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ABSTRACT

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Expertise, argumentation and scientific practice: a case study about environmental education in the 11th grade

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Abstract

This paper reports a case study about argumentation and scientific practice in the 11th grade. The objectives of the study are to identify argument patterns and dimensions of scientific practice in students' conversations and actions while engaged in an environmental management project in a wetland. The focus are the warrants that students employ to justify their claims in connection with scientific practice understood in a broad perspective (McGinn & Roth 1999) as the participation in a variety of communities and situations where science is created and used. Data sources include audio and video recordings, field notes of an external observer and students' productions collected in their portfolios. Students' conversations were analyzed using tools as Toulmin's (1958) and Walton's (1996) argument schemes and a scheme for dimensions of scientific discourse constructed by the authors as an heuristic for classroom discourse. Results show distinctive features in the argumentation patterns and warrants about environmental management as compared to standard science topics, such as Genetics, cell Biology or Buoyancy. The status of expert and the participation of citizens in scientific practice are among the dimensions identified in classroom discourse.

1 Argument and environmental education: rationale for the study and objectives

Science education should provide students with opportunities for developing a wide range of abilities and skills, including the ability to reason and particularly the ability to argument (Jiménez, Bugallo and Duschl, in press). By argumentation, in this paper, it is understood the ability to relate data to claim, in other words to evaluate theoretical claims in the light of empirical evidence or data from other sources (Kuhn 1992, 1993). In order to be able to build models which explain the natural world and to operate with them, the students need, besides learning meaningfully the concepts involved in them, the capacity to choose among different options or explanations and to reason which criteria lead to the option chosen. Kuhn (1992) findings imply that promotion of argumentative reasoning skills does not occur equally across all school environments, and she suggest that the ability to make reasoned judgments should be part of the ability of "think well". Underlying reasoned judgment, argumentation, Kuhn views a perspective of knowing as an ongoing process of evaluation, changing as new evidences and new arguments may appear. The focus of this paper is classroom dialogue on the assumption that, as Kuhn says, argumentative dialogue externalizes argumentative reasoning. This study focuses in natural discourse occurring in the science classroom rather than in responses obtained by means of a questionnaire or interview. The project of which makes part intends to explore the processes of reasoning related to learning science, as a different dimension of the study of products or learning outcomes.

To promote the capacity of argumentation is an objective of epistemic nature, having to do more with the ways of building scientific knowledge than with the content, but it should be kept in mind that in order to be able to participate –to a certain extent– in the building of science, one must handle concepts and theories. The focus of the study are the arguments which Toulmin (1958) called substantives, in which the knowledge of content is a requisite. Discursive processes and practices constitute an essential part in the building of scientific knowledge (Latour & Woolgar 1986), if science is viewed as a complex practice involving not only planning and performing experiments, but also proposing and discussing ideas, choosing among different explanations.

An adequate context to promote argument are classrooms organized as knowledge-producing communities where, as McGinn and Roth (1999) argue, scientific literacy is understood as preparation for participation in scientific practice; for McGinn and Roth, this participation is enacted not only in science laboratories but also in a variety of locations and communities where science is created and used, such as activist movements or the judicial system. The example about activist movements is relevant to

environmental education and in particular to this study about environmental management.

Environmental education offers good opportunities to promote argumentation, due to the complexity of the problems under study (Jiménez, Pereiro & Aznar 1998). The problem chosen is the impact of a project about water drainage in a wetland, in particular the convenience or inconvenience of building a drainpipe across the wetland. As other environmental issues it involves conflicts between contradictory interests and positions and cannot be dealt with straightforward affirmative or negative answers; also most solutions to the problem involve both benefits and inconveniences, which must be carefully weighed before a conclusion is reached. Problems without a single "right" answer have been chosen in other studies about decision-making in STS (Science-Technology-Society) issues, such as Ratcliffe (1996).

Argumentation and environmental education activities can be carried around simulated problems or fictitious issues, but in this case the conflict presented to the students is a real one: they were asked to assess the impact of a projected network of drainpipes in the marshes of the river Louro, a wetland including a small pond near the city where their school is located. Some features of the wetland and the outline of the teaching sequence are discussed in the next section, the focus here being the nature of the problem as authentic. The notion of authentic problems draws from the situated cognition perspective (Brown, Collins & Duguid 1989) the idea of designing classroom tasks according to scientific culture, that is the culture of the science practitioners, and not to stereotyped school culture. Roth and Roychoudhury (1993) discuss the importance of authentic contexts; in their study students developed higher-order process skills through laboratory experiences which provided them with open-ended problems of personal relevance. What means authentic problems? For Duschl and Gitomer (1996) on the one hand problems which have some relevance to the life of the students, and on the other hand, problems which are discussed using similar criteria about evidence and justification to the criteria the scientists would use. From these sources, the criteria for the problem were:

- Problem open-ended, several possible solutions or answers.
- Problem relevant to the life of the students.
- Reasoned debate about the solutions using available data, evidence and justifications.

According to these criteria, the issue could be considered an authentic problem, it is relevant for the students and it has the features of the problems which environmental scientists have to face. Solving problems with these features can be viewed as preparing students for participation in scientific practice. Authentic problems do not need to be "true", but the issue chosen for this study is a real problem. This is a question of

opportunity, as it is not always possible to find a real problem available, but if it could be done it adds motivation and interest for the students and offers the possibility of, besides discussing it in the classroom, trying to influence, to some extent, the real world outside the classroom, as was the case here.

The content domain of the problem is environmental management, integrated as a part from a Biology and Geology course in the 11th grade. It has to be noted that environmental education in Spain has been introduced as a cross-curricular subject since the Educational reform from 1990, but the orientations about how should this be implemented remain rather vague and, although the status of environmental education has raised among teachers, there are only a minority of classrooms where it is really enacted as a new dimension, while in many occasions the so-called environmental tasks are just anecdotal activities such as planting a tree or learning to prepare recycled paper. On the contrary, this teaching sequence was designed with the objective of developing skills and values related to environmental education such as learning to appreciate landscape features, including aesthetics, and developing the ability to assess the impact of human actions on the environment. The theoretical frame underlying the sequence views environmental education as a dimension impregnating the content-matter (in this case Biology and Geology) and not as a new subject. The task set for the students could be regarded as related to decision-making for, as Ratcliffe (1996) points, in educational literature these tasks are treated under this label, even if they do not imply a commitment to action, but rather the formation of opinions. As this author says, the development of decision-making skills is a complex area, and the purpose of the present study is not to claim an improvement in them, but to explore some of the dimensions involved in the process of argumenting about decisions.

The focus of the study are discursive practices in the science classroom while students are acting as a science community, involved in a project about environmental management. The authors are interested in arguments developed by 11th grade students and in the dimensions of scientific discourse found in their performances. The objectives explored in this paper are:

– The analysis of substantive arguments developed by students, particularly of the warrants used to justify their claims.

– The comparison among the arguments and warrants in environmental education and the arguments in standard science topics.

– The identification of dimensions of scientific discourse in the performances of students, particularly the status of expert attributed to different people and instances.

In the next section the methods of the study and the educational context are presented; then the results of the analysis are discussed, beginning with the arguments. The paper ends with a discussion about educational implications.

2 Methods, participants and educational context

Participants

The participants are 38 students, an intact group of the 11th Grade from a public High School in Vigo, a small city in the Northern coast of Spain, enrolled in a Biology and Geology course along the whole term, being their Biology and Geology teacher the second author. They belong to the evening shift, either because they work during the day or because they have failed in the day courses and are taking them at a slower pace, so instead of having 17 years, their ages range from 17 to 21 years.

Educational context: the unit about the "Budiño's Pipe"

The sequence about environmental management is part of their regular coursework, being directed by their regular teacher (second author), and took place during a month, in February-March 1998. The students worked distributed in teams with three different groupings along the sequence, first groups GI to GIV (sessions 1 to 5) were presented with the problem: the assessment of the environmental impact of a drainpipe in a wetland, the marshes of Budiño and took a field trip there; second six groups GA to GF (sessions 6 to 12) which analyzed different dimensions, from the landscape values and the plant and animal communities to the projected drainpipes, produced maps and reports and then shared their reports in new teams formed by jigsaw technique, J1 to J6 (from "Jigsaw", sessions 13 to 16). Each of the new J teams must produce a report including an assessment of the project and its predicted impact and these reports were debated in the class (session 17). The teaching sequence is represented in figure 1 and discussed in detail in a previous paper (Jiménez, Pereiro & Aznar 1998). The sequence and the study make part of project RODA (ReasOning, Discussion, Argumentation) carried on in the University of Santiago and supported by the Spanish DGESIC.

(Figure 1 about here)

The marshes of Budiño is a wetland in the basin of the river Louro, which has the status of area of natural interest, and includes a seasonal pond. Presently is surrounded by an industrial area and a granite quarry draining their sewage into the wetland and the river. All the area is heavily polluted, some of the small ponds are dry and plants (as one of the few carnivorous plants in Galicia, a small *Drosera*) and animals –particularly amphibian and migratory birds– are suffering the consequences of the destruction of their habitats. The project under discussion involves a network of underground drainpipes crossing the middle of the wetland, with the objective of collecting all industrial and domestic sewage and it has a budget of about 77,5 million Euros. In the first draft of the project the main drainpipe was surrounding the wetland and the pond,

but in the final project the layout was changed, and it crossed the wetland, dividing it in two, what means that all the land has to be removed in order to bury the pipes. Although the alleged reasons for the change are of technical nature –the scarce slope of the first network, difficulting the flow of water through the pipes– the available evidence points to reduction of the cost as the main reason.

The task for the students was to produce a report about the convenience (or not) of the pipe and, if this was the case, to produce alternative solutions. Through this, two main goals were intended for the unit:

– To apply Biology and Geology contents to the solution of the problem.

– To integrate the environmental education dimension, paying attention to procedural and attitudinal contents such as: perceiving the landscapes through the different senses; evaluating the quality of a landscape and its aesthetic values; assessing environmental impacts; developing tolerance towards contradictory opinions.

The drainpipes project was chosen, among other environmental issues, because of its complex nature: building the pipe would involve positive impact for the wetland, by avoiding the pollution from the sewage. But it would involve also negative impact to it, removing the land and destroying some fragile habitats. This double nature, was believed, would promote a variety of opinions, argumentation and debate among different positions, better than another issue (wood fires, for instance) about which everybody would agree.

Data sources and tools for analysis

Data sources include audio and video recordings of the sessions and small group discussions, field notes from an external observer (third author) and students' collective reports and productions collected in their portfolios, as well as their individual papers written at the end of the term. Interviews with the students were also conducted a year after, although they will be not discussed here.

Students' conversations were transcribed and then analyzed with several tools. For the purposes of discourse analysis three of them are relevant: first Stephen Toulmin's (1958) argument layout which establishes a series of components and their relationships in natural conversation. Toulmin's layout can constitute a powerful tool to analyse classroom discourse (Jiménez, Bugallo & Duschl, in press). It has to be noted that in this study the analysis does not focus on every sentence or group of sentences that could be considered an argument, but only on these called by Toulmin substantive arguments, having as requisite a knowledge of content. The argument components following Toulmin are: a) data: which can be administered or obtained, and of empirical or hypothetical nature; b) claim: which could be more (hypothesis) or less tentative (conclusion); c) warrants, reasons which justify the connection between data and conclusion; d) backing (background knowledge) of a theoretical or general character to

which the warrants are related. Sometimes there are also e) modal qualifiers, which specify conditions for the claim, and f) rebuttal, which specify conditions for discarding the claim.

The second tool, suggested by Duschl, Ellenbogen & Erduran (1999), is Walton's (1996) argumentation scheme for presumptive reasoning, which these authors see as more adequate for the dialectical structure and reasoning sequence of group dialogue. Walton's categories had been used in the construction of the scheme discussed below, in particular what he calls argument from expert opinion. Walton lists five critical questions related to this argumentation: 1) Is the expert a genuine expert in the domain?; 2) Did the expert really assert the proposition?; 3) Is the proposition relevant to the domain under discussion?; 4) Is the proposition consistent with what other experts in the domain say? and 5) Is the proposition consistent with known evidence in the domain?. In our scheme, discussed in the results section, we used two issues about expertise which are seen as relevant for classroom discourse:

1 Who has the status of expert; connected to Walton's first question.

2 Consistency in the expert's propositions, with other experts and with evidence; connected to Walton's fourth and fifth questions.

Walton's second and third questions are disregarded as it is assumed that they asserted the propositions debated and that all of them are relevant to the domain.

The third tool, a scheme for dimensions of scientific discourse in the classroom, has been elaborated by the authors using different sources, on the one hand a previous scheme used to analyze epistemic and procedural operations in students' conversations and actions (Jiménez, Díaz & Duschl 1998a), on the other hand, features drawn from Helms and Carlone (1999) proposal of an heuristic about the commonplaces of science, which following them we have grouped in three dimensions related to a) the empirical nature of science; b) the production of knowledge and c) the sociological dimensions of science. As to the empirical nature of science, the connection among theories and evidence is analyzed by means of the Toulmin's layout in the next section, and then the scheme for dimensions of scientific discourse is presented, together with results of its application to students' dialogue.

3 Results: substantive arguments in environmental education and in science

Analysis of substantive arguments in environmental education

About the first research question, the analysis of substantive arguments developed by students, particularly of the warrants used to justify their claims, the steps followed were: first, to identify in each session and small group the sequence of arguments, to identify the warranted arguments and categories of warrants. In this case it had been

considered only substantive arguments whose claim (explicit or implicit) constitutes an evaluation of the project. Several exchanges among students, whatever its length, are considered to be part of the same argument when they relate to the same claim; and to be part of different arguments when the claim is modified.

The focus are the warrants employed by the students in order to justify –internally, to other group members, or externally, to other teams– their evaluation about the projected net of drainpipes. Warrants justify the move from data to claim and here are viewed as the connection among theory (theoretical claims) and evidence. First the final claims from the six groups are presented, and then some of the main warrants used by the students are discussed to illustrate the analysis.

Not with this layout (5 groups)	A different layout (4 groups)	– Divert it to the West: J2 – Different trajectory (unspecified): J4, J5& J6
	Placing purifying plants near the industries: J1	
Yes with this layout 1 group: J3		

Table 1. Alternatives to the question: Should the network be built with this layout?

As it can be seen, there is a variety of alternatives; not only in the position, for or against the projected layout, but also among the five groups opposing it. Four of them propose a different trajectory, perhaps prompted by the available data about a previous project less threatening to the marshes, although not all of them specify which should be the new layout. One group suggests collecting the sewage directly from the industries, a completely new approach which would avoid building most of the pipes, although the cost would be definitely raised.

In order to compare these arguments to the ones produced in science topics, the warrants need to be analyzed. Warrants could be analyzed according to their strategy, referent or type (Kelly, Drucker & Chen 1996, Jiménez, Díaz & Duschl 1998b), but here the analysis will focus on the content. The warrants employed by group J3 in order to justify their positive assessment of the drainpipes' network are discussed elsewhere (Jiménez, Pereiro & Aznar 1998); and in another paper (Jiménez, Pereiro & Aznar, in press) there is an account of the change of position of the group leader after a debate in the classroom with the engineer responsible for the project. Then, although the nature of the warrants used by group J3 will be referred later, we will focus on the warrants offered by the other five groups, justifying their opposition to the project. The range of warrants is wide, but most of them could be grouped in five areas of content, related to:

ecological concepts, landscape, technical features of the project, values hierarchy and the status of the area. It is not possible to discuss all of them in this short space, and some excerpts of students' conversation are reproduced to illustrate them. Students are identified with pseudonyms respecting their gender.

One instance of warranted arguments, which reflect the path leading to the claim, are provided by discussions in group J1 during sessions 13, 14 and 15 when preparing the final report:

Group J1, session 15
*4 Alfonso: I don't know, I'll say another [*solution to river pollution*].*
5 Caio: Now you say another? That's cool, another.
*6 Alfonso: Because it [*the drainpipe*] would destroy all the landscape, but also...*
7 Edu: They have already destroyed enough, stop the destruction.
8 Caio: But the pipe would also try...
9 Alfonso: No, not the drainpipe! Not the drainpipe, the purifying plants would do it, located in... just there, close to the industries exit.
(...)
14 Alfonso: But because the purifying plants go where the industries are, that is, the drainpipe only carries the water to, to river Miño.

In lines 9 and 14, Alfonso is advancing a new proposal, locating the purifying plants near the industries. A proposal could be warranted, reasoned, or be just an occurrence, a wayward idea, so it is important to explore the reasons that the students offer to support it:

Group J1, session 15
34 Fito: You know, because of the industries the water flow arriving to the pond decreased, and with this is going to be left without any water.
(...)
38 Alfonso: (...) the little water remaining they want to channel into the pipe, it is polluted, they want to clean it and channel it, but if they clean it: What is the purpose to channel it? Why don't they let it flow and fill the pond again?

The focus of this discussion is not only, as in most groups, the damages caused by the land removal while burying the pond (although Alfonso refers to it later, in line 53) or the risks for plants and animals, but the decrease in the water flow as a consequence of channeling the water into the pipe. This idea, as seen above in lines 34 and 38, is repeated later in the debate by Alfonso as the main reason to support their own alternative, the purifying plants close to the industries, which would allow to restore their water flow to the pond. It has to be noted that Alfonso belonged, during the first sessions, to group GA, working on the features of the drainpipes network. Then, in a logic sequence, one would expect, perhaps, a discussion about why it is so important the question of the water flow, about ecological balance and conditions for an ecosystem to be balanced: in the pond a regular water flow would be such a condition. But as this is natural conversation, the students don't state this openly, they just talk

about the environment being ruined and "*the birds going away*" when they arrive there "*and see just a couple of puddles*" (instead of the pond). This argument is interpreted as using warrants related to ecological concepts and also to the features of the project. A representation of it, in Toulmin's layout, can be seen in figure 2, where the warrant (the damages to the ecosystem) belongs to the type of subsequent argument, supported by the reasons about the decrease in the water flow.

(figure 2 about here)

In Walton's scheme it would fit into the category of inference arguments –which, in Duschl *et al* proposal of comprehensive categories includes cause to effect and consequence, among others–. It has been necessary for the students to acknowledge, first, the consequences of the projected network for the water flow, and second the importance of an adequate flow of water for the existence of the pond. Although for ecology experts this path of reasoning could seem obvious, it is not so for high school students; in fact it seems much more difficult to appreciate environmental impacts which 'subtract' something from the environment that impacts consisting in the 'addition' of something, e.g. pollution. This is an instance of the degree of sophistication reached by the students.

Other brief examples of warrants related to ecological concepts are:

food webs, food chains:

J4, session 17

39.2 Diana: (...) and some plant species would also be destroyed, and then animals which depend on these plants will also die.

different time-scale for geological and ecological processes

J2, session 16

154 Begoña: Look, if they destroy houses, you can build another house, but not an ecosystem.
155 Emma: Sure.
156 Begoña: A house it takes... a house it could take a year, two years. An ecosystem takes... umm. Takes its time.

The difference in time-scale among a house and an ecosystem is relevant, particularly seen in the light of the difficulties experienced by students in understanding a time-scale so utterly different from the human life (Pedrinaci & Berjillos 1994). These warrants, related to Ecology, are of a similar nature to the ones employed in standard science topics, but there are others of a different nature discussed below.

Comparison with arguments in science

About the second research question, the comparison among arguments and warrants in environmental education and in standard science topics, the arguments of the students

were compared with others in studies making part from the same project in the contexts of buoyancy (Álvarez 1998), Genetics (Jiménez et al, in press) and labwork with cells and tissues (Jiménez, Díaz & Duschl 1998b). Some of the differences identified relate to:

– *Arguments of reference*: In the environmental education arguments there is not an unique argument of reference which represents the experts' view, this contrasted with the science topics, where there is only one and a clear consensus exists about it. This is seen as related to the different nature of the problems, for in Biology or Physics topics there is a common theoretical frame, while in environmental education issues the claims are supported not only in scientific concepts but also in values, which could differ greatly. Perhaps in environmental education it would be better to talk about 'qualified' arguments, meaning reasoned claims which take all relevant components of the problem into account. As an instance, the process of consensus among the three authors in search of an argument of reference, which took some time, produced a claim: the drainpipe should not be built with the projected layout (see Jiménez, Pereiro & Aznar 1998), different from the claim of group J1 reproduced above, which is also acceptable.

– *Number of warrants*: In a great proportion of the environmental education arguments there are several warrants and not only one; the argument in figure 1 could be an instance. In the science topics there are differences, in some of our studies we found that the reference arguments had several warrants too (see for instance Jiménez et al, in press), while in others there was just one, but almost all of the students' arguments had only one warrant. This could relate also to the nature of the environmental education problems, to their complexity and the need to take different components into account.

– *Relevance of values*: In the environmental education arguments many of the warrants are supported in backings (explicit or implicit) related to values, in contrast which standard science topics where models and theories act as backings. Some instances of values found in this study are the aesthetic values of landscape (see line 6 above), the conflict among economic Vs ecological, the pragmatism or the political nature of decisions. The hierarchy of values supported by the students seems decisive in the elaboration of the claim, an instance could be the discussions in several groups about the costs of the different projects:

J4, session 17

39.3 Diana: Then, the conclusion we reached is to do it with a different trajectory. Which means more money (...)
42 Teacher: The fact of this solution of yours being more expensive: Do you see it as a serious issue?
43 Diana: Serious issue? We see it as more serious crossing the middle of the pond.

A similar concern could be raised about the solution offered by group J1, more expensive than the actual project. The question here is whether the students can reason

with the same degree of sophistication in the field of Economy as they do in Ecology, which in this case means an awareness of the economical consequences and, at least, raising –if not answering– questions as: Is there money to pay for the increased cost? Where is the money to be found?; Would the population be ready to pay more taxes for it?. Of course the influence of the context has to be acknowledged and the context is a course about Biology and Geology, which could bias the ways the task is perceived by the students. In other words, the students may –even unconsciously– assume that they are expected to give an alternative which "favors" ecological and environmental values over economical or any other. There is a case however, group J3, where economical values are considered at the top of the hierarchy and used as warrant for the positive assessment of the project:

J3, session 17

64.3 Isaías: The economy is very important. We must be practical, and if they did it that way it is because there is no more money.

– *Controversial nature*: In the environmental education arguments the positive and negative outcomes are sometimes part from the same argument, this feature being also related to the nature of the problems and tasks. The acknowledgment of both positive and negative impacts of the project on the environment has been considered here as criteria for the quality of the student's arguments. In the science topics the students may debate about several alternatives, but in the end they choose one.

4 Results: the issue of expertise in classroom discourse

In our opinion the expertise and the status of expert should be considered as a part of the dimensions of scientific practice related to the production of knowledge. In the processes of knowledge production an important issue is which are the sources of knowledge and authority, in other words who (books, persons, instances) are the experts. This question has a great importance in the preparation of citizens which could actively participate in scientific practice, for instance in environmentalist movements. The production of knowledge and the sociological dimensions make part from the heuristic proposed by Helms and Carlone (1999) about the commonplaces of science and they could be useful as tools for studying classroom discourse. For this analysis we propose several categories inside these two dimensions as seen in table 2. It is not possible to present instances of all of them, and the discussion will focus on the issue of expertise and its relation to decision making, although other interesting questions arise such as the use of analogies related to ecological content, for instance compare ruining the habitat with the demolition of a house "*like if the house you live was*

demolished" (group J5, session 14) or the handling of quantitative data from the network: length and diameter of the pipes.

Dimensions	**categories**
production of knowledge	–Use of analogy, metaphor –Handling quantitative data –Inscriptions –Appeal to expert & expert status
sociological dimensions	–Social negotiation –Decision making

Table 2 Authors' dimensions to Helms & Carlone commonplaces of science

To explore the different aspects related to expertise, Walton's critical questions about argument from expert opinion have been collapsed in two which account for particular features of students' discourse: the status of expert and the consistency in the expert's propositions:

Who has the status of expert?

Along the sessions, the student expressed doubts about their own ability to assess the project:

Group GIV, session 5

57 Antón: ...then... if they [the Environmental Office] *if they say that it is... there is no need for me to explain it* (the ecological value) *again, you know.* (...)
61 Antón: The fact that they consider that there is a need of doing it (the project)... *is because they know that it isn't an ordinary piece of land.*

Group B, session 7

196 Teacher: ... and you decide...
197 Isaías: [interrupting her] *But... the authority...*
200 Teacher: You all... You are the authority here.

Some of them, like Antón, seem to think that the Environmental Office has to know the full importance of the wetlands, so the students would be in no position to challenge this view; other, like Isaías, raise doubts about their own capacity to prepare the report without the teacher. These doubts are carried until the last session, when the students are reporting to the whole class.

Group J5, session 17

10.3 Ana: If we build the drainpipe it is going to influence the biodiversity, because they are not reforesting it. We would look for a third... for a third...
12. Ana: ... system, to do it without so much damage. (...)
13 Teacher: Do you have any suggestion about how would this alternative be?

15 Isaura: Because... the question is that we don't know more systems for cleaning rivers. Then, not knowing them, we cannot criticize it accurately.

Group J3, session 17

62 Isaías: If the engineers, who know more than we do, made a project, there would be a reason for it...

Isaura is explaining the vagueness of group J5's proposal: not accepting the projected layout, while acknowledging the need for cleaning the river, which lead them to talk about a "third alternative"; this they cannot specify without knowing more about river cleaning, so the claim remains: no to the projected layout, yes to a new, different project for the marshes. Isaías position is different: he supports the positive assessment of the project on the grounds of the expertise of its authors, the engineers.

Here two different view about the expert status can be traced: while group J5 acknowledge their lack of technical expertise (and/ or information), but this is not an obstacle to criticize the project, for Isaías and group J3 the engineers are at the top of the experts' hierarchy, and the students are in no position to challenge their proposal. This position was to change later as discussed below.

Consistency with other experts and with evidence:

In different times the students question the authors of the project; at some times they are so involved in the simulation that they really feel as if the letter asking them to produce an evaluation of the project was true, as seen in excerpt from Group I:

Group I, session 1

235 Carlos: Let's see: Why do they [the Environmental Office] *ask our opinion? At the end they will do what they want.*

Group IV, session 2

56 Berta: If is crossing it [the marshes with status of preserved area]: *How do the people from the Environment* [Office] *allow it to be built there...?*
(...)
104 Berta: ... So, you mean that the people building it are the ones from the Environment [Office]?
105 Damián: But... it is here [in the written information]
107 Berta: The Environment people allow the pipe to cross there?

Group J1, session 15

49 Edu: Wait a moment, the person who had the idea of the pipe is a fool... How it is that he didn't consider the problems there!

Also in the transcripts from Group J1 session 15, quoted above in section 3, when Alfonso (line 38) points to the inadequacy of the project because of failing to the purpose of cleaning and keeping the water flow.

Along these dialogues there is a common thread: the students point to the lack of consistency among on the one hand, the evidence about, the status of preserved area of the marshes, its ecological value, and the damage which burying the pipes and channeling the water would do to it and, on the other hand, the authorship of the project by the same offices with have the responsibility to protect the environment.

One of the interesting questions on expertise is that, in general, although expressing doubts about their own, the students, as the sequence developed, were able to behave like experts, to point at the inconsistencies and project's flaws and to offer alternatives. After the whole class debate in session 17, two of the "real life" experts related to the public controversy about the drainpipe project accepted to discuss it with the students. They were the engineer who wrote the project and the president of *Erva* ("grass") an environmentalist group with a long involvement in the defense of the Budiño's marshes. That this debate was not recorded was a condition. Three months later, the students were asked again their opinion, as a personal statement to be included in their portfolios. As discussed in detail in another paper (Jiménez, Pereiro & Aznar, in press) the debate with the experts proved very influential on the students' positions producing a certain convergence: the ones which had evaluated negatively the impact of the project retained their opposition, but show an understanding of the need of an urgent action, while Isaías changed his view, on the grounds of the evidence offered by the environmentalist and the acknowledgement, from the engineer, of the inexistence in the project of measures for the ecological recovering of the area. This is interpreted as a new assignment of expertise, now shared by the environmentalist and even by the students themselves. It has to be noted also that in the month of September 1998, the journals informed of several changes to the project, which, although keeping the layout, now includes planned measures in order to repopulate the area and enhance its recovering. It is not possible to know whether these changes relate to the critiques that the engineer read and hear from the students, but many of them perceived it this way.

5 Expertise and critical thinking: educational implications

Although there are a number of papers related to one type of expertise, their focus is the question about expert-novice differences and we have been unable to trace the issue of expertise as a component of the scientific practice or classroom discourse as it is discussed in this paper. However, if science education and environmental education have as a goal to develop critical thinking and to promote the participation in decision-making, it seems that the acknowledgement of a variety of experts and expertises is of relevance to both. Otherwise citizens could be unable to challenge a common view which places economical issues and technical features over other types of values or concerns, such as ecological or related to landscape. As McGinn & Roth (1999) argue,

citizens should be prepared to participate in scientific practice, to be involved in situations where science is, if not created, at least used. The assessment of environmental management is, in our opinion, one instance of these situations and the citizens do not need to possess all the technical knowledge of the experts involved to be able to examine the positive and negative impacts and to weigh them.

In order to discuss the issue of expertise against the background of the alternatives and arguments offered by the students, the first section of the results compares these arguments with others in standard science domains. There were a great deal of arguments identified in the dialogues of the students and it is worth noting the variety of claims and of warrants supporting them, for instance warrants relying on ecological concepts, which show that the students' alternatives are not just occurrences, but are supported with reasoning. Some particular features of environmental arguments, as compared with standard science topics seem to emerge, such as the existence of several possible qualified arguments, which could operate as reference, the number, and variety of warrants, which sometimes are of contradictory sign in the same argument, the relevance of values. The difference among the problems in the two domains could account for great part of these differences: while in science the tasks set for the students –even in open-ended problems– use to have few variables and usually a path (when not an algorithm) of solution, the environmental problems have an extended number of variables, in the case of the drainpipes network more than twenty, and not a clear path could be followed to reach a solution, as the science frame alone is not enough to solve it. Environment problems are complex, messy, in many occasions of controversial nature. But science and environment problems which citizens would encounter in real life are not simple or straightforward, so having to take into account both positive and negative impacts of the same action perhaps is a good preparation for facing them.

The identification of instances of scientific practice is a difficult issue, if we view this practice as a complex process, not as a path of fixed "steps". Several instances were identified when it could be said that students acted as a knowledge-producing community; in the paper the focus is the expertise dimension. The students, particularly at the beginning of the sequence, expressed doubts about their capacities to assess a project, which had been written by experts and endorsed by a Government office. Perhaps these doubts could relate to the nature of the project, a "real life" object which made its way into the classroom, into the "school life", for as Brown *et al* (1989) point, usually there is a divorce among practitioners' tasks and stereotyped school tasks and, could be added, students are not used to be confronted with the complexity of life sized problems. However, as the sequence proceeded, the students were assuming the role of experts, exposing the inconsistencies in the project, offering alternatives and discussing it with one of their authors.

We think that the issue of expertise is worth of attention and that it need to be explored in connection with different contexts where the relationships among technical expertise, values hierarchy and possible bias caused by the content of the subject matter could be unraveled. It should be noted that one of the objectives of environmental education is to empower people with the capacity of decision-making; for this purpose the acknowledging of multiple expertises is crucial.

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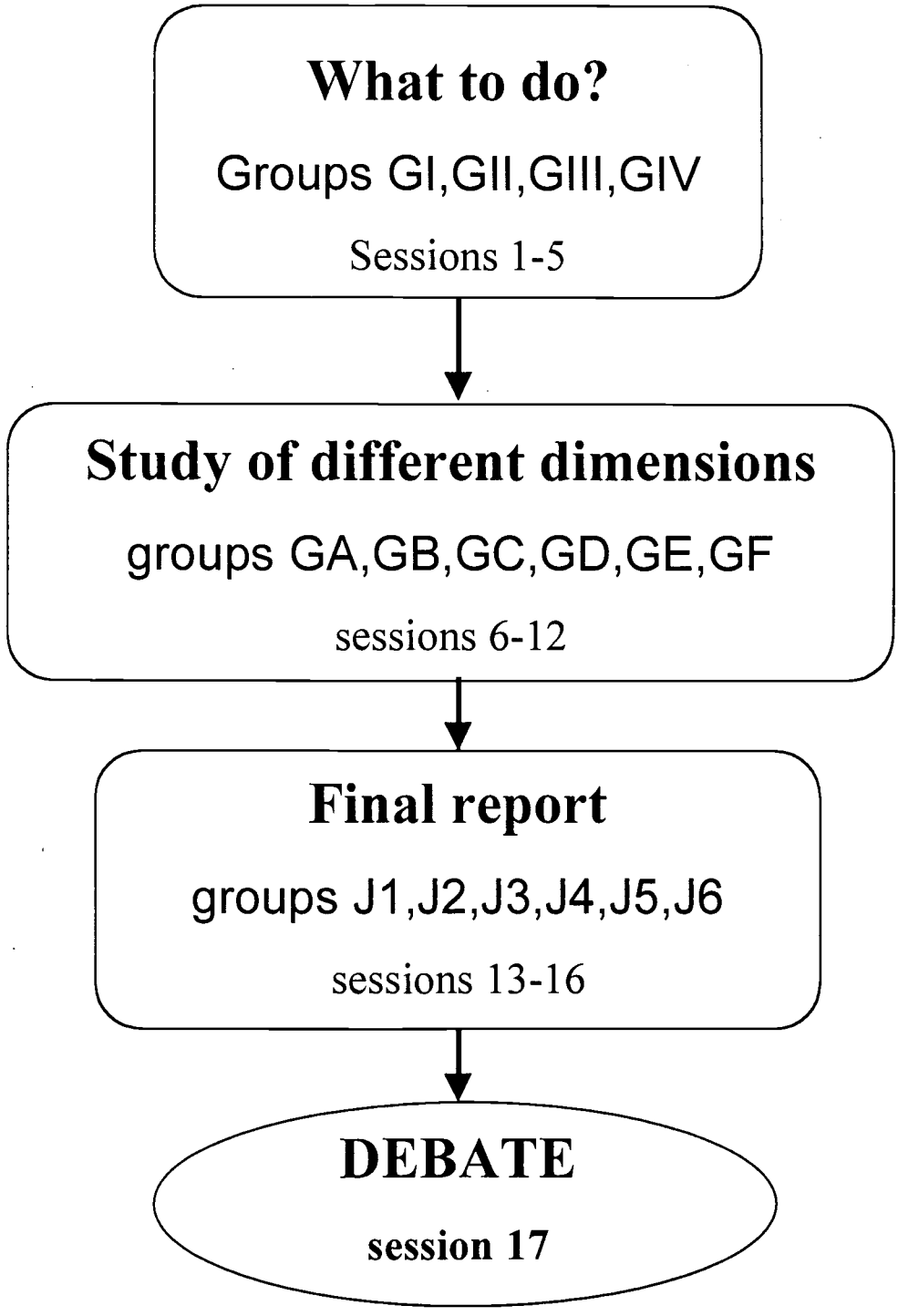
"Budiño´s pipe"



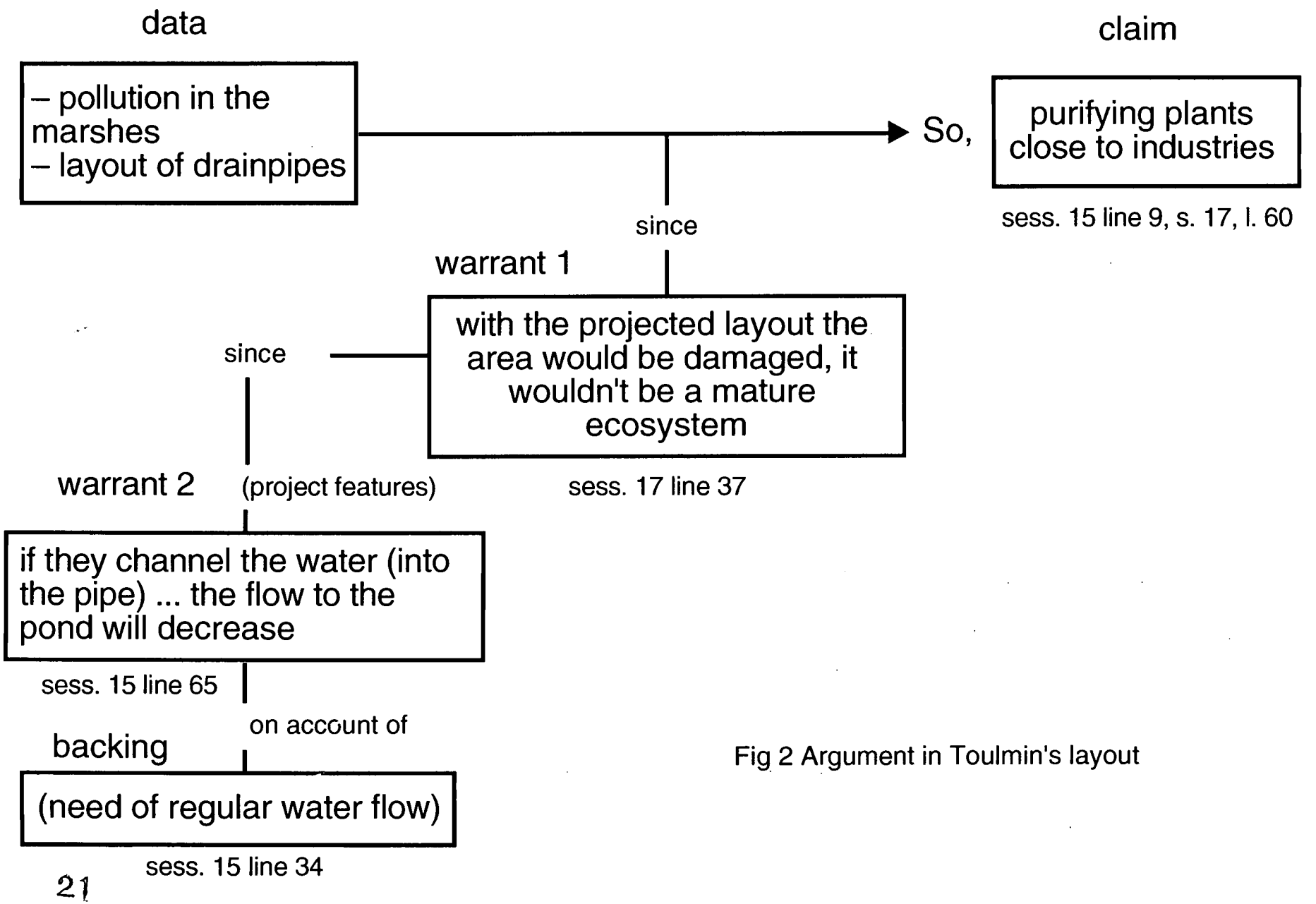


Fig 2 Argument in Toulmin's layout

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