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Knowledge producers or knowledge consumers? Argumentation and decision making about environmental management

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This paper describes a case study involving decision making and argumentation, in the context of wetland environmental management, by 11th-grade students (16–17 years old). The purpose was to study the components of knowledge and skills needed to reach a decision in socio-scientific contexts and to identify them in classroom discourse. The following dimensions of decision making were explored: the use of relevant knowledge to understand and make decisions about the problem; and the critical processing of sources of information and authority and the development of criteria for evaluating possible solutions to the problem. Students' conversations were recorded and analysed using Toulmin's (1958) and Walton's (1996) argument schemes. The students' arguments and warrants were compared with the argument of an external 'official' expert. Issues such as expert status, that is, who can be considered as a source of knowledge and authority and the participation of citizens in scientific practice are also discussed.

Decision making and environmental education

One of the objectives of environmental education is to prepare students for future participation in society. To be an informed citizen, one needs to be able to make decisions. Implicit in the concept of decision making in everyday situations is the skill of being able to present an argued point of view (Kortland 1997). Kortland (1996) points out that decisions are reasoned choices, built on criteria that are not formulated from the beginning, but developed in interaction with the evaluation of the choices available.

Reasoned choices and evaluation are often based on values but, although values are an important basis for making a judgement, the use of relevant conceptual knowledge is needed in order to weigh the advantages and disadvantages of the available options. If solving environmental problems through decision making promotes behaviour *for* the environment, conceptual knowledge must play an important role in environmental education. Changes in attitudes and behaviours, we argue, should be supported by relevant knowledge, by the understanding of the consequences of careless behaviour or, as in the case studied here, by the careful assessment of the different options for environmental management.

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The relationship between conceptual understanding and environmental attitudes has been explored, in the context of landscape interpretation, by Benayas (1992). Benayas found that university students possessing cognitive schemes of greater complexity and variety tended to choose a higher proportion of rural or local landscapes and reject scenarios including human intervention or those presenting exotic plants and animals than did other students. Moore (1981) found that university students assigning more importance to the need for taking steps to save energy were the ones who knew most about energy and the consequences of its mismanagement.

The focus of this paper is decision making and argumentation. We take argumentation as meaning the evaluation of theoretical claims in the light of empirical evidence or data from other sources (Kuhn 1992, 1993). Put another way, we see it as the capacity to choose between different explanations and to reason which criteria lead to the choice. For Kuhn (1992), the ability to make reasoned judgements should be part of the ability to 'think well', but she suggests that the promotion of argumentative reasoning skills does not occur equally across all school environments. This study focuses on natural science classroom discourse partly, as Kuhn says, because argumentative dialogue externalizes argumentative reasoning and partly as a way to study attitudes and values beyond the scope of paper and pencil instruments.

The focus of the study are not any arguments, but the substantive arguments (Toulmin 1958) in which the knowledge of content is a requisite. If science is viewed as a complex practice involving not only planning and performing experiments but also proposing and discussing ideas and choosing from among different explanations, then, discursive processes and practices constitute an essential part of the building of scientific knowledge (Latour and Woolgar 1986).

Decision making and argumentation require an adequate context, for instance classrooms organized as knowledge-producing communities, rather than knowledge-consuming communities, where, as McGinn and Roth (1999) argue, scientific literacy is understood as preparation for participation in scientific practice. Environmental conflicts offer good opportunities to evaluate options due to the complexity of the problems under study (Jiménez *et al*. 2000a). The students were asked to assess the impact of a projected network of drainpipes in the marshes of river Louro, a wetland near their school. This real-life issue involves conflicts between contradictory interests and cannot be resolved with straightforward affirmative or negative answers, a teaching strategy that has been advocated elsewhere (e.g. Ratcliffe 1996).

In terms of authenticity, the classroom tasks were designed according to the culture of the science practitioners and not according to a stereotyped school culture (Brown *et al*. 1989). For Roth and Roychoudhury (1993) authentic contexts mean laboratory experiences providing students with open-ended problems of personal relevance; for Duschl and Gitomer (1996) authentic problems, besides having relevance for students, should demand the use of criteria for evidence and justification similar to those the scientists would use. So, the criteria for choosing the wetland problem were that it was: open-ended, relevant to the life of the students and that it allowed reasoned debate about the solutions using available data and evidence. Authentic problems do not need to be 'true', but the issue chosen is a real problem and it adds motivation and interest for the students, offering them the possibility of discussing it in the classroom and trying to influence, to some extent, the real world outside the classroom.

Environmental education has been introduced as a cross-curricular subject in Spain since educational reform in 1990, but there are only a minority of classrooms where it is enacted as a new dimension. Usually, 'environmental' tasks are just anecdotal activities such as planting a tree or preparing recycled paper. In the wetland problem, the rationale underlying the teaching sequence views environmental education as a dimension impregnating the content matter (Biology and Geology), not as a new subject. The whole teaching sequence has been designed with the objectives of developing environmental skills and values such as: learning to appreciate landscape features, including aesthetics; and developing the ability to assess the impact of human actions on the environment.

The purpose of the study is to explore whether the students, in a problem-solving context, can act as knowledge producers, reaching decisions about environmental management. Their steps and arguments are compared to the ones by an external expert for the following dimensions:

(1) The use of relevant conceptual knowledge: through the analysis of the substantive arguments developed by them, particularly of the warrants used to justify their claims.
(2) The ability to process critically different sources of information and authority.
(3) The ability to develop criteria for evaluating options.

Methods, participants and educational context

Participants

The participants were an 11th-grade group of 38 students from a public high school in Vigo, a small city on the northern coast of Spain. They were enrolled in a Biology and Geology course taught by the second author. They belong to the evening shift, either because they work during the day or because they are taking the courses at a slower pace so, instead of being 16–17 years old, their ages ranged from 17 to 21.

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

The environmental management teaching sequence (which is discussed in detail in Jiménez *et al.* 2000a), is part of the regular coursework and took place during February/March 1998. The students worked in teams, but the teams were distributed and then blended three times using a 'jigsaw' technique:

- Sessions 1–5: groups I to IV were presented with the problem, the assessment of the environmental impact of a drainpipe in the marshes of Budiño and undertook a field trip;
- Sessions 6–12: six groups, A to F, analysed different dimensions, e.g. landscape values, plant or animal communities, the projected drainpipes; and each group produced maps and reports;
- Sessions 13–16: groups J1 to J6 ('J' from 'jigsaw') shared the six reports in teams. Each 'J' team (around 4–5 students each session) produced a final

report including an assessment of the project and its predicted impact and these reports were debated in the class in session 17.

After some days, a debate took place in the presence of outside experts; the engineer who wrote the drainpipe project and the President of *Erva* ('Grass') an ecology NGO with a long involvement in the defence of the Budiño marshes.

The marshes of Budiño are a wetland with a seasonal pond in the basin of the river Louro. The marshes have the European status of an 'Area of Natural Interest'. They are surrounded by an industrial area and a granite quarry, which drain their sewage into the wetland and the river. All the area is heavily polluted, some of the small ponds are dry and plants (e.g. one of the few insectivorous 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 the sewage. In the project's first draft, produced by the Water Office, the main drainpipe surrounded the wetland and the pond, but in the final project proposal the layout had changed, and it bisected the wetland, requiring removal of marshland in order to bury the pipes. Although the reported reasons for the change are technical, the available evidence points to the reduction of cost as the main reason.

The students had to produce a report about the suitability (or not) of the pipe proposal and, if they thought it appropriate, to produce alternative solutions. The drainpipes project was chosen because of its complex nature: building the pipe would involve a positive impact on the wetland, by avoiding the pollution from the sewage; but also negative impact, removing the land and destroying fragile habitats. The hypothesis was that this contradiction would promote a variety of opinions, argumentation and debate.

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 and students' individual and collective reports and other work collected in their portfolios. A year later, in 1999, interviews with some students were conducted and, later still, interviews with the outside experts. From these, only the interview with the engineer who was responsible for the project is discussed in this paper.

Students' conversations were transcribed and analysed using several tools. For the purposes of this analysis, two are particularly relevant. Toulmin's (1958) argument layout was employed because it can constitute a powerful tool to analyse classroom discourse. The analysis does not focus on every sentence, but only on the substantive arguments that require some content knowledge. The argument components, following Toulmin, are: (a) data; (b) claim; (c) warrants, that is, reasons that justify the connection between data and claim; and (d) backing (background knowledge) of a theoretical or general character to which the warrants are related. Sometimes there are also modal qualifiers and rebuttal.

The second tool was Walton's (1996) argumentation scheme for presumptive reasoning, which Duschl *et al*. (1999) view as more adequate than Toulmin's layout for analysing the dialectical structure and reasoning sequence of group dialogue. Walton's categories were used to focus on what he refers to as argument from expert opinion. Walton lists five critical questions:

(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?
(5) Is it consistent with known evidence in the domain?

These five questions were collapsed in two issues concerning expertise seen as relevant for classroom discourse:

(1) Who has the status of expert (connected to Walton's question 1).
(2) Consistency in the expert's propositions, with other experts and with evidence (connected to Walton's questions 4 and 5).

Three components related to knowledge and skills in decision making in socio-scientific issues were explored:

- the use of relevant knowledge to understand and decide about the problem;
- the critical processing of different sources of information and authority; and
- the development of criteria for evaluating alternative solutions to the problem.

Toulmin's layout was used as a tool to study these factors, particularly the first and third dimensions, use of knowledge and development of criteria. Walton's argument from expert opinion was used for the second. In the next sections, we apply these tools to student dialogue.

Use of relevant knowledge: substantive arguments and warrants in environmental management

In order to explore the use of knowledge, the warrants used by the students were contrasted against the ones used by the outside expert during interview. The steps followed were: to identify, in each session and in small groups, first the sequence of arguments, then the warranted arguments and then the categories of warrants. Only substantive arguments whose claim (explicit or implicit) constituted an evaluation of the project were considered.

The foci were the warrants employed in order to justify – internally, to group members, or externally, to other teams – their claims, that is, their evaluation of the proposed drainpipe network. Warrants justify the move from data to claim and were viewed here as the connection among theoretical claims and evidence. In table 1, the final claims from the six groups are presented, together with the warrants used to justify them.

The groups identified a range of solutions. Four groups proposed a different trajectory, perhaps prompted by the available data about a previous draft that was less threatening to the marshes, although not all of them specify it. One group suggested collecting the sewage directly from the industries and building more than one purifying plant, a new approach that would avoid building part of the pipeline network, although the maintenance problems and the whole cost would be raised.

Table 1. Warrants from the six groups related to: should the drainpipes' network be built with this layout?

Final conclusion (n = 6)	*Alternative solution*	Warrants
Not with this layout: a different layout (4 groups)	Divert it to the West: J2	E: to preserve the ecosystem E: long time for recovery E: present pollution T: buried pipes
	Different trajectory (unspecified): J4	E: destruction of ecosystem E: damage to plants, animals E: alter food chains E: present pollution T: layout across marshes T: buried pipes V: ecosystem more important
	Different trajectory (unspecified): J6	E: avoid damage to marshes E: alteration of habitat E: pollution affecting the area T: buried pipes I: aesthetic value of area
	Third alternative: J5	E: damage to biodiversity E: destruction of habitat E: present pollution T: buried pipes T: lack of reforestation V: designation of area (EU)
Not with this layout: a different solution (1 group)	Placing purifying plants near the industries: J1	E: damages to animals E: it wouldn't be mature E: present pollution E: less water flow T: buried pipes T: water channeled
Yes with this layout (1 group)	Build the drainpipe J3	E: present pollution T: buried pipes T: recovery is possible V: cost reasons: money V: the experts know more

Note: E: ecology; I: landscape impact; T: technical features of project; V: values hierarchy

To compare these warrants to the ones used by an outside expert, the interview with the engineer, who will be called here Mr Brey, was analysed. Mr Brey works in the Water Office and was responsible for writing the project proposal; he had featured several times in the newspapers defending it or clarifying its features. He had been very supportive of the teaching sequence, providing written information, maps and documents and also, after seeing the reports from the six groups, had agreed to participate in a debate with the students and with the President of *Erva*. It was agreed that this debate should not be recorded. The reasons for using the interview with the engineer rather than the ecologist was that most groups opposed the layout and it was probable that their warrants would be coincident with the ecologists'. So, using the engineer's interview challenges the hypothesis that students were acting as experts would do.

Argument warrants can be also analysed according to their strategy, referent or type (Kelly *et al.* 1998, Jiménez *et al.* 1998), but here the focus is on the content. The warrants employed by group J3 in order to justify their positive assessment of the project are further discussed in Jiménez *et al.* (2000a). The range of warrants, either supporting the project or justifying their opposition is wide, but most of them could be grouped into four areas, related to ecological concepts; landscape impact; technical features of the project; and, values hierarchy.

Sometimes it is not easy to distinguish warrants from backings. In Toulmin's (1958) scheme, the warrant justifies the move from data to claim, while the backing is an assumption that establishes the warrant. On many occasions during natural conversation, the backing is implicit and unstated. This, then, is one of the reasons for focusing the analysis on warrants, as only explicit statements were considered for this category. One of the criteria for considering warrants is conversational markers, such as 'because' or 'since', but again in natural conversation these could be present or not. One example of categorizing is shown below:

> 10.2 Ana (group J5): It is one of the few areas designated as of natural interest in Galicia
> 10.3: If we build the drainpipe it is going to influence the biodiversity, because they are not reforesting it.
> 10.4: We would look for a third . . . a third . . . [layout].
>
> (Session 17, whole group debate)

The claim in line 10.4 is a proposal of a third layout (the first one being the initial draft and the second the, then, current project) and the warrants for it are: (a) the EU designation of the area (line 10.2); and (b) the influence on the biodiversity (line 10.3). The second takes the form of what Kelly *et al.* (1998) call 'consequential arguments', this warrant being the claim of an argument whose warrant, in turn, is a technical feature of the project, the lack of reforestation. Only this third warrant has the marker 'because', being one of the reasons, perhaps, that the others precede the claim. The implicit backing for the second warrant would be the assumption that (high) biodiversity is a feature which mature ecosystems possess but that, without steps such as reforestation, is greatly affected when an ecosystem is altered or damaged. It is difficult to know for certain whether this is the meaning intended for the student, so, although other parts from the research intend to explore the backings, here the focus is on explicit justifications, on warrants.

In table 2 the different warrants in the three concept content areas are summarized with indications of whether they were mentioned by the students (S), the engineer (E), or by both. Values, which are discussed in a later section, are not categorized here. There are some warrants, for instance about maintenance (upkeep) of the purifying plants, about impact risks, the overflow channels or about the diameter of the pipes that were used by the students, but not in their discussion of the final reports, in the Jigsaw groups, but in the previous groupings. These warrants are included in table 2, but not in table 1, which refers to the final decisions. It is not possible to discuss them all. However, some illustrative excerpts of transcriptions are reproduced below. Students are identified with pseudonyms respecting their gender.

Table 2. Conceptual content areas of the warrants used by the students and the engineer.

Area	*Warrants used by students (S)/engineer (E)*
Ecological concepts	Preservation/damage/destruction of the ecosystem: S, E Avoid damage to marshes/pond: S Alteration/destruction of habitats: S Damage to biodiversity: S Damage to animals, plants: S, E Alteration of food chains: S It wouldn't be a mature ecosystem: S Time for recovery, long/not too long: S, E Control/diminution of water flow: S, E Present pollution affecting the area: S, E
Landscape impact	Impact on landscape: S, E Impact reports: E Risks: S, E Aesthetic value of area: S
Technical features of the project	Layout of network: S, E Slope of the terrain: E Buried pipes: S, E Diameter (2 m.) of pipes: S Water channelled into pipes: S Amending steps/lack of reforestation: S, E Possibility of recovery: S, E Maintenance (upkeep) costs/difficulties: S, E Position/number of purifying plants: S, E Overflow channels (spillways): S, E

As can be seen from table 2, the range of warrants used by the students and by the engineer covered the same content areas. Some of the concepts are used in very different ways, for instance, the long time the ecosystem would need for recovery (students), and the relatively short time of recovery (engineer). The references to the technical features of the project are along similar lines: there is only one relevant question among those mentioned by the engineer that is not mentioned by the students – the slope of the land, which increased the expected cost of the first draft project. However, the issue is complex and involves consideration of the maintenance of the purifying plants (technical difficulties and the lack of political agreement about who should be responsible of it, its costs), which are highlighted by both students and the engineer.

Warrants about ecological concepts

The wide range of warrants related to ecological knowledge can be seen in tables 1 and 2. Some of them are of a general character and refer either to the preservation of the ecosystem or to the damages to it that would result from the project. Others specify either particular places (damages to the marshes or to the pond) or ecological features that would be affected, e.g. biodiversity, as in the example from session 17 discussed above. Some instances of the warrants summarized in table 2 are:

Food chains

> 39.1 Diana (group J4): We believe that building the drainpipe would destroy a great deal of the ecosystem, because it crosses the pond in the middle
> 39.2: and some plant species would also be destroyed,
> 39.3: and then animals which depend on these plants will also die.
> 39.4: Then, the conclusion we reached is to do it with a different trajectory
> 39.5: which means more money.
>
> (Session 17, whole group debate)

Although several groups refer to animals when speaking about the threats to the ecosystem, the reference to plants is worth noting as they are forgotten on many occasions, not just by pupils, but also by the general public. Then, in line 39.3, Diana relates the damages to plants to the damages for animals, through the food chain. This type of indirect risk is not so easily perceived as the direct damages. Here the marker 'because' is explicit only for the first warrant, but there she adds 'and' when listing the others.

Maturity of the ecosystem and time-scale

> 154 Begoña: Look, if they destroy houses, you can build another house, but not an ecosystem.
> 156 Begoña: A house it takes . . . a house it could take a year, two years. An ecosystem takes . . . umm. Takes its time.
>
> (Group J2, session 16)
>
> 37.2 Caio: (from group J1) we believe that the drainpipe should not be built
> 37.3: because it would be a great disaster for the environment
> 37.4: and the area would be damaged and as a consequence it wouldn't be a mature ecosystem.
>
> (Session 17, whole group debate)
>
> 57 Mr Brey: (. . .) the issue of reforesting, they are trees which are not . . . species being there for 50 years, I mean, they are bank woods which grow relatively fast (. . .).
>
> (Interview with the engineer)

The concepts related to ecological succession and the notion that the mature stage (line 37.4) has a higher quality and it takes a long time to recover, are of greater complexity than simply references to general damage to the ecosystem or to the marshes. The difference in timescale (line 156) is relevant, seen in the light of the students' difficulties in understanding a timescale so different from human life (Pedrinaci and Berjillos 1994). For the engineer, it is the opposite: one of the reasons he offers in support to the project is that he views the species on the river bank (willow, alder) as quick growing.

Decrease in water flow and its consequences. One instance of warranted argument, reflecting the path leading to the claim, is provided by group J1 when preparing the final report.

> 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.
> 16 Alfonso: If they channel the water. . .it would be less [the water flow].
> (Group J1, session 15)

In lines 9 and 14, Alfonso is advancing a proposal: locating the purifying plants near the industries. As a proposal could be warranted or just an occurrence, it is important to explore the reasons offered to support it:

> 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 damage caused by land removal while burying the pipe or the risks for plants and animals, but the decrease in the water flow as a consequence of channelling the water into the pipe. This idea, seen above (34 and 38), is repeated later by Alfonso as the main reason to support their alternative, building purifying plants close to the industries, which would allow the water flow to the pond to be restored. In a logical sequence, for instance in a textbook, one might expect a discussion about why the question of the water flow is important. For example, about conditions for ecosystem balance, but in natural conversation the students do not make each step in the argument explicit, they simply talk about the environment being ruined and 'the birds going away' when they arrive there 'and see just a couple of puddles'. A representation of it in Toulmin's layout, including a warrant about mature ecosystems quoted above, can be seen in figure 1, where the warrant (damage to the ecosystem)

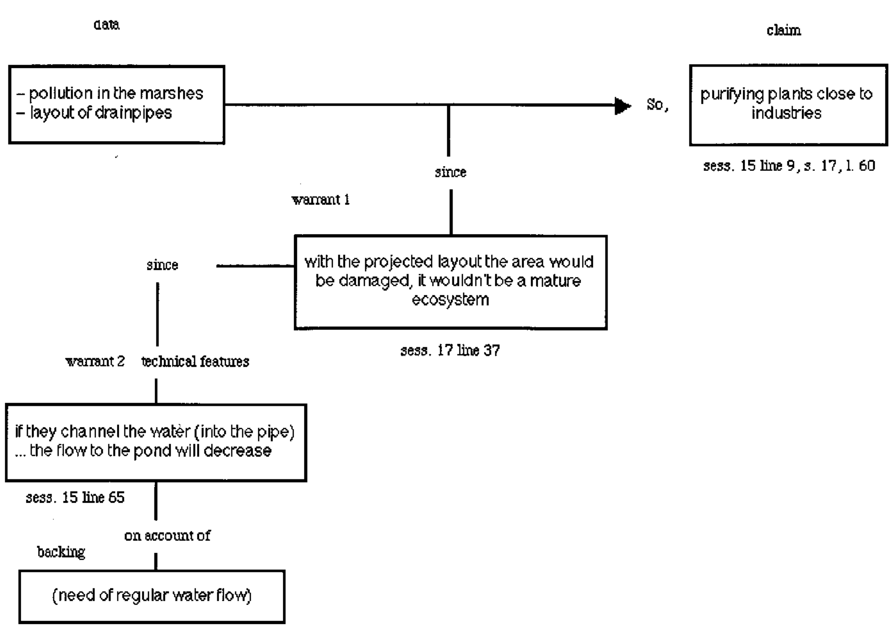

Figure 1. Group J1 argument in Toumlin's layout (all verbatim, except parentheses).

belongs to the type of consequential argument, supported by the reasons about the decrease in the water flow.

In Walton's scheme it would fit into the category of inference arguments. It has been necessary to acknowledge the consequences of the project for the water flow, and the importance of an adequate flow for the pond. For ecology experts, this reasoning seems obvious but it is not so for high-school students; probably it is more difficult to appreciate impacts which 'subtract' something from the environment than the 'addition' of something, for example pollution.

Warrants about landscape impact

One of the terms that presented greatest difficulties for the students in the first sessions, when the problem was introduced to them, was 'impact'. But later, some, as Antía shows below, appropriated the concept and were able to use it:

> 90 Antón: ... Forty thousand square meter the ... the marshes ... of a meter and a half of depth.
> 93 Antía: Look, this one they remove it ... Does it affect to landscape? Wouldn't be about impact?
> 95 Antía: It says here: how much land it would occupy ... It affects to the landscape: Doesn't refer to impact?
> 96 Antón: The building works. Sure, the land the works would take.
> 97 Antía: OK
> 100 Antón: The question is ... everything is related ... all these things.
> 101 Antía: [to Ana, who is writing] Write there: affects to the landscape.
> (Group A, session 10)

Antía and Antón are assessing the size of the land that would be affected by the drainpipe and how this would cause an impact on the landscape.

> 1.1 Caco: (group J6) In order to decide the convenience of building the drainpipe, we took into account mainly the importance of the valuable features of the area, aesthetics, social and all this
> 1.2: And also the for and against, above all taking into account the pollution ....
> (Session 17, whole group debate)

Here the aesthetic values of the landscape are placed at the beginning of the summary of the position of group J6.

> 30 Mr Brey: ... because the environment impact studies, many times [are] lost on unproductive catalogues of little practical use .... (Interview with the engineer)

Here Mr Brey is opposing the impact reports on the steps that would be demanded of the contractors (that part of line 30 is reproduced below), casting doubts about their relevance. This seems part of the dissociation that he establishes between real life and the environmental monitoring and will be discussed when talking about values. But there are other ideas such as the impact on the landscape or the assumed risks of the project that are used in a similar way both by the students and by the engineer.

Warrants about technical features of the project

The project involves burying 94 km of approximately 2 m diameter pipeline along the wetland. The impact of burying huge pipes in a natural area, which is very different from doing it in a city street, was not understood at the beginning, but some students realized it when discussing the project:

> 236 Ana: Underground [the pipes] and ... they are of concrete.
> [...]
> 242 Aldán: Here it says: two meters ... [the diameter of the pipes]
> 243 Teacher: Almost two meters.
> [...]
> 258 Aldán: Same as the gutters, more or less.
> [...]
> 264 Aldán: Damn it! To bury it, man, they would have to destroy all the ecosystem!
> (Group A, session 7)

Aldán is realizing what would happen when the pipe is buried and a wider security zone without plants would be established. This is an instance of the ability to establish connections between the technical features of the project (material, size, diameter, location) and its consequences for the ecosystem. After the groups were rearranged, Ana was in group J5, where she also insisted on the relevance of technical features.

> 75.1 Ana: And of ... for instance, where the drainpipe is going to cross it, you know, all the land must be removed and it is more than 94 kilometres
> 75.2: if then they do not replant it, with the areas ...
> (Group J5, session 13)

Besides the length of the pipes and the question of removal, the issue of reforestation, as a part of possible rehabilitation process which the project lacked, was pursued in later sessions.

> 451 Clara: If they do not replant it, no ... if they don't undertake the reforestation, then had better not carry [the project] out.
> 452 Ana: [if] They were doing a reforestation like this, good and all ...
> 453 Clara: Of course!
> 454 Ana: ... so it would stay as before. Listen, it would affect it, but not so much.
> (Group J5, session 14)

The issue of the remedial action worries the students and it was one of the questions that they asked the engineer when debating with him. In line 454, Ana is looking for a compromise: if the project included restoration of the area, then the impact would decrease. In the interview, the engineer is asked again about the absence of rehabilitation steps in the project:

> 26 Mr Brey: ... if it was possible, all the issues about impact should be considered in the project and so, among them, the amending steps. But I think that in a certain type of works, let's say, the benefits are so clear ... I mean here, in this section, the river is dead ...
> 30 Mr Brey: ... for the submission of applications we [the Water Office] are asking for amending actions, what we saw as more influential ... like monitoring the access to the area, the reforestation, care ... of the water regime, and all this was included.

First, Mr Brey recognizes, in line 26, the general need for restoration in a project, but then justifies the lack of planned steps in this particular project because its benefits are clear, as the area suffers from heavy pollution. Later, in line 30, he explains that these steps would be asked for from the contractors, who have to include them in their applications. Next he opposes this practical approach with the impact reports that he assesses as impractical, as mentioned above.

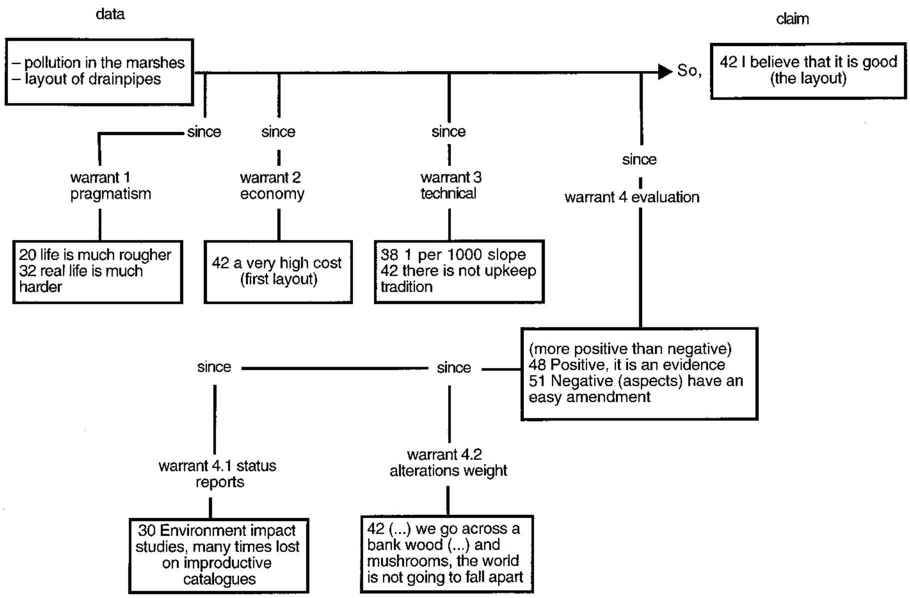

Figure 2. Mr. Brey argument in Toumlin's layout (all verbatim, except parentheses).

The main warrants that Mr Brey used along the interview: pragmatism (contrasting 'real life' against environmental monitoring), economical reasons, technical features and an evaluation of positive and negative aspects of the project are represented in Toulmin's layout in figure 2.

Ability to process critically different sources of information and authority: who is an expert?

In order to make a decision, it is important to identify which knowledge is relevant for the problem, and which sources are reliable. The next step would be a synthesis of the different areas or fields of knowledge that are considered both relevant and reliable. Ratcliffe (1996) explores the development of information processing and analysis as one important strand in decision making, showing the difficulties in increasing the use of an information base and calling for a careful assessment of pupils' abilities before grouping them. For her, a summary of steps in decision making could be: (1) identifying the nature of the problem; (2) identifying the possible outcomes available; (3) listing the objectives to be met by the solution; and (4) assessing the positive and negative consequences of the outcomes.

Identifying the problem, objectives of the solution and alternatives

The initial groups spent five sessions identifying the problems, the objectives to be met by the solutions and the strategy they had to follow in order to reach a decision. As a range of outcomes was not provided by the teacher, the students had to define them and to identify their consequences by analysing the information available to them. The main sources of information were: maps (geological, topographical, botanical and project maps); documents from the Water Office, which contained technical data about the project; booklets and other publications about the plant and animal communities of the area; press clippings on the public controversy, etc. Tables 1 and 2 and the discussion above indicate that the important outcomes of each option were identified in terms of (a) global consequences for the area (water flow, biodiversity), and (b) connections among components of the ecosystem and not just in terms of lists of affected plants or animals.

Authority and expertise

Expertise and expert status are considered here as a part of the dimensions of scientific practice related to knowledge production. In these processes the sources of knowledge and authority are important: who (books, persons, instances) are the experts? To explore the different aspects related to expertise, Walton's questions about expert argument have been collapsed into two: expert status and the consistency in the expert's propositions.

Who has the status of expert? In the first sessions, the student doubted their ability to complete the task, to assess the project:

> 57 Antón: ... then ... if [the Environmental Office] if they say that it is ... there is no need for me to explain [the ecological value] again, you know? ...
>
> (Group IV, session 5)

> 196 Teacher: ... you decide ...
> 197 Isaías: (interrupting her) But ... the authority ...
> 200 Teacher: You all ... You are the authority here.
>
> (Group B, session 7)

Antón implies that the Environmental Office (the 'sender' of the replica letter that asked the students to assess the project) knows the importance of the wetlands, the students would not be in a position to challenge them; Isaías doubts their own capacity to prepare the report. The doubts continue into session 17.

> 15 Isaura: Because ... the question is that we don't know more systems for cleaning rivers. Then, not knowing them, we cannot criticise it accurately.
> [...]
> 62 Isaías: If the engineers, who know more than we do, made a project, there would be a reason for it ....
>
> (Session 17, whole group debate))

Isaura is explaining group J5's proposal: not accepting the proposed layout, while acknowledging the need for cleaning the river; an option that they cannot specify without knowing more. Isaías supports group J3's positive assessment of the project on the grounds of the expertise of its authors, the engineers. Here, two different views about expert status can be traced: while group J5 acknowledges a lack of technical expertise (and/or information), this is not an obstacle to criticising the project, whereas for group J3, the engineers are the top of the experts' hierarchy, so the students cannot challenge them.

Consistency with other experts and with evidence. The students question the project's authors, the Water Office and the Environment Office which has to approve it.

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

(Group I, session 1)

56 Berta: If is it crossing [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]?
107 Berta: The Environment people allow the pipe to cross there?

(Group IV, session 2)

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

(Group J1, session 15)

The students point to the lack of consistency among on the one hand, the evidence, the status of the marshes, its ecological value, the possible damage, and on the other, the authorship of the project by the same offices with the responsibility to protect it. It is interesting that, although expressing doubts about their own expertise, the students were able to behave like experts, pointing at the project's flaws and offering alternatives. As discussed in Jiménez *et al.* (2000b) the subsequent debate with the two 'experts' proved influential on the students' positions. The debate produced a convergence: those who had evaluated the project negatively maintained their opposition but showed an understanding of the need for action. However, Isaías changed his view, on the grounds that the environmentalist, acknowledged by the engineer, identified the non-existence of measures for the ecological recovery of the area. This is interpreted as a new assignment of expertise, now shared by the engineer, the environmentalist and even by the students. In September 1998, local newspapers announced several changes to the project, which, although keeping to the overall plan, included measures to repopulate the area and to enhance its recovery. Although it is not possible to know whether these changes were in response to the critiques that the engineer read and heard from the students, many of them perceived it this way.

Development of criteria for evaluating alternative solutions

The analysis of the transcripts shows how, in the early sessions, the criteria used by the students were more general (and effectively equivalent to the objectives to be met by the solution) and that, as the sequence progressed, they became more refined and specific. For instance, in the first phase, the students constructed a concept bank, first individually ($n = 34$) and then in groups. The three concepts mentioned most frequently by individuals were: 'environmental damage' (34); 'environmental impact' (22) and 'natural/landscape value' (16). From the group answers, group III produced the most synthetic list: damage, industrial activity, ecosystem, sewage, drainpipe, layout.

Criteria for generating and evaluating alternatives

It is often the case that the more complex and close to the real world a problem is, the more solutions can be offered. The six groups offered not just positive or negative assessments about the convenience of building the pipes, but also offered alternative solutions for cleaning the river without so great an impact on the wetland. Once the solutions were generated, their advantages and disadvantages had to be evaluated. Four groups supported the proposition to build the drainpipe, but with a layout that was not so threatening to the environment.

> 103 Anxos: We should say: it is better to divert it to the West.
> 104 Cruz: ... West or any other direction ...
> 105 Anxos: ... so it wouldn't damage the ecosystem.
> [...]
> 142 Emma: So, instead of crossing ... of choosing the pond, divert it to the West.
> [...]
> 174 Damian: This alternative could be, in terms of money, more expensive, but ... ecologically ... um ...
> 175 Begoña: ... more profitable in the long run.
> (Group J2, session 16)

The discussion in group J2 evolved from choosing 'yes' or 'no' in earlier sessions, to an attempt to combine the two conflicting issues: the need for cleaning the sewage with the preservation of the ecosystem – making the option 'more profitable'. Incidentally, this alternative, of going back to the first draft of the projected layout, where the pipe was located around the pond and wetland, not across them, was also supported by the environmental NGO's in the pleas presented to the project.

Group J1 developed a more specific criterion: for them the ecosystems existence depended on the preservation of its water flow. This led to a different proposal: locating the purifying plants close to the industries; it also would combine both criteria (cleaning with preservation of the ecosystem) but through another method.

> 17 Edu: I believe that if they would clean, if the water would be purified then: what is the purpose of building the pipe?
> [...]
> 34 Fito: You know, because of the industries the water flow arriving to the pond decreased ... with this is the pond ... is going to have no water at all. ...
> (Group J1, session 15)

Edu, recognizing the importance of the diminishing water flow once it is channelled into the pipe, questions the purpose of building the drainpipe. They also discuss how the water flow had decreased already (because of the industrial area).

> 115 Brais: The birds which migrate, they break the migratory routes ... there would be no place to nest. (Group J1, session 15)

Brais draws one consequence for the birds that shows that the need for water is not used just as a general criterion, but is explored through its consequences for the ecosystem's components.

Making decisions: relevance of values. In the last step, in order to choose a solution, the students had to take into account not only scientific evidence, but also value judgements. In environmental decisions and arguments many of the warrants are supported through backings (explicit or implicit) related to values, in contrast to standard science topics where models and theories act as backings. Some instances of values in such situations are the conflict of the economic versus the ecological, the pragmatic or the political nature of decisions.

> 112 Denís: it is an ecosystem of particular interest because there are species in danger of extinction, unique species ... all these species depend directly or indirectly on the water ... if they continue with sewage ... they would die or not exist anymore
> (...)
> 116 Denís: on the other hand the drainpipe would destroy part of the ecosystem and it would damage also the species ... so another alternative would be needed.
> (Group A, session 11)

The claim 'it is an ecosystem of particular interest' refers not just to scientific evidence – rather it is a value judgement about the area and it influences the decision. The weighing up of evidence and values was also identified in other groups, for instance when discussing the costs of the different projects.

> 39 Diana: (group J4) 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.
> (Session 17, whole group debate)

The alternatives of groups J1 and J2 are also more expensive, as they point out. The question is whether the students can reason with the same degree of sophistication in Economics as in Ecology, which means, at least, raising – if not answering – questions such 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? The influence of the context – a Biology and Geology course – could bias how the task is perceived: the students may, even unconsciously, assume that the expected alternative has to 'favour' ecological/environmental values over economical ones. Only in group J3 were economic values, high in their hierarchy, used as a warrant for the positive assessment of the project:

> 64.3 Isaías: (group J3) The economy is very important. We must be practical, and if they did it that way it is because there is no more money.
> (Session 17, whole group debate)

This values hierarchy is close to the one expressed by Mr Brey, during his interview:

> 20 Mr Brey: ... the opinions, particularly on environment, they could be superficial, I mean, even a bit bucolic. Life is much rougher ...
> 32 Mr Brey: ... we had to be practical and ... we didn't forget them (the amending steps) ... but real life is much harder, I say, practical life is so dissociated from the purity of methods of environmental monitoring ...
> 42 Mr Brey: So then, a ... a very high cost for what would be, say, steps to protect the environment ...

Discussion and educational implications

Attitudes and values have a paramount role in environmental education. The importance accorded to values may be the reason why sometimes value development is discussed as if it could happen 'disembodied' from school knowledge. On the contrary, the perspective of this paper is that working with the goal of developing values in schools cannot rely on activities or tasks centred solely on attitudinal dimensions. Students can learn what attitudes to exhibit in order to fit the expectations of the teacher; and no doubt some activities and experiences may develop in them new attitudes and wishful thinking. But if the objective of environmental education is the development of a solid attitude, with a sound basis transferable to out-of-school contexts, then the values development needs to be related to understanding the complex conceptual issues involved in environmental problems.

In this paper, this issue is explored by trying to identify the particular concepts used by students and the relationship between the concepts and the decisions taken. Our interpretation is that the students constituted a knowledge-production community, combining ecological concepts such as impact, wetland or water flow, with technical information about the project they were evaluating. To reach a conclusion, they had to apply conceptual knowledge at more than a surface level, such as the effect of the drainpipe on the animals and plants through the lack of water or the destruction of their habitat. The comparison of the warrants used by them and by an external, 'official' expert shows a great amount of concordance in the content, supporting the claim that they were not just passive 'knowledge consumers'.

However, their decisions were not based solely on conceptual understanding or scientific evidence: value judgements played an important role. In particular, students assigned a higher position in their value hierarchy to ecological considerations over economic ones, or by discarding a position because the damages were perceived to be greater than the benefits. It is believed that the problem-solving context of the task, involving the students in authentic activities, of a similar character to tasks performed by experts in the field, facilitated the integration of conceptual knowledge and values. This would suggest that such integration should be one of the cornerstones of environmental education in the school.

If science education and environmental education have as a goal to develop critical thinking and to promote decision making, it seems that the acknowledgement of a variety of experts and expertise is of relevance to both. Otherwise citizens could be unable to challenge a common view that places economical issues and technical features over other types of values or concerns. As McGinn and 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 of these, and citizens do not need to possess all the technical knowledge to be able to examine the positive and negative impacts and to weigh them up.

The identification of instances of scientific practice in classroom discourse is difficult especially if this practice is viewed as a complex process, not as fixed 'steps'. Several instances were identified when it could be said that students acted as a knowledge-producing community in spite of the fact that the students, particularly at the beginning of the sequence, expressed doubts about their capacities to assess a project written by experts and endorsed by a government office. Perhaps these doubts relate to the nature of the project, a 'real life' object that made its way into the classroom, into the 'school life'. As Brown *et al.* (1989) point out, there is usually a difference between practitioners' tasks and stereotyped school tasks and, it could be added, students are not used to being confronted with the complexity of 'life-size' problems. However, as the sequence proceeded, the students assumed the role of experts, exposing inconsistencies in the project, offering alternatives and discussing it with one of its authors.

The issue of expertise is worthy of attention and it needs to be explored in different contexts where the relationships among technical expertise, values hierarchies and possible biases caused by the subject matter could be unravelled. One of the objectives of environmental education is to empower people with the capacity of decision making; for this purpose the acknowledging of multiple expertise is crucial.

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