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ABSTRACT

Video tapes of student teachers micro-teaching in a high school biology class were analyzed. Attention was focussed on students' interpretations of data and the teacher's responses to these interpretations. Examples are given of student explanations which teachers find unsatisfactory but which are valid alternatives based on the data available to students. This problem is discussed in relation to the history of science and the teacher's own theoretical background. It is suggested that some forms of guided inquiry in the classroom may prevent students from understanding how knowledge is acquired. (EB)

Alternate Theory Formation By Students

R. Keith Hanson

This report considers the interaction of student teachers and students in inquiry sessions. In doing so, it also examines the relationship of the student teacher to his knowledge, and contrasts this relationship with that of the student and his knowledge. This study was descriptive and was based on video recordings of micro-teaching sessions and interviews with those involved in the study. The student teachers in the study were seniors that were enrolled in a science methods course at the University of Illinois in the Spring of 1969. The students in the study were high school freshmen at the University High School of the University of Illinois Curriculum Laboratory. The specific interactions that were studied were those in which students posited explanations for data provided by the teacher. Those explanations that were contrary to what the teacher held to be appropriate or unacceptable are termed alternate theories and were the focus of the study (Fig. 1).

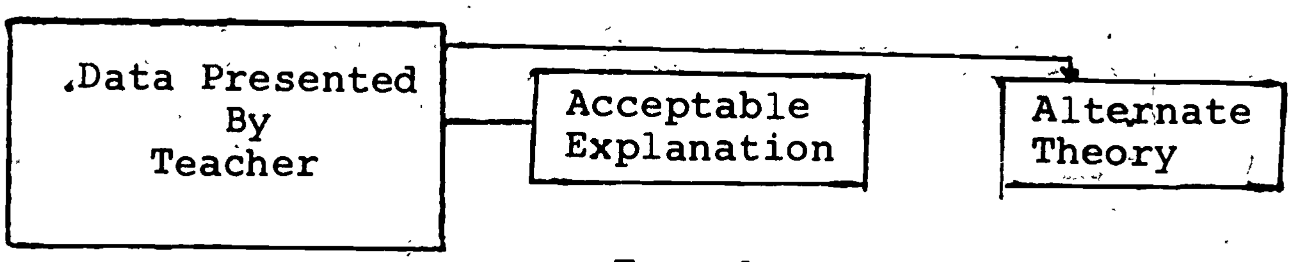

Fig. 1

The importance of alternate theories in the classroom is easy to overlook, but the importance of these theories cannot long be ignored when we examine the role that alternate theories have played in the development of science. We must also consider them when we realize that they play an important role in the development of knowledge in the individual. I want to consider first how alternate theories have influenced the development of scientific knowledge and then consider how they influence the developing knowledge of the individual.

In The Structure of Scientific Revolutions, T. S. Kuhn holds that science develops by revolutions in thinking rather than by accretions of knowledge that produce a continuous growth of knowledge. Figure 2 is a schematic that illustrates this belief. Kuhn notes that scientists are guided by a paradigm or model that

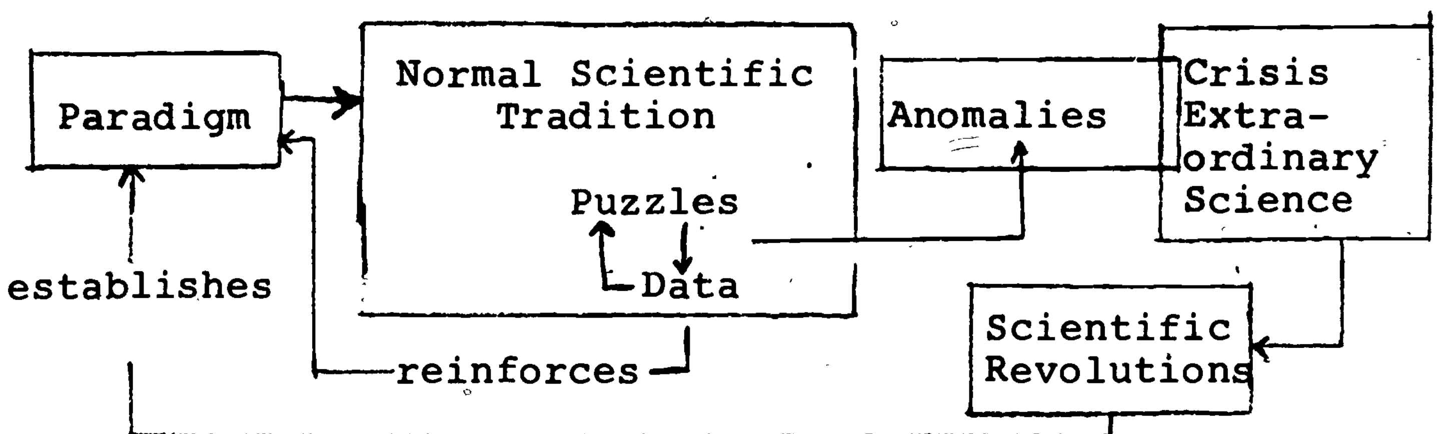

Fig. 2

allows them to practice puzzle solving in a normal scientific tradition. The puzzle solving that scientists engage in produces data that reinforces and refines the paradigm that guides the scientific community in its work. However, there are data that do not fit the puzzle solving behavior and the guiding paradigm. These are anomalies that, when they are few in number, are ignored. However, when the number of anomalies is greater than the number of successes they can no longer be ignored. The paradigm that guides normal scientific work fails, and scientists look for another or an alternate model or paradigm that will solve the anomalies and will also establish anew the normal scientific tradition guided by a paradigm. A scientific revolution produces a new way of looking at the world. The Coperican theory replaced Ptolemaic theory. In doing so, one view replaced another. Pasteur's vitalistic view of life replaced the view of spontaneous generation. In doing so, scientists were able to incorporate the older data into the new way of looking at the world with new kinds of data they could now find. They could also fit anomalies into the new system. Note, however,the new system is not the result of a gradual accumulation of knowledge. Some concepts are done away with. When Harvey postulated his view of blood circulation, some terms did not become modified and incorporated into the new theory. As examples, consider how pneuma, vital spirits, or natural spirits of the pneumatic theory were modified. The answer is, they weren't. The new conception of blood circulation did not require the explanatory power of these terms so they disappeared. The term cell that Hooke applied to cork was incorporated into cell theory. However, the term in the new theoretical framework of cell theory did not have the same meaning that it did originally.

In a similar manner, alternate theories arise in the classroom. However, they do not have the same effect on the classroom as alternate theories have in science. Neither the students nor the student teachers recognize the theories that the students advance as alternate theories. Since the students are engaged in inquiry, they posit what they feel is a reasonable explanation, and don't consider it to be an alternate theory. Teachers may recognize the alternatives as hindrances to making progress toward the accepted answer, and, hence attempt to avoid or suppress them. There are at least two reasons that teachers don't recognize alternate theories arising in the classroom as worthy of attention. First their training in the sciences obscures their recognition of the role of alternate theories in the advancement of science. The "history of science" that they are taught gives an impression of a continuity that Kuhn notes "never existed". The second major problem associated with non-recognition of the worth of alternate theories by teachers is that they have been taught unknowingly to thwart any deviation that could lead to a different answer than the accepted answer. The science that is taught by student teachers is the established normal science that reinforces the currently accepted model. Most teachers have never experienced a scientific revolution - even vicariously. They grow up with a paradigm and don't recognize the potency of other models.

Let us examine some alternate theories that occurred in teaching episodes. By doing so, I will illustrate that the teacher's training in his major field and pedagogy prevent recognition of alternate theories. By implication, this will have relevance for teacher education. In the first episode T is the teacher, K and S are the students. I will discuss only one of these episodes.

The episode began with the students looking at different preparations of plant and animal cells. The teacher wants the students to notice the difference she feels is important. That difference is the presence of a cell wall in plants which is absent in animal cells. The teacher starts the discussion of the lab session:

T: Some are grouped closer together. Do you mean that they are closer, like this? [She makes a drawing of a brick-like wall.]

S: Yeh, and they [plant cells] are in columns and touching each other, but animal cells are moving around.

K: [Referring to plant cells] Specific pattern, they, that you reproduce the pattern.

Student S has made an elementary distinction between plants and animals. The teacher has missed the significance of this distinction here, and we will see it again in a moment. Student K is "playing the game" and trying to guess what the teacher feels the answer is. The teacher isn't satisfied with either answer.

T: Maybe you should look in your lab books; so while you are answering these questions . . . because, maybe you can look at the diagrams you've drawn and see more easily, more apparent differences. You notice anything else?

S: You couldn't see the internal structures as well as in the plant cells.

K: Oh, I know! Cell wall! I don't know if this is important, the plants are more defined, diagrammed.

T: Because they are more defined, what would you say about them?

K: Stronger

T: Now give me a couple of characteristics of animal cells.

K: Cell walls aren't as strong.

The teacher has discovered that the difference [cell walls] which is readily apparent through the microscope to her is not apparent. So she has the students turn to their books, hoping that the apparent difference will be recognized there. K, who was attempting to discover the correct answer, remembered that the text mentioned the "fact" of cell walls. [Notice that the fact came from a text.] The teacher then asks what "defined" means, and the student says it means strength. The student's answer is based on an assumption that does not come from the observation of data, namely, that plants are more rigid and less mobile than animals.

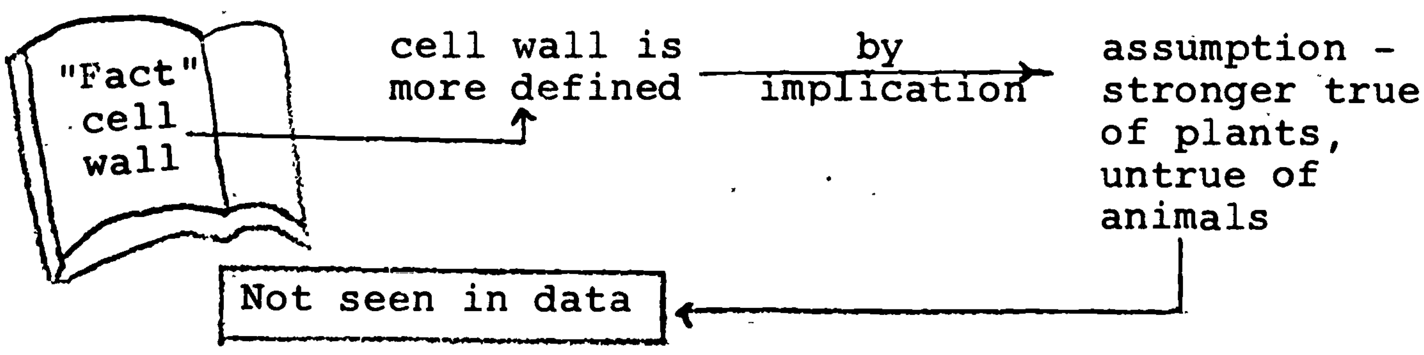

Fig. 3

I have said that the teacher missed student S's alternate theory in the two previous indications of it. Here it is more fully developed, and missed again.

S: [Referring to animal cells] Moved around freely. The ones we say weren't like the plant cells -- next to each other.

T: Some have movement. Chloroplasts . . . [The teacher was going on with her lesson.]

S: They don't need them because they are animals. Plant cells are producers and animals are consumers. [The plants] sat there, didn't eat or go after anything. Animal cells moved around.

T: [Then dropped the subject completely and went on with the lesson.]

I selected this episode because this alternate theory occurs rather commonly, and many in the audience have encountered it themselves. The episode illustrates how a teacher is able to see things students cannot see. The diagram below lists the various preparations that the students had observed.

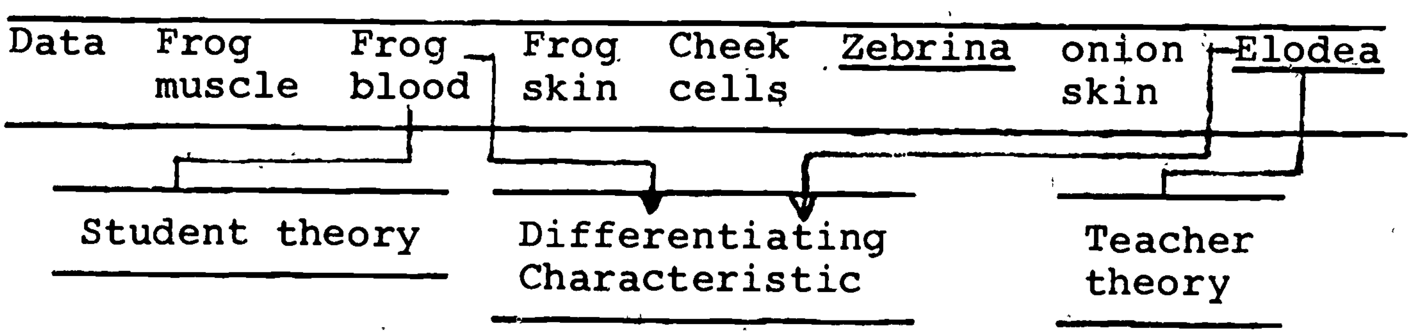

Fig. 4

It was primarily her observation of thick cell walls in *Elodea* which reinforced, for the teacher, her generalization about the principal difference between plants and animals. The training that enables the teacher to "observe" the *Elodea* cell walls is her theory base. Cell walls are otherwise not very obvious. Changes in the focus of the microscope can vary the apparent thickness of the cell walls. The student was also able to generalize. The apparent difference that she could "see" was the movement of one kind of cell.

Notice that the teacher didn't even realize that the student had posited an alternate theory. Instead she started to ask the students about chloroplasts, and the student didn't realize that the student teacher was changing the subject. The student took the term "chloroplasts" as stimulus to develop her theory further. Because the animals were consumers they didn't need chloroplasts. This all left the student teacher puzzled. She reported afterwards that she didn't see how the student could get to such a conclusion from the data she had.

In this second episode, the student was able to advance an alternate theory that is wrong, but for the right reasons. The theory is wrong in the sense it is not acceptable to the teacher. T is the teacher, K and S are the students.

T: Two substances in protoplasm. [Can you name them?]

K: Proteins and sugars.

T: S, [Can you think of any?]

S: Carbohydrates.

K: I can give two more . . . starches and fats.

T: By looking at those substances, do you think it would be safe to assume that protoplasm would be [useful] to a cell for food or nutrition?

The teacher attempted to establish a function for the protoplasm. She pointed out that there are various food substances in the protoplasm and asked what they could be doing for the cell.

K: Provides energy.

S: Provides or gets it from the outside? [S is asking K]

K: Provides itself.

S: Gets it.

The two students had a disagreement, but K closed off the discussion by providing an alternate theory to explain the function of protoplasm.

K: It feeds them nucleus. When they took these cells and clomped them. [She is referring to an earlier inquiry that involved the cutting of cells, so that one half had a nucleus, and the other half didn't have a nucleus.] Protoplasm can't feed itself, but the nucleus had some . . . a bit . . . . [the] protoplasm could feed the nucleus and it divided.

T: That's partially true . . . but . . . remember . . . .

The student gave what we would call a teleological explanation. The teacher was not satisfied, but it is apparent that the student formed a "wrong" conclusion for an earlier inquiry and now applied that conclusion to a new situation. This is an example of arriving at the wrong answer for the "right" reasons.

In this third episode, the student advanced an alternate theory that is also one that is an historical theory. The student applied it to the situation that they tried to find a solution for. T is the teacher, C and K are the students.

T: Where does the leaf get its water? And its food?

C: From the roots and the water goes up in the plants.

T: The water goes up into the plants from the roots?

C: I guess.

T: How do you know?

C: I don't know, I just guessed.

T: Do you know that? How do you know that the water is coming up?

C: Well, you irrigate crops. The water always sinks down, and the roots get all the water . . . and it waters the rest of the plant.

The teacher established that there was movement of water. She pressed the student for an answer. She then asked why does it move?

C: Well, it just goes up.

T: Why does it go up?

K: Well, there are these special kinds of veins. I never remember the difference there either. They are either xylem or phloem, and one brings the water and everything up, and one brings it down after it . . . [she is interrupted by C and her alternate theory.]

C: A plant breathes! A plant breathes!!

T: [Very surprised] How does it breathe? Does it have lungs?

C: No! No! See! Well, I don't know how it would breathe, but when it breathes . . the water comes up . . and it is just like in any body, when you breathe blood goes up, it _just has to_!

T: The blood goes up when you breathe?

K: The heart's pumping it.

C: [The breathing] Still has some force.

K: Your breathing isn't bringing . . . when you breathe in, the blood doesn't come up, and when you breathe out, [the blood] it doesn't come down.

C: Something like that.

This alternate theory was one that the student brought to class. It was one that she felt explained blood circulation. She then applied it to a plant's "circulation." It is interesting to note that this theory is one similar to the one that was replaced by Harvey's concept of blood circulation. It is also interesting, to me anyway, that many students apparently have held this same view of blood circulation. They held this view in spite of the "fact" they have been taught the currently accepted view of blood circulation.

I have collected several dozen episodes that have alternate theories in them. All of them show that the data presented to the students can lead to conclusions very different from those we would like students to reach. They also raise a very serious problem associated with inquiry teaching. It may not be possible to get to the intended concepts or theory without already knowing the theory. Any attempts to guide the student to the concept or theory, no matter how slowly, may be dishonest inquiry. I feel that recognition of alternate theories points out the need for research in two areas. The first area is in typical student concepts. What do students think the data leads to? What theories could the students develop? From this would it be possible, by inquiry to reach the currently accepted explanations? A second important area of research would be in the training of student teachers. Inquiries in science are developed by people who already know the theory. If, for most teachers, the data lead to the theory, how can this erroneous view of science be prevented or corrected? Can we in fact develop a theory about alternate theories? The difficulty is that assumptions derived from theory help advanced students see the data-to-theory relationship. The beginning student doesn't see the same relationship, and attempts by teachers at inquiry teaching can be viewed by students as dishonest.

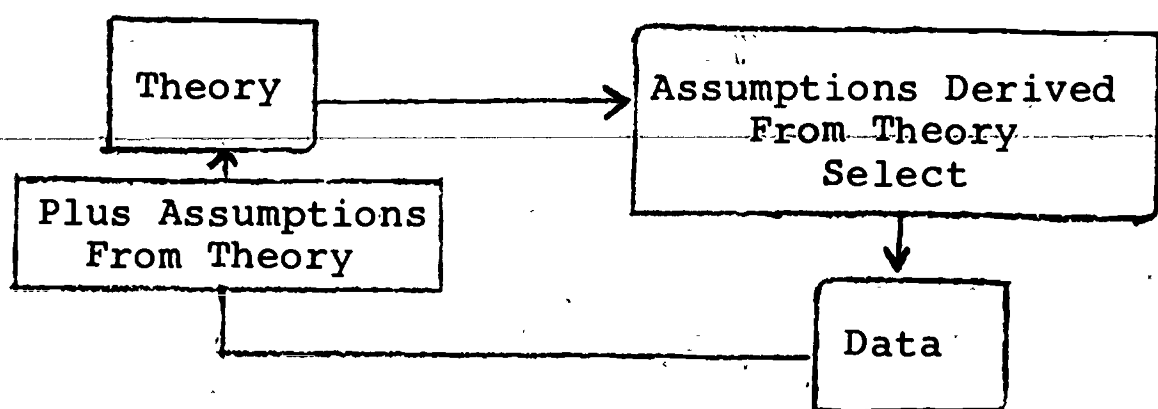

Fig. 5

If student teachers can be trained to recognize that their data-to-theory relationship isn't obvious to the student and that the student is able to give a different, logically consistent explanation to the data, then we have the way open to making inquiry inquiry. When the student inquires, he is intellectually transforming the world he sees. Piaget has noted that children do this all the time. He has illustrated how children are able to put different explanations onto the same data at different times. For them the systems they use to explain the world about them are logical. When a teacher guides the student and introduces information and ideas he knows from theory and demands the student use it, he is saying to the student, "to find the solution, use the solution."

My research serves to illustrate the existence of alternate theories but not to solve the problems they pose to the educator. They do pose problems. I would like to speculate on how teachers should deal with alternate theories. When the students examine the data, they should not be expected to be inductive. They can't get to the currently accepted answer. They should not be expected to be deductive either; inquiry doesn't proceed from theory - but retroductive; they should be problem solvers and users of heuristic. An original scientific inquiry, before it became an example used by teachers to teach students, succeeded because the investigator was able to generate a theory that was contrary, and thus alternative to, the then currently held beliefs. Investigating how he did this, and how can we teach students to do likewise may lie the solution to the problem presented by alternate theories.

This paper is based on thesis research that I conducted at the University of Illinois during the Spring semester, 1969. I wish to acknowledge the guidance and criticism of Professor John Easley in the preparation of this paper. The list of books is only a guide to the areas of reading that are incorporated into this paper. Most of the ideas in this paper are derived from these sources.

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