“Doing the Lesson” or “Doing Science”: Argument in High School Genetics

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ABSTRACT: This article focuses on the capacity of students to develop and assess arguments during a high school genetics instructional sequence. The research focused on the locating distinction in argumentation discourse between “doing science” vs. “doing school” or “doing the lesson” (Bloome, Puro, & Theodorou, 1989). Participants in this classroom case study were high school (9th grade) students in Galicia (Spain). Students were observed, videotaped, and audiotaped while working in groups over six class sessions. Toulmin’s argument pattern was used as a tool for the analysis of students’ conversation and other frames were used for analyzing other dimensions of students’ dialogue; (e.g., epistemic operations, use of analogies, appeal to consistency, and causal relations). Instances of “doing science” and instances of “doing the lesson” are identified and discussed as moments when the classroom discourse is dominated either by talking science or displaying the roles of students. The different arguments constructed and co-constructed by students, the elements of the arguments, and the sequence are also discussed, showing a dominance of claims and a lesser frequence of justifications or warrants. Implications for developing effective contexts to promote argumentation and science dialogue in the classroom are discussed. © 2000 John Wiley & Sons, Inc. *Sci Ed* **84**:757–792, 2000.

ARGUMENT AND CLASSROOM DISCOURSE: BACKGROUND AND OBJECTIVES OF THE STUDY

The conceptualization of science learning as argument has been proposed by Driver and Newton (in press), Kuhn (1993), and Duschl (1990), as well as others. Such a view of science learning has broader goals than just learning scientific contents. Argumentation theory embraces analytical, dialectical, and rhetorical schemes for the evaluation and communication of knowledge claims (van Eemeren et al., 1996). Thus, a pedagogical emphasis on argumentation is consistent with general education goals that seek to equip students

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with capacities for reasoning about problems and issues, be they practical, pragmatic, moral, and/or theoretical. Siegel (1995, p. 163) writes "[e]ducation and argumentation are united . . . by their mutual concern with rationality and the normative dimensions of reasons and reasoning."

Argumentation is particularly relevant in science education since a goal of scientific inquiry is the generation and justification of knowledge claims, beliefs, and actions taken to understand nature. Commitments to theory, methods, and aims are the outcome of critical evaluation and debates among communities of scientists. Argumentation and argumentation theory are strategies for resolving questions, issues, and disputes. The decisions associated with making commitments and resolutions are guided by "the goodness, normative status or epistemic forcefulness, of candidate reasons for belief, judgment and action" (Siegel, 1995, p. 162). In addition to learning about what we know in science, science education programs need to also develop learners' capacities to understand how we have come to know and why we believe what we know. A goal of a science education program rooted in teaching from a scientific inquiry orientation, according to Connelly and Finegold (1977), should be the learner's ability to assess the degree of legitimate doubt that can be attached to a knowledge claim. Such an ability is dependent on rendering decisions about the beliefs, judgments, and actions of inquiries by scientists or students of science. Driver, Leach, Millar, and Scott (1996) emphasize the same idea when they write: "if it [school science] is to contribute effectively to improved public understanding of science, [it] must develop students' understanding of the scientific enterprise itself . . . [s]uch an understanding, it is argued, is necessary for students to develop an appreciation of both the power and the limitation of scientific knowledge claims" (p. 1).

Argumentation, as a structural element of the language of science, is an essential cog in both doing science and communicating scientific claims. As such, argumentation needs to be carefully studied in order for us to better understand how to promote students' appropriation of conversational genres that support their doing science and talking science (Applebee, 1996; Lemke, 1990). Of particular interest to us is the nature of conversation that occurs within discussion groups both during and immediately following laboratory and practical investigations. Precisely, we seek to understand how the mutual design of curriculum, instruction, and assessment can leverage whole class, group, and individual discourse to reflect argumentation schemes — scientific and otherwise.

Another way to frame the goal of our research is by asking how to move classroom discourse away from what Bloome, Puro, and Theodorou (1989) call *procedural display activities*. Classrooms are complex settings where any number of interaction dynamics take place. As Lemke (1990) has shown in his description of "triadic dialogue," there is a large portion of the conversation exchanges in classrooms that seem conducted to preserve the social structure of teacher/student relationships. Bloome et al. see classroom interactions as social actions, a set of which they label *procedural display* and define as "(a) the display by teacher and students, to each other, of a set of academic and interactional procedures that themselves count as the accomplishment of a lesson, and (b) the enactment of lesson is not necessarily related to the acquisition of the intended academic or nonacademic content or skills but is related to the set of cultural meanings and values held by the local education community for classroom education" (Bloome et al., 1989, p. 272). An example of a procedural display in a science classroom would be requiring students to complete a graph for each and every lab investigation regardless of the purpose of the inquiry. Procedural displays are the social habits, so to speak, of life in classrooms that are enacted without question and often without a purpose to the students. Procedural display is what one does in a classroom when one is going through the motions or simply "doing school."

Thus, we feel that an obstacle to "talking science" is the set of actions and activities or procedural displays that make up the routines and ritual of "doing school." Applying the concept of procedural display to science classrooms is to ask whether what is done in science classrooms is to (1) fulfill expectations of what students and teachers do while in school (e.g., review homework assignments, take lecture notes, take tests, and complete lab activities) or (2) provide a learning environment that both promotes and facilitates students' construction, representation, and evaluation of knowledge claims and investigative methods. For purposes of this article, the distinction is "doing the lesson" or "doing school" (procedural display) vs. "doing science" (scientific dialogue or argumentation).

This study is part of a project focusing on student's capacity to develop and assess arguments, as related to the design of science curriculum and learning environments in secondary school in which the discussion about the choice of theories, evidence, and explanations plays a central position. We are guided by a philosophical perspective (Giere, 1988) which considers choices among competing theories essential in the building of scientific knowledge; that is, scientific reasoning should be understood not so much as a process of inference, but as one of decision making, of choice among theoretical and evidential claims. In brief, scientific reasoning involves making arguments to defend choices.

In this project, the design of units and activities is centered around problem solving, a condition to promote argumentation. In standard Spanish classrooms, there is little or no interaction among students, and there are few opportunities for solving problems or discussing science issues. We (Bugallo Rodríguez & Jiménez-Aleixandre, 1996) have previously explored some patterns of argument in a genetics context with no intervention and the results show that students' argumentation skills are very poor. Thus, in order to explore the ways in which secondary school students develop arguments, there was a need to create learning contexts where students were asked to solve authentic problems, to compare the solutions given by different groups, and to justify their choices (Jiménez-Aleixandre, 1998). While these kind of learning environments are designed to involve students in asking questions, revising what they know in the light of evidence, justifying responses to classmates, analyzing and interpreting data, and requiring the consideration of alternative explanations, we actually know very little about how the communication surrounding the move from evidence to explanation or premises to conclusions proceeds and, more importantly, breaks down.

The purpose of our paper is to report on the conversational dynamics in the form of argumentation patterns and epistemic operations students employ while solving a problem in the science classroom. One goal of the research is to understand the discourse patterns students employ in discussion groups in terms of the "doing school" vs. "doing science" perspective. An understanding of these patterns will help inform the design of classroom-based assessment strategies and, subsequently, teacher feedback. Another related goal is to develop a deeper understanding of how to design curriculum, instruction, and assessment models to promote and facilitate students' self-monitoring of scientific reasoning and meaningful participation in doing science.

This article has four sections. The first section is a review of argumentation theory and contemporary developments in science education, as well as, a rationalization for using Toulmin's model of argumentation as a method of analyzing students' discourses. This is followed by a description of the methodology, setting, and context for the study. The results section presents transcribed segments of the discussion groups accompanied by annotations of the argumentation patterns and epistemic operations being used, or, on the contrary, of instances of "doing the lesson." The paper finishes with a discussion and implications section.

Reasoning and Argument in Science Learning

Argumentation has three generally recognized forms: analytical, dialectical, and rhetorical (van Eemeren et al., 1996). *Analytical arguments* are grounded in the theory of logic, proceeding inductively or deductively from a set of premises to a conclusion, and include examples such as deduction, material implications, syllogisms, and fallacies. *Dialectical arguments* occur during discussion or debate, involving reasoning with premises that are not evidently true; they are a part of the informal logic domain. *Rhetorical arguments* are oratorical in nature and are represented by the discursive techniques employed to persuade an audience. In contrast to the other two forms of argument where a consideration of the evidence is paramount, they stress knowledge and persuasion.

The application of formal logic to the sciences represents the cornerstone of "logical positivism." The platform was that all scientific claims of observation and theory were translatable into analytical statements to which formal rules of logic could be applied. The capstone event of applying argumentation to the sciences is perhaps Hempel-Oppenheimer's Deductive-Nomological Explanation Model, wherein the argumentation form is used as an account to establish the objectivity of scientific explanations. However, both historical studies and case studies of scientific inquiry show that rules of logic are often abandoned in the quest for scientific information. Scientific theories are typically underdetermined by the evidence; that is, scientists begin to operate with theories as if true and valid long before all the necessary evidence is brought forth. Consequently, discourse studies of science-in-the-making reveal that a great deal of dialectical argumentation strategies are used in addition to analytical arguments (Dunbar, 1995; Latour & Woolgar, 1979; Longino, 1994). Similarly, research in the sociology of science (Collins & Pinch, 1994) has also demonstrated the importance of rhetorical devices in arguing for or against the public acceptance of scientific discoveries.

Designing learning environments to facilitate and promote argumentation is a complex problem given that the discourse of science can and will involve these three forms of argumentation in different contexts. The central role of argumentation in doing science is supported by psychologists (Kuhn, 1993) and philosophers of science (Siegel, 1995) as well as science education researchers studying the discourse patterns of reasoning in science contexts (Driver & Newton, in press; Kelly, Chen, & Crawford, 1998; Kelly & Crawford, 1997; Lemke, 1990). Argumentation is held to be a reasoning strategy and, thus, also comes under the reasoning domains of informal logic and critical thinking.

An influential contributor to our understanding of argumentation is Stephen Toulmin. Toulmin (1958) sought to describe argumentation in practice and thereby challenge the notion of validity. He made a distinction between idealized notions of arguments as employed in mathematics and the practice of arguments in linguistic contexts. The latter he felt should have close ties with epistemology. Consequently, we find in his layout or model for argumentation (see an application of it in Figure 1) the need for an argument to make appeals to warrants, backings, and qualifiers. Such appeals, in addition to the data, are context dependent. For him, the agenda was to be "devoted to studying the structure of argumentation in the various academic disciplines and sciences in order to discover the qualities and defects of the various sorts of argumentation that are characteristic of different fields" (van Eemeren et al., 1996; p. 134). Toulmin was committed to a procedural interpretation of argumentation form as opposed to the rigid idea that all arguments have the form "premises to conclusions." Any justification of a statement or set of statements is for Toulmin an argument to support a stated claim.

Examining the form of arguments from different fields (e.g., law, science, politics, etc.), Toulmin was able to discern that some elements of arguments are the same while others

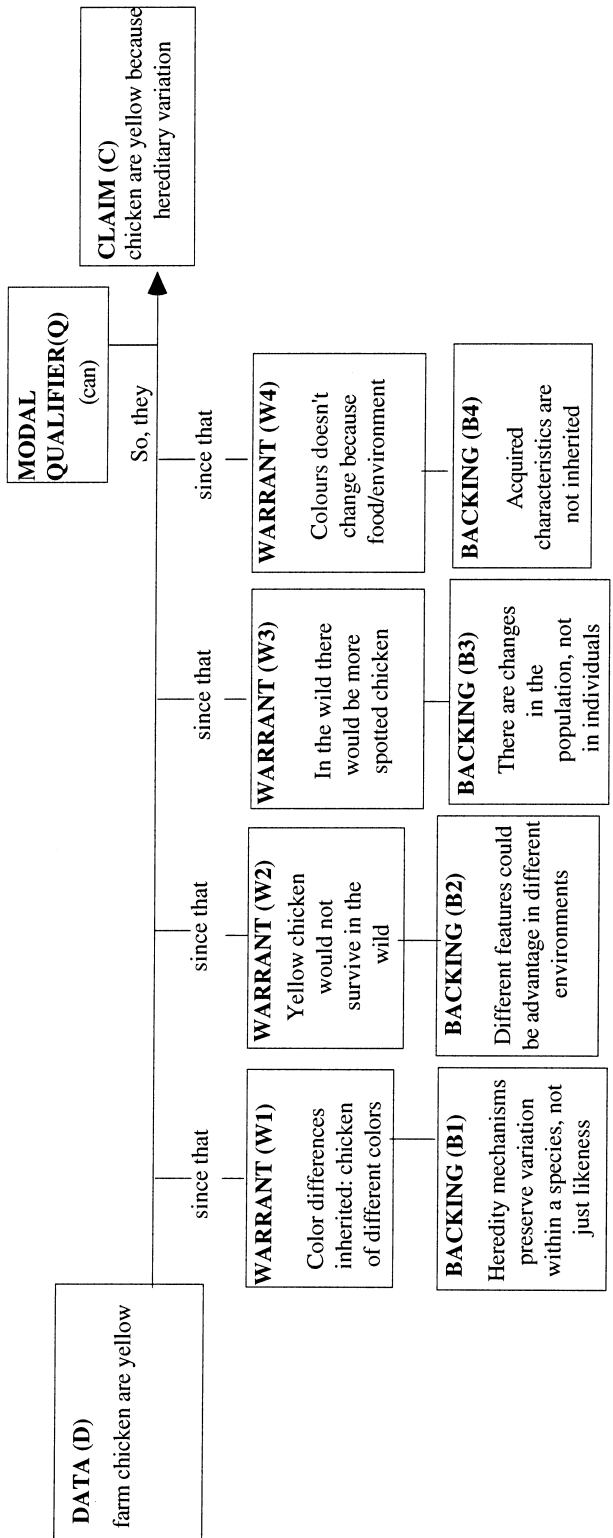

Figure 1. School science argument pattern.

differ with fields. The former he terms *field-invariant* features of arguments and the latter *field-dependent* features. The strength of the model he proposed resides in its ability to evaluate arguments. Data, claims, warrants, backings, rebuttals, and qualifiers are field-invariant features of arguments. What counts as a warrant, backing, or data, however, are field-dependent features. Thus, appeals to justify claims used to craft historical explanations would not necessarily be the same kind of appeals used to support claims for causal or statistical-probabilistic explanations. The flexibility of Toulmin's model to function in both field-dependent and field-invariant contexts is an advantage for understanding the arguments posed by students in science classrooms. Appeals to justify beliefs, justifications, or actions may derive from either "doing science" or "doing school" contexts.

Looking at reasoning from the perspective of cognitive psychology helps us to understand the reasoning contexts used in science classroom. Kuhn, García-Milá, Zohar, and Andersen (1995), in their study about strategies of knowledge acquisition, examined the problem of learners' coordinating theories and evidence. Their conclusions indicate that in learning, as it happens in the development of scientific knowledge, theoretical beliefs shape evidence, and subjects drew conclusions virtually from the outset, on the basis of minimal or no data. For Kuhn et al., one of the steps in the development of this coordination is the differentiation of theory-based and evidence-based justification.

Giere's (1988) philosophical model and Kuhn et al.'s (1995) psychological model share a concern about the interaction of different components when individuals have to solve problems and reason about their choices. From a science education perspective, when we set the capacity to develop an argument as a goal, that means an interest not only in the students *solving* the science problems (cognitive or strategic level), but also implies attention be given to the *criteria* which leads to one or another solution, why some solutions have been discarded, how this process of comparison is understood, which analogies or metaphors led to this understanding (epistemic level), as well as in students' monitoring their own learning (metacognitive level). In other words, we have to pay attention to these different components or levels of cognitive processing, trying to promote their development and assessing them.

Ohlsson (1992) has made a distinction between understanding the content of a theory and understanding how to use/apply it; the latter he says is a poorly understood practice among science learners. Research by Carey and Smith (1993) and Driver et al. (1996) supports this contention. Both groups of researchers found evidence that students' hold naive epistemological beliefs that do not adequately distinguish between theory, hypothesis, and evidence. Hodson (1992) advocates that our curriculum, instruction, and assessment models in science education need to clearly distinguish between and involve students in learning science, learning to do science, and learning about science.

As Lemke (1990) points out, one of the main problems in science classrooms is that many times communication fails. Osborne and Freyberg (1985) report that students and teachers often do not share the same "purpose" for a lesson or activity. Sometimes teachers and students are assigning (constructing) different meanings for the same concept; other times the confusion surrounds what counts as evidence, what counts as data, or what counts as explanation. These failures in communication cannot be ignored, and one step toward solving these failures is by beginning to document and understand them.

Objectives

This study is part of a project on the development of students' capacity to develop arguments in different science contexts. This article focuses on argument patterns from high school students solving genetics problems. The questions explored here are:

1. The identification of instances of “doing science” vs. instances of “doing school” or “doing the lesson.”
2. In the instances of “doing science,” which argumentative operations (claims, warrants, etc.) were used by students and which relations were established among them.
3. The identification of use by the students of epistemic operations (e.g., explanation procedures, causal relations, and analogies); that is, operations related to knowledge construction, specific from the science domain.

EDUCATIONAL CONTEXT, PARTICIPANTS, AND METHODOLOGY

The data presented here were drawn from one whole class group of high school students (9th grade, 14–15 years old) who were observed during the six 1-h sessions (two weeks) devoted to genetics in May–June 1996. When they broke into groups, a small group (four students) was audiotaped and observed, and then the discussion in the whole group was also audiotaped and observed. The school is a public high school in a medium-sized town near Santiago. The teacher is a Biology graduate, with 5 years of experience. During this term (1995–1996), no intervention was attempted in relation to the methodology of instruction, and the teacher conducted the sessions as usual. One of the goals was to discuss the data with her as a stimulus for reflection leading to a design based on problem solving. The only modification introduced by the authors, in collaboration with the teacher, was the problem posed to students that took place during sessions 5 and 6, following four sessions during which the teacher lectured students about Mendelian genetics and the students solved problems in small groups.

The classroom could be described as midway between teacher-centered and student-centered. Clearly, the intention of the teacher was to shift some of the learning responsibility to the hands of the students, but frequently she lacked the skills to succeed. For instance, she didn’t allow enough time for students to answer or to discuss different hypotheses. Instead, she provided the answer herself. Also, most of the questions that she posed to the students had only one “right” answer.

To describe the instruction in terms of talking science (Lemke, 1990), a distinction has to be made among sessions 1, 2, 3, and 4, with a pattern of triadic dialogue, which Lemke characterizes as sequences of teacher’s question–student’s answer–teacher’s evaluation; and sessions 5 and 6, during which students solved a problem in small groups and there were instances of what Lemke calls true dialogue of talking science. Lemke (1990, p. 168) quotes, as examples of talking science, situations when students are asking questions,; reporting from individual or group work, performing true dialogue or cross-discussion, working in small groups, and writing following oral discussions. From all of these instances, the ones which were found in this classroom during sessions 1 to 4 follow.

Student Questions

Most questions from students came following the thematic development set by the teacher. Nevertheless, there are some examples of what seem to be students’ own questions and some of them were ignored by the teacher.

In session 1, the teacher drew on the board an ovule and a spermatozoid roughly of the same size:

Student (pointing to the spermatozoid): So big?

The intonation of the student seems to indicate that he knows that the spermatozoid is smaller, implying that the drawing is not accurate. The teacher chose to ignore the question and continued, explaining that in humans, both have 23 chromosomes each.

In session 2, doing an exercise from the book about albinism, during which the teacher didn't mention mutations, the following exchange took place:

> Teacher: And two normal (pigmented) parents: Could they have albino children?
>
> Fran: Yes. A mutation. If their ancestors had some gene it could appear in another generation. It . . . there was a law . . .

(The teacher ignores the reference to mutation and she proceeds to develop on the board the results of a crossing among hybrid parents, *Aa x Aa,* and the possibility of offspring with a genotype *aa,* and therefore albinism.)

> Brais: And if they are normal and they have a mutation: Couldn't they be albino?
>
> Teacher: Yes.

(She doesn't explain her answer)

> Rita: And if they are albino: Couldn't they have a mutation and be normal?
>
> Teacher: Yes.

(She doesn't explain her answer)

It has to be noted that in these last two questions the teacher seems to understand (and answer) the question as it referred to children's pigmentation, whereas, as it is worded it looks as if it is asking about a change in the parents' pigmentation, which wouldn't occur.

Student Individual or Group Report

Only occurs during sessions 5 and 6.

True Dialogue

For Lemke (1990, p. 55), true dialogue occurs when teachers ask questions that have a wide range of possible answers, or ask for a student's opinion or real-life experience; in other words, questions for which there is not a unique "correct answer." This only occurs during sessions 5 and 6, as all the exercises and problems during the first four sessions had only one answer.

Cross-Discussion

Lemke describes cross-discussion as dialogue directly between students, with the teacher playing only a moderating role. We interpret the dialogue between students in sessions 5 and 6 as cross-discussion, whereas in sessions 1 to 4 there are only a few examples of student exchanges with one another. In session 2, students even ignore a teacher's question at the beginning of the discussion about albinism:

> Carlos: The white gorilla . . .
>
> Rita: They have to be albino (the children of albino parents), because they are all albino.
>
> It can't be the other way round.

Teacher: How are the genotypes?

Charo: Lowercase a, lowercase a.

Teacher: Which gametes will they produce?

Rita: But, Is it always like that?

Teacher: Always, when the two parents are . . .

When Rita asks if it is always like that, she is addressing Charo's statement about the genotypes and ignoring the teacher's question about the gametes. The teacher doesn't wait for the student's reply and initiates an answer, left unfinished.

Small Group Work

There are instances of small group work, not only in sessions 5 and 6, but also during sessions 1 and 3. In session 1, the activity is not a problem, it is an illustration of monohybrid crosses with cardboard models and the objective is to evidence the double set of chromosomes and the existence of recessive traits. In session 3, the students solved standard Mendelian problems in small groups followed by whole class discussion.

Science Writing Following Oral Discussion

There were no instances of science writing.

In summary, the classroom conversation during sessions 1, 2, 3, and 4 could be described as dominated by triadic dialogue initiated by the teacher and almost completely under her control. The questions that students were asked had only one answer and usually a very brief one. Nevertheless, there were some attempts by the teacher at using a dialogue strategy that could be interpreted as joint construction, described by Lemke (1990, p. 104) as thematic development closely shared between student and teacher contributions, as in the following instances from the fourth session when the teacher is discussing Lamarckism and Darwinism:

Teacher: The acquired traits . . .

Fran: . . . during the lifetime . . .

Teacher: . . . are inherited.

Teacher: . . . evolves by Natural Selection. What means Natural Selection?

Brais: The strongest is the one to survive.

Teacher: The strongest?

Brais: The ones that are better adapted.

The first is a summary of the Lamarckian explanation shared between teacher and student, while the second is an attempt at explaining the meaning of Natural Selection.

Although we interpret the conversation as triadic dialogue, it has to be noted that this particular teacher always avoided explicit evaluation of students' answers; she never qualified an answer as "right" or "wrong," although this evaluation could be inferred from her next move. Also, it can be said that she almost never addressed the student questions or answers as individual statements, but tried to keep the dialogue with the whole group. As a result, the classroom climate was of confidence and students did seem at ease to pose or answer questions. She frequently interrupted her lectures in order to ask questions to students, probing their understanding, challenging them to explain the concepts in their own words, and then reformulating them.

The sequence used in the sessions was as follows.

Session 1. The teacher introduces basic genetic concepts (gene, zygote, chromosome, etc.), asking the students questions continuously. She discusses Mendel's experiences and first law, is questioned by students who have difficulties with proportions (fractions), and has to explain it again. The students work in small groups with simple simulations of crosses with cardboard models. The students are asked to copy definitions and to answer application questions.

Session 2. The teacher defines mutation with examples from human beings (albinism). The students solve, in the whole class group, four qualitative problems from their textbook (problems set in everyday contexts); for instance, "Which is the probability that two albino parents have a child with regular pigmentation?" After each problem they held a whole class discussion.

Session 3. They finish the discussion about the solution of the problems of session 2. Then the students, in the whole class group, answer questions and problems related to six traits easily observed in humans (earlobes, etc.) aimed at emphasizing variety inside a species. Then they break into small groups and solve standard Mendelian genetics problems.

Session 4. The teacher lectures about biological change and evolution, and its relation to genetics. She discusses Creationism, Lamarckism, and Darwinism.

Session 5. First part of the chicken problem: the students broke into small groups and were given the first sheet of the handout (see dialogue that follows). They discussed it.

Session 6. Second part of the chicken problem: the students were given the second sheet of the handout with different hypotheses (as described following). They discussed it in small groups and then in the whole class.

This was the first part of the problem given to the groups in the fifth session:

> As you know, different animals, such as chickens, pigs, or cows, are raised on farms, in order to get meat and eggs without having to kill animals which live in the wild.
>
> But, since chickens are raised on farms, there is a problem: many chickens are born with yellow feathers instead of the spotted brown of the chickens that live in the wild. Some people don't want to buy them, because they looked awkward, and this causes the farms to lose a lot of money.
>
> Near our town a new chicken farm, "The Happy Hen," was set two years ago, with huge buildings where they raise chickens. But in the last year, they had some problems, because

many chickens have yellow-colored feathers, instead of spotted. The farm gathered their biologists' team to solve the problem.

You are asked to advise the biologists, studying what could be the cause of this color change in the chickens, but always giving reasons that sustain your answer. If you give an answer and cannot back it up with arguments, then this answer has no value.

You can also suggest which tests you would perform to show that you are right.

The situation is an adaptation of a real marketing problem encountered by fish farms raising turbot: the fish were white or very pale instead of dark, their natural color, and people refused to buy them. The reasons for the color change are still under discussion, some believe it to be an effect of natural selection (pale individuals would not survive in the wild as opposed to a tank), others relate it to the effect of food in pigmentation. Which reason is accurate is not clear.

Following the strategy to solve the problem by Eichinger et al. (1991), we then decided to add the hypotheses in the second day (sixth session). These alternative hypotheses were drawn from real answers of students of the same age in a paper and pencil test from a study about learning of Natural Selection (Jiménez-Aleixandre, 1992).

This is the second part of the handout given to students in the sixth session:

Here are some possible causes that other people suggested:

Possible causes	**Reasons in favor of it**	**Reasons against it**
Food		
Hereditary variation		
Color in the environment (farm)		
Other		

You have to discuss which one of these (or a different one) looks appropriate, and give reasons for it.

Data Analysis

The audiotapes were transcribed and the sentences broken into units of analysis. The transcripts are analyzed in three dimensions.

First, we sought to identify in each unit if students were "doing the lesson" or "doing science." This category of analysis is related to the differences between scientific culture, what Brown, Collins, and Duguid (1989) call culture of a domain and school culture, and to the rules — both explicit and implicit — set for classroom tasks. Under the category of school culture, we coded the interactions which could be viewed as "doing the lesson" as procedural display (Bloome, Puro, & Theodorou, 1989) or "acting as students." Under the category of science culture, we coded the instances of "talking science" or "doing science." The purpose of identifying the instances of the two contrasting cultures was to explore which of them dominate the dialogue.

Then, for the instances of "talking science," two analyses were performed, one relating to the argumentative operations in the discourse, and the other relating to the epistemic operations which could be considered relevant for the development of scientific knowledge. The argumentation analysis followed Toulmin's (1958) argument pattern. Their components, illustrated in Figure 1, are: (1) *data,* that in this case are hypothetical, and given in the problem statement; (2) claims, or conclusions, here the different hypotheses for causes of the color change; (3) warrants, reasons which justify the connection between data and conclusion; and (4) warrants related to a theoretical backing, of a general character. Sometimes there are also: (5) qualifiers, which specify conditions for the claim; and (6) rebuttals, which specify conditions for discarding the claim (this last component is not included in Figure 1).

For the argumentative operations analysis, a reference argument pattern was developed using the ideas from instruction prior to students solving the problem (see Figure 1). Several warrants and backings were introduced following the pattern developed for a water state problem by Eichinger et al. (1991), as required by the complexity of the problem. Warrants 1 (inheritance of color differences), 2 (advantage conferred by a given trait), and 3 (changes in proportions in the population) are part of the experts' explanation.

For the epistemic analysis, a set of epistemic operations relating to science was constructed using several sources: epistemic operations in other fields, such as History (Pontecorvo & Girardet, 1993), philosophy of science, and classroom conceptual ecology. The elaboration of this frame of analysis and the input from the different sources are discussed in detail in Jiménez-Aleixandre, Díaz, and Duschl (1998). The list of epistemic operations appears in Table 1.

The analysis of the transcripts is presented in columns, beginning with the pseudonyms and the number of the turn, then the transcribed units and three columns for the analysis: the argumentative operations, the epistemic operations, and the science culture vs. school culture. Part of the transcriptions correspond to discussion among one of the eight small groups inside the class, identified as group A, the other to the whole class discussion.

The small groups of students are identified by letters A to H. The four students in group A, to which the first part of the transcriptions correspond, are identified by pseudonyms with respect to their gender (all of them were girls).

TABLE 1
Epistemic Operations

Induction		Looking for patterns, regularities
Deduction		Identifying particular instances of rules, laws
Causality		Relation cause–effect, looking for mechanisms, prediction
Definition		Stating the meaning of a concept
Classifying		Grouping objects, organisms according to criteria
Appeal to	— analogy — exemplar/instance — attribute — authority	Appealing to analogies, instances or attributes as a means of explanation
Consistency	— with other knowledge — with experience — commitment to consistency — metaphysical (status object)	Factors of consistency, particular (with experience) or general (need for similar explanations)
Plausibility		Predication or evaluation of own/others' knowledge

The abbreviations used refer to the categories of analysis, either in terms of school culture, of argument operations, or of epistemic operations, and are predicat. (predication); c. task (classroom task); opposit. (opposition); consistenc. (consistency); and anthropoc. (anthropocentrism).

Following Pontecorvo and Girardet (1993), we have coded as "opposition" particular claims which contradict another previous claim.

RESULTS: "DOING THE LESSON" AND "DOING SCIENCE"

The results of the analysis are presented in this section, beginning with the identification of instances of "doing the lesson." Then, in the instances of what we code as "doing science," the argumentative and epistemic operations are discussed. Some instances of transcriptions are quoted to illustrate the analysis and a longer excerpt is reproduced in Appendix 1.

As discussed in section two, the first three sessions were devoted to introduction of basic genetic concepts and to solving qualitative problems about Mendelian genetics. In session four, the teacher lectured about evolution, and in session five, the students, distributed in small groups, began to discuss the chicken problem. All of the transcriptions reproduced correspond to session six, after the students were given the second part of the handout.

"Doing the Lesson": Procedural Display

A substantial part of students' conversation is devoted to clarify, or simply to speak aloud, the task set for them, as shown in lines 14.1, 16, or 34 which follow. The issue here seems not so much to explain why they are choosing the food hypothesis, but to fulfill the task of "writing why."

Name	Line	Transcribed Talk, Group A	Argument Operation	Epistemic Operation	School Culture
Rita	14.1	And now we have to write why.			Classroom task
	14.2	Shall we write because of the food or Because of weather?			Classroom task
Isa	15	Food	Claim		
Bea	16	Do we have to write why here?			Classroom task
		....			
Rita	33	And now: what should we do?			Rules for task
Isa	34	You have to tick this box [hand-out]			Rules for task
Bea	35	Tick what?			Rules for task
Rita	36	Yeah, I was going to tick in the food . . .			Rules for task

The directions given by the teacher or the handout are invoked as justification for changing the explanation: as the directions are to choose one explanation, one and only one must be chosen, even if they do not have good reasons to decide between two, as seen in line

99. It has to be taken into account that both in Spanish and in Galician, languages used in the classroom, the word (una or unha) has two meanings: the article a and the numeral one.

Name	Line	Transcribed Talk, Group A	Argument Operation	Epistemic Operation	School Culture
Rita	97.1	But, look, I believe that it is because of food.		Predicat.	
	97.2	The food makes them to have the spotted body. I think so	Claim	Causal	
Bea	98	Then: why did you say hereditary variation?	Request		
Rita	99	Because it says that there could be just one			Rules for task

A clear instance of what we mean by "doing the lesson" in the frame of the school culture is provided by Isa in lines 115 and following. After a discussion with a number of exchanges which repeat the same arguments (food yes, food no), the warrant provided by Isa is of a different nature, being related not to data or to scientific theories, but to school culture: if we are studying genetics, then the answer to this question has to be related to genes, not to food or other. This seems to have an effect on Rita, who until now has been switching back and forth to food, and now (118) states a theoretical support for the genes hypothesis (backing).

Name	Line	Transcribed Talk, Group A	Argument Operation	Epistemic Operation	School Culture
Isa	115.1	But look, we are talking about genes	Data		Classroom task
	115.2	And then, probably, if we are talking about genes what is the use in talking about eggs, about food; let's talk about hereditary variation, about genes.	Claim		School culture
	115.3	I would write this in a test. I am not talking about eggs if we are studying Genetics	Warrant	School culture	
Rita	116	No	Predicat.		
Isa	117	I am not talking about eggs if we are studying Genetics.	Warrant		School culture
Rita	118.1	I see, you will write . . .			C. task
	118.2	Lamarck says that if it changes during life, it passes to the genes,	Backing	Deduction	Appeal to book
	118.3	and Darwin says that it cannot change, what happens in life it doesn't change to genes.	Backing	Deduction	

Still, one person in the group, Rosa, is unconvinced and she suggests a new hypothesis: a dye put into the chickens by the farmers (see line 133 in next section). This hypothesis and the argument that follows will be discussed later, but the issue relevant to school culture is that, although Rosa does not agree with the heredity hypothesis, she does not want to have her opinion written in the group report or discuss it aloud, so in line 192 she shows agreement with the group report (hereditary variation). But, her disagreement is expressed later on, during the whole class discussion (line 202), although she avoids saying it in front of the whole class and says it in a low voice just to be heard by the students in her group. In other words, there is a contradiction between what she agrees to be reflected in the group report or said in front of the class and what she believes as an explanation. Adolescents have a need to be part of a group, to be accepted by it, and they usually fear to be outsiders, to sustain opinions different from their peers.

Group/ Name	Line	Transcribed Talk, Whole Class	Argument Operation	Epistemic Operation	School Culture
A/Bea	201	(to group A, inside talk) We all agree [in the hypothesis about heredity]		Predicat.	
A/Rosa	202	(to group A, inside talk) I do not agree [about heredity]		Predicat.	School culture

In our opinion, what can be interpreted from these instances are moments in the students' dialogue which are dominated by school culture; in these moments, students seem worried about "doing school" rather than about "doing science." Nevertheless, there are also moments when they are talking science, as discussed next.

"Doing Science": Sequence of Arguments and Epistemic Operations

We interpret "doing science" as exchanges when students are evaluating knowledge claims, discussing with each other, offering justifications for the different hypotheses, and trying to support them with analogies and metaphors.

The first hypothesis proposed by the group for the change in color is food (Isa, line 6.1) and the warrant she offers in 6.2 could be, in our opinion, an instance of analogical thinking establishing a corresponding natural food — natural color, manipulated food — changed color.

Name	Line	Transcribed Talk, Group A	Argument Operation	Epistemic Operation	School Culture
Isa	6.1	Food, yes	Claim	Causal	
	6.2	because before they ate natural things	Warrant	Analogy	

Then a discussion follows and Isa (line 32) proposes hereditary variation, changing the line of argument. Asked by the other three students to explain her claim, Isa offers for the first time a tentative argument about color being inherited, appealing first to the data in 60.1 (they are different in color from the other, wild chickens), and then to a warrant about identity in 60.2, which could be interpreted in terms of an implicit backing: siblings resemble each other because of inherited traits. This leads to the claim: if they resemble each other in color, color must be a question of inheritance.

Name	Line	Transcribed Talk, Group A	Argument Operation	Epistemic Operation	School Culture
Rita	59.1	And why?	Request		
	59.2	Look, you who said hereditary variation			School culture
	59.3	Why do you think that it is hereditary variation?			
Isa	60.1	They have a different color,	Data	Appeal to attributes	
	60.2	they are identical	Warrant		
	60.3	and it is hereditary variation	Claim		

A summary of the argument in Toulmins' layout, including the implicit backing, appears in Figure 2. It is worth noticing that Isa does not offer an explanation for the change in color, just an argument about color being a matter of inheritance, rather than relating to food or environment.

Isa is asked again to provide reasons, as she was the first to talk about hereditary variation, and she and Rita (see lines 71–78 in the appendix) advance in a tentative way the idea that a change in color may be related to a change in the genes. It is interesting that the definition of mutation as a change in the genes seems not to be clear for Rita. This shows the problem of communication in classrooms, when students use words and terms without a clear idea about their meaning.

The argument path is not straight, and Rita goes back to the food explanation (see line 97 above), then tries to relate hereditary changes to food changes, appealing to an analogy with an example used previously by the teacher about the beak of hummingbirds. Then an exchange follows with repetitions of the same ideas, food yes, food no, until Isa (line 115) justifies her choice of hereditary variation on the grounds of the topic being currently studied in the lesson, as discussed in the "doing the lesson" section previously.

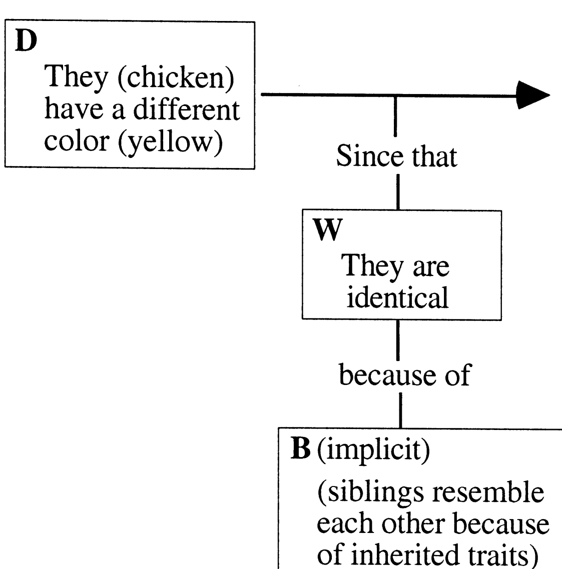

Figure 2. Argument in line 60: heredity.

Although Isa's explanation seems to convince Rita and (partially) Bea, Rosa is still unconvinced and she (line 133) suggests a new hypothesis: the farmers put a dye in the chickens, to which Isa (134) argues that offspring don't have a color related to the dye put on parents. Rita argues in the same direction, first (135) appealing to consistency with what happens in humans, and then, in one of the few explicit backings (137), relating this possibility to Lamarck's theory.

Name	Line	Transcribed Talk, Group A	Argument Operation	Epistemic Operation	School Culture
Rosa	133	Couldn't be the color from the farm, they put it on them so they looked prettier?	Claim	Analogy	
Isa	134.1	Look here, and then that they put on pigment	Opposit. (to 133)		
	134.2	and if they put on pigment on them: Why did they have offspring also painted?	Request		
	134.3	It doesn't make sense.	Opposit.	Predicat.	
Rita	135	Now, if you dye your hair yellow: would your children be born with yellow hair?	Warrant	Appeal to consistency	
Bea	136	No. To dye your hair yellow. She is fair.	Opposit.		
Rita	137.1	That would be if Lamarck's theory were right,		Deduction	Appeal to authority
	137.2	but because it isn't right.	Backing		

As Lamarckism has been the subject of session 4, perhaps this could be interpreted also as an implicit appeal to the teacher and textbook authority. The argument of Rita in opposition to 133 is represented in Figure 3.

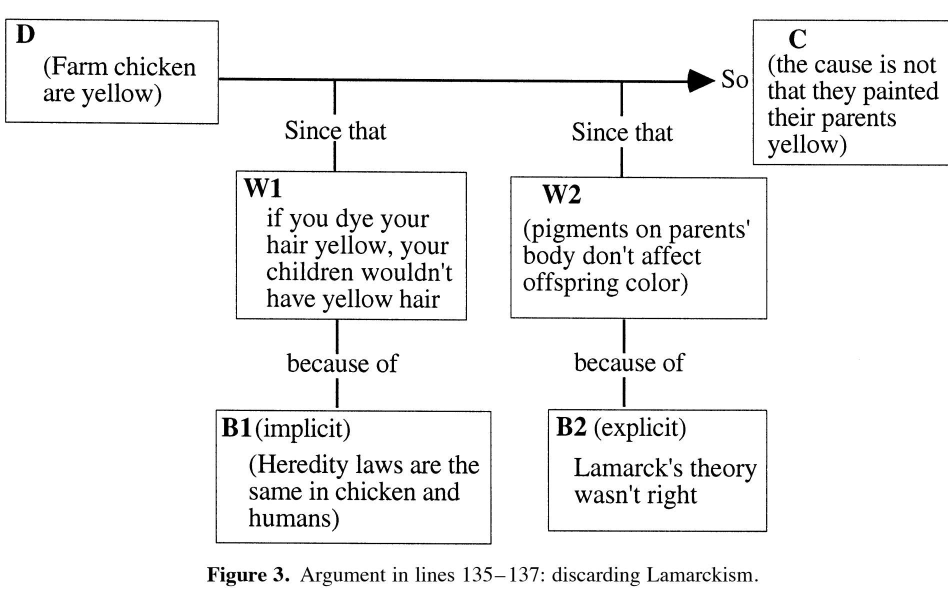

Figure 3. Argument in lines 135–137: discarding Lamarckism.

An interesting issue is the appeal to consistency, an epistemic operation characteristic of scientific explanations, which must account for phenomena in different contexts or, in this case, organisms. After Rita does it, she and Isa will appeal repeatedly to consistency, both in the small group and in the whole class discussion, particularly to oppose food and environment (color, temperature) hypotheses.

Name	Line	Transcribed Talk, Group A	Argument Operation	Epistemic Operation	School Culture
Bea	154.2	I also heard that it was because of eating yellow feed.	Claim	Analogy	
Isa	155.1	Well, no,	Opposit.		
	155.2	because you, even if you eat a lot of salad, your face doesn't turn green.	Warrant	Appeal to consist-ency	

Bea's hypothesis (perhaps overheard from another group) could be interpreted as an analogy with brown color in eggs, related to substances in the feed, and Isa, appealing to consistency, discards it. The sequence of arguments from group A, and the warrants used are summarized in Figure 4.

In the whole class discussion, only two from the eight groups, A and E, favored the heredity hypothesis, whereas the other six groups used the environment, color of the farm hypothesis, seen as follows in the interventions from groups B and D. Isa and Rita from group A challenged this hypothesis, appealing to consistency, as they did in the small group, and engaged in a true science dialogue with the speaker from group D.

Group/ Name	Line	Transcribed Talk, Whole Class	Argument Operation	Epistemic Operation
B	197.1	They were spotted, but the light and the color in the farm made that, along time, they turned yellow	Warrant	Appeal to analogy
	197.2	in order to go unnoticed	Warrant	
		(..........)		
D	218.1	The color of the farm	Claim	
	218.2	because in the farm they don't need to camouflage themselves in the plants	Warrant	
A/Rita w	219	And do they change color every five minutes? First they are spotted and then turn yellow?	Opposit. (to 218)	
		(..........)		
D	222	No, it depends from the situation	Qualifier	
		(..........)		
A/Isa w	225	Then: if we go to China we will get yellow?	Opposit.	Appeal to consistency
D	226.1	No, if you put a chicken in a farm, it doesn't turn white,	Claim	Appeal to analogy
	226.2	but with time it does.	Qualifier	
A/Rita w	227	But they don't get yellow	Opposit.	
D	228	But when they have descendants they are getting paler and paler in order to mimicry like predators	Warrant	Appeal to analogy

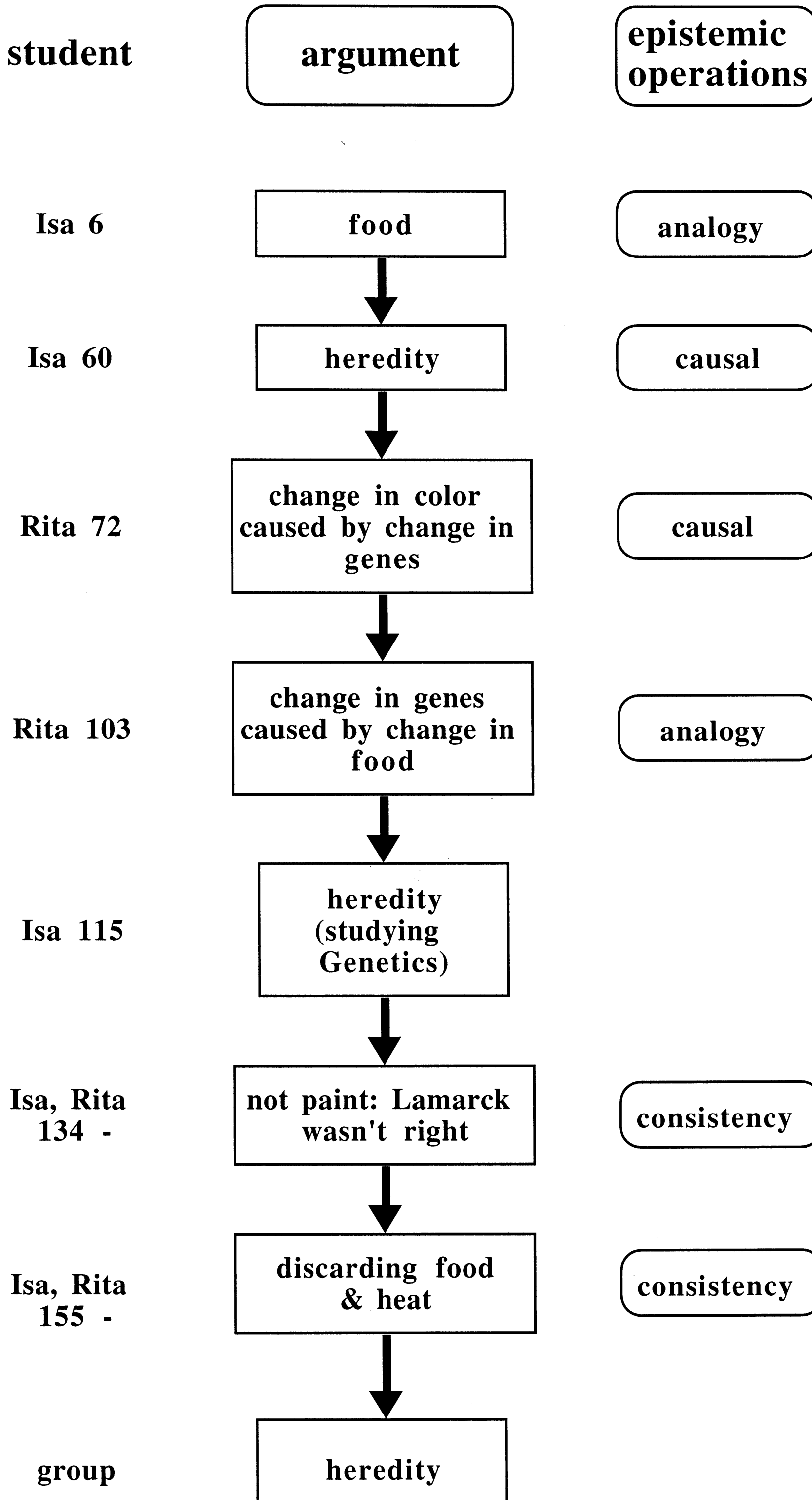

Figure 4. Sequence of arguments and epistemic operations in group A.

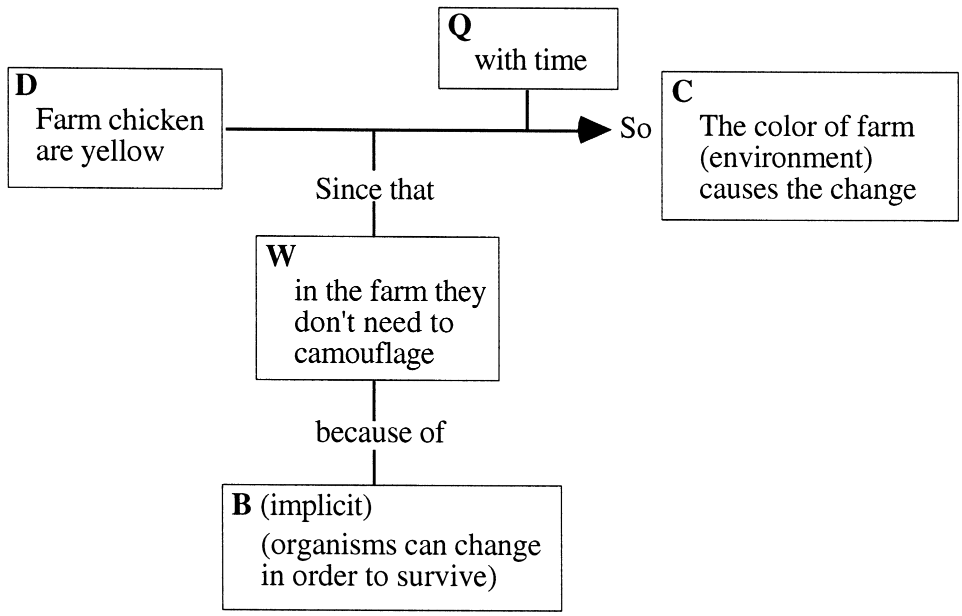

Figure 5. Argument from group D (218–226).

A/Isa w	229	But no, because the traits that you pick during your life are not inherited	Backing	Deduction
A/Rita w	230	You go to live in China and your children are Chinese?	Opposit.	Appeal to consistency

Concerning the argument components, the answer from group D (line 226) introduces a qualifier: the change is a question of time, and this argument is developed in 228, to which Isa offers, not a warrant this time, but a theoretical backing (used before by Rita in 137 with a different wording and represented in Figure 3): acquired traits are not inherited. The argument of group D in 218, 226, and 228 is represented in Figure 5.

The discussion between groups D and B on one side and group A (Rita and Isa) goes on, and they are supported by Pat, from group E (which has not reported yet). Both Isa (249) and Pat (252) appeal to consistency with instances in which food or environment don't have an effect on human color, and then group F sustains also the environment hypothesis, and an interesting discussion about genetics concepts occurs.

Group/ Name	Line	Transcribed Talk	Argument Operation	Epistemic Operation
E/Pat w	244	Mutation doesn't occur because the chicken . . .	Claim	Appeal to consistency
A/Rita w	245	. . . want to be yellow	Claim	
D	246	So, why does it occur?	Request	
A/Isa w	247	Because of something natural	Claim	Attribute
B	248	Because of feed	Claim	
A/Isa w	249.1	No, why would they change like this?	Opposit. (to D)	Appeal to consistency
	249.2	Now I am spotted, and because I eat bananas I turn yellow [ironically] (..........)		

E/Pat w	252	Sure. You go there outside and, do you turn green?	Opposit. (to D)	Appeal to consistency
		(..........)		
F	263.1	. . . because of the environment . . .	Claim	
	263.2	not all environments are the same	Warrant	
A/Isa w	264	What has the environment to do?	Opposit.	
A/Rita w	265.1	Of course, you go to China and you turn yellow. [ironically]	Opposit (to 263)	Appeal to consistency
	265.2	It is nonsense.		Predicat.
A/Isa w	266	You go to Venice and you grow water things . . .	Opposit.	Appeal to consistency
F/Luisa	267.1	Genetic variation doesn't mean that some had yellow genes, and others spotted.	Opposit.	Definition
	267.2	If all were spotted: how is possible that they had yellow genes?	Warrant	Deduction
A/Isa w	268	There was a mutation	Warrant	

The students here are really talking science, hotly engaged in the debate about crucial genetics concepts: Luisa tries to define genetic variation, stating that it doesn't mean different types of genes (alleles). This shows an understanding of variation quite different from school science, in which variation means precisely the existence of different alleles. Isa's answer (line 268) seems to show that she is sharing this idea, and that different color could be caused by mutation, rather than by changes in the frequencies of genes. Then Pat (see the appendix) explains the change in color because the yellow gene turned from recessive to dominant, identifying expressed traits with dominant alleles, a problem frequently encountered in genetics learning.

The commitment to consistency which some students from groups A and E show is not shared by all pupils. On the contrary, other students from groups C and G claim that chickens and people are not the same, implying that acquired characteristics could be inherited in animals. This explicit lack of commitment to consistency could be interpreted as an instance of anthropocentrism, of viewing humans as different and apart from other organisms. Then Pat, Rita, and Isa switch to animals (see Appendix 1), picking rabbits as an instance of color resulting from inheritance and not from environment, in an attempt to avoid the conflict about humans.

Group/ Name	Line	Transcribed Talk, Whole Group	Argument Operation	Epistemic Operation
E/Pat	283	I marry and go to Africa and have a child, and it is white.	Opposit.	Appeal to consistency
A/Isa	284	It's true, all right, Pat		Predict.
C	285	This is comparing chicken to people	Rebuttal	Attribute
		(..........)		
G/Carlos	295.1	You cannot confuse them [with people]	Rebuttal	Anthropoc.
	295.2	The animals often they are seeking camouflage, mimicry with the environment	Claim	
		(..........)		
E/Pat	307	You have a white rabbit, and you set it free in the wild . . .	Opposit.	Appeal to consistency
A/Isa	308	And it doesn't change, my white rabbit	Opposit.	Appeal to consistency

The discussion gets hotter, but the statements are not new. Then the teacher offers a reformulation of the problem, and the school science argument, as represented in Figure 1. A summary of the two opposed paths of arguments in the whole class is represented in Figure 6.

As a quantitative summary of the contributions from each of the four students in group

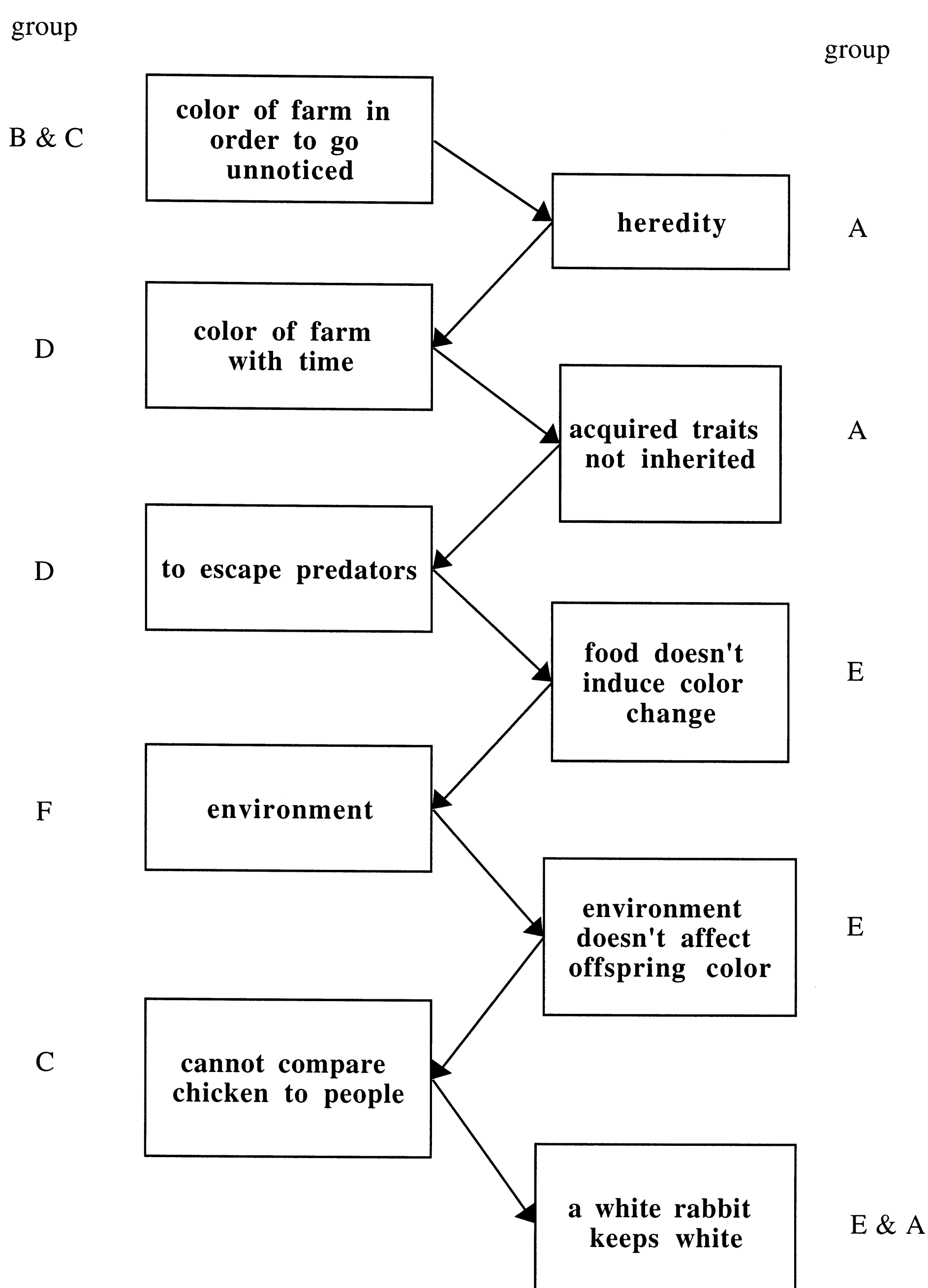

Figure 6. Two opposed paths of arguments in the whole group.

A, out of 193 turns (interventions by the teacher or observer are not numbered), Rita with 75 (39%) and Isa with 65 (33.5%) contributed the most, whereas Bea with 33 (17%) and Rosa with 20 (10.5%) had fewer contributions. A different question is the relevance of these contributions, discussed in the last section.

DISCUSSION AND IMPLICATIONS: WHAT GOVERNS THE CLASSROOM DISCOURSE?

The purpose of our study was to explore trends in the classroom discourse, in the first place to identify instances of "doing school" and instances of "doing science." Our question was about what governs the discourse in the classroom: is it the school culture, the procedural display, or the science culture?

The study was conducted in a group where argument had not been taught and the teacher did not have the development of the capacity about argumentation among her stated goals. However, we expected that a change in the classroom setting, in this case a problem-solving task which explicitly asked the students to provide reasons for their choices, would provide students with an opportunity to "talk science." This was possible also because the students were used to working in groups and discussing their opinions in a friendly climate. This study corresponds to an initial phase of our project about argumentation, and in the next phase, we have developed full teaching sequences based on problem solving (Álvarez, 1998; Jiménez-Aleixandre, Pereiro, & Aznar, 1998) which have as a goal promoting reasoning and argumentation.

"Doing Science" and "Doing School"

In reference to the first objective of the study, the identification of instances of "doing school" and instances of "doing science," as seen in the results section, a substantial part of the exchanges between students could be described as belonging to the school or classroom culture — what Bloome, Puro, and Theodorou (1989) call procedural display, defined by them as interactional procedures which count as doing a lesson, but are not necessarily related to the stated goals for learning. These interactions and dialogues are more related to acting as "science students" than to the explicit objective of the task: discuss the causes of the change of color in farm chickens. We have interpreted as "doing school" or "doing the lesson," on the one hand, interactions that refer to the rules for the task, like what to write, or the discussion about choosing only one hypothesis. On the other hand, there are instances where the appeal to school culture is less explicit and refers not to a particular rule, but to the perceived features of classroom or lessons; for instance, Isa's argument in 115 and 117 about what is the topic of the lesson "we are talking about genes" or "if we are studying genetics," or the apparent agreement reached at the end, when Rosa accepts the opinion of the group although different from her own. Something to be noted is that, as discussion proceeds, the contributions of students relate more to the science issue in discussion and less to rules or to incidental talk. This trend accentuates in the whole-class discussion where, as seen in the transcripts, they are talking science almost all the time.

Arguments and Argument Components When Talking Science

In reference to the second objective, the development of arguments, the move from data and evidence to conclusion, the analysis shows that the students developed a variety of arguments, in some cases more sophisticated (using justifications, backings) than in others. There were only two groups, A and E, which favored the heredity hypothesis, and from the perspective of the comparison between the reference argument (Figure 1) and the arguments from these two groups, represented in Figures 2, 3, and in the right column in Figure 6, it appears that warrant 1, inheritance of different colors, is contemplated by the students, and the same could be said about warrant 4, non-inheritance of acquired characteristics. It is not clear whether the students contemplate warrant 2, about different features (colors) being advantageous in different environments, and it seems that they don't take into account at all warrant 3, changes in the proportions in the population. On the contrary, for them the reason for change is a mutation; that is, a change in individuals. It seems that when the students talk about "hereditary variation" it doesn't mean for them the same as it does for the school science; that is, the existence of different forms (alleles) from a gene in the population.

In reference to the argument construction, some issues which emerge are:

Co-Construction and Unbalanced Participation. In group A, two students, Rita (39%) and Isa (33.5%) made nearly three-quarters of the 193 contributions. Moreover, in the contributions from the other two students, it can be seen that for Bea only 13 out of 33 can be interpreted as part of an argument, while the other 20 are either incidental talk, comments related to the rules for the task or to the school culture, predications about other students' contributions, or requests for clarification. For Rosa, 9 out of 20 are part of an argument, and 11 are not. Rita and Isa shared the leadership in the course of the argument: the first hypothesis discussed by the group is food, until Isa (32) proposed hereditary variation and then advanced a first argument (60) represented in Figure 2: the change in color is a question of inheritance, because all siblings have changed in an identical sense. The next move, initiated by Rita in 72 and then followed by Isa — perhaps prompted by the word "variation" — is to relate the change in color to a change in the genes. Rita goes back to the food hypothesis (97, 103), but Isa in 115 and 117 gave a new reason related more to the school culture than to scientific reasoning. From this moment on, Rita supported Isa in the defense of heredity. In fact, in her next contribution (118), she advanced a backing for the heredity hypothesis. Then followed a process of discarding hypotheses: food (Isa 164), heat (Rosa 166), and then they agreed on heredity. In summary, it can be said that two students, Isa and Rita, shared the construction of the arguments, as in 115–118, 134–137, or 227–229, and offered most of the warrants coherently stated. Another question is the difficulty in knowing the reasons that convinced the other students to support Isa's opinion about heredity. In fact, as the dialogue during the whole class discussion reveals, Rosa was not convinced, but at the same time she was not willing to speak for herself and agreed to write that the opinion of the group was hereditary variation.

Argument components used by students: in the discussion in group A, we have coded 99 elements as part of an argument (including arguments related to school culture, like "we are talking about genes"). From these two-thirds, 66 are claims (including oppositions), 21 warrants, 10 data, and 6 backings. In the small-group discussion there are no qualifiers or rebuttals. In the whole group, claims were also the elements more frequently used, and warrants (as required by the task). It is interesting to note the use of qualifiers, like time by group D (226) and rebuttals, as shown in line 285 by group C. As noted by Eichinger et al. (1991) discussing construction of argument by 6th graders, there is little systematic exploration of the theoretical backing which will support (or turn back) a given claim. Most of the time the claims were offered without any relation to other elements in the argument, which accounts for its higher proportion. There are a few cases where it can be said that there were some related elements, and some of them are represented in Figures

2, 3, and 5. As seen in the figures and in the transcripts, the backings were, in nearly all cases, implicit.

Epistemic Operations

The purpose of the task was the identification of causal mechanisms for the change in color, so it is not surprising that a great proportion of the epistemic operations could be coded under this category of causality. Analogies are also used in the discussion, relating natural color to natural food (6), the change in color to cosmetics (133), or yellow color of chickens to yellow feed, like what happens with brown eggs (133). An interesting question is the appeal to consistency first made by Rita (135) relating the non-inheritance of acquired traits in humans with what happens in chickens — she uses an example of what happens when humans dye their hair. Warrants similar to this will be used several times by Rita and Isa during the discussion. Sometimes it is said that students, particularly adolescent students, do not have a commitment to consistency, and this is probably true in many cases. The universality of explanations is one characteristic of scientific reasoning: students need to recognize that, for instance, heredity laws apply to different organisms and not just to the ones used in an example. The lack of consistency is an obstacle in the attaining of the goals related to transfer of knowledge and to the application of knowledge to different instances and situations. That Rita appealed to consistency and did not simply use an analogy was supported by her next contribution (137) when she related this issue to Lamarck's theory "because it isn't right," and also by the development of the discussion, with Isa and herself using different examples of the non-inheritance of acquired traits, inside the small group, and in the whole class. Rita (219) challenged the color of the farm hypothesis supported by group D, and then she and Isa appealed to consistency with an instance used before in the small groups: color in human offspring is not affected by environment. It is interesting to note that the backing offered by Isa in 229 is formulated not implicitly as Darwin's or Lamarck's opinion, but stated "the traits that you pick during your life are not inherited," which shows an attempt to relate claims and warrants to theory (backing). That Rita's and Isa's contributions were perceived by the other students as an appeal to consistency was shown, in our opinion, by contributions from groups C (285) and G (295), which deny that you could compare chickens and people. In summary, the dialogue provided some instances of the conceptual ecology of 9th grade students, such as anthropocentrism (humans are one thing and chickens are another), about consistency, and inconsistency as well.

Implications

The ability to develop arguments is a goal not usually set in science classrooms. Our previous observation of classrooms where instruction was conducted in a standard way (Bugallo Rodríguez & Jiménez-Aleixandre, 1996) shows that not much argument occurs in them. For us, the attainment of such a goal is not a matter connected to a single feature of the designed curriculum or of the instructional strategies, but rather is related to a learning environment characterized, among other things, by a perspective of science learning and teaching as inquiry. This includes a variety of dimensions, one of them being that students solve problems. As Duschl and Gitomer (1996) indicate, discussing the design principles of Project SEPIA, whereas the outcome of inquiry may be of interest for the cognitive goals, it is the process of inquiry that is relevant for the epistemic goals, the ones related to the understanding of the structure of knowledge.

In the classroom observed in this study, the efforts of the teacher, who created a climate of confidence which encouraged students to express and defend their opinions, combined with the use of tasks which required students to work collaboratively and to solve problems, resulted in a certain degree of argumentation, of students requesting one another to explain or support their claims, of some instances of developing warrants and even theoretical backings to support their positions. This is one positive aspect of the discussion, and we believe that it was possible because students were used to working in groups and having to reason about their opinions during the whole term. When studying the construction of arguments, first we have to design or identify an adequate classroom environment.

It should be noted that our focus in this study was not the formal layout of argumentation, because students had not received instruction about this, but the natural form of argumentation. The arguments that interest us are only the substantive ones (Toulmin, 1958) — the ones in which the knowledge of content is a requisite for understanding and involve the use of subject matter, in this case genetics. In other words, we are interested in discussions about science. Although we call this form of argumentation "natural," our previous data seem to indicate that argumentation of this nature is not common in the classroom. Students are not given many occasions to discuss scientific issues, relate data, and offer explanations. For this reason, we believe that our study supports the interest of providing the students with opportunities to solve problems, discuss science, and talk science, showing that, given this opportunity, even on a small scale, students will use a number of operations (argumentative and epistemic) which make part of the scientific culture. By doing so, students will learn certain aspects of science that are different from conceptual comprehension.

The question of concept and model comprehension leads to the issue of the outcomes related to the teacher's goals — the use of genetic concepts. In the transcriptions, conceptual confusion is evidenced by a great deal of the contributions. Genetics — and the same could be said about evolution — is one of the most difficult topics in Biology education. Some of the difficulties related to it are: the degree of abstraction of the heredity model and the mathematical operations related to it; the difficulties associated with probabilistic (vs. deterministic) reasoning (Jiménez-Aleixandre, 1994); the lack of connections between reproduction and heredity in the curriculum; and the persistence of alternative ideas and a mechanical way of solving problems by means of just algorithms. In the students of this group, some difficulties are evidenced. For instance, even those students who sustained the heredity hypothesis viewed the color change as individual (mutation) rather than population change. The issue of the inclusion of such topics in the science curriculum in 9th grade, much discussed in Spain, is once again raised. Perhaps it could be said that, if genetics is included, some changes need to be made. The subject would need more than six sessions, allowing time for application exercises of the complex models in different contexts, and attention should be paid to questions about prior ideas and the process of problem solving. For instance, following our problem about chickens, the next step would be not just to ask the students to look for the causes of the color change, but also to design a way to reverse the process of change. This would require a real community of learners involved in inquiry, where the students teach one another and convince one another using the arguments that apparently convinced themselves, like in some of the instances discussed previously. A last question about conceptual issues is the distinction (Mayr, 1997) among Biology and other science disciplines in relation to the importance of new concepts along History. For Mayr, what is different is that in Biology new concepts are more important that new laws or theories (which could be more relevant in physics or chemistry). Perhaps this is important also for the students' explanations when they discuss the meaning of mutation or of genetic variation.

Another question relates to the difference among data of a different character. The data that students were handling in this problem were hypothetical and not to be doubted. This data was supported by the teacher's authority, but the way students construct arguments is different when they have a problem with empirical, unknown data, as shown in the study by Kelly, Drucker, and Chen (1998) about electricity or in our own study with microscopes (Jiménez-Aleixandre, Díaz, & Duschl, 1997).

This study is an example of how we need a variety of approaches and instruments to explore the classroom conversation. The argument pattern from Toulmin was not enough to interpret some exchanges, and that is why we developed a frame for epistemic operations, for analogies or appeals to consistency which constitute a different level from the cognitive one. For a more holistic analysis, the use of Bloome et al.'s notion about "doing school" proved, in our opinion, fruitful.

Central to argumentation is the move from evidence to explanation, and some fragments from the transcriptions document show how the students relate the changes in color to a variety of explanations and how they strive to find coherence between the explanations and previous knowledge (Lamarck or Darwin theories) or everyday experience (influence of food in color). A question that deserves more detailed studies is the field dependence of some features, particularly of "what counts" as explanation, warrant, or even data, and we are currently exploring these issues.

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APPENDIX 1: TRANSCRIPTION, SESSION 6

The codes used in it are: . . . , transcription not reproduced; notes in `courier 9` between square brackets [ ] indicate clarification by observer; 1, 2 correspond to contributions; 1.1, 1.2 to different elements in a contribution; T, teacher; O, observer (not numbered in the sequence).

Name	Line	Transcribed Talk, Group A	Argument Operation	Epistemic Operation	School Culture
Isa	6.1	Food, yes	Claim	Causal	
	6.2	because before they ate natural things	Warrant	Analogy	
Isa	7.1	`[reads from handout]` Hereditary variation			Classroom task
	7.2	Color `[Spanish 'color']` of the mother	Claim	Causal	
Isa	8	Color what?	Request		
Rosa	9	Heat `[Spanish 'calor']` of the mother	Claim		
Bea	10	You said color `[to Isa]`		Predicat.	
		....			
Rita	14.1	and now we have to write why,			Classroom task
	14.2	Shall we write because of the food or because of weather?			Classroom task
Isa	15	Food	Claim		
Bea	16	Do we have to write why here?			Classroom task
Isa	17	The group thinks that the cause of the change in feather color it is . . . it is because of the food that they ate before and after living in farms . . .	Claim	Causal	
		....			
Rita	29	So we agree with this		Predicat.	
Isa	30	It could be only one			Rules for task
Rita	31	Only one? We agree on this one, and this one and that. We write this one `[food]`			Rules for task
Isa	32	Hereditary variation	Claim	Causal	
Rita	33	And now: what should we do?			Rules for task
Isa	34	You have to tick this box `[handout]`			Rules for task
Bea	35	Tick what?			Rules for task
Rita	36	Yeah, I was going to tick in the food . . .			Rules for task
Isa	37.1	Because of hereditary variation	Claim	Causal	
	37.2	And now, what else should be write?			Classroom task

From 38 to 58, Isa is asked by the other three students to explain her claim in 32 about hereditary variation

Name	Line	Transcribed Talk, Group A	Argument Operation	Epistemic Operation	School Culture
Rita	59.1	And why?	Request		
	59.2	Look, you who said hereditary variation			School culture
	59.3	Why do you think that it is hereditary variation?			
Isa	60.1	They have a different color,	Data	Appeal to attributes	
	60.2	they are identical	Warrant		
	60.3	and it is hereditary variation	Claim		
Bea	61	And: why do they have another color?	Request		
Rita	62.1	But you don't have to explain why.			Rules for task
	62.2	I see it as obvious		Plausibilit.	
Isa	63.1	I said it and you wrote it.		Predicat.	
	63.2	Why did you write it?	Request		
Rita	64	Because you said it		Appeal to authority	

From 65 to 70, Bea and Rita ask Isa again to provide reasons.

Name	Line	Transcribed Talk, Group A	Argument Operation	Epistemic Operation	School Culture
Bea	71	Because of hereditary variation	Claim	Causal	
Rita	72	Yeah, there was a change in a gene	Warrant	Causal	
Isa	73	So, there was a change in the genes, a Mutation	Warrant (72)	Definition	
Rita	74	It is not a mutation	Opposit.		
Isa	75	It is a mutation. [they laugh]	Counter-opposit.		
Rita	76.1	It is a change in the genes . . .	Opposit.	Definition	
	76.2	well, perhaps it is a change, yes	Conces.		
Isa	77	In the DNA	Warrant		
Rita	78	Before. In the cells that . . . the organisms, they come from the firsts . . .	Warrant		

From 79 to 95, they further discuss the meaning of mutation as a change in the genes.

Name	Line	Transcribed Talk, Group A	Argument Operation	Epistemic Operation	School Culture
Isa	96	What should we write?			Rules for task
Rita	97.1	But, look, I believe that it is because of food.		Predicat.	

	97.2	The food makes them to have the spotted body. I think so	Claim	Causal	
Bea	98	Then: why did you say hereditary variation?	Request		
Rita	99	Because it says that there could be just one			Rules for task
Isa	100	And all this is caused by hereditary variation	Claim	Causal	
Rita	101	No	Opposit.	Predicat.	
Bea	102	Look, I have to . . . in the group			Rules for task
Rita	103.1	What you say it's nothing new, See? [to Isa]		Evaluation	
	103.2	I believe that a hereditary variation,	Claim	Causal	
	103.3	because it had two different foods,	Warrant		
	103.4	is like in the flower, the beak was adapted [example used in instruction]		Analogy	

From 104 to 110, repetitions of the same lines, food yes, food no.

Name	Line	Transcribed Talk, Group A	Argument Operation	Epistemic Operation	School Culture
Isa	111.1	If we don't agree, I'm sorry, but I tell it			Rules for task
	111.2	I believe that it is hereditary variation	Claim	Causal	
Rita	112	And, what causes a hereditary variation?	Asks for warrant	Looks for mechan.	
Isa	113	That is what I'm trying to look for		Predicat.	
Rita	114	But then, it was said . . . first you say one thing then another . . .		Predicat.	
Isa	115.1	But look, we are talking about genes	Data		Classroom task
	115.2	and then, probably, if we are talking about genes what is the use in talking about eggs, about food; let's talk about hereditary variation, about genes.	Claim		School culture
	115.3	I would write this in a test. I am not talking about eggs if we are studying Genetics.	Warrant		School culture
Rita	116	No		Predicat.	
Isa	117	I am not talking about eggs if we are studying Genetics.	Warrant		School culture
Rita	118.1	I see, you will write . . .			C. task
	118.2	Lamarck says that if it changes during life, it passes to the genes,	Backing	Deduction	Appeal to book
	118.3	and Darwin says that it cannot change, what happens in life it doesn't change to genes.	Backing	Deduction	

From 119 to 132, they ask to the teacher, who says that they have to discuss it themselves and write their own opinion and began to discuss the reasons for the change.

Name	Line	Transcribed Talk, Group A	Argument Operation	Epistemic Operation	School Culture
Rosa	133	Couldn't be the color from the farm, they put it on them so they looked prettier?	Claim	Analogy	
Isa	134.1	Look here, and then that they put on pigment	Opposit. (to 133)		
	134.2	and if they put on pigment on them: Why did they have off-spring also painted?	Request		
	134.3	It doesn't make sense.	Opposit.	Predicat.	
Rita	135	Now, if you dye your hair yellow: would your children be born with yellow hair?	Warrant	Appeal to consistenc	
Bea	136	No. To dye your hair yellow. She is fair.	Opposit.		
Rita	137.1	That would be if Lamarck's theory were right,		Deducation	Appeal to authority
	137.2	but because it isn't right.	Backing		

Then from 138 to 152, they repeat their positions about the dye question.

Name	Line	Transcribed Talk, Group A	Argument Operation	Epistemic Operation	School Culture
Isa	153	But she says that there was no mutation.		Predicat.	
Bea	154.1	But we say that there was. She doesn't know if it is true, we say there was a mutation.	Warrant	Predicat.	
	154.2	I also heard that it was because of eating yellow feed.	Claim	Analogy	
Isa	155.1	Well, no.	Opposit.		
	155.2	because you, even if you eat a lot of salad, your face doesn't turn green.	Warrant	Appeal to consistenc	
Bea	156	Well, if . . .			
Isa	157	No, and your hair neither	Warrant	Appeal to consistenc	
Rita	158	You are absolutely right.		Predicat.	

Time for small group debate is finishing, and they begin to discuss each hypothesis.

Name	Line	Transcribed Talk, Group A	Argument Operation	Epistemic Operation	School Culture
Isa	164	Food, discarded; they wouldn't be like this because of food.	Claim	Causal	
Rita	165	No, not at all.		Predicat.	

Rosa	166.1	It cannot be the heat from the mother	Claim		
	166.2	because the mother, even if she gives it a lot of heat, perhaps it would be more yellow or less yellow, I don't know	Warrant	Causal	
Rita	167	No.			
		....			
Rita	174	A white child born in Africa is not black.	Claim	Appeal to consistenc.	
Bea	175	You go too fast.			Task
Isa	176	A white child born in Africa is not black.	Claim	Appeal to consistenc.	
		....			
Bea	180	But, why a child?	Request	Predicat.	
Rita	181	A white child born in Africa is not black.	Claim		
Rosa	182	If it is white, it cannot be black	Warrant	Appeal to consistenc.	
		....			
Rita	186	There is hereditary . . .	Claim		
Isa &	187	variation . . .	Claim		
Bea	188	. . . variation [teacher asks them to finish the task]	(complet)		
Isa	190	Shall we vote? [about heredity]			Task
Rita	191	we agree		Predicat.	School culture
Bea	192	ok			
Rosa	193	ok			

Whole class discussion: there were eight groups; the other seven are identified as B to H (the brief contribution from group H, at the end is not reproduced); individual students from these groups are not identified by name when reading from their worksheets or summarizing their groups' opinion, only when they are expressing individual opinions. The students from A are identified, coding with **g** (group) the talk among them in a lower key, and with a **w** (whole) their contributions aloud to the general discussion.

Group/ Name	Line	Transcribed Talk, Whole Class	Argument Operation	Epistemic Operation	School Culture
B	194	The color of the farm	Claim		
		....			
B	197.1	They were spotted, but the light and the color in the farm made that, along time, they turned yellow	Warrant Data	Appeal to analogy	
	197.2	in order to go unnoticed [teacher says that any group which disagree with B can express their opinions]	Warrant		
		....			
A/Bea g	201	We all agree [in the hypothesis about heredity]		Predicat.	Classroom rules
A/Rosa g	202	I do not agree [about heredity]		Predicat.	
		....			
C	211.1	The color of the farm	Claim	Appeal to analogy	

	211.2	because the chicken in the wild are spotted	Data
	211.3	in order to camouflage, to go unnoticed, but in the farm they didn't need the speckles	Warrant

Group/ Name	Line	Transcribed Talk, Whole Class	Argument Operation	Epistemic Operation
A/Isa w	214	Hereditary variation [teacher asks them reasons]	Claim	
A/Isa w	215	Because there was a change in the genes and they produce the change in color.	Warrant	
D	218.1	The color of the farm	Claim	
	218.2	because in the farm they don't need to camouflage themselves in the plants	Warrant	
A/Rita w	219	And do they change color every five minutes? First they are spotted and then turn yellow?	Opposit. (to 218)	
D	220	No . . .		Predicat.
A/Rita w	221	When they want they are spotted, and when they want yellow or what?	Opposit.	Appeal to consistenc.
D	222	No, it depends from the situation	Qualifier	
A/Rita w	223	But they cannot go changing color	Opposit.	
A/Bea w	224	If they go out they become spotted [ironically]	Opposit.	
A/Isa w	225	Then: if we go to China we will get yellow?	Opposit.	Appeal to consistenc.
D	226.1	No, if you put a chicken in a farm, it doesn't turn white,	Claim	Appeal to analogy
	226.2	but with time it does.	Qualifier	
A/Rita w	227	But they don't get yellow	Opposit.	
D	228	But when they have descendants they are getting paler and paler in order to mimicry like predators	Warrant	Appeal to analogy
A/Isa w	229	But no, because the traits that you pick during your life are not inherited	Backing	Deduction
A/Rita w	230	You go to live in China and your children are Chinese?	Opposit.	Appeal to consistenc.

Group/ Name	Line	Transcribed Talk	Argument Operation	Epistemic Operation
D	238.1	It is true	Claim	Predicat.
	238.2	Because if they in farms were not yellow, the predators would see them, and then it couldn't be	Warrant	
A/Rita w	239	Come on! Are they changing color because the predator sees them?	Opposit.	Causal
A/Isa w	240	The mutation they don't made it because they want	Claim	Appeal to consistenc.
E/Pat w	244	Mutation doesn't occur because the chicken . . .	Claim	Appeal to consistenc.

A/Rita w	245	. . . want to be yellow	Claim	
D	246	So, why does it occur?		Predicat.
A/Isa w	247	Because of something natural	Claim	Attribute
B	248	Because of feed	Claim	
A/Isa w	249.1	No, why would they change like this?	Opposit.	Appeal to
	249.2	Now I am spotted, and because I eat bananas I turn yellow [ironically]	(to 238)	consistenc.
		....		
E/Pat w	252	Sure. You go there outside and, do you turn green?	Opposit. (to 238)	Appeal to consistenc.

Group/ Name	Line	Transcribed Talk	Argument Operation	Epistemic Operation
E	256	This is a genetic variation, but not . . . [interruption]	Claim	
E	258	These are matters from Nature	Warrant	
		....		
F	263.1	. . . because of the environment . . .	Claim	
	263.2	not all environments are the same	Warrant	
A/Isa w	264	What has the environment to do?	Opposit.	
A/Rita w	265.1	Of course, you go to China and you turn yellow. [ironically]	Opposit.	Appeal to consistenc.
	265.2	It is nonsense.		Predicat.
A/Isa w	266	You go to Venice and you grow water things . . .	Opposit.	Appeal to consistenc.
F/Luisa	267.1	Genetic variation doesn't mean that some had yellow genes, and others spotted.	Opposit. (to 256)	Definition
	267.2	If all were spotted: how is it possible that they had yellow genes?	Warrant	Deduction
A/Isa w	268	There was a mutation	Warrant	
		....		
F/Luisa	270.1	Even if they had some yellow genes	Concession	
	270.2	some chicken would come yellow,	Claim	Prediction
	270.3	but not all of them.	Qualifier	
E/Pat	271.1	No, not if they are not dominant.	Rebuttal	Definition
	271.2	Because the yellow gene turned dominant, and before it was recessive, but it has nothing to do with it.	Claim	
	271.3	You can have a blue-eyes gene, and it doesn't show, but is there. Your sons could have blue eyes . . . not for the moment.	Backing	Appeal to instance

From 272 to 282, they repeat their positions.

Group/ Name	Line	Transcribed Talk, Whole Group	Argument Operation	Epistemic Operation
E/Pat	283	I marry and go to Africa and have a child, and it is white.	Opposit.	Appeal to consistenc.
A/Isa w	284	It's true, all right, Pat		Predicat.
C	285	This is comparing chicken to people	Rebuttal	Attribute
		....		

G/Carlos	295.1	You cannot confuse them [with people]	Rebuttal	Anthrop.
	295.2	The animals often they are seeking camouflage, mimicry with the environment	Claim	
E/Pat	307	You have a white rabbit, and you set it free in the wild . . .	Opposit.	Appeal to consistenc.
A/Isa w	308	And it doesn't change, my white rabbit	Opposit.	Appeal to consistenc.
G/Carlos	309	The snow partridge gets white	Data	Appeal to instance
A/Rita w	315	There are white rabbits here as well	Opposit.	Appeal to instance
G/Carlos	316	But not . . .	Opposit.	
A/Isa w	317	There are white rabbits here as well and this is not the North Pole	Data	Appeal to consistenc.
T		[teacher begins reformulation and explanation] . . . they are yellow now, How did they change?	Question	
A/Isa w	332	there was a mutation	claim	
T		There was a mutation and then: what happened?	Request	
A/Rita g	333	Hereditary variation. When the genes changed there was a mutation.	Claim	Tautology