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ABSTRACT

This paper reports on a case study focusing on the development of students' capacity to develop and assess arguments in the context of instruction in high school genetics. It is part of a wider project whose goals were: (1) the identification of the conditions for argument (and in general scientific reasoning) to occur in science classrooms; (2) the analysis of argument patterns used by students; and (3) the exploration of the degree of specificity or subject-matter dependence of these argument patterns. The methodology involved observation, video and audiotaping of students while working in groups to design and solve problems. Toulmin's argument pattern was used as a tool for the analysis of students' conversation and this was coded using a framework for epistemic operations. The different arguments constructed by students are discussed along with what could be viewed as the students' version of the pattern (claims and warrants) which was used the most. The epistemic operations with relation to consistency and the evidence of school culture are also discussed. Implications for the context required for argumentation and true science dialogue in the classroom are suggested. Contains 22 references. (Author/JRH)

Argument in High School Genetics

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Abstract

This paper reports a case study focusing on the development of student's capacity to develop and assess arguments in the context of instruction in High School Genetics. It makes part from a wider project whose goals are a) the identification of conditions for argument (and in general scientific reasoning) to occur in Science classrooms, b) the analysis of argument patterns used by students and c) the exploration of the degree of specifity, or subject-matter dependence of these argument patterns. Participants in this classroom study are High School (9th Grade) students in Galicia (Spain). The methodology involved observation, video and audiotaping of students while working in groups in designing and solving problems during 6 sessions. Toulmin's argument pattern was used as a tool for the analysis of students' conversation, and this was coded also using a frame for epistemic operations. The different arguments constructed by students are discussed, and also what could be viewed as a students' version of the pattern, (claims and warrants) which were used the most. The epistemic operations, in particular with relation to consistency are also discussed, and the evidence of school culture. Implications for the context required for argumentation and true science dialogue in the classroom are suggested.

1 Introduction: background and objectives of the study

The conceptualization of science learning as argument has been proposed among others by D. Kuhn (1993) and R. Duschl (1990). Such a view of science learning has broader goals that just learning scientific contents, and aims at equiping students with the capacity of reasoning about scientific problems and issues.

This study is part of a project focusing on the development of student's capacity to develop and assess arguments, that we see related to the design of Science curriculum and learning environments in Secondary School in which the discussion about the choice of theories and explanations play a central position. Promoting these discussions is an attempt to incorporate a philosophical perspective which considers the choice among competing theories (Giere 1988) essential in the building of scientific knowledge. Giere proposes that scientific reasoning should be understoood not so much as a process of inference, but as one of decision making, of choice among theories, and has suggested a schema for theory evaluation which involves putting theories into argument form.

In this project, the design of units and activities centered around problem-solving is viewed as a condition for argument to occur. 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 have previously explored some patterns of argument in Genetics offered by individual students in standard classrooms where no intervention was attemped, and they show to be very poor (Bugallo & Jiménez 1996). In other words, real argument doesn't occur in every Science classroom, and in order to explore the ways in which Secondary School students develop arguments, first there is a need to create learning environments where students are asked to solve authentic problems, to compare the solutions given by different groups, to justify their choices (Jiménez-Aleixandre 1997). These learning environment are designed in an inquiry perspective (Connelly 1972, National Research Council 1996) aiming to involve students, among others, in asking questions, revising what they know in the light of evidence, analyzing and interpreting data and requiring the consideration of alternative explanations. An instance of the application of such design to the Laboratory work with microscope in Biology is discussed in Jiménez & Díaz (1997). As inquiry has been critiziced in the past decade identifying it with hands-on activities disconnected from theories or concept issues, it is worth noting the central role that reasoning plays in the inquiry perspective: as early as 1972 Connelly defined «inquiry in biology as the development and use of logical forms and explanatory accounts» (Connelly 1972, page 386). In designing the prototype units and activities we draw on the project SEPIA design principles (Duschl & Gitomer 1996), particularly on building the units and activities around tasks wich asked from students to solve authentic problems.

In this first section of the paper the rational is discussed, and the objectives of the study outlined, in the second the methods and tools of analysis are presented, then the third and fourth sections are devoted to the analysis of transcripts and discussion.

Reasoning and argument in Science learning

Looking at reasoning from the perspective of Cognitive Psychology, D. Kuhn, García-Milá, Zohar and Andersen (1995), in their study about strategies of knowledge acquisition, discuss the problem of 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 (1988) philosophical model and Kuhn *et al* psychological model share a concern about the interaction of different components when individuals have to solve problems and to reason about their choices. From a Science Education perspective, when we set the capacity to develop argument as a goal, that means an interest not only in the students *solving* the science problems (cognitive or strategic level), but also in the open discussion about the *criteria* which led to one or other 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 assesing them.

When the students are discussing a science problem, developing an argument on a science subject, they are, at least to some extent, talking Science, participating in the discourse of Science. «Discourse» here being used in the way Lemke (1990) defines it, not just as language, but as the language-in-use in a community. As Lemke points, one of the main problems in the Science classroom is that many times communication fails; in some occasions teachers and students are assigning (constructing) different meanings to the same word; in other occasions what counts as evidence, what counts as data, what counts as explanation is not perceived in the same way. These fails in communication cannot be ignored, and one step towards its solution is trying to document them.

Reasoning in Genetics

Genetics is a content field of particular interest in Biology Education. It plays a central role in theorethical models in modern Biology, and on the other hand it is related to a number of social and ethical issues. In the literature about Genetics learning, we are not aware of studies about argument, however there is a related field: the studies about model use and model revision when solving Genetics problems by Stewart and his colleagues. As Stewart (1982a) indicates, there is an interaction between theoretical models explaining a given phenomena and the process of problem solving. In this paper Stewart discusses not only the way in which students solve the problems, but also how they justify or explain why they were performing each step, what he calls meaningful performance, as shown in this fragment of interview (Stewart 1982a page 82)

*«**Interviewer:** I notice that when you make your Punnett square you put one H over each of the boxes and one H next to each box. Why did you put the H's like that?*
***Student I:** I don't know, that's just the way we do it in class.*
***Interviewer:** Is there any reason why you couldn't have had two H's over one box?*
***Student I:** I suppose you can do it like that. It's just easier this way, because then you can pair them together without having three of something in one box.»*

We would interpret in this excerpt the first response of student I as an instance of classroom or school culture, of what Bloome et al (1989) define as «acting as student»; student I acknowledges that he or she does not know the reason for putting one H, placing the justification at a different level, the level of the things that are performed in class. The second answer of student I is of a different nature: he or she offers an explanation related to a model «*because then you can pair them together without having three or something in one box*». This justification (we could code it as «warrant» using Toulmin's pattern described below) can be seen as connected to the implicit assumption of the genetic mechanisms in terms of pairs (not tryads).

Stewart (1982b) sees meaningful problem solving as having two components: procedural knowledge component, represented as a set of steps, and conceptual knowledge component, represented as semantic networks. Using the GCK (Genetics Construction Kit), a simulated laboratory environment in which studentes solve problems similar to those that a geneticist would face when trying to infer genotype information from phenotipic data, Slack and Stewart (1990) analyse the problem-solving strategies of students; the GCK problems are designed in order to develop a model of student performance asking for explicit connections between problem solving and the conceptual knowledge required for it. The justification of solutions has been analyzed by Stewart, Hafner and Dale (1990), who studied the mental models of meiosis, chromosomes and genes that high school students construct and manipulate to justify solutions to genetic problems. They suggest that students should be asked to justify their answers and solutions; they point also at the communication issue, saying that «As scientists the students have to persuade their peers that the results of their research (problem solving) are logical and that there is a consistency between theory, data and claims». Many of the issues raised in these studies are relevant to the exploration of argument patterns.

Objectives

The study is part of a project on the development of students' capacity to develop and assess argument in different Science contexts: Biology, Geology, Environment and Physics. This paper analyses argument patterns used by High School students when solving Genetics Problems. The questions we explore here are:

– Which elements of Toulmin's (1958) argument pattern were used by students, which relations were established amont them.

– Which epistemic operations (explanation procedures, causal relations, analogies, predications...) which could be interpreted as being specific from the science domain –as parallel to the ones specific from Historical content used by Pontecorvo & Girardet (1993)– are used by the students

2 Methodology

Educational context and Participants

The data presented here where drawn from one whole class group of High School students (9th Grade, 14-15 years) who were observed during the six one-hour sessions (two weeks) that were devoted to Genetics in May -June 1996. When the students broke in groups, a small group (4 students) was audiotaped and observed while solving the problems, 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. During the term 1995-1996 no intervention was attempted in this classroom in relation to the methodology of instruction, and the teacher conducted the sessions in the usual way. Then the data were discussed with her as a stimulus for reflection leading to the collaborative design of an inquiry approach. The only modification introduced by the authors, in collaboration with the teacher, was the problem posed to students that took two sessions, following four sessions during which the teacher lectured students about Mendelian Genetics, and they solved problems in small groups. The sequence followed during these four sessions was:

Session 1: The teacher introduces basic Genetic concepts (gene, zygote, chromosome etc); discusses Mendel's experiences. The students work with simple simulations with cards.

Session 2: The students, working in groups, solve qualitative problems from their textbook (innovative materials setting problems in everyday contexts). Then they hold a whole class discussion.

Session 3: The students solve questions and problems related to six traits easily observed in humans (earlobe etc) aimed at emphasizing variety inside a species.

Session 4: The teacher lectures about biological change and evolution, and its relation to Genetics.

The teacher is a Biology Graduate, with 5 years of experience. 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 classroom climate was of confidence and students did seem at ease to pose or answer questions.

Problem

This was the problem given to the groups in the fifth session:

> "As you know different animals, such as chicken, pork or cows, are raised in farms , in order to get meat and eggs without having to kill animals which live in the wild.
>
> But since chicken are raised in farms, there is a problem: many chicken are born with yellow feathers instead of the spotted brown of the chicken that live in the wild. Some people didn't want to buy them, because they looked awkward, and this caused 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 chicken. But in the last year they had some problems, because many chicken have yellow colored feathers, instead of spotted. The farm gathered their biologists' team to solve the problem.
>
> You are asked to advice the biologists, studying which could be the cause of this color change in the chicken, but always giving reasons that sustain your answer. If you give an answer and cannot back it with arguments, then this answer has no value.
>
> You can also suggest which tests you would perform to show that you are right"

In the sixth session they were provided with several alternative hypothesis

"Here are some possible causes that other people suggested:

Possible causes	Reasons in favour 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."

The problem is based in a widely found difference; being the only simulation introduced the reluctance of customers (chicken, anyway, are sold without feathers). The situation follows a real marketing problem encountered by fish farms raising turbot: the fishes were white or very pale, and people refuse to buy them. But the reasons for this change in color 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 the color, which is not clear. The use of computer simulations such as GKC is not possible in Spanish schools, where at the moment there are only a small number of computers, if any, which could be used by students.

Following the way of setting the problem by Eichinger et al (1991) it was decided to add the alternative hypotheses in the second day. These alternative hypothesis 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 1992).

Data analysis:

The tapes were transcribed and the sentences broken into unit of analysis. Then for each unit two analysis were performed, one relating to the argumentative operations in relation with Toulmin's (1958) argument pattern, and the other relating to the epistemic operations which could be considered relevant for the development of scientific knowledge. The elements in Toulmin's argument pattern, illustrated in the example in figure 1, are a) **data**, that in this case are hypothetical, and given in the problem statement; b) **claim**, or conclusion, here the different hypothesis for causes of the color change; c) the students are asked to support their claims with **warrants**, reasons which justify the connection between data and conclusion; d) the warrants are related to a theoretical **backing**, of a general character. Sometimes there are also e) **qualifiers**, which specify conditions for the claim, and f) **rebuttal**, which specify conditions for discarding the claim (this last not included in figure 1).

For the first analysis, related to argumentative operations, a "school science" argument pattern was developed using the ideas from instruction prior to students solving the problem. (Figure 1). Instead of one, 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. As it will be discussed in the last section, 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.

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 - comittment 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

Table 1 Epistemic operations

For the second analysis, a list of epistemic operations relating to Science was constructed. Its source were different accounts about scientific development (e.g. Chalmers 1985) Philosophy of Biology (Sober 1993), and the conceptual profile of science (Thagard 1988), drawn from the Philosophy of Science field on the one hand; and on the other work about conceptual ecology in the science classroom (Thorley 1992) drawn from Science education. The list of epistemic operations appears in table 1.

Following the transcription we had to add a third category of analysis, related to the school culture and to the rules –both explicit and implicit– set for classroom tasks

3 Analysis of the transcription

The analysis is presented in columns: the transcribed units appear in the first column, the argumentative operations in the second, the epistemic in the third and the school culture in the fourth. The first segments transcribed correspond to dicussion among one of the eight small groups inside the class, identified as Group A, then appears the whole class discussion.

Codes

- ... transcription not reproduced
- notes in `courier 10` between square brackets [ ] indicate clarification by observer
- 1, 2 correspond to contributions in session 6; 1.1, 1.2 different elements in a contribution
- T: teacher; O: observer (not numbered in the sequence)

Following Pontecorvo and Girardet (1993) we have coded as «opposition» particular claims which contradict another previous claim

Session 6, June 4th 1996

transcribed talk Group A	argument. operations	epistemic operations	school culture
Isa 6.1 Food, yes 6.2 because before they ate natural things	claim warrant	causal analogy	
Isa 7.1 [reads from handout] Hereditary variation 7.2 Color [Spanish 'color'] of the mother	 claim	 causal	classroom task
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, 14.2 Shall we write because of the food or because of weather?			classroom task 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 one. Then 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 37.2 And now, what else should be write?	claim	causal	 classroom task

The group discusses their first hypothesis for the change in color: food. The warrant offered by Isa in 6.2 could be, in our opinion, an instance of analogical thinking establishing a correspondence natural food----natural color, manipulated food----changed color. Then, related to the similarity in Spanish of 'color' (color) and 'calor' (heat), Rosa introduces a new claim in 9, then reformulated by Rita in 14.2 as "weather".Then a discussion follows (not reproduced above) about spelling. In 30 and 31 they are writing on the handout, and the issue is raised about the task set for them: to choose several (Rita) or only one, and Isa (32) proposes hereditary variation, changing the line of discussion they have been following about food. In fact it is not the first time that Isa speaks about heredity, but in 7.1 she is reading from the handout, so we do not code it as part of the argument, although what she says in 7.2, 'color of the mother' could be a first attempt to discuss the hypothesis of hereditary variation. However in 15 and 17 she goes back to the food hypothesis, and then no other hypothesis is offered until the need of choosing just one cause arises, and she proposes hereditary variation in 32. From 38 to 58 (not reproduced) the other three students ask Isa to explain her claim in 32 and 37.1, questioning about the reasons for it, like in 59 transcribed below

transcribed talk Group A	argument. operations	epistemic operations	school culture
Rita 59.1 And why?	request		
59.2 Look, you who said hereditary variation 59.3 Why do you think that it is hereditary variation?			school culture
Isa 60.1 They have a different color,	data	appeal to	
60.2 they are identical	warrant	attributes	
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	

A tentative argument: color is inherited

After Rita in 59 requests an explanation, Isa in 60 offers for the first time a tentative argument, appealing first to the data in 60.1, 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, and this leads to the claim: if they resemble each other in color, color must be a question of inheritance. A summary of the argument 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. Bea's question in 61 points at the question of change, and Rita turns the path of justification towards plausibility (62.2), but when questioned appeals to authority (64). Then from 65 to 70 (not reproduced) Bea and Rita ask Isa again to provide reasons, as she was the first to talk about hereditary variation.

transcribed talk Group A	argument. operations	epistemic operations	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... 76.2 well, perhaps it is a change, yes	opposit. concesion	definition	
Isa 77 In the DNA	warrant (72)		
Rita 78 Before. In the cells that... the organisms, they come from the firsts...	warrant		

Change in color caused by change in genes

In the exchange from 71 to 78 the idea that a change in color may be related to a change in the genes is advanced in a tentative way. Another question in the dialogue is the definition of mutation, that seems not to be clear for Rita, showing an instance of the problems of communication in classrooms, when students use words and terms without a clear idea about their meaning. From 79 to 95 (not reproduced) they further discuss the meaning of mutation as a change in the genes.

transcribed talk Group A	argument. operations	epistemic operations	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 [reference to example used in instruction]		analogy	

The apparent agreement about inheritance is broken by Rita, who goes back to the food explanation (97), then trying to relate this to hereditary variation (103) appealing to an analogy with an example used previously by the teacher about the beak of hummingbirds. As different studies about the meaning of adaptation have shown, many students like Rita have problems with this concept. Rita understanding of this idea seems to be rather different from school science (survival of birds with an adequate beak), and she relates the hereditary differences in color to the different food eaten by chicken in the wild and in farms. This argument is represented in figure 3. Then an exchange follows (from 104 to 110, not reproduced) with repetitions of the same lines, food yes, food no.

transcribed talk Group A	argument. operations	epistemic operations	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	

School culture

Isa (115) gives a different type of argument, 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 the theorethical support for the genes hypothesis (backing). From 119 to 132 they ask to the teacher, who says that they have to discuss it themselves and write their own opinion, and they begin to discuss ideas to test whether a change in genes has happened. But still one person in the group, Rosa, is unconvinced:

transcribed talk Group A	argument. operations	epistemic operations	school culture
Rosa 133 Couldn't be the color from the farm, that 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 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,		deduction	appeal to authority
137.2 but because it isn't right.	backing		

Rosa (133) suggests a new hypothesis: the farmers put a dye in the chicken, to which Isa (134) argues that offspring doesn't have a color related to the dye put on parents, and Rita argues in the same direction, first (135) appealing to consistency with what happens in humans, and then (137) relating this possibility to Lamarck's theory. As this question has been subject of session 4, perhaps this could be interpreted also as an implicit appeal to teacher and textbook authority. The argument of Rita in opposition to 133 is represented in figure 4. Then from 138 to 152 they repeat their positions about the dye question.

transcribed talk Group A	argument. operations	epistemic operations	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.	

Discarding the food

In 154 Bea discusses another hypothesis (perhaps overheard from another group) that we interpret as an analogy with brown color in eggs, related to substances in the feed, and Isa (155), using an argument similar to the one used by Rita in 135, discards it. Rita argument would be relevant in the whole class discussion. The time for small group debate is finishing, and they begin a process of discussing each hypothesis.

transcribed talk Group A	argument. operations	epistemic operations	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 heath, 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 174 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	(complet)		
[the teacher asks them to finish the task]			
Isa 190 Shall we vote? [about heredity]			task
Rita 191 we agree Bea 192 ok Rosa 193 ok		predicat.	school culture

Discarding heat and environment influence

After Isa (164) summarizes the opinion discarding food, Rosa (166) begins the statement about heat, completed by Rita and Isa from 167 to 173 (not reproduced); then Rita (174) brings another justification for discarding heat as cause of color change, implicitly appealing to consistency; in the exchange that follows she is supported by Isa and Rosa, whereas Bea (175, 180) seems to have difficulties in understanding the relevance of discussing the child example. From 182 to 185 they repeat similar statements, and finally they agree on hereditary variation as the group opinion.

As a quantitative summary of the contributions from each of the four students, 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 (33, 17%) and Rosa (20, 10,5%) had fewer contributions. A different question is the relevance of these contributions, discussed in the last section.

Analysis of the whole class discussion

There were eight groups in the class. In the analysis that follows, the other seven groups are identified by a letter from B to H, following the order of intervention in the discussion; individual students from these groups are not identified by name in the transcription when they are reading from their worksheets or summarizing their groups' opinion, only when they are expressing individual opinions; their talk inside their groups was not recorded. The four students from group A are identified, coding with a **g** (group) the talk that they keep among them in a lower key, and with a w (whole) their contributions to the general discussion.

It could be noted that, as discussed below, only two from the eight groups, A and E, favor the heredity hypothesis, whereas the other six groups used the environment, color of the farm hypothesis (the brief contribution of group H, at the end of the discussion is not reproduced). Only selected fragments from the transcription are reproduced, the interruptions expresed by ...... as well as by discontinuity in numbers.

transcribed talk, whole class	argument. operations	epistemic operations	school culture
group B 194 The color of the farm	claim	[illegible]	
....			
group B 197.1 They were spotted, but the light and the color in the farm made that, along time, they turned yellow 197.2 in order to go unnoticed	warrant data warrant	appeal to analogy	
[teacher says that any group which disagree with B can express their opinions]			
....			
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.	
....			
group C 211.1 The color of the farm 211.2 because the chicken in the wild are spotted 211.3 in order to camouflage, to go unnoticed, but in the farm they didn't need the speckles.	claim data warrant	appeal to analogy	

The first group to report, B, favors color (194) and then justify it appealing to the color in the farm (197) in order to go unnoticed, what we interpret as a warrant not in Genetics terms, but related to finalism, and particularly to intentional explanations. In the group A, they are discussing whether they agree or disagree, and still Rosa (202) manifests her disagreement with the rest of the group, altough in 193 she has accepted heredity as the group opinion, and she is not disagreeing aloud. This inconsistency between a stated opinion, and the manifestation in front of the class, we consider in terms of school culture. The second group C (211) offers an argument similar to group B, being both represented in Figure 5 in argument form.

transcribed talk, whole class	argument. operations	epistemic operations	school culture
group A (Isa, w) 214 Hereditary variation	claim		
[teacher asks them reasons]			
A Isa w 215 Because there was a change in the genes and they produce the change in color.	warrant		
....			
group D 218.1 The color of the farm 218.2 because in the farm they don't need to camouflage themselves in the plants	claim warrant		
A Rita w 219 And they do change color every five minutes? First they are spotted and then they turn yellow?	opposit. (to 218)		
group 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	
group 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	
group D 226.1 No, if you put a chicken in a farm, it doesn't turn white, 226.2 but with time it does.	claim qualifier	appeal to analogy	
A Rita w 227 But they don't get yellow	opposit.		
group 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 A challenges the environment hypothesis

Until 219, the groups have been reporting their opinions without reactions from the others; here for the first time Rita challenges group D opinion, with an implicit appeal to consistency in 221; then Bea and Isa join in, and Isa (225) offers an example in humans which appeals also to consistency. The answer from group D (226) introduces a qualifier: the change is a question of time, and this argument is developped in 228, to which Isa offers, not a warrant this time, but a theorethical backing (used before by Rita in 137 with a different wording and represented in figure 4): acquired traits are not inherited. The argument of group D in 218, 226, 228 is represented in figure 6.

transcribed talk	argument. operations	epistemic operations	school culture
group D 238.1 It is true	claim	predicat.	
238.2 Because if them 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		
group D 246 So, why does it occur?		predicat.	
A Isa w 247 Because of something natural	claim	attribute	
group 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	

The discussion between group D and group A (Rita and Isa) goes on, and they are supported by a student 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.

transcribed talk	argument. operations	epistemic operations	school culture
group E 256 This is a genetic variation, but not...	claim		
[interruption]			
group E 258 These are matters from Nature	warrant		
....			
group F 263.1 ... because of the environment... 263.2 not all environments are the same	claim 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] 265.2 It is nonsense.	opposit	appeal to consistenc 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. 267.2 If all were spotted: how is possible that they had yellow genes?	opposit. (to 256) warrant	definition deduction	
A Isa w 268 There was a mutation	warrant		
....			
F Luisa 270.1 Even if they had some yellow genes 270.2 some chicken would come yellow, 270.3 but not all of them.	concesion claim qualifier	prediction	
E Pat 271.1 No, not if they are not dominant. 271.2 Because the yellow gene turned dominant, and before it was recessive, but it has nothing to do with it. 271.3 You can have a blue-eyes gene, and it doesn't manifest, but is there. Your sons could have blue eyes... not for the moment.	rebuttal claim backing	definition appeal to instance	

Some Genetic concepts

When group F reports (263), the students from group A keep their opposition. From 267 to 271 there is an interesting exchange about crucial Genetics concepts: Luisa, in opposition to group E, discusses a definition of 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 in 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. In 270 Luisa seems to acknowledge the existence of different alleles (she speaks of «genes»). In 271, Pat claims that the yellow gene turned from recessive to dominant, thus explaining the change in color; this identification of expressed traits with dominant alleles is one of the problems frequently encountered in Genetics learning. Then from 272 to 282 group F repeats their position, and groups A and E oppose the China / Africa example.

transcribed talk, whole group	argument. operations	epistemic operations	school culture
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.	
group 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		

Are Heredity laws the same?

In 283 Pat repeats the Africa example that the students from group A have been using, and then there is an opposition (285) in terms of the inadequacy of comparing chicken and people. Each side repeats their arguments (286 - 294), the one opposed to uniformity in humans and animals being summarized in 295. The discussion follows in a similar pattern (296 to 306)

transcribed talk, whole group	argument. operations	epistemic operations	school culture
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.		
....			
G Carlos 309 The snow partridge gets white	data		
....			
A Rita w 315 There are white rabbits here as well	opposit.	appeal to instance	
G Carlos 316 But not...			
A Isa w 317 There are white rabbits here as well and this is not the North Pole	data	appeal to consistenc	
....			
[teacher begins reformulation and explanation] T... they are yellow now, How did they change?			
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	

In the last part of the discussion, Pat, Rita and Isa switch on to animals, picking rabbits as instance, in what seems an attempt to avoid the human vs animals issue. We interpret the offering of the existence of white rabbits as a data as part of an argument in which the implicit warrant would be the independence of color from environment, and the implicit claim that a change of color is not caused by any feature in the environment, as seen in figure 7.

From 318 to 329, where it finish, the discussion gets hotter, but the statements are not new. Then the teacher begins to offers a reformulation of the problem, and the school science argument, as represented in figure 1. Still, in the small group, the students from group A congratulate themselves about their "right" solution to the problem, and insist on a mutation as the cause of the change in color.

4. Analysis Discussion

From the perspective of the comparison between the school science argument (figure 1) and the arguments from groups A and E which favor heredity, represented in figures 2, 4 and 7 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, but it is not clear whether they 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 reasons 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 for the school science, that is the existence of different forms (alleles) from a gene in the population.

About arguments, we will discuss first the dialogue in group A, and then in the whole class.

Argument in group A

Our interest is focused in the construction of the arguments, and from this perspective, the dialogue in group A has some features:

1) Unbalanced participation: two students, Rita (39%) and Isa (33,5%) made nearly three quarters of the contributions. Moreover, in the contributions from the other two students it can be seen that Bea (17%) has 33, from which 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; only 13 can be interpreted as part of an argument. Rosa (10,5%) made 20 contributions, from which 11 are not part of an argument, and 9 are part of one.

2) Two persons leading the course of the argument: the first hypothesis discussed by the group is food, until Isa (32) proposes hereditary variation and, after the other three students question her, advances a first argument (60) represented in figure 2: the change in color is a question of inheritance, because all siblings have changed in identical sense. The next move, initiated by Rita in 72 and then followed by Isa, is to relate the change in color to a change in the genes –perhaps this is prompted by the word «variation»–. Rita goes back to the food hypothesis (97, 103), with the argument represented in figure 3, but Isa in 115, 117 gives a new reason («if we are studying Genetics») related more to the school culture than to

scientific reasoning. From this moment, Rita will support Isa in the defence of heredity, in fact in her next contribution (118) she advances a backing for the heredity hypothesis.

There is a turn when Rosa (133) offers a new hypothesis related to environment: a dye, but this is discarded by Isa and Rita (134 - 137), with the argument represented in figure 4 which has an explicit backing, what is quite unusual. As a part of this argument, Rita (135) uses an example of what happens when humans dye their hair, and whether this affect to hair color in their children. This we interpret as an appeal to consistency, and warrants similar to this will be used several times by Rita an Isa during the discussion. Bea (154) goes back again to food, opposed by Isa and Rita. Then they begin a process of discarding hypothesis: food (Isa 164), heat (Rosa 166), and then agreeing in heredity, as a group, although, as made apparent in the whole-class discussion, Rosa does not agree with it. In summary it can be said that two students, Isa and Rita, lead the discussion and offer most of the warrants coherently stated.

3) Elements of Toulmin's pattern used by students: It has to be noted that, although there were 193 contributions in the group A, not all of these can be interpreted as part of an argument, because many of them, particularly at the beginning of the discussion, were just incidental talk, statements about the task (e.g. «you have to tick this box»), predications about others statements (e.g. «you said color») etc. At the same time, there were some contributions in which there are more than one element, which we have represented as 60.1, 60.2 etc in the transcription. In the discussion in the small group, we have coded 99 elements as part of an argument (including arguments related to school culture, like «we are talking about genes»). From these nearly two thirds, 66, are claims (including opposition to another claim), 21 warrants, 10 data and 6 backings. In the small group discussion there are not qualifiers or rebuttal. As noted by Eichinger et al (1991) discussing construction of argument by sixth 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 when it can be said that there were some related elements, and some of them are represented in figures 2, 3 and 4; as seen in the transcripts and in these figures, the backings were in nearly all cases, implicit. Another question is the difficulty to know the reasons which 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 she agreed to write that the opinion of the group was hereditary variation.

4) 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. 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 chicken to yellow feed, like 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 chicken. 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 recognise that, for instance, heredity laws apply to different organisms and not just to the ones used in an example; so the lack of consistency is an obstacle in the attaining of the goals related to transfer of knowledge, to the application of knowledge to different instances and situations. That Rita is appealing to consistency and not simply using an analogy is supported by her next contribution (135) when she relates this issue to Lamarck's theory («because it isn't right»), an also by the development of the discussion, with Isa and herself using different examples of the non inheritance of acquired, inside the small group, and in the whole class, as discussed below.

5) School culture: in the classrooms there are interactions that are related to the content and skills, and there are others which may belong to the school or classroom culture, being part of these which Bloome, Puro & Theodorou (1989) call procedural display, defined by them as interactional procedures which count as doing a lesson, but are not necessarily relate to the stated goals for learning. That is, there are interactions, dialogue, more related to acting as «science students» that to which could be the explicit objective of the task: discuss the causes of the change of color in farm chicken. In the fourth column of the tables we have coded, 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 other 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 argument in 115 and 117 about what is the topic of the lesson «we are talking about genes» ... «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 see in the transcripts, there are little interactions not related to the question.

Whole-class discussion

The whole class debate would be discussed in less detail, but some features to note are:

About argument: at the beginning of the debate the groups B, and C were reporting without reactions from others, but after group D reports, Rita (219) challenges the color of the farm hypothesis, and then she and Isa appeal 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 stating «the traits that you pick during your life are not inherited», what shows an attempt to relate claims and warrants to theory (backing). That Rita and Isa contributions are perceived, also by the other students, as an appeal to consistency is shown, in our opinion, by contributions from Group C (285) and G (295), which deny that you could compare chicken and people.

Like in the small group, claims were the elements more frequently used, and also warrants (as required by the task). It is interesting the use of qualifiers, like time by group D (226) and rebuttal, like in 285 by group C.

About epistemic operations, the dialogue provides some instances of the conceptual ecology of 9th grade students, such as Anthropocentrism (one thing are humans and another thing chicken), and inconsistency. But there are other examples of appeal to consistency as discuted above.

About school culture, it is interesting to note that, in the whole group discussion, it can be said that the student were most of the time «talking Science», and there was very little of incidental talk or even references to classroom rules or norms.

Implications

The ability to develop arguments is not usually set in Science classrooms. Our previous observation of classrooms where instruction was conducted in a standard way (Bugallo & Jimenez 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 it is related to a learning environment characterised, among others, by a perspective of Science learning and teaching as inquiry. This means that students work in order to solve authentic problems, connected to real life and of some relevance to them. 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, is the process of inquiry which is relevant for the epistemic goals, the ones related to the understanding of the structure of knowledge. Explicit discussion of the learning objectives and the assessment standards and criteria, which allows what we have termed "fair play" between teachers and students is also a desirable feature.

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 innovative materials which required students to work collaboratively and to solve open-ended problems, resulted in a certain degree of argumentation, of students requesting one another to explain or support their claims, of some instances of developping 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. In our opinion this supports Brown (1992) claim about the interest of research on innovative classrooms rather than in standard classrooms. When studying the construction of argument, first we have to design or identify an adequate classroom environment.

One negative aspect that can be noted is the conceptual confusion evidenced by a great deal of the contributions. Even the 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 is once again raised; in any case it could be said that, if it is included, it would need much more than six sessions.

In our opinion the next step would be, not just ask the students to look for the causes of the color change, but also design a way to reverse the process of change. This would require a real community of learners involved in inquiry, who take charge of their own learning and share their expertise (Scardamalia, Bereiter, Hewitt and Webb 1996). In such a community the students teach one another, convince one another using the arguments that apparently convinced themselves, like in some of the instances discussed above.

One last question relates to the difference among data of different character. The data that students were handling in this problem were hypothetical, and were not to be doubted, they were supported by the teacher's authority; but the way they construct arguments is different when they have a problem with empirical, unknown data, like in the study by Kelly, Drucker & Chen (1996) about electricity, or our own study with microscope (Jimenez & Díaz 1997).

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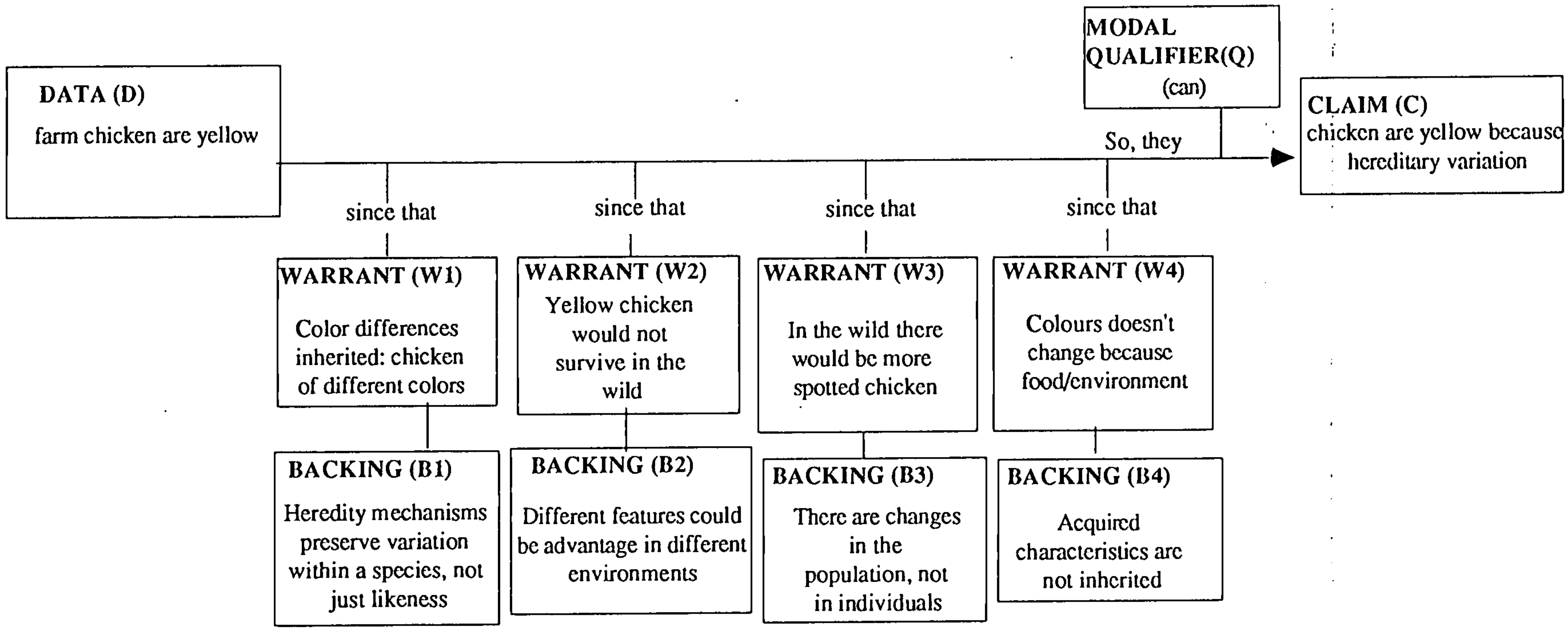

Figure 1. School Science argument pattern

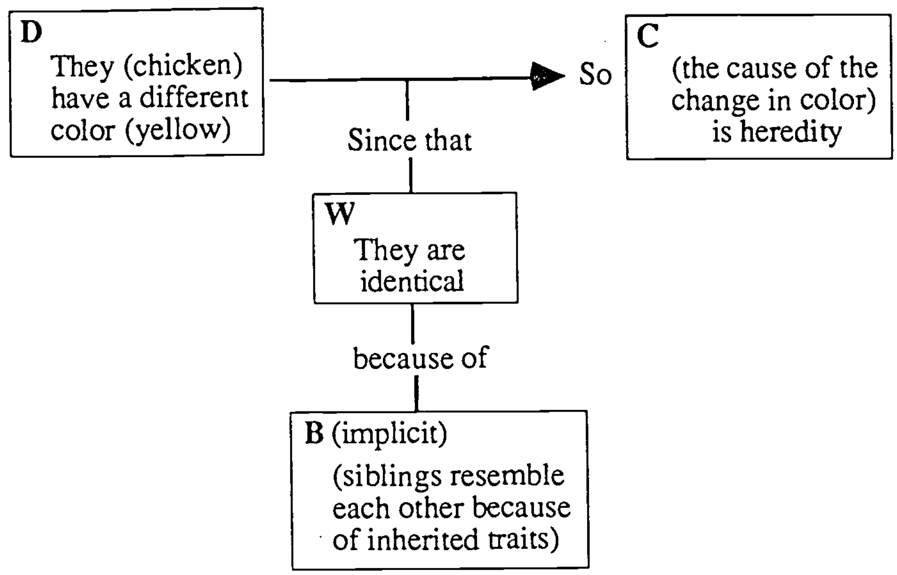

Figure 2. Argument in line 60: Heredity.

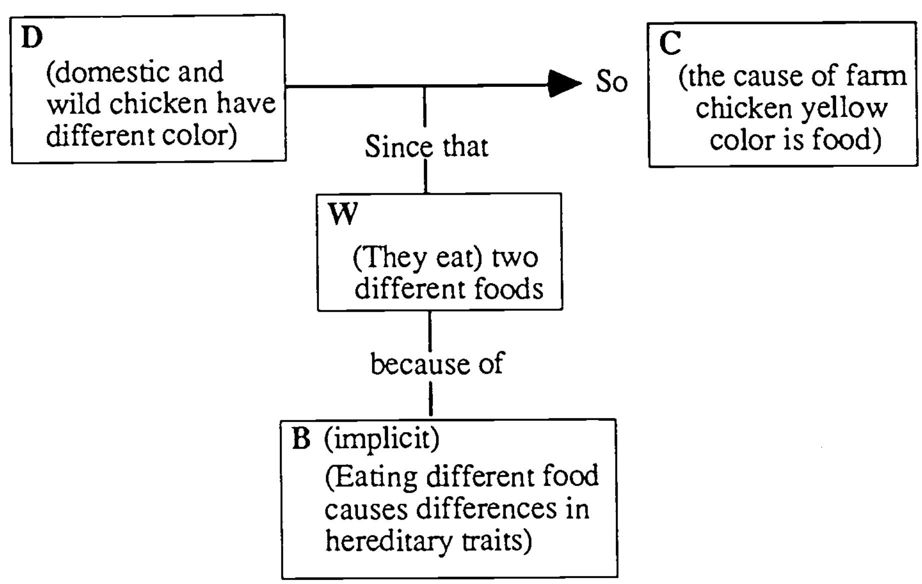

Figure 3. Argument in line 103: Food.

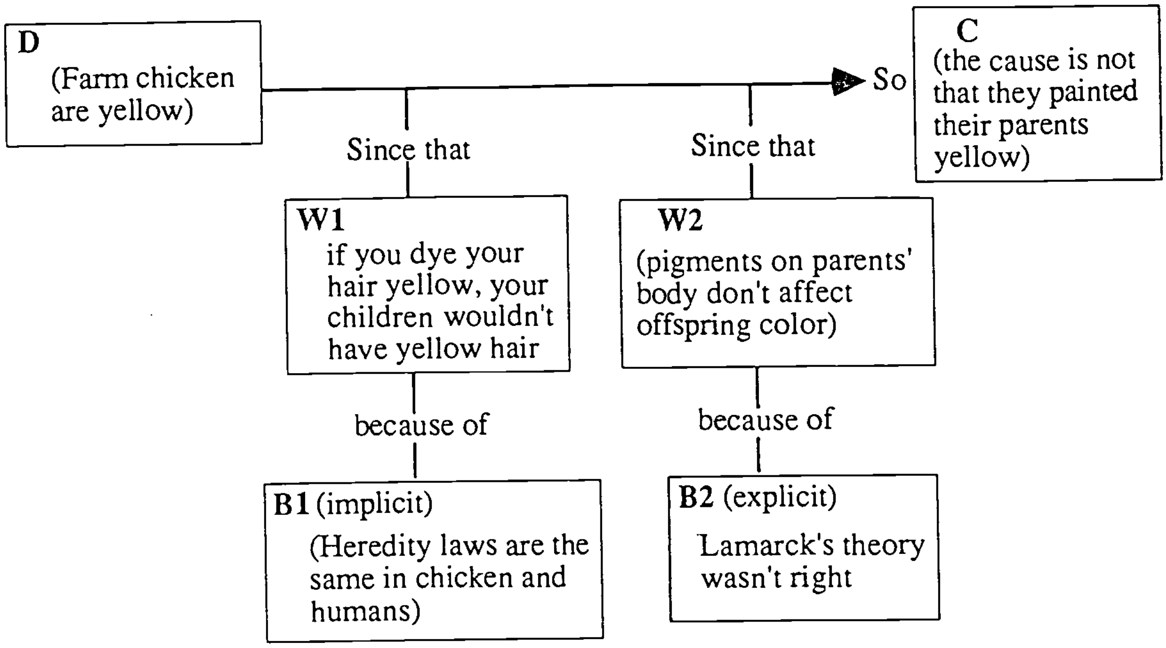

Figure 4. Argument in line 135-137: Discarding Lamarckism.

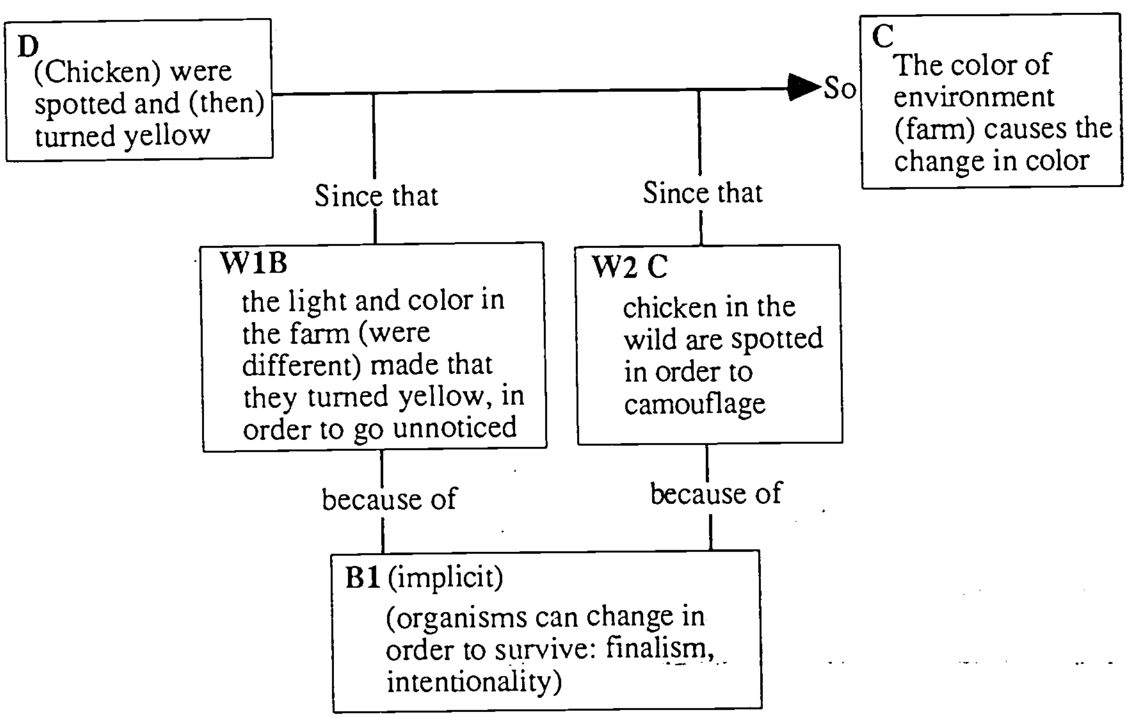

Figure 5. Argument from Groups B (197) and C (211).

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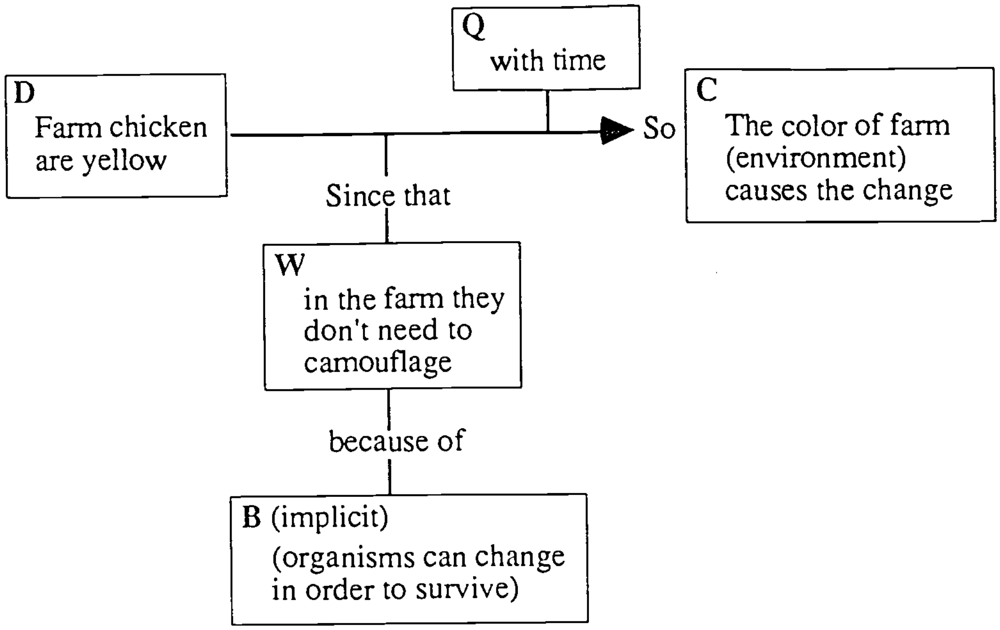

Figure 6. Argument from Group D (218-226).

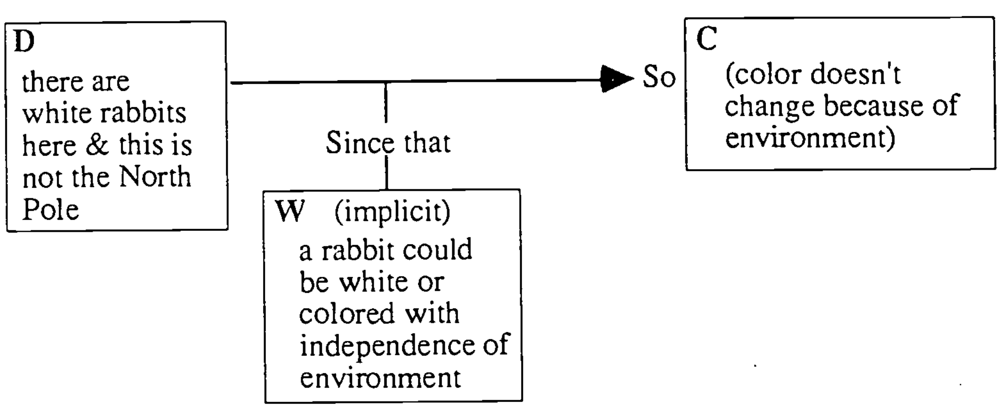

Figure 7 Argument from lines 307 - 317

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