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ABSTRACT

An analysis of classroom discourse is reported in which the use of questions by science teachers is assessed in terms of arguments to establish knowledge claims. Questions are analyzed not for their form or frequency but for their function in the development of arguments which establish claims rationally. Seen in the context of rational argument, question sequences may be assessed as consistent with or distorting of the nature of scientific authority. The study seeks to develop and demonstrate a plausible conceptual linkage between a science teacher's use of questions to develop student understanding and the associated provision for students to understand scientific authority. Excerpts from three high school science lessons are analyzed in detail in the study, revealing three different and subtle ways in which the use of questions to develop a knowledge claim has failed to establish a rational argument. The study demonstrates that it is possible and informative to analyze science classroom discourse in terms of suggested attitudes toward authority. Use of the analytical scheme by science teachers wishing to review the use of questions in personal teaching behavior is also discussed. (Author/CS)

Analyzing Arguments in Classroom Discourse:

Can Teachers' Questions Distort Scientific Authority?

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Introduction

Typically, teaching involves the asking of extended sequences of questions (Bellack et al., 1966; Hoetker & Ahlbrand, 1969) which enable a teacher to control the direction and duration of subject-matter discussion, while also maintaining a necessary degree of attention and order (Westbury, 1973). Science teachers have been urged to consider the form of their questions (as in the contrast between convergent and divergent questions), and in general there has been considerable attention to questions as means of instruction. At the same time, science teachers stand before their students as representatives of the discipline of science and of the community of active scientists. Although the nature of explanatory change in science is certainly not agreed upon, there is definite reluctance to base authority in science upon the pronouncements of particular individuals. Instead, reasons and evidence support the explanatory conclusions of the discipline. As an end of science instruction we would have students view scientific authority in terms of reasons and evidence.

This paper reports an analysis of classroom discourse in which the use of questions by science teachers is assessed in terms of arguments to establish scientific knowledge claims. Questions are analyzed not for their form or frequency but for their function in the development of arguments which establish claims rationally. Seen in the context of rational argument, question sequences may be assessed as consistent with or distorting of the nature of scientific authority.

Purpose and Methodology

This study develops and demonstrates the potential of an analytical scheme which permits one to assess the attitude toward authority suggested by science teaching discourse. The particular focus is on making a comparison between teachers' questions within arguments and the attitude toward authority suggested by the argument itself. The form of questions (convergent-divergent; higher order) has been suggested as important in its own right. This study goes further, to consider the potential impact of the sequence of questions which guide consideration of a specific knowledge claim in science.

The methodology of the study involves two distinct stages. First, an appropriate analytical scheme is developed, drawing upon philosophical considerations relevant to the interest in attitudes toward authority suggested by arguments. Then the phenomena of interest--instances of science teaching--are analyzed according to the scheme. The results of the analysis speak both to the usefulness of the scheme and to the initial question--can teachers' questions distort scientific authority? (This methodology is discussed in Roberts and Russell, 1975, and illustrated by the studies reported in Munby, Orpwood, and Russell, 1980.)

The data analyzed in the study are verbatim transcripts of episodes from three high school science lessons. The issue considered in the study emerged as I reflected on some "disturbing" personal reactions to observation of twelve science lessons, including the three presented here. The analytical scheme is constructed primarily from the systematic philosophical work of Peters (1966, 1967) on attitudes toward authority, and Toulmin (1958) on the pattern of rational arguments. The analytical scheme specifies two conditions which must be met, for a teaching argument to suggest to students that scientific authority is rational.

1. All elements of a rational argument must be present in the instructional discourse.

2. The elements of the argument must be in proper relationship to each other.

Argument elements and their proper relationships are those specified by Toulmin (1958). Failure to satisfy these two conditions entails a judgment that an argument's sequence of questions could suggest a distorted image of authority in science.

At first glance, the use of questions by teachers seems both appropriate and straightforward, and the teacher's challenge is to develop and maintain competence in the use of questions. To show that the matter may deserve more attention, I like to set beside each other the titles of two papers published in the same year.

> "Using Questions to Enhance Classroom Learning" (Napell, 1978)
> "Using Questions to Depress Student Thought" (Dillon, 1978)

Napell's (1978) argument, richly illustrated with examples of questions, is a positive one, encouraging teachers to reflect on questioning patterns which may need to be reduced or increased. "We teachers are charged with difficult tasks, not the least of which are modeling learning behavior and encouraging the development of intellectual independence and a positive self-image in students" (p. 197). Dillon (1978) is much more analytical, in a review of theory, pedagogy, and research related to the use of questions. His conclusion (pp. 60-61) presents a challenge to researchers.

> Whether teacher questions stimulate student thought or whether they depress it, I do not yet know. I have come to favor the second view but look to scholarly advocates to trenchantly confute and elegantly articulate either position. For, in examining the immense educational literature on questions, I am most struck by what I perceive as conceptual fastness. Newly focused rather than merely increased inquiry into the effect of questions would soon bring to surer ground the place that they now uncritically enjoy, so it seems, in all major sectors of the enterprise.

This study provides a new perspective on the study of questions, by developing the position that arguments are an appropriate unit of analysis and that suggested attitude toward authority is a significant issue in considering the effects of questions.

The study is reported in three sections. Attitudes toward science, scientific authority, and authority in education, are considered first, to develop the context and theoretical concerns of the study. Peters' (1966, 1967) analyses of authority in education are considered in detail. The second section of the argument is the data analysis, beginning with an account of Toulmin's work, which makes it possible to conduct the analysis. Minimal commentary is provided with the analysis of three episodes of science teaching, to give the reader an opportunity to react personally to the perspective on science teaching provided by the analytical procedure. In the third section, each episode is discussed and a judgment is reached about suggested attitude toward authority. The analytical scheme is shown to be applicable, and the implications of the results are explored.

Educational Authority and Its Implications for Attitudes toward Science

This study addresses the possibility that a teacher's use of questions and other strategies for presenting the subject matter of science may distort students' understanding of scientific authority. The argument and evidence presented do not address the actual effects of science teaching on students. The intent is to make a plausible case for a possible effect, by demonstrating a rigorous procedure for analyzing arguments to infer a suggested attitude toward authority.

Authority in education

Drawing upon Weber's analysis of three different authority systems--legal-rational, traditional, and charismatic--Peters (1967) sees a fundamental distinction between rational and traditional "attitudes toward authority." The distinction is comparable to that between "having good reasons" and "taking someone else's word" (pp. 13-24). Applying his analysis of authority to current issues in education, Peters argues that the manner in which a teacher passes on "traditions, skills, and information" has direct consequences for how students come to regard these (pp. 96-107). As an ideal, rational rather than traditional authority is seen as more desirable and appropriate in Western education. This position, stressing the importance of reasons in teaching, is familiar in philosophical discussions. Komisar (1968) argues that teaching, in its strictest sense, is an activity which seeks to achieve students' awareness of a point by the explicit provision of reasons which support and establish the point. Green (1971) argues that "instruction" attempts to establish beliefs that are held on the basis of reasons and evidence, while "indoctrination" is concerned not with the basis but with the content of the beliefs it attempts to establish.

Peters (1966) sees the teacher as an authority figure in two distinct senses: in authority to do a certain job, and an authority on some aspect of the culture of the community (p. 240). These two senses of authority are quite different in kind. Being an authority refers to a teacher's knowledge, while being in authority refers to a teacher's position. Peters notes that knowledge requires supporting reasons and public procedures for testing them, and it does not depend "upon the appeal to particular men" (p. 251). Briefly, then, a teacher is an authority in authority.

The teacher's authority of knowledge is fundamental. Typically, we do not appoint, and thereby confer authority of position upon, individuals who cannot present evidence of a specified level of knowledge (however inadequately it may be measured by university course credits). This conforms to our educational philosophy which would have students acquire knowledge on the basis of reasons and develop a rational attitude toward authority. It is a teacher's knowledge as an authority in a subject which permits the giving of reasons to one's statements, and rational authority to one's arguments. For purposes of this study it is essential to recognize that a teacher's position in authority makes it possible to present knowledge claims without reasons. A teacher's authority of position seems necessary to maintain or manage a classroom learning situation. Unintentionally and unknowingly, the same authority of position may be used by a teacher to "support" knowledge claims. Substituting authority of position for authority of knowledge requires students to change beliefs by taking someone else's word for them, rather than by having reasons and evidence for the beliefs. Instructional moves based on the authority of one's position are regarded here as suggesting to students a traditional attitude to authority.

Implications for attitudes toward science

The literature on attitudes toward science is substantial, complex, and problematic. Research (Mead & Métraux, 1957; Shallis & Hills, 1975) has shown that actual attitudes may be a mixture of positive, negative, and neutral elements. I have argued recently (Russell, 1981) that attitudes toward science can be influenced positively by science teachers, but not by half-hearted, casual efforts which fail to consider the messages about science which students encounter outside the classroom.

Students' understanding of authority in science is one significant element of their potential knowledge about science and attitudes toward science. If students believe scientific knowledge is established, even in part, by the personal authority of the individual scientist, then their beliefs run counter to the ideal toward which practicing scientists are said to strive. If students are not given opportunities to judge scientific knowledge claims in the light of reasons and evidence but instead are required to accept claims on the personal authority of the science teacher, then they could develop a negative image of scientific authority. (Recall how easy it is, in everyday conversation, to express an inability to understand science as a positive, desirable attribute.)

To summarize, then, there are several reasons for teaching science in ways which suggest a rational, rather than a traditional, attitude toward authority. One is the reason of accuracy, encouraging students to view scientific authority as scientists do. Another reason emerges from the Western ideal of rationality, which leads us to reject procedures which could be viewed as indoctrinating. Yet another reason arises from our desire to encourage positive attitudes toward science.

At the same time, however, the preceding analysis of authority recognizes the possibility that knowledge claims may be presented on the authority of the teacher's position. Management of many children in the same classroom requires a teacher to assert such authority. Perhaps the socialization goals of teachers, identified in the Case Studies in Science Education (Stake & Easley, 1978), also require the authority of the teacher's position. As well, the teacher typically makes a variety of decisions about how classroom interaction will proceed, and students' recognition of the teacher's right, or duty, to make such decisions is a recognition of the teacher's authority of position.

Analysis of Argument-Patterns in Three Episodes of Science Teaching

In science teaching judged to suggest a rational attitude toward authority, we would expect to find reasons and evidence being provided in support of knowledge claims. Yet the presence or absence of reasons and evidence is not an adequate criterion for the judgment desired. We need to determine whether reasons and evidence are used in a manner which provides a complete rational argument for the knowledge claim being presented. A suitable scheme, capable of serving as a "clue structure" for making the desired judgments about instances of science teaching, is provided by Toulmin (1958) in The Uses of Argument. In his introduction, Toulmin indicates that the book is an attempt "to characterise what may be called 'the rational process', the procedures and categories by using which claims-in-general can be argued for and settled" (p. 7). Using the field of jurisprudence to guide his consideration of rational arguments in general, Toulmin develops a framework in response to the problem of "how we are to set out and analyse arguments in order that our assessments shall be logically candid--in order, that is, to make clear the functions of the different propositions invoked in the course of an argument and the relevance of the different sorts of criticism which can be directed against it" (p. 9).

A clue structure for analyzing arguments

Specifically, Toulmin provides a "pattern" for the analysis of arguments. The pattern indicates six possible elements of an argument and their proper relationship to each other. The three most basic elements are Data, Conclusion (or claim), and Warrant. (Capitalization of first letters indicates use of terms in the sense given them by Toulmin.) A Warrant is a statement which justifies the move from Data to Conclusion. Thus a Warrant says, "Given Data D, one may take it that C" (p. 98). Toulmin (p. 99) provides this diagram to illustrate.

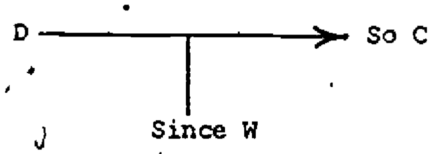

Figure 1. The basic argument-pattern.

Three additional elements--Qualifiers, conditions of Rebuttal, and Backing--complete the argument pattern which Toulmin develops. Qualifiers indicate the degree of force with which the Data support the Conclusion, as when a Conclusion is only probable, rather than necessary, given the available Data. Conditions of Rebuttal consist of special circumstances in which the Warrant in question may not apply. Finally, Backing refers to the general conditions which support the acceptability or authority of a Warrant (pp. 101-103). Thus the complete argument pattern is represented by Toulmin (p. 104) in the following diagram.

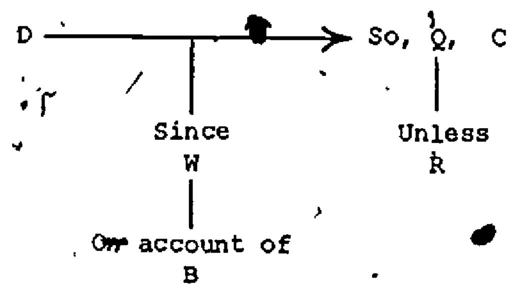

Figure 2. The complete argument-pattern.

To illustrate the terms used by Toulmin, Figure 3 shows the pattern of the complete argument under discussion in Segment A-1, in the data analysis which follows. The teacher seeks an explanation for the acquisition of electrons by ebonite rubbed with wool. Notice that presentation of the argument does not require use of the elements Qualifier or conditions of Rebuttal. This is frequently the case in the analyses which follow. In this particular instance, a Qualifier might refer to the effect of humidity on transfer of electrostatic charges.

Datum: *When ebonite is rubbed with wool* → So, **Conclusion:** *ebonite receives electrons from the wool, and thus acquires a negative charge*

Since

Warrant: *Ebonite attracts electrons more strongly than wool, when the two substances are rubbed together*

On account of

Backing: *The atomic model of matter indicates that electrons in the atom's outermost shell are somewhat free to move.*

Figure 3. The pattern of the argument in Segment A-1.

Toulmin's argument-pattern is well-suited to the analysis of arguments made within specific disciplines. The analyzed data which follow illustrate some of the intricacies involved in matching details of classroom discourse to the six elements suggested by Toulmin. However, two broad features of arguments which Toulmin notes in discussing his argument-pattern illustrate the specific suitability of the pattern to the analysis of arguments within scientific disciplines. In distinguishing between Warrant and Backing, Toulmin explains that the Backing usually remains implicit, at the outset and before a challenge of the argument is made. Backing refers to the facts which authorize the Warrant which permits an inference from Datum to Conclusion. Furthermore, the <u>kind</u> of Backing which can authorize a Warrant differs from one field of argument, or discipline, to another (pp. 103-106). Backing appears to capture the changes which occurred in physics, for example, when Einstein's theory of special relativity (a Warrant) superseded Newton's Laws by taking as fundamental a different set of "facts." Thus we may expect the element of Backing to be particularly significant when alternative explanations (or Warrants) are being considered.

Turning to a second broad feature of arguments, Toulmin notes that arguments may be "Warrant-using" (reaching a Conclusion from Data by citing a Warrant) or "Warrant-establishing" (demonstrating that a Warrant is successful for a number of instances of Datum and Conclusion). The distinction is comparable to that between deduction and induction (p. 120). Pedagogically, we can recognize here the distinction between explaining a law or theory in the first instance and subsequently using a law in problem-solving or laboratory activities. Once a Warrant has been established, its Backing is implicit in the use of the Warrant to reach Conclusions. We may expect Backing to play a more crucial role in establishing a Warrant than in using a Warrant.

Toulmin's argument-pattern gives valuable detail to the concept of a rational argument. For purposes of this study, suggesting a rational attitude toward authority is regarded as requiring provision of all the elements of an argument in proper relationship. Were the teacher only <u>an</u> authority, not <u>in</u> authority, students would have no basis for accepting an argument (for a Conclusion, or for a Warrant) if the teacher omitted an element or related elements incorrectly. When a complete and correct argument is not provided, the authority of a teacher's position may permit the lesson to proceed, at the price of suggesting a traditional attitude toward authority. In the analysis which follows, the concept of an argument-pattern is applied to determine whether a rational or a traditional attitude toward authority seems to be suggested to students. The attitude toward authority suggested by an argument is judged to be rational if two questions can be answered positively.

1. Are all necessary elements of a rational argument present in the instructional discourse?
2. Are the elements of the argument in proper relationship to each other?

Analysis of three episodes of science teaching

From an initial set of transcriptions of twelve science lessons recorded in Ontario secondary schools (for the purpose of another study), portions of three lessons have been selected for analysis. Episodes A, B, and C contain the arguments of three teachers on particular topics within the chosen lessons. Preliminary analysis separates each episode into segments containing only one argument, to which the concept of an argument-pattern may be applied. An individual segment is presented on a single page (or two pages if length requires). The left-hand column of each page presents the verbatim transcription of tape-recorded classroom discourse. Questions are shown in capital letters, to call attention to that aspect of a teacher's remarks which so often signals the direction of the discourse. The right-hand column, in italics, indicates what each successive speaker appears to be doing in terms of elements of an argument. For example, the teacher's first speech in Segment A-1 is described as "Teacher provides Data and solicits Conclusion."

Each episode is introduced by a single page which provides a summary of the content of the episode and the arguments conducted within individual segments. Only brief comments are made about the failure of each episode to present arguments suggesting a rational attitude toward authority. This is done to permit the reader to enter into the analysis of each segment's argument, studying each teacher's use of questions, and checking the identification of argument elements.

EPISODE A: "Predicting and Explaining Electrostatic Charges"

Grade 10 (eight girls, twelve boys)

Pages 1-4 of 24

In this episode, the teacher continues earlier work on static electricity. In Segment A-1, the teacher seeks a Warrant to explain why electrons move from wool to ebonite, when the two substances are rubbed together. Brad is unsuccessful (lines 13-19). Part of Mary Jo's response is accepted by the teacher (lines 35-45) and the teacher returns to Brad to explain his error. In Segment A-2, the teacher presents a list of non-conductors, including the two used in A-1. From the list (lines 72-74), one can predict the charges resulting when any two of the substances are rubbed together.

Segments A-3 and A-4 are two instances of application of the general Warrant given by the teacher in A-2. In each of these segments, the teacher first solicits a Conclusion and then solicits the Warrant supporting the Conclusion. (Interestingly, A-4 involves the same pair of substances as A-1.) Both A-3 and A-4 end not with elaboration of steps in the arguments but with attention to stating the Warrants in terms of "strength" of holding electrons.

Segment A-1: Seeking a specific Warrant for ebonite and wool

Teacher: Okay. We were talking about the electric charges on different kinds of objects. WHAT CHANGES TAKE PLACE IN AN EBONITE ROD WHEN IT'S RUBBED WITH WOOL? (Pause) Only two people? Dave.	*Teacher provides Data and solicits Conclusion*
Dave: Er, it received electrons from the wool.	*Conclusion*
Teacher: Right. It received electrons from the wool. Er, CAN YOU SUGGEST ANY REASONS WHY THE ELECTRONS MOVED FROM THE WOOL OVER ON TO THE EBONITE? Brad.	*Teacher judges Conclusion and solicits Warrant*
Brad: There's a shortage of electrons on the ebonite rod and there's a surplus on the wool, so they move to the greater...	*Student implies a Warrant that electrons move from surplus to shortage, as he states Conclusion*
Teacher: There's some people shaking their heads. Er, Gary, WOULD YOU DISAGREE WITH THAT?	*Conclusion is rejected*
Gary. Well it must be...the atoms on the wool...the electrons on it are... repelled from the nucleus, so they want to move...	*Student alludes to aspects of Backing for a Warrant*
Teacher: You people at the back hear? Cathy. Better repeat that Gary, please.	
Gary: Well the, the electrons in the wool like, they are far out from the nucleus so they have a tendency to move.	*Backing*
Teacher: Er, possibly. SOMEONE ELSE EXPLAIN WHY THE ELECTRONS MOVE FROM THE WOOL OVER ON TO THE EBONITE. Mary Jo.	*Teacher again solicits Warrant*
Mary Jo: Um, the ebonite rod has, er, like positives that have stronger pull on them. And, like the friction between them makes the positives attract more.	*Student provides two candidates for "Warrant" status*
Teacher: All right. Apparently, or possibly, the ebonite has a stronger attraction for electrons than the wool, so that when we rub the two together the electrons move from one over on to the other. Okay Brad? GOING TO CHANGE YOUR THEORY?	*Teacher repeats one aspect of the student's Warrant, and gives Data and Conclusion*
Brad: Umhm.	

Segment A-1 continues

Teacher: HOW DO WE KNOW THAT YOUR THEORY WASN'T CORRECT? WHAT WAS THE ONE THING THAT HE FORGOT?

Pupil: That, um, the...the ebonite rod is neutral and you had the same amount of, er, er, positive as negative.

As this segment closes, ingredients of the Backing for for the Warrant are treated as simple features of the initial Data.

Teacher: Okay. You started out with each of them in the neutral state so they would have the same. All right, then we say that one of those two substances has a stronger attraction for electrons than the other.

Teacher states desired Warrant (Note teacher's use of the word "stronger")

Segment A-2: Establishing a general Warrant for nine materials

Therefore it would be possible to take a list of substances and arrange them in a list, or in an order, which would, er, put those which have, say, a strong attraction for electrons on top of the list and those with a weak attraction at the bottom of the list. So we have such a list here--you'll notice that some of the materials that we have listed here we've used in the experiments that we've been doing. The first one, for example, glass... (writing on the board, "Glass, Wool, Cat's fur, Silk, Cotton, Paraffin wax, Ebonite, Rubber, Sulphur"). Okay. Now, I'm going to tell you this about the list: as we go down the list there is increasing ability to hold electrons. (An arrow is drawn pointing down the list with the label, "increasing ability to hold electrons.")

In this brief segment, the teacher generalizes many specific Warrants into a single Warrant.

Teacher states Warrant

Note teacher's use of the word "hold," in speech and writing

Segment A-3: Applying the Warrant to cat's fur and paraffin wax

NOW WHAT DOES THAT MEAN WHEN WE COMPARE, SAY, CAT'S FUR AND PARAFFIN WAX? Jerry.	*Teacher solicits Conclusion*
Jerry. The paraffin wax will hold electrons better than cat's fur?	*Student states Warrant, implying the Conclusion*
Teacher: Er, BETTER? CAN WE GET ANOTHER WORD THERE?	
Jerry: Er, more?	
Teacher. More strongly. All right, this list is called an electrostatic series (writing "Electrostatic Series").	*Teacher returns to the word "strong" (l. 58) although Jerry has used "hold" as teacher did in line 77*
And I think you can now see the use of an electrostatic series. Before we just memorized that ebonite became charged negatively when it was rubbed with wool.	*Teacher names the general Warrant*

Segment A-4: Applying the Warrant to ebonite and wool

If we look at this list and notice the position of wool and ebonite, IF WE RUB THESE TWO SUBSTANCES TOGETHER, WHAT'S GOING TO HAPPEN?	*Teacher solicits Conclusion*
Pupil: You get a negative charge.	*Incomplete Conclusion*
Teacher: WHY?	*Teacher solicits Warrant*
Pupil: Because there is, um,...because most, more, er, electrons go on to the rod.	*Conclusion*
Teacher: WHY WOULD MORE ELECTRONS GO FROM THE WOOL TO THE ROD THAN THE OTHER WAY?	*Teacher solicits Warrant*
Pupil: Because the wool's lose them... wool will lose them.	*Conclusion*
Teacher: WHY WOULD THE WOOL LOSE THE ELECTRONS? You're not answering why. (no response) Steve, or er, Jerry rather.	*Again, Teacher solicits Warrant*
Jerry: Er, er, the ebonite will hold more electrons so it'll take it out of the wool.	*Student states Warrant, using the word "hold"*
Teacher: WILL HOLD MORE?	*Teacher questions wording*
Jerry: Er, take more away.	
Teacher: You're missing the one word, I think, that explains it properly. Gary?	
Gary: The ebonite will hold the electrons...	*Second student uses "hold"*
Teacher: ...or strength with which they hold the electrons. Okay, let's see if we can use this then.	*Teacher uses "strength," as he did in l. 58, rejecting "hold" as in l. 77 and on the blackboard*

EPISODE B: "Prelude to Snell's Law"

Grade 9 (nine boys, twelve girls)
Pages 9-11 of 18

In this episode, the teacher seeks from the students a Warrant which relates Data (angles of incidence) to Conclusions (angles of refraction). In Segment B-1, Susan proposes a Warrant which is based on the arithmetic differences between successive angles of refraction in the table of data. In line 25, Susan appears to sense the teacher's criticism of her Warrant, which she modifies to the "average" difference. In lines 26-27, the teacher dismisses averages as unacceptable.

In Segment B-2, Rick and Bill speak on behalf of another Warrant based on arithmetic differences in the "Conclusions" column. With some difficulty, Rick (lines 50-51) manages to state the tendency for the difference between angles to decrease by one degree. The teacher appears to accept the Warrant as deserving of consideration, and proposes a test (lines 54-58). In the dialogue from line 59 to line 72, the teacher appears to discredit the Warrant.

In Segments B-1 and B-2, students have proposed two Warrants which assume that arithmetic differences are the appropriate Backing. In Segment B-3, the teacher begins his presentation of another Warrant--Snell's Law--which uses as Backing the geometric relationship of each pair of angles. His explanation (which is too long to present in its entirety) never returns to consider the fundamental difference, at the level of Backing, between the students' Warrants and the Warrant developed by Snell.

Segment B-1: The first request for a Warrant

Teacher: Okay, here we have our results on the side board. (The table reads:

10°	7°
20°	13°
30°	19°
40°	26°
50°	31°
60°	36°
70°	40°)

Data (left column)
Conclusions (right column)

CAN ANYONE SEE A RELATIONSHIP BETWEEN THE ANGLE OF INCIDENCE AND THE ANGLE OF REFRACTION FROM THOSE RESULTS? Just look at that for a couple of minutes. (Pause. He writes "SNELL'S LAW.") Susan.

Teacher solicits Warrant

Susan: Um, when the angle of incidence increases by 10, most of the angles of refraction increase by 6

Student states Warrant (with Qualifier)

Teacher: That's interesting. As the angle of incidence increases by 10, the angle of refraction increases by 6. Let's see: 7 from 13 is 6, 13 from 19 is 6, there's 7, there's 5, there's 5, ... there's 4.

Teacher restates Warrant (without Qualifier) and tests each instance

Susan: Well, the average is 6.

Student revises Warrant

Teacher: Oh, well, averages aren't good enough here (some laughter). Rick.

Teacher judges Warrant to be unsuitable

Segment B-2: The second request for a Warrant

Rick: The, er, like, first of all when you increase it by 10, er, there's an increase of...there's a...first of all 7, then it goes down to 6, then it goes down to 5, and then it goes down to 4.	*Student attempts to state Warrant*
Teacher: SO WHAT?	
Rick: If you take the difference, like er, from 6 to 7 you've got a difference like 10--like you've got...this, er, goes back to 4 degrees of difference between 36 and 40. And between the 31 and the 36, we have to have a 50 and 60 increase by 10, and then you have 5. And then at 26 and 31, and that's 5. And then you go 6...like. (Laughter)	*Student continues attempt to state Warrant*
Teacher: You're just telling me the results up here. WHAT, WHAT...	*Teacher seems to say student has not provided a Warrant*
Rick: Yeah, well er, you said, um, see this 5 thing, when the angle of incidence increases by 10, the angle of refraction is increased by 1.	*Student tries again to state Warrant*
Teacher: IT IS?	
Rick: Like, er, when you subtract, the difference increases by 1.	*Student states Warrant*
Teacher: You mean it decreases by 1.	*Teacher corrects Warrant*
Rick: Decreases...yeah, decreases.	*(Student accepts correction)*
Teacher: All right. Yes, it is decreasing by 1. CAN WE MAKE A PREDICTION FROM THOSE RESULTS? CAN WE PREDICT WHAT THE ANGLE OF REFRACTION WILL BE FOR 80°? Bill.	*Teacher asks if Warrant can be used to predict an unknown Conclusion*
Bill: 43°?	*Student states Conclusion*
Teacher: HOW DID YOU GET THAT?	*Teacher requests explanation of argumen*
Bill: Er, just a guess. (Laughter)	*(Student claims he guessed)*
Teacher: Er, WHAT WAS YOUR GUESS BASED ON?	*Teacher solicits Warrant*
Bill: Er, it's going down 1. Sometimes it stays the same, other times it goes down 1. So, it'll be 3 for 80°.	*Student states Warrant, Qualifier, and Conclusion*
Teacher: SO, WHAT MADE YOU...WHAT MADE YOU THINK IT WAS GOING TO GO DOWN 1 THIS TIME?	*Teacher requests explanation of the Qualifiers*
Bill: Oh.	
Teacher: So, in other words, you don't know.	*Teacher "discredits" argument*
Bill: No.	

Segment B-3: Presentation of *the* Warrant--Snell's Law

Teacher: Well, a person by the name of Snell came along and he looked at these angles and he came up with a law, which we now call "Snell's Law." And the way it works...well, let's first draw a diagram on the board, and you'll see how it works.

Teacher presents Snell's Warrant at length. He appears to assert the superiority of this Warrant, by failing to compare the three Warrants at the level of Backing, and by not calling attention explicitly to the Backing for Snell's Warrant.

EPISODE C: "Separating lead from lead oxide, in a study of affinity of metals for exygen"

Grade 9 (eleven boys, ten girls)
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This episode, forming part of a lesson on affinity, follows a discussion of the decomposition of mercuric oxide by heat. In Segment C-1, the teacher pursues an argument for decomposition of lead oxide based on an analogy to the decomposition of mercuric oxide by heating. In Segment C-2, the teacher indicates that the analogy is not valid and seeks an explanatory Warrant.

Segments C-3 and C-4 are the portions of Episode C in which lead oxide is actually decomposed. Segment C-3 focuses on producing a reaction; charcoal is mixed with lead oxide, as a specific response to a general suggestion from a student that something with higher affinity for oxygen be added.

Segment C-4 contains the analysis of the reaction, and focuses on identifying the second product, in addition to lead. In lines 109-110, the teacher identifies the components of the second product in a manner which produces the desired Conclusion (line 112) without constructing a complete argument.

Segment C-1: Predicting the behavior of lead oxide when heated

(A discussion of the decomposition of mercuric oxide by heat has just been completed.)

Teacher: So...another metal which we could use to extract from its oxide is lead, lead oxide. If you think about it, you've only got to heat lead up a little bit and it looks quite like mercury, doesn't it? Liquid lead you've probably seen--it's like silver.	*Teacher suggests that Warrant appropriate to mercury is also appropriate to lead*
Now. IF WE HEAT LEAD OXIDE, WHAT WOULD YOU EXPECT, RICK? It's not as liquid as lead, it's not as soft as gold.	*Teacher solicits Conclusion* *Data*
WHAT WOULD YOU EXPECT TO HAPPEN IF WE HEAT LEAD OXIDE? (no response). Hm?	*Solicits Conclusion*
WELL WHAT COULD HAPPEN...WHAT, WHAT COULD POSSIBLY HAPPEN? (Some dark powder is tipped into an evaporating dish and heated over the burner.)	*Solicits Conclusion*
Rick: It would start it melting?	*Conclusion*
Teacher: Well, it...yeah, it might melt if you heated it strongly. BUT BY ANALOGY WITH WHAT HAPPENED TO MERCURY, WHAT MIGHT HAPPEN TO THE LEAD OXIDE?	*Teacher solicits Conclusion using previous Warrant*
Rick: Change to a gas?	*Conclusion*
Teacher: Change to a gas. It would give off oxygen, yes...give off oxygen gas.	*Teacher adds to, repeats, and accepts Conclusion*
AND WHAT WOULD BE LEFT AT THE BOTTOM? (No response) Lead would be left at the bottom, wouldn't it? Yeah.	*Teacher solicits and states Conclusion*

Segment C-2: Explaining the failure of the prediction

Well now, in fact this doesn't happen, because...WHY DOESN'T IT HAPPEN?	*Teacher states conflicting Conclusion* *Teacher solicits new Warrant*
Janet...What am I talking about Janet (correcting himself) Nancy? 'WHY DOESN'T LEAD FORM FROM MER...FROM LEAD OXIDE WHEN YOU SIMPLY HEAT IT BY ITSELF?'	*Teacher solicits Warrant, giving Conclusion and Data*
Nancy: Because it, er...it has a high affinity...	*Warrant*
Teacher: Because it has a...well, a higher...a higher affinity for oxygen than has mercury. All right?	*Teacher modifies and adds to Nancy's statement*

Segment C-3: Testing a prediction for obtaining lead from lead oxide

So, how can we get, how can we get lead--because most of the lead that's mined is found mostly as the oxide. HOW CAN WE GET LEAD FROM LEAD OXIDE IF IT DOESN'T RELEASE OXYGEN AND FORM LEAD ON HEATING?	*Teacher states Conclusion, and solicits Data and Warrant*
Pupil: Mix something that has a higher affinity.	*Warrant ("higher affinity") and Data ("something") are suggested*
Teacher: Mix it with something which has a higher affinity for the oxygen which is combined with the lead. Good. AND THAT SUBSTANCE WOULD BE?	*Teacher states Warrant more completely and asks for Specific Datum*
Pupil: Um. Mercury.	*Datum*
Teacher: Well, you've probably seen that I've been playing around with something black which you might know is charcoal, right. Okay. (Some laughter) Now, you can...you can see that this is not apparently changing color or changing texture in any way, IS IT? There's no little bubbles of anything. Er, I think it should be just about hot enough. (Pause) I think it...you'd better just stand back a little bit because it sometimes pops around the place a bit. I'll take the heat away just to make it a little bit less vigorous. Now if I add some charcoal to the lead oxide... (some is added and sparks are emitted)	*Teacher provides specific Datum without explanation* *Data (referring to material being heated since lines 14-16)* *Datum*
Pupil: Oh. Cool.	
Teacher: If the, if the thing is hot enough and if the charcoal wants to combine with the oxygen more than the lead wants to hold onto it, then you get this vigorous reaction...I'll just leave it and you'll find it'll...CAN YOU ALL SEE WHAT'S GOING ON? It's like a little miniature volcano, ISN'T IT?	*As the demonstration proceeds, teacher provides Qualifier, Warrant, and indication that a a reaction will occur*
Pupils: Cool. Firecrackers...	
Teacher: Like bonfire night, yes.	
Pupil: Firecrackers. Does anybody have any marshmallows. Aw, no. (Laughter)	
Teacher: Stand back a little bit, because it does hop around.	
Pupils: Cool, eh. Firecracker Day (many times). Hey that is good.	

(C-3 ends) Segment C-4: Identifying the products of the reaction

Teacher. Now, I'll just keep it...I'll just keep it heated a little bit more and we should expect...yes, you can in fact see...if you look over, look over the top here, you can see a little globule of liquid lead.	*Teacher states that Conclusion for Segment C-3, lead, has been obtained*
Pupil: Looks like mercury.	*Possible Conclusion*
Teacher. Looks like mercury. Right, yes.	*Teacher accepts possibility*
Pupil: Isn't it? (Some comments, pause)	*Student solicits Conclusion*
Teacher: All right. So what do you think...WHAT DO YOU THINK WAS FORMED...	*Teacher solicits Conclusion*
I mean, we got to...we got to start off, we start off with a certain number of things, we see that they react together, and we end up with something else.	*Teacher provides a general Warrant for all reactions*
Well now, we see that one of the things we end up with is lead. Shirley, WHAT WOULD BE THE OTHER STUFF THAT WE PRODUCED BY THAT REACTION? (Pause)	*Teacher provides part of the Conclusion (lead) and solicits the second part (other product)*
LEAD AND OXYGEN FORM LEAD OXIDE, RIGHT?	*Teacher refers to Data*
Shirley: Carbon?	*Conclusion*
Teacher: Carbon is added to it, removes the oxygen from the lead oxide. YOU GET LEAD AND WHAT?	*Teacher indicates role of carbon and solicits Conclusion*
Some compound containing carbon and oxygen, WHAT WOULD...WHAT WOULD THAT BE LIKELY TO BE?	*Teacher provides composition of Conclusion*
Pupils: Oxide. Carbon dioxide. Carbon dioxide.	*Conclusion*
Teacher: Carbon dioxide, good. All right. So, let's put that (the evaporating dish) on one side; it's a little warm.	*Teacher accepts Conclusion*

Inferring Suggested Attitudes toward Authority

The purpose of the preceding analysis of arguments in science teaching discourse is to permit judgments about the attitude toward authority--rational or traditional--which may be suggested to students by a teacher's use of questions. In the three episodes considered here, the teachers fall short of the goal of suggesting a rational attitude toward authority. The purpose of the following discussion is not to judge these teachers but to develop an initial understanding of the various teaching moves which may suggest a traditional attitude toward authority. Each episode is considered in turn, and a more general discussion then relates the results of the analyses to the original concerns of the study.

Episode A: Warrant-Using Becomes "Warrant-Stating"

Episode A is the opening portion of an electricity lesson which reviews phenomena of static electricity and continues with an introduction to current electricity. In Segment A-2, the teacher presents a general Warrant which is introduced by the discussion in A-1 and applied in A-3 and A-4. The available evidence does not permit an assessment of Segment A-2, which appears to rely on previous work. Segments A-1, A-3, and A-4 share a common emphasis on correctly stating Warrants, and these discussions can be judged for suggested attitude toward authority. Each segment involves a Conclusion that electrons have moved from one material to another; this Conclusion cannot be checked by direct observation and hence relies heavily on the Backing provided by the atomic model of matter.

Segment A-1 involves the use of a Warrant, but, as the teacher's questions indicate, the emphasis is on obtaining a clear statement of the Warrant which permits Dave's Conclusion (lines 6-7). Brad's answer (lines 13-16) implies a

misunderstanding of the initial neutrality of the substances, a consideration at the level of Backing. Backing and Warrant are intermingled as the discussion proceeds and, at the close of the segment, the teacher appears to treat Backing as initial Data. In line 58, the teacher speaks of one substance having a "stronger attraction for electrons" than another, but in lines 77-80 he speaks of "increasing ability to hold electrons." Segments A-3 and A-4 show the students using the word "hold" and the teacher speaking of "strength" of attraction. In A-3, Jerry states a Warrant which implies the desired Conclusion, and the teacher's questioning of the word "better" implies that "more strongly" is simply an alternative. The teacher's preference reappears but remains unexplained in A-4, where the teacher's questions again seek first a Conclusion and then a suitable Warrant. (A-4 is longer than A-3 because a request for a Warrant is twice followed by repetition of the Conclusion, in lines 102-104 and 107-108. Toulmin's terms might have helped the teacher explain why the responses were not answering the question.)

Segments A-1, A-3, and A-4 are judged to suggest a traditional attitude toward authority because they are dominated by "Warrant-stating," rather than the required Warrant-using arguments, and because little attention is paid to bringing Data, Warrant, and Backing into clear and proper relationship so that Conclusions could be seen to rest on rational authority. In this instance, it is possible for a student to answer the teacher's initial question by referring to the list on the blackboard (the "Electrostatic Series"). The students' repeated use of the word "hold" (which is written on the blackboard) suggests that this is what they are doing. In the end, the teacher settles for statements of Warrants, rather than for clear evidence that a Warrant has been <u>used</u> to reach each Conclusion. The unexplained preference for "strength" is consistent with the judgment that Warrants are being stated rather than used and

that a traditional attitude toward authority is suggested.

Episode B: Warrant-Establishing Becomes "Warrant-Asserting"

Episode B is part of a lesson which examines angles of incidence and refraction and then presents Snell's Law and the term "index of refraction." Earlier in the lesson, the teacher used an optical disc to obtain the evidence shown in lines 3-9; after Episode B, the teacher explained the geometric relationship given by Snell's Law and its use to calculate an index of refraction. Segments B-1 and B-2 show the students attempting to satisfy the teacher's request for a Warrant by which one may move from the given Data (angles of incidence) to the observed Conclusion (angles of refraction). The situation clearly calls for the establishing of a Warrant, and Backing should be included to suggest a rational attitude toward authority.

Segments B-1 and B-2 proceed from the teacher's question in lines 10-12, a question which implies that one could "see a relationship" in the evidence available. Susan's suggestion in B-1 is perhaps the most obvious arithmetic relationship, but the teacher rejects her Warrant because "averages aren't good enough here" (lines 26-27). Because the teacher does not explain himself, this move could suggest a traditional attitude toward authority. In B-2, Rick speaks five times (lines 28-53) before stating, with the teacher's help, a second Warrant, less obvious than Susan's but similarly backed by an arithmetic view of the Data. Initially, the teacher's questions to Rick imply that no Warrant has been given. Later, with Bill responding, the teacher's questions test the Warrant by seeking a prediction. Like B-1, Segment B-2 ends with the students' attempt to "see" a Warrant being rejected as unsatisfactory.

Segment B-3 begins very abruptly, as the teacher names and begins to explain Snell's Law. His subsequent presentation (not included because of its length)

includes the geometric relationship for which Snell is given credit, but the context is one of "this is how it works" rather than "this is how it is established." The teacher never returns to the discussions of B-1 and B-2 to compare Snell's geometric Backing to the arithmetic Backing used by the students. From the perspective of having the students understand how Snell's Law works, no criticism of the teacher is implied in these comments. However, from the perspective of rational arguments, Episode B is judged to suggest a traditional attitude toward authority because students are never made explicitly aware that the Backing required to establish a Warrant was not available to them. Perhaps ironically, Segments B-1 and B-2 could have motivated the students very effectively for the point that Snell's Warrant rests on a non-arithmetic Backing. By requiring the students to accept and use the Warrant on his personal authority alone, the teacher is in effect asserting Snell's Law as an acceptable Warrant.

Ultimately, this analysis reminds one that there is more to a law or theory than its use as a predictive device, and that it is appropriate to consider Backing when first presenting a Warrant to students. Once a Warrant has become familiar and can be used easily, its Backing is virtually taken for granted. Typically, the Backing for a Warrant indicates how one "sees" the situation when applying the Warrant. Thus Backing may be important for learning the Warrant, as well as for suggesting a rational attitude toward authority.

Episode C: Warrant-Establishing Becomes Circular

Episode C is part of a lesson on the topic "affinity of metals for oxygen," and it follows a demonstration that mercuric oxide may be decomposed by heating. The four segments of Episode C build toward the demonstration and argument in C-4 that lead has been separated from oxygen by heating with charcoal, which has a "higher" affinity for oxygen. As in Episode B, the teacher appears to

use a motivational technique of beginning with an approach which does not work. In C-1 students are asked to use an analogy, and in C-2 they are told that the analogy fails. In C-3 a successful reaction is demonstrated, but in C-4 the teacher's treatment of a question about the identity of a product of the reaction makes the argument circular and forces the judgment that a traditional attitude toward authority is suggested in this Episode.

The teacher's questions in Segment C-1 require students to use a Warrant established for mercuric oxide to reach a Conclusion about the behavior of lead oxide. The authority of the teacher's position enables him to pursue this line of questions and then, in C-2 (line 28), reject the analogy to mercuric oxide and seek a Warrant which permits the Conclusion that lead oxide will not decompose when heated. These are introductory moves, and it would be premature to assess a suggested attitude toward authority at this point. In Segment C-3 the teacher's questions focus on identifying a substance which will separate lead from oxygen. The concept of affinity is used correctly, but the teacher provides charcoal (line 54) as additional Data, and summarizes the argument clearly (lines 69-73) just as the desired reaction begins and provides impressive empirical support for the argument.

Segment C-4 is crucial. In C-1, the teacher supplied a Warrant, which he withdrew in C-2 by providing a Conclusion that lead is not obtained by heating. The argument in C-3 requires both Warrant and Data, and the latter is supplied by the teacher. Much of the argument thus far rests on the authority of the teacher's position. C-4 contains two pieces of evidence that students have <u>not</u> followed the argument. In line 94, a student asks if the product which "looks like mercury" is mercury. The teacher states that lead has been produced (line 90 and line 102), certainly a reasonable Conclusion if one accepts the identification of lead oxide as a reactant. The teacher's remaining questions focus

on the second product, and Shirley suggests carbon (line 106), which was a reactant. When the teacher elicits "carbon dioxide" by naming carbon and oxygen as the elements in the compound, the question has been "answered" but all signs of argument have vanished. In C-4, the teacher has supplied both products on his own authority.

Recall that earlier segments of Episode C focused on finding a rule or procedure (a Warrant) for separating lead from oxygen. From the point of view of argument, events in C-4 reduce the original Warrant-establishing activity to a circular line of reasoning in which virtually every ingredient is provided by the teacher. Thus Episode C is judged to suggest a traditional attitude toward authority.

Three episodes and the issue of authority

This study is rooted in a concern that teachers' use of questions in their arguments for scientific knowledge claims could suggest an attitude toward authority at odds with that to which scientists aspire. Toulmin's pattern for rational arguments has made it possible to analyze three selected episodes of science teaching. Systematic analysis has shown that each of the three episodes, originally chosen as "disturbing," does suggest a traditional attitude toward authority.

We have no evidence to indicate that the three teachers were either aware of this possibility or inclined to view their own teaching as suggestive of any attitude toward authority. The assessed suggestions of traditional authority appear unintentional. In Episode A, the teacher pursued a line of questioning which converted Warrant-using situations into Warrant-stating ones, complicated by his preference for a particular word. In Episode B, the teacher encouraged the students to try to establish a Warrant, but then, in effect, asserted the

Warrant and failed to identify the distinctive difference between the students' suggestions and "the answer." In Episode C, a demonstration intended to establish a Warrant is converted, at the last moment, to a circular argument when the teacher is required to deal with student confusion about the products of a chemical reaction in which the reactants are known. The students say the right word, but all traces of genuine argument are lost.

The teaching strategies demonstrated in these episodes will not appear unusual to experienced classroom teachers or observers. Indeed, in Episodes B and C, the teachers seemed to establish successfully situations which would motivate students to come to terms with the phenomena in question. Yet in each of these three episodes, the teacher seemed to be diverted from completing a rational argument as the end of the discussion approached. In each instance, clear statement of "the answer" seemed to become a high priority. Only minor, not major, modifications would be involved in adapting these episodes to provide complete rational arguments, and thereby move toward suggesting a rational attitude toward authority. We should not be surprised that it is easy to be diverted from one's line of argument, during teaching, or that presenting a complete rational argument is not the highest priority for some teachers.

This study serves several purposes. It provides both argument and data to the point that concern for the <u>function</u> of questions in <u>arguments</u> is a significant issue. The elements in Toulmin's argument pattern <u>can</u> be used to analyze arguments in science classroom discourse, to provide a basis for inferring what attitude toward authority could be suggested by a teaching episode. The analytical procedure developed here could be used by any teacher or observer interested in assessing teaching in terms of suggested attitude toward authority.

At this point, the link between pattern of argument and suggested attitude

toward authority is postulated rather than demonstrated. A different form of inquiry is called for, to consider whether students do "read" arguments in science teaching for an attitude toward authority and relate that to their attitudes toward science. Nothing in this analysis suggests that these are not significant possibilities. Again, a different form of inquiry is required to generalize about science teaching practices relevant to these issues. Nevertheless, the data analyzed here suggest that failure to complete a rational argument is "an easy trap to fall into," and also a situation which can be corrected with minor modifications.

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