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Multiple Paper Set (Session 400840)

Argumentation in Science Education

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Theoretical Barkground and Objectives for Paper Set

In recent years, international policy documents (e.g. National Research Council, 2000; Department for Education and Employment, 1999) have promoted that the teaching of science should accomplish much more then simply detailing what we know in science. Of growing importance in science education is the need to educate students about *how* we know and *why* we believe in certain claims (Driver, Leach, Millar, & Scott, 1996). The shift from what-we-know to how-we-know requires a renewed focus on how science education can promote students' skills in justifying claims with evidence. Put another way, the learning and teaching of argumentation i.e., the coordination of evidence and theory to support or refute an explanatory conclusion, model or prediction (Suppe, 1998) has emerged as a significant educational goal.

The case made is that argumentation is a critically important discourse process in science (Toulmin, 1958), and that it should be taught and learned in the science classroom (Kelly, Druker, & Chen, 1998; Simon, Osborne, & Erduran, 2003; Zohar & Nemet, 2002).

In this session, three papers are presented which detail the findings from research projects on argumentation in secondary schools conducted in three international perspectives from Spain, Germany and the United Kingdom. Our overall purpose is to contextualize the role of argumentation in science learning and teaching as well as to illustrate the potential that argumentation as a pedagogical strategy can enhance science learning.

The first paper investigates the arguments of secondary students working in groups. The study uses analytical perspectives, for instance, derived from work of Toulmin (1958) and Walton (1996) to investigate individual written reports as well as the recorded transcriptions of group discussions. The second paper's focus is on the relation of argumentation skills and conceptual development. The study concentrates on small group discussions to identify the 'content' and 'abstraction' in students' knowledge derived from a diverse range of lesson contexts. The analyses show how students develop knowledge within a context and how this development changes with respect to similar tasks, problems or activities. The third paper investigates the nature of the oral input provided by teachers to faciliate argumentation. The study described utilises a coding system for analysing teachers facilitation talk and identifying the kinds of teacher interventions that could be associated with good quality argumentation.

All three papers use Toulmin's Argument Pattern (Toulmin, 1958) as an analytical tool devised for different outcomes: students' group discussions in the case of the first paper; the relation of conceptual development and argumentation in the second paper; and the teaching strategies in the third paper. In this sense, the papers not only build on the

literature on methodological aspects of the study of argumentation in science education but also provide a comprehensive account of teaching and learning processes involved in argumentation .

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Paper 1: Scientific Authority and Empirical Data in Argument Warrants about the *Prestige* Oil Spill

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Abstract

The arguments of 12 Grade students, working in groups about scientists' opposed predictions on the evolution of the *Prestige* oil spill, which hit the Galician coast in November 2002, are analyzed. The focus is on warrants used to support one or another position, on the articulation of scientific authority and empirical data from sources including their own experience. Participants are a group of 24 students and their teacher; enrolled in a Geology and Environmental Science course. The paper focuses on a debate in small groups, about a controversy among scientists on the possibility of degradation of the oil before arriving to the shoreline. Data include the individual written reports and the recorded transcriptions of the discussion. The analysis draws on Toulmin (1958) argument layout, Walton (1996) categories for experts' arguments, and Scott & Mortimer (2002) frame for dialogical discourse. Five groups supported the scientist who predicted that the oil degradation was slow, and one criticized both. The students placed higher their own experience than the opinion of the scientist who predicted a quick degradation, whose status as expert was undermined by her affiliation to a tanks' owner organization. The articulation of empirical and theoretical evidence in students' arguments is discussed.

Objectives

The Galician schools lived, during the term 2002-2003, through an ecological catastrophe: the oil spill caused when the Prestige hull sank in front of the Galician coast the 19th of November. The black tide caused, besides terrible ecological and economical damages, great social commotion, from which the schools were part. We have outlined a characterization of the school actions in another paper (Federico, Jiménez, Eirexas, Cienfuegos, 2003). Here the focus is how scientific information related to the spill –filtered through the media–, is interpreted by High School students, and which criteria do they use to contrast two opposed claims. In particular we are interested in how they perceive the scientists' authority (the source of the notice) and the weigh assigned to the empirical data about the spill. The research questions are:

– Are the students able to distinguish between claim and justification in the opinions of the scientists about the degradation of the oil?

– Which criteria guide their choice between two opposed views on the subject? Which are the weight of the experts' scientific authority and the weight of empirical data? Could they point to bias in the experts' claims?

Theoretical Background

Discourse analysis is a way to explore the construction of meaning in science classrooms (Crawford, Kelly & Brown, 2000). As Brown & Palincsar (1989) and Collins, Brown & Newman (1989) point, we need to design ways of making public, open, processes that are private, covert, and so difficult to observe. We cannot enter the inner thought, but recording students' discussions in small groups is a way to gain access to their reasoning

processes. The reasoning processes studied here relate to the development of critical thinking, framed in the distinction established by critical theory (Carr & Kemmis, 1986) among the discourse of *technical rationality*, pretending to present all problems as technical issues and the discourse of *critical rationality*, which emphasizes the people capacity of reflecting about reality and modifying it. Technical rationality leads to the assumption that people have not possibility of controlling their environment or their lives, leading to a decreasing of the capacity of reflecting about the situations and of modifying them. The first research question relates to one dimension of critical thinking: the capacity of distinguishing between a claim or opinion and the justifications or warrants supporting it. This is an important distinction in order to doubt of or dismiss unsupported claims. The second research question relates to the authority of experts, to the weight assigned by students to claims by scientists. For the analysis of students' conversations, Toulmin's (1958) argument layout and his notion of substantive arguments have been used, for instance the definition of warrant as the reasons which justify the connection between data and claim. Walton's (1996) argumentation scheme for presumptive reasoning is relevant for the study of expert opinion. Walton lists five questions related to it that we collapsed in two: the *status of expert*, in this case whether the students see the scientist as reliable experts; and the *consistency* of the expert's propositions with other experts and with evidence in the domain, here if the students can detect inconsistencies with evidence.

Methods

The participants are an intact group of 24 students from the 12th Grade (17-18 year old) in a public High School and their regular teacher, a person with more than 20 years of

experience and active in environmentalists organizations; they were enrolled in a Geology and Environmental Science course, from which the unit about oil and fossil fuels make part. During the unit they answered to written tests about their previous knowledge on oil and oil spills and performed activities including a visit to the shoreline. This paper focuses on a debate, which took place on the last week of January 2003, in groups of four, about newspapers' information –from the beginning of January– on a controversy among scientists about the possibility of degradation of the oil before arriving to the shoreline. Data include the individual written reports from each student and the transcriptions of the discussion in each group that were recorded. The analysis draws on Toulmin (1958) argument layout, Walton (1996) argumentation scheme, particularly his categories for experts' arguments, and Scott & Mortimer (2002) frame for dialogical discourse. All the names that appear below are pseudonyms respecting the gender; names of students from the same group begin with the same letter: A to F.

Results

The students were given two pages with press clippings: one from *La Voz de Galicia* (VG), an independent journal which provided sound information about the oil spill, and another from *O Correo Galego* (CG), which minimized the crisis. The one from CG reproduced claims from Kathy Scanzel, identified as Biologist "member from ITOPF", and consultant for the Galician Government, who said that the fuel coming from the sunken ship would not reach the coast, because part of it would evaporate and part will be broken in little drops that will be destroyed by microorganisms in the process of biodegradation. The VG reproduced statements by Guy Herrouin, speaker from the

French Oceanographic Institute IFREMER, denying that the fuel could evaporate. The VG also quoted other scientists saying that only a 5% from the fuel was volatile and that laboratory tests showed a biodegradation of 12 % in a month. Although information about ITOPF was not provided, we searched the web, and found that it corresponded to International Tanker Owners Pollution Federation, information that was shared with the students. They were asked: 1 & 2) to summarize the claims from both experts and the reasons for them and 3) to state their opinion, justifying it with evidence or anything supporting it. Table 1 summarizes the opinions from the written reports. When the claims from the four memebers of a group were similar, they have been collapsed.

Group	Claim	Justifications
1	a) Scanzel lies saying that the oil will not reach the coast. b) Manipulation of information	a) What the sea carries will arrive / Going to the shoreline. b) Name the spill with "cooking" names in order to make it look harmless
2	The oil will reach the coast	– It spills 80 tons each day – Scanzel belongs to the ITOPF, she backs these who pay her. – We were there and saw it.
3	a) The two journals contradict each other b) The spill arrives and will arrive	a) Scanzel is consultant for the Government b) Herrouin has more foundations

	c) Herrouin's opinion is more sound d) The oil will arrive to Galicia and France	c) She is not here (and he is) d) It will not evaporate.
4	a) Against both positions b) Scanzel lies. Herrouin is light	a) We see the oil arriving to the shoreline / It will form a great stain b) Altough she is biologist, Scanzel says it will evaporate
5	The oil will reach the coast	– Its evaporation is difficult – Until now it has not evaporated
6	Herrouin position is more coherent	– the oil is arriving – Scanzel has to consider criteria as tides, winds, etc.

The results show that five groups supported the view from the scientist who predicted that the oil degradation was slow, and group 4 criticized both views. The students placed high their own experience in the Galician shoreline and the media, assessing its reliability higher than the opinion of the scientist who predicted a quick degradation. The status of this second person as expert was undermined, for the students, by her affiliation to a tanks' owner organization, as seen in transcription from group 2.

133 Branca: We could write that we went to the beach and see it [*the oil*]

142 Brais: I agree with Guy [*Herrouin*] that it will reach the coast... Because them [*Herrouin and col*] saw it (...) They are there, out in the sea (...)

144 Brais: Because the other [Scanzel] was not there. She backs her people, the ones who pay her.

The importance assigned to empirical evidence in students' arguments is seen in 142, which support Herrouin's position because he was in the submarine Nautile, exploring the hull. There is a complex articulation of empirical and theoretical evidence in the discussions of the students.

Conclusions and Implications

The arguments of 12 Grade students show their capacity of discriminating among positions based in available evidence and other slanted towards minimizing the catastrophe. The warrants used by students to justify their support to Herrouin position show that they placed more value on empirical data from other sources, including their own experience, than to the scientific authority or status from experts. Discriminating among unfounded and founded claims is an important step in the development of capacity of students of having their own ideas and not being subject to manipulation. The issue of the oil spill promoted the involvement of the students who perceived its relevance to their lives, pointing to the need of connecting science to its social context.

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Paper 2: Argumentation and Cognitive Processes in Science Education

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Abstract

Within the last years a consensus about the importance of argumentation in school science has developed. Students should not only be able to follow and judge scientific debates in public, it is also assumed that argumentation contributes directly to science learning. However, detailed studies on the connection of argumentation and the development of science knowledge are rare in research on students' learning. In the study reported in this paper, junior high school students' processes of argumentation and cognitive development occurring in science lessons based on argument were investigated.

Referring to video and audio documents of small group and classroom discussions students' performance of argumentation was analysed and ascribed to different levels. Addressing first the difficulty of the activities students' had to carry out and second, content and complexity of students' knowledge a perspective on teaching and learning of content was added. Results show that patterns of argumentation seem to be sensitive to the difficulty of the learning environment and that argumentation has an important function in improving students' knowledge.

Objectives

The objectives of this study were to address the following research questions:

a) How does the context of the lesson (width of content and level of abstraction of tasks, activities, and problems offered to students) influence the quantity and quality of arguments occurring in the lesson?
b) In lessons based on argument, how do students develop and use science knowledge? How is this development related to patterns of argumentation (Toulmin categories on argument)? Does the level of science understanding have an impact on the developed patterns of argumentation?

Theoretical Background

Empirical research on argumentation mainly addresses the processes of teaching and learning in science. Patterns of students' and teachers' discourse are investigated with

respect to Toulmin structures (Toulmin 1958). These structures are basically described as *data*, *claims*, *warrants*, *backings*, and *rebuttals*. Categories referring to these structures are used to investigate the nature of discourse in science classrooms (Osborne, Erduran, & Simon, 2003; Kelly, Drucker, & Chen, 1998). Investigations consider both quality and quantity of students' argumentations. Due to the assumption that quality and quantity of argumentation have an impact on students' learning of science, some research also concentrates on teacher performance and teacher training (Simon, Osborne, & Erduran, 2003). In contrast to research on argumentation, research on students' development of science knowledge basically addresses "products" rather than processes. Using pre- and post-test designs (interviews, questionnaires, or tests) students' conceptions prior to instruction and their changes after instruction are investigated (Hestenes, Wells, & Swackhamer, 1992). Although these methods can show what kind of knowledge students have, they cannot describe how this knowledge has developed through instruction, i.e. which specific features of teaching were helpful and which were not. To relate argumentation to the development of knowledge, a process based perspective on students' learning is needed (Roth, 1995). Within such perspective, development of knowledge can at least be described referring to (1) the number of contents that are connected and (2) the level of abstraction students reach (C. von Aufschnaiter & S. von Aufschnaiter, 2003). Although both frameworks address their own field, there is an increasing interest in connecting students' argumentation and their learning. Whereas some studies relate investigations of processes of argumentation to post-test measurements of science concepts (Zohar & Nehmet, 2002), other studies try to reconstruct students' understanding directly from processes (Jiménez-Aleixandre,

Rodrígez, & Duschl, 2000). Results of these studies indicate that not only students' engagement in science contexts but also their learning can be improved.

Methods

Data were gathered in the project "Enhancing the Quality of Argument in School Science" (funded by the Economic and Social Research Council, UK). Within the first phase of the programme, 12 teachers were trained on argument. Their teaching in London junior high schools was investigated using video and audio recording of lessons on science and socio science issues (Osborne, Erduran, & Simon, 2003). In a second phase, research concentrated on six of these teachers who have shown to improve their teaching most towards supporting argumentation in the classroom. Using material developed in phase one, these teachers again did at least nine instructions on argumentation in science and socio science issues (e.g. light, acids and bases, moon, funding a zoo) in London Junior High Schools. Focusing on two groups per classroom, four lessons of each teacher were documented with video and audio. These documents build the data basis of the research presented in this paper. Documents of students' processes during group work and classroom discussions were transcribed and both research on argument and research on content were carried out.

Within a more general investigation about the distribution of argumentation v discourse without argumentation a relation about the quantity of argumentation and content of the lesson becomes possible. Furthermore, Toulmin's categories were used to analyse patterns of argumentation for those dialogues in which students opposed each other.

Here, their structure of thinking becomes more visible and more easy to access by an observer. Patterns of argumentation were grouped so that different levels in argument could be reconstructed. Whereas the lowest level 1 would consist of arguments that are simple claims v a counter claim or a claim v a claim, the highest level 5 would display an extended argument with more than one rebuttal (for details on the research of argumentation see Osborne, Erduran, & Simon, 2003).

Investigations of students' knowledge referring to the dimensions of (1) content and (2) abstraction were used to analyse the structure of the context and students' knowledge. Focusing on students' situated constructions of knowledge in a second order perspective (Marton & Booth) it can be described to which contents students refer within their argumentation and which levels of abstractions they reach (concrete v abstract (conceptual) knowledge). The analyses show how students develop knowledge within a context and how this development changes with respect to similar tasks, problems, or activities. Furthermore, dimensions number 1 and 2 were also used to investigate the difficulty of the problems offered to students (for more details see C. von Aufschnaiter & S. von Aufschnaiter, 2003). In a final step, process based analyses on argumentation and students' development of knowledge were combined to answer the research questions given in the first section.

Results

Investigating quantity and quality of argumentations differences between science and socio science issues (funding a zoo, deciding about a leisure centre) occurred as well as amongst science contexts. This happens even for the same teacher and a focus on the

same groups within the class. Searching for factors that might have caused the differences it becomes apparent that contexts (tasks, activities, problems) used to initiate argumentation did not refer to the same level of abstraction and/or the same width in content. For example, to argue (successfully) about funding a zoo, students can refer to their concrete experiences (like "zoos are horrible because cages for lions are very small"). In contrast, arguing about what makes a face turn red after exercise students need a more complex understanding about the physics of blood pressure. Furthermore, also within a single lesson, the difficulty of the problems/tasks to argue about was not identical. Contrasting different statements about the phases of the moon, students could amongst other things decide between "the rest of the moon is blocked out by the clouds" (which can be understood in relation to concrete experiences) or "you can't always see the part that is lit by the sun" (which refers to two different contents – what you see and what is lit – and needs abstract considerations about light travelling in space). So, although the lessons were structured similar in terms of supporting argumentation the lack of focus on similarity in context might be one explanation for differences in the result that can be found for the quantity and quality of argumentation.

Focusing on individual students' development and usage of science knowledge, the number of contents that students connected and the level of abstraction they reached while discussing different aspects was ascribed and followed throughout the lesson. Especially when comparing students' initial ideas at the beginning of the lessons and their ideas at the end of the lesson it became apparent that only slight changes occurred. These changes basically related to reducing the number of contents to the most important

aspects and being more "fluent" in describing the own thinking. In only a very few cases some sort of new understanding which might have developed within the lesson based on argumentation was reconstructed. This happened for example when a student had started to argue that the colour of the face after exercise has to do with sweating (referring to a concrete experience) but ended the lessons with the more abstract and expanded idea that water comes through the skin as steam, which is, from his perspective, heat and sweat. Besides these few cases indicating some learning of new aspects, students basically improved with what they already knew (were able to construct initially). So, argumentation did not only result in students' engaging in the context but also in being more precise and fluent in their thinking.

Conclusions and Implications

Some qualitative results of the study and the implications of the results are as follows:

(1) Content and difficulty of instruction have an impact on students' performance of argumentation. Further research projects trying to relate quality and quantity of argumentation in different contexts to each other should not only concentrate on argumentation but also on the nature of the activities itself.

(2) Although argumentation seems to have a strong potential for students' engagement in science contexts the learning of new science concepts via lessons based on argumentation solely seems to be limited. Future research should focus on ways to improve both argumentation and conceptual development.

(3) Toulmins' categories are well established to describe the quality of argumentation but their use to address science understanding is limited. A direct link between

performance of argumentation and science knowledge is not supported by the data. Descriptions (categories) relating argumentation to science understanding might result in a more precise assumption about students' knowledge.

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Paper 3: Developing the Teaching of Argument in School Science

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Abstract

The paper presents a study investigating secondary teachers' oral contributions reflected through implicit goals for students' engagement in argumentation. It was assumed that if teachers did not have these goals, the processes would not be fore-grounded in their teaching. A tentative hierarchy, or progression, of student argument processes was drawn up and matched to types of teacher interventions. Codes were developed to examine the processes of teachers' interventions to faciliate argumentation. These codes were mapped to the nature of arguments generated in the classroom coded using Toulmin's Argument Pattern (1958). Those teachers whose talk included all the features of facilitation talk were found to be those with the highest quality of argument and who also demonstrated significant improvement in their use of argument features. The two teachers who showed no significant improvement did not demonstrate any faciliation codes.

Objectives

The original objectives of this research were to identify the strategies necessary to promote argumentation skills in young people in science lessons, and determine the extent to which implementation of these strategies enhances teachers' pedagogic practice with argumentation. To this end, an analysis based on the application of Toulmin's Argument Pattern (TAP) (Toulmin, 1958) was used to compare teachers' initial and post-intervention practice in the teaching of argument. The findings from this analysis, coupled with a further study of video material and lesson transcripts, led to a more detailed analysis of teachers' discourse. It was hypothesised that an important factor in facilitating good quality argumentation was the nature of the oral input provided by teachers at critical points in their lessons (Simon *et al*, 2003). Therefore additional objectives were: to devise a coding system for analysing teachers' facilitation talk, to compare both sets of outcomes and to identify the kinds of teacher intervention that could be associated with good quality argumentation.

Methods

A lesson format for a socio-scientific activity based on the issue of whether a zoo should be funded was developed. This lesson served to initiate the teachers' use of argumentation and enabled the research to evaluate changes in practice occurring over a period of one year. Twelve teachers took part in the study, from urban and suburban schools located in the greater London area. Their students were aged 12 – 13 years and were from mixed ethnic groups representative of a range of academic ability. The teachers taught the zoo lesson at the beginning of the project and again after one year,

with comparable students each time. They attended six workshops during the course of the year to gain theoretical understanding and to develop nine other argument lessons using different generic frameworks (Osborne *et al*, 2001). They received coaching (Joyce & Showers, 1988) in their schools during the year when teaching some of these lessons. During each zoo lesson, audio-tape recorders were wired on the teachers so as to capture their oral contribution to the lesson as well as their interactions with students during small group discussions. Each transcript of these tapes was analysed for TAP to determine the quality of argumentation occurring in the lessons. In this way comparisons could be made between teachers and from one year to the next. From these results, five teachers were selected who demonstrated a range of TAP outcomes, that is, some had more good quality argumentation in their lessons than others. The transcripts of these teachers' lessons were used for more detailed analysis.

The transcripts were examined for teacher talk that was oriented to the processes of argumentation. Teachers' oral contributions reflected implicit goals for students' engagement in argumentation. It was assumed that if teachers did not have these goals, the processes would not be fore-grounded in their teaching. A tentative hierarchy, or progression, of student argument processes was drawn up and matched to types of teacher intervention. The following table shows this hierarchy and summarises the processes and codes for teacher talk that arose from this analysis. The codes were refined and applied across the transcript data for the five teachers. The occurrence of these codes was then matched to the TAP results.

Student argument process	**Codes for teacher facilitation**
Talking	Encourages discussion
Listening	Encourages listening
Knowing meaning of argument	Defines argument Exemplifies argument
Reviewing arguments for different positions	Encourages ideas to be expressed
Taking a position	Encourages positioning
Justifying with evidence	Checks evidence Provides evidence Prompts justification Emphasises justification
Constructing arguments	Reviews arguments/sets written task/gives roles
Acknowledging different positions	Values different positions
Anticipating counter-arguments	Encourages anticipating counter-arguments
Evaluating arguments	Encourages evaluation Evaluates arguments for: process – using evidence content – nature of evidence
Defending a position	Encourages further justification plays devil's advocate

Changing a position	Asks about mind-change
Engaging in debate	Sets up debating situation
Reflecting on argument process	Encourages reflection

Results

The TAP analysis showed that the trends in teachers' use of the components of TAP were similar across two years. There was a consistent pattern for each teacher but teachers were different from each other. This would suggest that there is no common pattern and that the use of argumentation is teacher dependent. However, there were shifts within some teachers' TAP results that indicated an improvement in the quality of argumentation. Across all twelve teachers, significant improvements were noted for eight teachers in the sample (six at $p<0.01$, two at $p<0.05$). Further analysis was undertaken for three teachers who showed TAP improvement and two who did not. The codes for teachers' facilitation talk were applied across the ten transcripts. The teachers whose talk included all the features of facilitation were found to be those with the highest quality of argument and who also showed significant improvement. The two teachers who showed no significant improvement did not have any codes seen in the lower end of the table.

Conclusions and Implications

The variations between teachers and the consistent pattern of TAP for each teacher over the two years demonstrate the uniqueness of pedagogy. In addition, the variations in the degree of change demonstrated by each teacher show that progression in learning is

variable. The hierarchy of teacher facilitation codes has helped to guide the formation of the development of in-service training materials and to recognise the barriers to learning in less experienced teachers. Teachers need to develop strategies for getting students listening to each other and working in small groups before they can expect high quality student argumentation. The research showed that teachers with more basic knowledge and understanding of the nature and purpose of the innovation were more likely to adopt the new approach. Thus a teacher's basic capacity for change is dependent on their existing knowledge and thinking (Leithwood *et al*, 1999; Fullan, 2001). The message here, that teachers' interpret new materials and ideas differently and so there are no homogeneous outcomes, reinforces the work of previous studies of in-service training (Harland and Kinder, 1997). If professional development is to impact on practice, such differences need to be recognised and taken into account by policy makers.

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