not be a problem. Nonetheless, it is a problem and one that could even develop with the use of multiple-competing-hypotheses. Simply because several different ideas are put forth does not imply that they have equal merit. Rather, it means that these ideas have not been disproved as of yet. One hypothesis will eventually survive over the others. That is, one hypothesis will offer a more complete explanation, or a more accurate prediction. The determination of which of the various hypotheses will do this is yet to be established. Thus, judgement is, for the moment, suspended as to which is the more accurate. It should be stressed though that this is not the same thing as saying that all hypotheses are equally good answers: Only that prior to further testing, all hypotheses are equally plausible.

Before proceeding any further it is necessary to elaborate upon just what is meant by the term multiple-competing hypotheses. Basically it refers to hypotheses which are constructed in such a way that if one is true then the other(s) must be false. It is, or should be, logically impossible for more than one hypothesis to be correct. For example in the discussions that were held regarding the shape of the earth one might have come up with the following hypotheses:

(I)
H_1: The world is spherical in shape.
H_2: The world is flat and two demensional in shape.

One could come up with more but the point can be made easily with these two. If H_1 is found to be highly confirmed then H_2 must necessarily be false; it is logically impossible for the world to be both flat and spherical at the same time.

Another example might be developed from a political campaign. In 1972 a student could have developed several competing hypotheses regarding the nominee of the Democratic party:

(11)

H_1: Senator Humphrey will be the nominee of the Democratic party for President

H_2: Senator Jackson will be the nominee of the Democratic party for President

H_3: Senator McGovern will be the nominee of the Democratic party for President

H_4: Senator Muskie will be the nominee of Democratic party for President

Still others might be added but these four will serve our purpose as examples. Namely, only one of the above can be true; and if one hypothesis is confirmed the others must be false. It is logically impossible for more than one to be confirmed.

This is quite different from simply stating a null hypothesis. A null hypotheses states that H_1 is false; it tells us nothing regarding the condition of the other hypotheses. In a multiple-competing-hypotheses model we are interested in the whole series of probable results and not in a single case. Returning to the example of the shape of the earth, a null hypothesis would simply state H_1 or not H_1. Testing would be done on the basis of seeking to disconfirm the null hypothesis, which in effect would confirm one's hypothesis. In the model being advocated one is dealing not with null hypotheses, but with <u>different</u> <u>competing</u> <u>hypotheses</u>. The major difference is that instead of working with only one hypotheses at a time, the students are working with several competing hypotheses. This is very significant for it puts the emphasis on the generation of <u>different</u> ideas, or solutions rather than on the seeking of a single possible solution to a given problem or question. In hypothetico-deduction the student has already committed himself, at least to some extent, with the formation of an hypothesis. In this new model the student must remain open to the existence of a large number of possible solutions to a problem. The process of inquiry quite simply is no longer centered around the goal of proving one's hypothesis.

Deducing The Consequences of Hypotheses

After the student has formulated as many possible competing hypotheses as he can, he is ready to begin the next stage in this inquiry model. The important thing is that this stage is a purely deductive one. When one uses the term deduction in education there is a need for explanation since in the past few years there has been some sort of holy connection between induction and the idea of good teaching. Indeed, good teaching and the term induction have become synonomous in many circles. This has meant that deduction has become a term synonomous with inferior, if not bad, teaching and this is most unfortunate. The important thing to remember is that a deductive argument is one in which the conclusion follows necessarily from the premises of the argument and at the same time is non-ampliative in nature.[34] In the arguments being constructed in this model the hypotheses become the premises and the conclusion of the argument is the consequent of the hypothesis.

It is from the hypothesis, which is but a tentative idea, and one which has not been justified in any way, that the conclusions or deductions are drawn.[35] Here one of the hypothesis formulated in the previous section is used as an example.

(I) The World is flat and two demensional
It is only possible to go from A to B in one direction.

The important thing here being that both arguments are deductions from the original hypotheses, and the conclusion follows logically from the premise or hypothesis.

Testing and Eliminating Hypotheses

After completing the deductive argument for each of the hypotheses the student is ready to begin testing his conclusions. Here is where the greatest break comes from the hypothetico-deductive model of inquiry, for rather than looking for confirming data the student must look for data which will prove his conclusion false. For instance in (I) above the student must prove that it is possible to go from point A to point B in opposite directions. If it is possible to prove this then the conclusion of (I) is rejected. At the same time the premise of the argument must also be rejected since in a deductive argument the truth of the conclusion is logically linked to the truth of the premise. At this point it is important to remember that the premise of the argument is also one of the several hypotheses we earlier formulated.

This idea of locating data which proves an hypothesis false is what separates this model from hypothetico-deduction. In the hypothetico-deductive model the student was only required to demonstrate that his hypothesis was a possible explanation and was supported by some data. Any classroom teacher can testify as to how these points were stretched in practice. That the process generally lacked a certain amount of rigor would be stating the case mildly. The only reason that most students had for rejecting their hypothesis in hypothetico-deduction was the persuasive force of the teacher's argument against it, which may have been augmented by the arguments of other students in the classroom.

The whole argument in hypothetico-deduction is based on the notion that some standard exists upon which knowledge, correct knowledge that is, is measured. It is also assumed that people, or investigators, will agree ultimately as to what this is. Campbell in his little book entitled What is Science discusses the idea that science is really that body of knowledge, or judgements, about which there is universal agreement.[36] A great many others would agree with his position, and indeed the definition does have some merit. The problem is that it describes a social convention agreed to by scientists; and as a group of individuals they are very demanding before admitting agreement with another person's, or even their own, judgement. This is part of the socialization process that one experiences in becoming a scientist. A process which students, needless to say, have not experienced.

Neither do students exhibit the friendly hostility that surrounds science. Science has what Jerome R. Ravetz calls a built in quality conrol mechanism.[37] Attempts have been made to duplicate this whole structure of norms, along with a system to distribute rewards and sanctions, in the classroom. No attempt really appears to have been successful. The basic problem is that the degree to which students require a fellow student to substantiate his hypotheses, has been vastly overrated. The process works rather well when one speaks of scientists — especially scientists who are seeking the same set of career rewards. The process does not work quite so well with students in the classroom. In an effort to turn students into junior scientists it seems to have been forgotten that they are not junior scientists. Students are not hostile towards each other in the same way that scientists are. (Anyone who doubts this hostility among scientists need only read The Double Helix and compare Watson, Crick, et. al to his own students.)

This lack of a structured social system regarding the testing of hypotheses, along with the reality of David Hume's critique of inductive reasoning means that some new method, other than proof, must be developed. The easiest procedure is to simply concentrate on disproof. Rather than having the student concentrate on what kind of information would prove an hypothesis correct the students should ask: "What kinds of data will prove an hypothesis false?" This is perhaps the greatest departure from the conventional model of inquiry. Whereas previously students were required to search out data which would support their hypothesis now the reverse is required: The student needs to locate data which will disprove the hypotheses.

The way one goes about this is to seek data which will invalidate the consequences formulated in the previous stage. For instance, in (I) if a student were able to locate data which demonstrates that it is possible to leave point B in opposite directions and still arrive at point A, he will then have proven the hypothesis false and have one less hypothesis or possibility to deal with. This continues until the student is left only with those hypotheses which cannot be disconfirmed. These hypotheses, or hypothesis, thus constitute a possible answer to the original problem. One can only have hypotheses which have not yet been disconfirmed. This is a crucial aspect of the model. It must be kept in mind that the entire basis for seeking resolution of the problem at this point does not center around problem resolution, but rather around hypothesis elimination. As one hypothesis after another is eliminated, the focus is concentrated on fewer and fewer possible explanations for the original problem.

This is an important part of the rationale for the use of multiple-competing - hypotheses. With this model correct answers, or even verified solutions, do not exist, at best what the student is left with are a set of hypotheses, or hypothesis, which he has been unable to refute. If two remain then there exist two tentative answers-both equally possible. This is designed to impress upon the students the tentative nature of knowledge. When the student had only one hypothesis it was always easy to simply intellectually accept the notion that one's conclusion was tentative but at the same time psychologically accept it rather firmly. Basically this psychological response allowed for one to avoid the logical problem. If, on the other hand, a student is confronted with two hypothesis that cannot be disproven, then it is almost impossible to admit to having solved the original problem in any final sort of way.

Actually one can never reach total confirmation with the hypothetico-deductive system of inquiry either, but this does not mean the students really accept the tentative nature of knowledge. It is simply too difficult a concept for many people, not only students, to accept. An elimination process is, by comparison, fairly straight forward. Thus, the elimination of hypotheses should have a fairly significant impact on the whole manner in the way a student reacts to the nature of knowledge. Rather than viewing knowledge as something which is fairly certain, or at best slightly tentative, he should come to view empirical knowledge as that which has not yet been proven false. The ubiquitus quest for certainty might come to be replaced by a more probing mind. No longer is it certainty that one is looking for; rather it is knowledge which can withstand repeated efforts to disprove it.

One of the major problems with falsification is that it is not as psycholically comforting as is proof. There is a feeling of achievement which exists with proof: A feeling that may not exist with a theory constructed around falsification. The problem is that one must choose between a theory of inquiry which is realistic and powerful or one which provides psychological satisfaction. Of course the choice is not really that simplistic but nonetheless one should not select a model of inquiry on the basis of the psychological comfort it gives to the user. One must select a model on the basis of how effective it is in helping the student acquire knowledge, and at the same time be prepared to reject or modify, previously acquired knowledge. "All acquired knowledge, all learning, consists of the modification (possibly the rejection) of some form of knowledge, or disposition, which was there previously. . ."[38] Thus the best pedagogical approach would be to select a model of inquiry which allows for the development of a skeptical attitude towards knowledge. If there is nothing like absolute certainty in knowledge, then it is best to prepare students for such uncertainty.

> Our propensity to look out for regularities, and to impose laws upon nature, leads to the psychological phenomenon of dogmatic thinking or, more generally dogmatic behavior: We expect regularities everywhere and attempt to find them even where there are none; events which do not yield to these attempts we are inclined to treat as a kind of 'background noise'; and we stick to our expectations even when they are inadequate and we ought to accept defeat.[39]

This is what falisfication is designed to battle against. The idea that things exist in a unchanging form with a binding set of relations is simply not true. Nonethless a dogmatic nature, or attitude, allows for the construction of just such a artifical world of certainty. This unrealistic conception of acquired knowledge is what must be balanced against the psychological discomfiture of falsification. Students should learn to live with uncertainty and the schools should foster programs which allow the students " . . . to invent and elaborate theories which are inconsistent with the accepted point of view, even if the lat er should happen to be highly confirmed and generally accepted."[40]

Another advantage of the multiple-competing hypotheses model being advocated here is the different demension such a model gives to the research effort. In hypothetico deduction the student is asked to locate data which would lend support to his hypothesis. This is very similar to the earlier example of asking a person to go out and locate unsolicited testimonials in favor of a new product. No matter how bad thd product is a couple of people can be found who think it is great. Likewise no matter how bad an hypothesis is students have always seemed to find some data which backed them up. In many ways this goes back to the earlier problem of cherishing an hypothesis more than researching it. It is simply too distressing to give up the only hypothesis that one has. It is preferable to locate some (any) reasons for believing that one has been correct all along rather than simply starting all over again. That students react this way should not be suprising - a great many scientists have done likewise. The point to keep in mind with a multiple-competing hypothesis - falsification model is that by eliminating an hypothesis the individual is actually making progress. Given the situation if A or B, and B is eliminated one only has A remaining as a plausible situation. Nothing is lost, rather something is gained. The choice of possible explanation has been narrowed. This is what is meant by reducing the range of possible alternative hypotheses. One is able to do this fairly easily because of the specific nature of the data necessary to disprove the hypothesis. With the older hypothetico-deductive style of inquiry one would merely attempt to locate information which would prove why the hypothesis would be corredt. This type of information is all too easy to locate. Thus, another problem with hypothetico-deduction is overcome with multiple-competing hypotheses.

SUMMARY

In positing this new model of inquiry the assumption been made that a pedagogical inquiry model need not necessarily be an accurate reflection of scientific inquiry. Basically we require different things of the different models. In a pedagogical model we must expect two things of the model: First, it should encourage students to make bold conjectures. Secondly, it should also encourage students to severly test these same conjectures. To the extent which any model does this better than the traditional hypothetico-deductive one, it is the model of choice for school settings. An argument might be made that these two criteria would also hold for a scientific model of inquiry, and indeed it may be true, but a full consideration of this issue would add considerable length to a paper that perhaps is already too long. The argument here is basically that a multiple-competing hypotheses model will allow for bolder conjectures and more severe testing of these conjectures than does hypothetico-deduction. To the extent which this is true then this new model is an advance.

FOOTNOTES

[1]Morton White, Science and Sentiment in America: Philosophical Thought from Jonathan Edwards to John Dewey, (New York: Oxford Univ. Press, 1972), p. 286.

[2]Noretta Koetge, "Towards an Integration of Content and Method in the Science Curriculum," (mimeo, 1968). In this very interesting paper Dr. Koertge raises the question as to whether one can design a theory of pedogogic order; i.e., a theory which will consider the order and manner of presentation of science and which will make full use of the logical and epistemological features of science. Essentially the problem one encounters is that there is very little in the way of guidelines for the structure of a logical curriculum outside of the slogans about the scientific method, which as we shall later attempt to show, is not always thought of as logical process, especially the process of hypothesis formation.

[3]In Logic: The Theory of Inquiry, (New York, Henry Holt and Co., 1938) Dewey writes that "this formulation agrees up to a certain point with current statements about scientific inquiry as hypothetical-deductive in nature. But it emphasizes two necessary conditions which are usually slurred in statements of that position: (1) the necessity of observational determinations in order to indicate a relevant hypothesis, and (2) the necessity of existential operational application of the hypothesis in order to institute existential materials capable of testing the hypothesis." (pp. 427-428).

Dewey's first point is well taken if one agrees that hypothetico-deduction is an accurate description of the way science gets done. The problem is though, as Masterman points out, that a hypothetico-deductive system is basically a problem-solving artifact.

[4]One of the few who have been able to bridge this gap between the technical philosophers and the educationists is Professor Scriven. His impact in education is minimal though since he has not engaged in much of the daily work of the teacher, nor does he appear to exhibit the reformer zeal of John Dewey.

[5]Arthur Pap in An Introduction to the Philosophy of Science, (New York: Free Press of Glencoe, 1962) pointed out ". . . that most philosophers nowadays are almost as ignorant of science as most scientists are of philosophy." (p. 4) The two groups seem to operate in worlds which are separate from one another in every way possible. As far as the scientist is concerned though his primary task ". . . is not to reflect upon his own scientific activities, but to perform them. His primary interest is in the investigation of his subject-matter, and theories of the methods of discovery and principles of argument are the work of the philosopher and logican." Errol E. Harris, Hypothesis and Prediction: The Roots of Scientific Method, (New York: The Humanities Press, Inc., 1970, p. 20. This does not really answer the question though as to what the relationship between the philosopher

and scientist ought to be; at best it gives the scientist a rationalization for being uninformed about philosophy. According to Harris's view a scientist could be forever uninformed about theoretical flaws in science because he would be so involved in his empirical studies. Thus, Harris tells us only why a situation exists, and not a very profound reason at that. Bergmann in Philosophy of Science, (Madison, Wisc.: Univ. of Wisconson, 1957), offers a rational for the existence of philosophy of science by pointing out that the analyst can keep the scientist "out of the dead alleys of intellectual confusion." (p. 10) The problem still remains as to how they will notify each other upon approaching this alley. The problem is that scientists try to make interesting deductions, /and/ philosophers of science describe the role deduction plays in science." (p. 10) Thus Bergmann has philosophers watching scientists, but he does not have scientists paying much attention to philosophers. One is only left to wonder how significant the most brilliant insight into science is if no one is paying any attention to it.

It might be best to simply admit that philosophy ". . . has become a special science itself which is more spearated from mathematics, physics, biology, etc. than these branches are separated from themselves.", Philipp Frank, "Science Teaching and the Humanities," Synthese, Vol. 6, p. 391. Actually the problem is that there are very few philosophers of science who are themselves interested in filling this gap. Ronald N. Giere, "The Structure, Growth and Application of Scientific Knowledge," Boston Studies in the Philosophy of Science Vol. VIII, edited by Roger C. Buck and Robert S. Cohen, (Dordrecht-Holland: D.Reidel Publ. Co., 1971).

[6] Stephen Toulmin in Human Understanding, Vol. I, (Princeton: Princeton Univ. Press. 1972), p. 4, points out that " . . . any excessive separation between the theory of knowledge and the knowers should prompt us to ask "Are scientists becoming unreflective? Or are philosophers losing their sense of relevance.?"

[7] Abraham, Kaplan, The Conduct of Inquiry: Methodology for Behavioral Science, (Scranton, Pa.: Chandler Pub. Co., 1964), pp. 3-11.

[8] Bernice, Goldmark, Social Studies: A Method of Inquiry, (Belmont, Calif.: Wadsworth Pub. Co., Inc., 1968), p. 2.

[9] Byron G. Massialas, and C. Benjamin Cox, Inquiry in Social Studies, (N.Y.: McGraw-Hill Book Co., 1966), p. 91.

[10] Robert H. Ennis, Logic in Teaching, (Englewood Cliffs, N.J. Prentice-Hall, Inc., 1969), p. 436. This offers a set of criteria for judging explanatory conclusions. A more ambitious project may be found in "A Concept of Critical Thinking," Harvard Educational Review, 32 (1) (Winter, 1962), p. 91, by the same author.

[11] Wesley C. Salmon, "Baye's Theorem and the History of Science." Minnesota Studies in the Philosophy of Science, Vol. V., (ed.) Roger H. Stuewer and Wesley C. Salmon, (Minn, Minn.: Univ. of Minn. Press, 1970), p. 75. "According to this view / Hypothetico-Deduction/, a scientific hypothesis is tested by deducing observational consequences from it, and seeing whether these consequences actually do transpire."

The interesting feature here is that there appears to be a relatively simple way of checking for the truth of such an hypothesis - simply compare it to nature. As Braithwaite writes: "Man proposes a system of hypotheses: Nature disposes of its truth or falsity. Man invents a scientific system, and then discovers whether or not it accords with observed fact." Richard Bevan Braithwaite, Scientific Explanation: A Study of the Function of Theory, Probability and Law in Science, (Cambridge: Cambridge University Press, 1953), p. 368. The problem lies with the assumption that an objective reality exists. A great many of the more recent arguments deny the existence of such an objective reality. Another possibility is to assume that a previously structured science is already in existence and work on that basis. Richard J. Blackwell, Discovery in the Physical Sciences, (Notre Dames: Univ. of Notre Dame Press, 1969), p. 7.

[12] Braithwaite, Scientific Explanation, "Thus, the empirical evidence of its instances never proves the hypothesis: in suitable cases we may say that it established the hypothesis, meaning by this that the evidence makes it reasonable to accept the hypothesis; but it never proves the hypothesis in the sense that the hypothesis is a logical consequence of the evidence." (p. 14).

[13] Nelson Goodman, Problems and Projects, (New York: The Bobbs-Merrill Co., Inc., 1972), p. 371.

[14] David Hume, An Inquiry Concerning Human Understanding, Part IV, (Harvard Classics: New York: P.F. Collier and Son Corp., 1910), p. 316 - 317.

[15] Wesley C. Salmon, The Foundations of Scientific Practice, (Pittsburgh: Univ. of Pittsburgh Press, 1967. pp. 6-7.

[16] Norwood Russell Hanson. "The Idea of A Logic of Discovery," What I believe and Other Essays, (eds.) Stephen Toulmin and Harry Woolf, (Dordrecht, Holland: D. Reidel Publ. Co., 1971). "Contemporary logicians of science have described how one sets out reasons in support of an hypothesis once it is proposed. They have said almost nothing about the conceptual context within which such an hypothesis is initially proposed." (p. 288, emphasis in the original text) This essay originally appeared in Dialogue, Vol. 4, (1965), pp. 48-61, under the same title.

[17]Ronald A.M. Trickler, The Assessment of Scientific Speculation, (New York: American Elsevier Pub. Co., 1965), p. 8.

[18]Errol E. Harris, Hypothesis and Prediction: The Roots of Scientific Method, (New York: Humanities Press, Inc., 1970) p. 202.

[19]John Dewey, How We Think, (Boston: D.C. Heath add Co., 1933), p. 109.

[20]Trickler, The Assessment of Scientific Speculation, p. 87.

[21]Karl R. Popper, Conjectures and Refutations:The Growth of Scientific Knowledge, (2nd Ed.) (New York: Harper and Row, Pub., Inc., 1965), p. 36.

[22]Thomas S. Kuhn, The Structure of Scientific Revolutions, (2nd Ed.), (Chicago: The Univ. of Chicago Press, 1970), pp. 36-37. ". . . one of the things a scientific community acquires with a paradigm is a criterion for choosing problems, that while the paradigm is taken for granted, can be assumed to have solutions." (p. 37).

[23]Dewey, Logic: The Theory of Inquiry, pp. 104-105.

[24]Along this same line it is interesting to note that Dewey's definition of inquiry admits only of successful inquiries. In Logic: The Theory of Inquiry he defines inquiry as ". . . the controled or directed transformation of an indeterminate situation into one that is so determinate in its distinctions and relations as to convert the elements of the original situation into a unified whole." No mention is made of the situation where an individual is not able to convert the elements into a whole indeed in a strict sense one would be forced to hold that such an activity is not inquiry. This peculiar feature of Dewey's definition of inquiry has received little attention in the literature which is peculiar, for I suspect that more student inquiries culminate in failure than in success.

[25]N.R. Hanson, "The Logic of Discovery," The Journal of Philosophy, Vol. LV (25), p. 1074.

[26]Ibid, p. 1077.

[27]Ibid.

[28]Ibid.

[29]Hanson, "The Idea of A Logic of Discovery," p. 300.

Hunt and Metcalf in Teaching High School Social Studies: Problems in Reflective, Thinking and Social Understanding (2nd ed.) (New York: Harper and Row, Publishers, 1968), offer what they call The Rule of Simplicity. At first glance this appears to be very similar to Hanson's idea of simplicity as a guide to hypotheses formation. Actually though it is quite different. Hunt and Metcalf use s . . l[illegible] as a rule to follow when one has two alternative hypotheses to select from. If two such hypotheses explain the same facts then one should choose thesimpler one. This is quite different from attempting to conceptualize the simplest possible solution to the problem. Hunt and Metcalf already assume that their hypotheses have been discovered before they utilize the rule of simplicity whereas what is advocated in this paper is that simplicity be used as a guide in forming hypotheses, not eliminating them.

[30] Dewey, How We Think, p. 109.

[31] Hunt and Metcalf, Teaching High School Social Studies, p. 68.

[32] Ibid.

[33] K.R. Popper, Objective Knowledge: An Evolutionary Approach (New York: Oxford Univ. Press, 1972), p. 71.

[34] Richard F. Newton, "Induction in the New Social Studies," Theory and Research in Social Education, Vol. I, No. 1.

[35] K.R. Popper, The Logic of Scientific Discovery, p. 32.

[36] Norman Campbell. What is Science? (New York: Dover Publications, Inc., 1953), p. 27.

[37] Jerome R. Ravetz, Scientific Knowledge and its Social Problems, (New York: Oxford Univ. Press, 1971).

[38] K.R. Popper, Objective Knowledge: An Evolutionary Approach (New York: Oxford Univ. Press, 1972), p. 43.

[39] K.R. Popper, Conjectures and Refutations: The Growth of Scientific Knowledge, (2nd ed.), (New York: Harper and Row, Pub., Inc., 1965), p. 49.

[40] Paul K. Feyerabend, "Against Method: Outline of an Anarchistic Theory of Knowledge, Minnesota Studies in the Philosophy of Science, Vol. IV, (eds) Michael Randner and Stephen Winokur, (Minn., Minn.: Univ. of Minn. Press, 1970), p. 26.